NEUROGENIC DISORDERS OF THE URINARY BLADDER

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"Again, by the knowledge of physical causes there cannot fail to follow many indications and designations of new particulars, if men in their speculation will keep one eye upon use and practice."

(Francis Bacon - "The Advancement of Learning")

The nervous connections of the urinary bladder which are subservient to micturition are complicated and incompletely understood, but it is necessary for clinicians to have some knowledge of neurophysiology and neuro-anatomy so that the diagnosis and therapy of neurogenic bladder disorders can have a rational basis. An awareness of those aspects of the nervous control of bladder function which remain ill-defined is essential before any further elucidation of these problems can be obtained from clinical work as opposed to animal experimentation. The psychological and social aspects of micturition in man require an intricacy of functional control which is unique to the human species and which presents serious clinical problems when deranged.

The purpose of this thesis is to present a series of cases of neurogenic bladder disorder, correlated with their neurological state as relevant to their urological management and with reference to any further understanding of the physiology of micturition.
INTRODUCTION

In the cerebral cortex micturition has a functional conception which is largely dissociated from any anatomical representation of the organs involved, and requires the will to be directed to the complete act. In this respect, micturition is not comparable to simple willed voluntary movement as generally understood, for it entails thought of the completed process (Genouville, 1894) and is not analysed consciously. Disturbances of micturition might therefore accompany a wide variety of psychological and physical disorders in the absence of definite neurological or urological disease, whereas pathology in the nervous system might present a urological clinical picture of great complexity incompletely resolved by routine investigation and only partially responding to surgical treatment.

These ill-defined features of the higher centre control of bladder function must be constantly borne in mind, but do not necessarily invalidate a more simple physiological concept of the mechanism of micturition as based on the phylogenetic and ontogenetic sequence of development of the nervous and muscular structures involved. It is therefore important to review briefly the embryology of the bladder so that the muscular structure of the organ, its peripheral nerve supply and its central nervous connections can be appreciated as anatomical entities before any attempt is made to integrate them into a functional system.
The Embryology of the Bladder

The dilated caudal end of the primitive gut incorporates the termination of the allantois into the entodermal cloaca, the ventral surface of which is in contact with surface ectoderm to form the cloacal membrane. During the fifth week of development the pronephric (mesonephric) ducts open into the lateral walls of the cloaca and a coronal septum then projects into the cloaca from the angle between the allantois and the hind gut proper. This urorectal septum separates the cloaca into a dorsal rectum and a ventral urogenital sinus which has the mesonephric ducts opening into it and is still partly formed by cloacal membrane extending upwards to the cranial end of the allantois or urachus; the external margins of this portion of cloacal membrane are encroached upon by primitive mesoderm to contribute to the formation of the infraumbilical abdominal wall and external genitalia. The urogenital sinus is further subdivided into an upper vesicourethral primordium and a lower urogenital sinus proper by the site of entrance of the mesonephric ducts. The vesicourethral primordium is thus of entodermal origin from parts of the cloaca and allantois and dilates to form the dome, side walls and fundus of the bladder, which is connected by the urachus as a fibrous band to the umbilicus as the allantois regresses; the musculature of the bladder vault is laid down from overlying splanchnopleuric mesoderm.
The terminal parts of the mesonephric ducts enlarge and become incorporated into the lower part of the vesico-urethral primordium to form a mesodermal component of the bladder wall destined to become the trigone which is delineated by the separation of the mesonephric ducts (vasa deferentia) from the metanephric ducts (ureters) as the latter migrate in a cephalad direction. In the fully formed posterior male urethra the prostatic utricle and the openings of the ejaculatory ducts mark the anterior limitation of this mesodermal element which does not contribute to the formation of the more distal urethral musculature. The circular muscle coat of the urethra is continuous above with the musculature of the bladder neck, whilst at a lower level it blends with striated muscle fibres (constrictor urethrae) surrounding the membranous urethra as the external urethral sphincter. These striated fibres are not developed from the urogenital sinus but from the sphincter cloacæ (Keith, 1948), which was classified by Popowsky (1899) as a "skin" muscle though it is probable that all the voluntary muscles of the external genitalia and anal canal derive from the ventro-lateral divisions of the 3rd sacral to the 1st coccygeal myotomes along with the levatores ani and coccygeus muscles (Hamilton et al., 1952).
The Musculature of the Bladder

The work of Versari (1897) and Kalischer (1900) led to the prevalent concept that the musculature of the bladder vault is arranged as three layers of fibres to form outer and inner longitudinal and middle circular coats. More recent studies by Hunter (1954) have re-emphasised the observations of Stein (1876) that these layers are by no means distinct and have established that there is continuity of single bundles of fibres through all three layers. These studies further indicated that the innermost longitudinal bundles in the ventral bladder wall and around the ureteric orifices are continuations of the ventral layer of outer longitudinal bladder musculature with even further extensions forwards as the ventral and lateral longitudinal muscles of the urethra. Miller (1958) has described more obvious differences between the inner layer of the vault musculature and the rather thin strata of the middle and outer layers. The inner coat muscle fibres are arranged as a net of anastomosing bundles with intervening spaces; the bundles and the spaces vary in thickness and size respectively, though both increase their proportions towards the lower regions of the posterior and lateral walls of the bladder as the trigone is approached.

The musculature of the trigone itself would appear to be quite distinct from that of the bladder vault, as might be expected from its diverse development. It is in continuity with the longitudinal muscle coats of the ureter (Wesson, 1920), or at least reinforced by bundles which course /
course down from the ureters along the edges of the trigone and blend with the musculature of the internal vesical orifice (Bell, 1826) where elliptically arranged circular fibres and longitudinal fibres of the vault musculature are concentrated and where a submucosal musculo-fascial sheath descends towards the urethra (Uhlenhuth, 1953). There is no simple circular sphincteric arrangement of smooth muscle at the vesico-urethral junction, but there is a very complex intermingling of bundles which perhaps function as an internal sphincter but anatomically form the "bladder neck".

Below the bladder neck the smooth muscle bundles extend around the urethra (Cadiat, 1876; Wesson, 1920; McRae, 1926; Sitkery, 1942) in further complexity (Fig. 1) and are reinforced by striated muscle fibres which lie in the anterior and lateral aspects of the prostatic urethra and the urethral slope of the anterior bladder neck (Bors et al., 1954); whilst some extend proximally into the trigonal region (McRae, 1926). Distally, these striated fibres are continuous with the constrictor of the membranous urethra, located in the deep perineal pouch and referred to as the external urethral sphincter.

It is thus apparent that the muscular structure of the bladder and urethra does not allow for subdivision of these organs into muscular units to which elementary actions can be allocated on an anatomical basis. In particular the complicated mixture of smooth and striated muscle bundles at and below the bladder neck repudiates any concept of internal/
Fig. 1.— Arrangement of muscle fibres around the bladder neck and urethra, as seen in sagittal section. (Wesson, 1920.)

V = vesical orifice; L.M. = longitudinal muscle; C.M. = circular muscle; T.M. = trigonal muscle; E.V.S. = external vesical sphincter (striated muscle); Ur. = ureteral orifice; S.V. = seminal vesicle; E.D. = ejaculatory duct; P. = prostate.
internal (lisso) sphincter and external (rhabdo) sphincter as an anatomical basis for surgical treatment and forms the first stumbling block in urological management.

Nevertheless, the embryological distinction between bladder vault, trigone and cloacal musculature remains as a sound premise on which to subdivide these anatomical units on a functional basis. It is then apparent that the bladder vault when relaxed forms the main cavity for the acceptance of urine and provides the forces of expulsion in contraction; the trigone provides the apparatus for the discharge of urine in relaxation, and the forces of retention when contracted, whilst skilfully separating renal and reproductory secretions.

It is obvious that these functions are largely reciprocal and therefore require integration by a nervous system; their subservient adaptability to the organism as a whole and the uneven temporal relationship of their different phases are cared for by the autonomic innervation of their smooth musculature, whilst the incorporation of somatic elements does to some extent allow the introduction of voluntary control.

These functions cannot be dissociated from the nervous connections of the different embryological components of the bladder, and it is, therefore, necessary to trace the peripheral anatomical pathways of the bladder nerves in order to lay the foundation for any understanding of the mechanism of micturition as a co-ordinated muscular process and to map the possible sites where it may be suitably modified by surgical intervention.
The Innervation of the Bladder and its Sphincters

The nerve supply of the bladder is from both the sympathetic and parasympathetic divisions of the autonomic system whereas the urethra and its striated musculature are innervated by the somatic pudendal nerves.

Sympathetic Nerves

The efferent sympathetic nerves are derived from the lateral horns of the 11th and 12th dorsal and 1st lumbar segments and travel out in the corresponding roots (Head, 1894; Harman, 1898). Their peripheral connections through the sympathetic chains to form the presacral nerve are shown in Fig. 2. The presacral nerve is located in Codman's triangle on the anterior aspect of the body of the 5th lumbar vertebra between the two common iliac arteries, and this is the most suitable site for surgical ablation. The presacral nerve divides into the two hypogastric nerves, each of which runs downwards and forwards, partly dissociating, before synapsing in the corresponding hypogastric ganglion. On its medial aspect this ganglion is in contact with the bladder, seminal vesicles, vas deferens, ureter and rectum, to which organs the post-ganglionic fibres are distributed. Twigs from the 3rd and 4th sacral sympathetic ganglia also pass from the hypogastric ganglion /
Fig. 2.- Nerve supply of the bladder.
ganglion into its branches (Learmonth, 1931a). Denny-Brown and Robertson (1933) maintained that no precise histological data are available about the relationship between pre-ganglionic and peripheral neurones in the intricate vesical plexus, but compared it with the superior cervical ganglion where fibre and cell counts showed that each pre-ganglionic fibre divides repeatedly to control many ganglionic neurones and to provide a basis for extensive correlation (Billingsley and Ranson, 1918).

Afferent sensory sympathetic fibres reach the spinal cord at least as high as the 9th dorsal segment, and probably as low as the 4th lumbar segment (Learmonth, 1931b). However, recent clinical reports by Beck (1949) and Kuhn (1950) indicate that occasionally there may be afferent fibres within the sympathetic chain which enter the cord as high as the 3rd or 4th dorsal segment.

Parasympathetic Nerves

The parasympathetic innervation of the bladder is by way of the pelvic nerves which carry both afferent and efferent fibres and are derived from the 2nd, 3rd and 4th sacral segments of the spinal cord. The fibres travel in the roots of the same segments (Waldeyer, 1899), and though it is probable that the 3rd and 4th segments are predominant, Schlyvitsch and Kozintzev (1939) maintain that in 12 per cent of subjects contributions are also made from the 2nd sacral roots, and in a further 12 per cent from the 5th /
The pelvic nerves are very difficult to expose in their course from the sacral nerves, but they pass through the hypogastric ganglia without relay to emerge with postganglionic sympathetic fibres for distribution to pelvic viscera. Those parasympathetic fibres which reach the bladder synapse in both the intra and extramural portions of the vesical plexus.

The surgeon who wishes to interrupt the parasympathetic supply to the bladder must perforce attack the efferent branches of the hypogastric ganglia, so that the operation becomes one of subtotal denervation of the bladder because these branches contain both sympathetic and parasympathetic fibres (Learmonth, 1931a).

Nerve Endings and Ganglion Cells. (The vesical plexus)

Nerve endings occur in the adventitia, muscularis and mucosa of the bladder (Stöhr, 1926), and a further asynaptic submucosal plexus has also been described (Meyling, 1953). Intra and extramural ganglia are present in greatest concentration at the bladder base, seminal vesicles and uretero-vesical junctions, though the ganglia of the muscularis are smaller than those of the adventitia (Stöhr, 1926), whilst Hryntschak (1923) failed to demonstrate ganglia in either the mucosa or the trigonal muscle.
Pudendal Nerves

The somatic afferent and efferent nerve supply of the urethra and its voluntary musculature are contained in the pudendal nerves, each of which is a terminal branch of the sacral plexus and arises from the anterior primary rami of the 2nd, 3rd and 4th sacral nerves (Jamieson, 1935). After descent over the anterior aspect of pyriformis muscle, the pudendal nerve leaves the pelvis by curling round the lateral end of the sacrospinous ligament medial to the internal pudendal vessels. This neurovascular bundle thus passes through the lesser sciatic foramen from without in, to enter the pudendal canal of Alcock formed in the fascial covering of obturator internus muscle in the lateral wall of the ischiorectal fossa. On entering the posterior end of the canal the nerve immediately divides into three branches – the inferior haemorrhoidal nerve, the dorsal nerve of the penis or clitoris and the perineal division of the pudendal.

The inferior haemorrhoidal nerve runs medially with the inferior rectal vessels through the ischiorectal pad of fat and divides to supply the levator ani muscle, the external anal sphincter and peri-anal skin.

The dorsal nerve of the penis or clitoris runs forward in the pudendal canal above the internal pudendal vessels and enters the deep perineal pouch; it later pierces the perineal membrane, gives a branch to the crus of the penis or
or clitoris, and is distributed to the skin of the penis or clitoris, ending in the glans.

The perineal division also runs forward in the pudendal canal, but lies below the internal pudendal vessels; it divides into two posterior scrotal or labial nerves and a muscular branch. The scrotal or labial nerves pierce the wall of the fascial canal, traverse the ischiorectal fossa to pass closely to superficial transverse muscles of the perineum and are distributed to the skin of the scrotum or labium majus. The muscular branch continues forward and is distributed to the muscles of the urogenital triangle and to the bulb of the urethra.

By an approach through the ischiorectal fossa, the pudendal nerve is readily accessible for percutaneous infiltration or surgical division and the detailed knowledge of its peripheral distribution is of fundamental clinical importance.

The peripheral innervation of the bladder and urethra is thus by sympathetic, parasym pathetic and somatic nerves; the central connections of the parasym pathetic and somatic nerves share the same cord levels in the conus medullaris, whilst the sympathetic connections are at a higher level.

Any attempt either to subdivide the peripheral fibres into motor or sensory groups or to evaluate their precise distribution in the urinary organs must take into account their central connections, but cannot have an entirely anatomical /
anatomical basis. Further consideration of the neuro-anatomy will therefore be considered along with the neuro-physiology of micturition.
NEURO-ANATOMY AND NEUROPHYSIOLOGY OF MICTURITION

The Motor Supply of the Bladder

Stimulation of the peripheral stump of the presacral nerve leads to powerful contractions of the ureteric orifices with increased tonus in the trigone and contraction of the internal urethral sphincter (Learmonth, 1931b) and ejaculatory ducts, whilst section of the sympathetic supply produces an immediate relaxation of the ureteric orifices, the entire trigone and the internal sphincter with reflux of ejaculation (Retief, 1950), but there is no observable change in the musculature of the bladder vault.

Stimulation of the peripheral segment of the cut pelvic nerves in animals produces powerful contraction of the musculature of the bladder vault with relaxation of the internal vesical sphincter (Gianuzzi, 1863; von Zeissl, 1893, 1901), whilst section of both pelvic nerves occasions a profound depression of micturition with an atonic distended bladder (Lannengrace, 1892; Elliot, 1907; Barrington, 1914, 1915).

Though the pudendal nerve carries the established motor supply of the striated external urethral sphincter, it has been shown by Bors (1952) that stimulation of the peripheral stump of the divided nerve also leads to contraction of the bladder.
bladder neck (internal sphincter) but not of the levator ani. On the other hand, anaesthesia of the pudendal nerve merely retards inhibition of micturition in man (Lapides et al., 1955) and does not interfere with the initiation of the act (Emmett et al., 1948).

It is thus established that the sympathetic supply is motor to the musculature of the mesodermal component of the embryonic bladder and to the involuntary forces of urinary retention, whilst the parasympathetic supply is motor to the musculature of the endodermal bladder vault or detrusor component. There is no certain evidence that these motor innervations overlap, and it therefore follows that any nervous reciprocity of the forces of retention and expulsion occurs at a more central location in the nervous system. The somatic innervation is motor not only to the external urethral sphincter but also to the "internal sphincter", presumably by its control of the proximal extensions of the striated musculature of the urethra. Despite this extensive pudendal distribution to the forces of retention, integrity of these particular motor pathways does not appear to be essential for adequate control of micturition.
Sensory Supply of the Bladder

It has been established that all three sources of innervation so far described convey afferent fibres from the bladder and urethra; in animals it is known that one-tenth of the fibres in each hypogastric nerve are sensory as compared with one-third of each pelvic nerve (Langley and Anderson, 1895, 1896; Langley, 1900).

According to Bors (1957) the vesical and prostatic urethral mucosa contains pain receptors but not touch receptors, and impulses from them reach the spinal cord by way of the spinal ganglia and posterior nerve roots at D.12 and L.1. Learmonth (1931b) maintained that painful sensation may be transmitted by both sympathetic and parasympathetic afferent fibres and it was later shown by Petersen and Franksson (1955) that the pathways of both pain and touch sensation are different for the trigone as compared with the bladder vault. Sensations from the trigone are distributed among the 1st to the 3rd sacral segments and occasionally the 5th lumbar segment, while those from other parts of the bladder are distributed among the 2nd lumbar to the 2nd sacral segments though only to a slight degree through the 4th and 5th lumbar segments. Though these differences in segmental afferent innervation correspond to the different embryological derivation of the trigone.
trigone and bladder vault, they would not necessarily explain the failure of presacral neurectomy to anaesthetise completely either of these subdivisions of the organ (White et al., 1952) and it remains probable that both sets of autonomic nerves are accompanied by afferent fibres which convey various sensations (Bonica, 1953). Thus, although stimulation of the central stump of the divided presacral nerve in man causes suprapubic pain, the complete interruption of the preganglionic sympathetic bladder supply does not alter the desire to micturate, the ability to micturate or the production of pain by overdistension of the viscus (Nesbit and McEllan, 1939). At a more central level and despite the segmental overlap, the sacral input is of greater importance than the dorso-lumbar, though the latter must be intact for correct lateralisation of bladder sensibility.

Vesical pain may originate in the mucosa or muscularis of the bladder and the impulses pass through the sympathetic and parasympathetic afferent fibres via the spinal ganglia and posterior nerve roots to enter both dorso-lumbar and sacral segments of the cord; they then ascend in the spino-thalamic tracts. Pain from detrusor contraction travels by this same route (Nathan and Smith, 1951), but pain from overdistension may take a different ascending pathway in the spinal cord, probably located in the posterior columns (Kuru et al., 1953).
The absence of any clear distinction in territorial distribution of sensory bladder nerves is in contrast to their motor counterparts and requires that the proprioceptive aspect of bladder sensation should receive separate consideration at this stage before the upper and lower centres for micturition are completely defined.

Sensations Associated with Micturition

When the nervous connections of the bladder are intact the sensations normally associated with micturition are three in number:

(1) the desire to micturate;
(2) the sensation that micturition is imminent, and
(3) the sensation that urine is passing.

The Desire to Micturate (Void)

Any increase in the content of the bladder causes alternate contraction and relaxation of the smooth muscle fibres until their tonic response to filling becomes quite marked and is accompanied by a desire to micturate; the intensity of this desire is proportionate to the strength of the detrusor contraction. The changes in tonus of the muscle fibres are not always manifest as changes in intravesical pressure because the adaptation of the viscus to increasing volume tends to be isomanometric until filling is physiologically adequate. The desire to void is consequently /
consequently not directly related to bladder volume or to bladder pressure, but is induced by an increase in either of these factors because they produce passive stretching or active contraction of the smooth muscle fibres to their threshold of tonus. As the bladder fibres are stretched the central nervous system receives a stream of impulses which arise in the same receptor unit in the muscle coat and may summate to constitute the desire to void, whether the stimulus be passive distension or active contraction (Iggo, 1955). These impulses travel into the spinal cord via the pelvic nerves, spinal ganglia and posterior sacral roots; within the cord they travel in the spino-thalamic tracts on the surface of the cord approximately opposite the dorsal lateral process of the anterior horn (Nathan and Smith, 1951). In this same region of the cord there also lie the fibres that convey the impulses interpreted as pain, warmth and cold from the sacral segments of the body and the afferent fibres concerned with defaecation (Nathan and Smith, 1953). From the spino-thalamic tracts the desire to void is relayed to the thalamus and to the subcortex and cortex of the cerebrum.

The Sensation that Micturition is Imminent

It has been shown by Nathan (1956) that this sensation originates in the urethra and not in the bladder itself. It is sometimes experienced by patients during the introduction /
introduction of a catheter or cystoscope and is located to the perineum, deep in the pelvis, or in the suprapubic region with urethral radiation. In man it is not associated with any rise in bladder pressure as the result of urethral stimulation or irrigation. According to Nathan (1952), such reflex contraction of the bladder does not occur in man, though it was clearly described in the cat by Barrington (1921, 1941). The impulses concerned with this sensation of imminent micturition arise from a pull on all the muscles around and along the urethra and travel via the pudendal nerves and ascend in the posterior columns of the spinal cord.

The Sensation that Urine is Passing

This sensation is associated with the movement of the perineal muscles as the sphincteric mechanism opens, with the sensation of something passing along the urethra and also with thermal sensation in the urethra itself (Nathan, 1956). The impulses subserving thermal sensation in the urethra travel via the pudendal nerves and in the spinothalamic tracts in the lateral columns, whilst the other elements in this sensation share the pudendal nerves but ascend in the posterior columns.

Reflex /
Reflex Centres concerned with Micturition

The neuromuscular activity of the bladder is integrated to a varying degree at three neuronal levels known as the peripheral, spinal and supraspinal centres.

The Peripheral Centre

This is embodied in the intra and extramural vesical plexus and is capable of maintaining bladder tonus whilst allowing for a certain amount of adaptability to changes in volume of the bladder content. This centre alone is not able to initiate a true voiding contraction (Boyce et al., 1953) but continues to maintain bladder tonus when the peripheral nervous connections are interrupted by spinal anaesthesia (Nesbit and Lapides, 1948).

The Spinal Centre

The true reflex centre for micturition is located in the sacral cord segments to which the afferent and efferent fibres of the pelvic and pudendal nerves are connected. In this cord centre the expulsive and retentive forces of the bladder are reciprocated and integrated with the activity of the striated musculature of the external urethral sphincter and pelvic floor as shown in Fig. 3. The direct motor effect of a neuronal discharge from this centre is to produce /
Fig. 3.- Central neuronal connections of the bladder and striated pelvic floor musculature; these connections constitute the sacral spinal reflex centre for micturition. (Modified from Bors and Blinn, 1957.)
produce a powerful co-ordinated contraction of the detrusor musculature of the bladder with concomitant reduction in tonus of the bladder neck and the striated urethral musculature to allow for complete evacuation of the bladder. In its simplest sense, this discharge represents the efferent arc of a spinal reflex which is dependent upon the integrity of the afferent arc in the pelvic and pudendal nerves supplying proprioceptive impulses from the bladder musculature, the urethra and the pelvic floor with some exteroceptive impulses from the same structures. It is considered that the centre itself may allow for a latency in this reflex by the incorporation of an intermediate neurone which can inhibit the anterior horn cells (Band, 1958). Reflex micturition will thus be abolished by destruction of the sacral segments in the conus medullaris or by division of either the motor or sensory roots of these segments in the cauda equina.

The Supraspinal Centres

The localisation of the higher centres for micturition has proved difficult because of the widespread autonomic representation which exists generally in the visceral brain, and because the results of animal experiments are not directly applicable to man. It has been shown by Pool (1954) that cortical facilitation and inhibition of micturition may originate in Brodmann's areas 6 and 8 respectively.
respectively in the frontal cortex of the human brain. Long tracts connect these higher centres with the sacral centre by descending pathways lying in the corticospinal tracts in the lateral columns of the cord and a majority of these pyramidal fibres end in the lateral rather than the anterior horns. Widespread distribution of autonomic extrapyramidal fibres occurs in the anterolateral columns (Johnson et al., 1952). According to Barrington (1933), the centrifugal and centripetal paths of micturition in the cat undergo extensive crossings in the segments from which the pelvic nerves arise but there is no significant crossing above these levels.

From animal experiments, Levin and Langworthy (1937) produced evidence that a distinct subcortical mechanism is also concerned with micturition and arises in the extrapyramidal system. In the intact subject it is probable that these basal centres are subservient to the cortical centres by short tracts connecting the cerebral cortex with the hypothalamus, midbrain and cerebellum, and forming possible routes whereby emotion may easily interfere with micturition.
THE MECHANISM OF MICTURITION

Though it is fundamental that any individual aspect of this complicated mechanism of bladder control is necessary for completely normal micturition and may be responsible for specific urological problems if deranged, it is necessary to abstract a more simple concept of the mechanism which can be reasonably applied to clinical practice and which will serve as the basis for a classification of neurogenic bladder disorders. Such a simple conception is shown graphically in Fig. 4.

As the bladder slowly fills with urine there is a limited adaptation of the bladder musculature to the concomitant stretching of its muscle fibres. This adaptation is one of tonus, and is partly intrinsic in the muscle fibres themselves, perhaps aided by the peripheral nerve centre in the wall of the viscus, but for the most part it is under the control of the sacral spinal centre to which the proprioceptive stretch stimuli are referred through the pelvic nerves. During the early stages of filling the normal contraction response of the bladder wall, as mediated through the sacral centre, is restrained at a subconscious level, but as the volume increases and active vesical contractions reach a threshold intensity, the afferent stimuli intrude upon consciousness as a desire to void /
Fig. 4.- Diagrammatical representation of the anatomical basis of the mechanism of micturition. (After Ross, 1956.)
void. This desire can be deliberately ignored if micturition is unacceptable and higher centre inhibition of the sacral centre will then allow for a further degree of bladder filling. The contractile response to this further filling becomes stronger and is accompanied by a steeper rise in bladder pressure; the desire to void will become more urgent and will eventually become constant and painful; overdistension will also lead to painful sensations transmitted via sympathetic afferents to a higher segmental level.

Voluntary restraint inhibits the spontaneous nervous discharges from the sacral centre, but there is associated contraction of the perineal musculature and direct and immediate closure of the external sphincter.

At any stage of bladder filling, even without a desire to void, willed effort to micturate removes the higher centre inhibition of the sacral centre, so that powerful co-ordinated contractions of the bladder are evoked by a motor discharge down the pelvic nerves. The contraction of the detrusor muscle leads to an involuntary reflex inhibition of the internal sphincter or bladder neck via the sympathetic efferent fibres and to reflex inhibition of the external somatic sphincter via the pudendal nerves. The movement of the urethral sphincters gives rise to the sensation that micturition is imminent, whilst the presence of urine in the posterior urethra gives rise to afferent /
afferent pudendal impulses which are appreciated as the sensation that urine is passing, but in man do not appear to reinforce the pelvic nerve stimulus to detrusor contraction though they may well take part in the reflex facilitation of the voluntary musculature of the pelvic floor and abdominal wall during micturition.

Willed brisk interruption of micturition originates physiologically with the contraction of the striated musculature of the external sphincter and pelvic floor, though such voluntary peripheral contraction is essential only for immediate cessation of the urinary stream. Volitional inhibition of the sacral segments will of itself cause a fading of detrusor activity and thereby lead to a reflex closure of the smooth muscle component of the forces of retention at the bladder neck and around the urethra; this smooth musculature is not under any direct voluntary control and a latent period precedes its contraction after the voluntary striated external sphincter has been deliberately and voluntarily controlled. It is important to stress that the striated external sphincter cannot be voluntary relaxed and that the internal sphincter will remain tonically closed as long as detrusor contraction of the bladder is inhibited. In the words of Denny-Brown and Robertson (1933): "Normal micturition is entirely secondary to active contraction of the bladder. From the direct nature of the effort of voluntary restraint and /
and the indirect nature of voluntary facilitation, voluntary control of micturition is regarded as being effected solely by variation in voluntary and subconscious inhibition of the mechanism of spontaneous reaction to distension".
THE CLASSIFICATION OF NEUROGENIC BLADDER DISORDERS

From many studies of the disturbances of micturition that have followed circumscribed lesions of the central nervous system (reviewed by McLellan in 1939) it has been found possible to classify neurogenic bladder disorders into the following broad groups:—

1. uninhibited neurogenic bladder;
2. spinal reflex neurogenic bladder;
3. autonomous neurogenic bladder;
4. atonic neurogenic bladder.

The relationship of this classification to the normal mechanism of micturition is shown in Fig. 5. The main distinguishing features of each group have been described by McLellan (1939) and Band (1945) as follows:—

Uninhibited Neurogenic Bladder

This type of derangement results from lack or loss of cerebral inhibition caused by failure of development, unilateral cerebral cortical disease or subtotal destruction of the spinal cord pathways. Micturition is imperative but voluntary; sensory pathways are intact and the bladder empties completely. From the functional point of view, this bladder shows the least variance from normal and the patient /
Fig. 5.- Types of neurogenic bladder disorder in relation to levels of the spinal cord lesion. (After Ross, 1956.)
patient presents symptoms of urgency both by day and by night, whilst in the more severe cases precipitant micturition and nocturnal enuresis may occur. The capacity of the bladder may be slightly reduced but the patient has voluntary control over the external sphincter and is continent.

Reflex Neurogenic Bladder

This type results from widespread disease of the upper motor neurones, or from destruction of the cerebral cortex, spinal cord pathways or from complete section of the cord above the sacral segments. The bladder reflex is thereby entirely cut off from cortical or supranuclear control and responds effectively and immediately to the intact spinal reflex arc which has been preserved in the sacral segments. The detrusor response to the stretch reflex is automatic, and the mechanism of micturition lies entirely within the sacral reflex arc. Cortical awareness of the condition of the bladder and the normal inhibitory influences on the spinal reflex arc thereby abolished. The reflex detrusor activity is co-ordinate so that micturition, though imperative or precipitant and without voluntary control, generally leads to complete evacuation of the bladder content. Bladder sensibility is frequently absent in this type of disorder but there may occasionally be an awareness of bladder fullness which is mediated through sympathetic afferent /
afferent fibres entering the spinal cord above the level of disease or section (see pp. 8 and 111). This sensation does not constitute a desire to void but is experienced as a lower abdominal feeling of fullness. Occasionally, peripheral autonomic disturbances may be associated with bladder fullness and it may be possible to educate individual patients to interpret either of these bizarre sensations as a precursor to the detrusor reflex.

**Autonomous Neurogenic Bladder**

This type results from interruption of both afferent and efferent fibres of the reflex arc through the parasympathetic trunks, by destruction of the sacral segments in the conus medullaris, the cauda equina, the sacral plexus or the hypogastric plexuses. The detrusor muscle is thereby dependent upon intrinsic myoneural activity and its contractions are consequently ineffective and incoordinate, though bladder tonus is high; bladder sensation is abolished and micturition is involuntary and incomplete. The inability of the intrinsic myoneural element in the vesical plexus to integrate the detrusor force may possibly be due to the unopposed and intact sympathetic innervation of the bladder in these cases. Likewise, the failure of reciprocity of the forces of expulsion and retention may be responsible for the characteristic hypertrophy of both the detrusor muscle and the internal sphincter. Micturition is inconstant /
inconstant and irregular, and even a thin urinary stream must be sustained by abdominal straining. The high tone and the incomplete emptying of the bladder lead inevitably to dilatation in the upper urinary tract with grave risk of infection.

**Atonic Neurogenic Bladder**

This bladder results from destruction of the posterior sacral roots with selective interruption of the afferent limb of the reflex arc, leaving the motor roots and efferent fibres intact. There is absence of both normal voluntary and reflex micturition, and sensation is abolished. In the early stages the bladder is hypotonic rather than atonic but the intrinsic tonus of the bladder musculature is quickly lost as the bladder becomes over-distended without projection of either proprioceptive or exteroceptive impulses to the central nervous system. Retention with overflow supervenes unless the patient is able to maintain a urinary stream deliberately and regularly by increasing the intra-abdominal pressure. The detrusor muscle of the bladder may become finely trabeculated but the bladder neck is often relaxed and the bladder outlet typically funnelled. This syndrome is found characteristically in the tabetic and in advanced cases of severe sacral spina bifida.
CLINICAL MATERIAL

Urological investigations were carried out in 115 patients in whom primary obstructive urological pathology was excluded and neurological disorder was either established or suspected as the cause of disturbed bladder function.

Eighty-nine of these patients were referred for urological opinion from departments of neurosurgery, neurology, psychiatry, orthopaedics, plastic surgery, general medicine and general surgery, and were subdivided into the following broad groups:

- Traumatic injuries of the central nervous system - 35.
- Miscellaneous - 25.
- Enuresis - 8.
- Parkinsonism - 6.
- Bilateral upper dorsal cordotomy - 5.
- Neoplastic involvement of the nervous system - 4.
- Intrinsic neurogenic bladder disturbance - 4.
- Severe spina bifida - 2.

The remaining 26 patients all suffered from Parkinsonism; their urological investigation was carried out as part of the clinical assessment of the treatment of this condition by stereotaxic surgery.
PRESCRIBED DRUGS

Anticholinergic Agents (bladder relaxants) -

Probanthine (Searle): propantheline bromide.
Monodral (Bayer): pethienate bromide.
Buscopan (Pfizer): hyoscine N-butyl bromide.

Cholinergic Agents (bladder stimulants) -

Moryl (Savory and Moore): carbamylcholine chloride.

Antispasmodics in Parkinsonism -

Artane (Lederle): trihexyphenidyl.
Cogentin (Merck, Sharp and Dohme): tropane methanesulphonate.
Disipal (Camden B.S.5930): ethylidimethylamine hydrochloride.
Kemadrin (Burroughs Wellcome): procyclidine hydrochloride.
Lysivane (May and Baker): ethopropazine hydrochloride.

Striated Muscle Relaxants -

Before embarking on a full neurological and urological assessment a careful history was taken from each patient, and the general physical examination was completed.

The evaluation of any neurological features which presented during history-taking was made by a neurologist. From the urological aspect, exact information was requested regarding bladder function in addition to the usual enquiries about frequency, pain, haematuria and urinary deposit. The incidence and the duration of symptoms of urgency, imperative micturition or precipitant micturition were related to the intensity of the desire to void, the sensation of imminent micturition and the sensation of urinary stream. Straining or hesitancy at initiation of micturition was related to the force of the stream, its continuity and to the abruptness of its cessation both with and without voluntary interruption. In this way evidence was obtained of normal or reflex micturition and of the presence and force of detrusor activity. In those cases in which reflex micturition was suspected careful enquiry was continued regarding the mechanism whereby micturition could be begun, such as the location of trigger spots and the effectiveness of abdominal percussion, compression or straining.
straining; the experience of any associated sensation of bladder fullness or autonomic disturbance was also noted. The symptom of urinary incontinence was carefully evaluated as urge incontinence, overflow incontinence, terminal dribbling, exertion incontinence or mass evacuation of the bladder.

Neurological Assessment

Expert assistance was usually requested for this aspect of the problem and in the traumatic cases was integrated with orthopaedic and radiological opinions. In this way the nature and the site of the damage to the nervous system were defined as accurately as possible, and the nature of the bladder derangement was correlated with other neurological signs as presented diagrammatically in Fig. 6.

Urological Assessment

This included routine assessment of renal function by estimation of the blood urea nitrogen levels and intravenous pyelography. Urine specimens were submitted for analysis and bacteriological examination, and the following special investigations were then undertaken:

(1) Cystometry.
(2) Ascending cystography.
(3) Cysto-urethroscopy.
(4) Ascending urethrography with sphincterometry.
Fig. 6.- Diagram showing the relation of the vertebrae to the segments and the roots of the spinal cord, together with the functions controlled by the respective segments and roots. (Hardy, 1956.)
Cystometry

Records of intravesical pressure and the changes occurring with detrusor activity have been used experimentally in animals and in man since 1882, when Mosso and Pellacani described slow fluctuations of vesical volume occurring spontaneously and in response to attempts to micturate.

The instruments and techniques most generally used in the past were described by Rose (1927), Munro (1936), Lewis (1938) and Denny-Brown and Robertson (1933). The physiological significance of recordings of pressure within a hollow muscular viscus is largely related to the particular method employed but water manometers, mercury manometers and aneroid instruments have all been applied to cystometry. In clinical practice it is important that cystometry be used simply as a source of clinical information rather than as a method of physiological enquiry so that expensive equipment is unnecessary and a very simple assembly such as is shown in Fig. 7 can provide useful information. All the recording techniques require an indwelling catheter for attachment to the manometer, and though stimulation of the bladder by the catheter can be reduced to a negligible level, continuous or incremental filling /
Fig. 7.— Simple form of double "Y" tidal irrigator and cystometer.
filling of the bladder by the retrograde route may seriously detract from the physiological value of the recordings obtained. The technique of excretory cystometry devised by Comarr (1957) approaches more to the physiological ideal but it is time-consuming and in many patients and clinics might prove impracticable. Other techniques involving isometric or injection filling of the bladder at a constant rate endow a clinical instrument with many disadvantages and in many centres cystometry has fallen into disrepute as a method of clinical investigation.

A continuous recording technique for cystometry was devised and reported by Band in 1945; it was found to be of diagnostic and prognostic value in cases of bladder dysfunction and implemented the classification of neurogenic bladder disorders already described. The apparatus was later developed into a compact and portable precision instrument, as shown in Figs. 8 and 9; this instrument was used throughout the present studies. The recording paper is calibrated to a pressure of 100 cm. H₂O and travels on the revolving drum at a speed of 0.1 mm. per second. An identical technique was used in each case, so that the records were comparable one with another and though each procedure did not represent a physiological experiment, it provided a graphic recording of the response of the individual bladder to that same stimulus which was applied to the other cases in the series under identical conditions.
**Fig. 8.** The Band recording cystometer.

**Fig. 9.** Diagrammatic representation of the Band cystometer.
Technique of Cystometry

The patient rested comfortably on a urological diagnostic table, with the knees supported in crutches and the hips flexed and slightly abducted. With full aseptic technique a lubricated two-channel (4 Ch.) red rubber catheter (overall size 15 Ch.) was passed gently into the bladder without urethral anaesthesia; the patient's emotional reaction to this procedure, any complaint of pain or other sensation and any difficulty in instrumentation were noted. A specimen of the first urine drained down the catheter was sent for bacteriological examination, and where it had been possible for the patient to void immediately before the examination was begun, the volume of urine which was drained from the bladder was measured and recorded as the "residual urine". Whilst the bladder was emptying, the glass filling flask was adjusted to a height of 50 cm. above the symphysis pubis which was on the same horizontal level as the base of the recording instrument. The sterile connecting tubing was then freely irrigated to remove all air bubbles and was then carefully clamped before being divided into inlet and outlet circuits and joined to the limbs of the two-way catheter. The control taps on the cystometer allowed for the irrigation of the instrument with antiseptic fluid before it was connected to the patient and for the adjustment of the recording pen to a true /
true zero with the aneroid open to atmosphere. The glass reservoir was then replenished with a sterile $12\frac{1}{2}$ per cent aqueous solution of sodium iodide; the lengths of tubing connecting the flask to the inlet limb of the catheter and the outlet limb to the cystometer were clipped to the drappings of the patient so that dependent loops were avoided and possible siphonage artefact eliminated. At this stage it was usually found that the patient had accustomed himself to his position and was feeling assured that the procedure was not painful; the opportunity was then taken to explain to him that the bladder would be gently filled, and to ask him to mention any feeling of desire to void as soon as it developed, and to indicate its intensity whilst inhibiting voiding as far as possible. The onset of pain during the procedure was likewise noted. After these preliminaries both connecting tubes were unclamped synchronously and any immediate rise in recorded pressure was noted as the resting pressure. Filling then proceeded and all sensations were recorded as they developed and as indicated by the patient. When any sensation associated with the procedure became sufficiently intense as to be unpleasant, the patient was then instructed to void. Though the resultant rise in bladder pressure, if any, was designated on the tracing as a "voluntary contraction", careful observation of the patient enabled some distinction to be made as to how much of this terminal rise in pressure was /
was due to contraction of the bladder as distinct from abdominal or diaphragmatic straining. The tubing leading from the filling flask to the inlet limb of the catheter was not controlled by a screw clip and did not incorporate a drip chamber. It was found that with the filling flask at the height already indicated, the rate of bladder filling though not unduly fast was not sufficiently slow as to prolong the investigation so that it became tedious or unnecessarily unpleasant; this was particularly important in view of the fact that so many of these patients were seriously disabled and emotionally labile. The omission of the screw clip and the drip chamber removed the temptation to adjust the rate of filling and made it more certain that consecutive recordings in the same or different patients were the result of identical stretch stimuli of the bladder. Moreover, at the time of "voluntary contraction" or of strong uninhibited contractions free reflux of fluid into the filling flask was thus available, so that the tracing obtained would be more representative of bladder activity during unobserved micturition.

The following abbreviations were used to note the sequence of events on the tracings as they occurred during cystometry -

D.V. - Desire to void.
F.D.V. - First desire to void.
S.D.V. - Strong desire to void.
F.F. /
F.F. - Feeling of fullness.
V.C. - Voluntary contraction.
B. - Deep breath.
C. - Cough.
S. - Peripheral muscular spasm.
I.V.C. - Involuntary contraction.

Reflux refers to reflux of fluid into the filling flask from the bladder.

Bypass refers to voiding of fluid from the bladder around the catheter.

The Normal Cystometrogram

In a few patients who were subsequently found to have neither urological nor neurological disease, cystometrograms obtained by the above technique showed no essential differences from the normal tracings obtained by Band (1945) in a larger series of volunteer controls. His description of the normal cystometrogram was as follows -

"In the normal individual a considerable allowance must be made for variations in vesical sensibility and detrusor tone. The stretch reflex may become apparent as a desire to void earlier or later in relation to bladder capacity. As a rule bladder tone rises gradually from 5 to 10 cm. of water pressure until an average bladder capacity of 300 c.c. has been obtained, when the pressure may rise to 15 or 20 cm. of water. Thereafter, with the desire to void, detrusor contractions appear which may produce /
produce an intravesical pressure of 40 or 60 cm. of water.
In the normal individual, early sensations of the desire
to void at capacities of 50 to 100 c.c. which may produce
contractions are damped down or voluntarily inhibited. In
an excitable subject, the entire tracing may show a shift
to the left and the cystometrograph exhibit a degree of
hypertonus. Conversely, the tone may remain exceptionally
low throughout the experiment, and the accommodation of the
bladder prove so ample that large capacities of 500 to
600 c.c. do not give rise to more than the low normal tones
of 10 to 15 cm. of water, and the desire to void remains in
abeyance. In such a cystometrogram the shift is to the
right, and the curve resembles that of an atonic neurogenic
bladder. Nevertheless, the desire to void and the
subsequent contraction of the detrusor muscle follow one
another in proper sequence as evidence of the integrity of
the bladder reflex and the cystometrograph is normal in
type. When there is hypertonus and a tendency to early
detrusor contraction, I have placed reliance on the ability
of the patient to exert voluntary inhibition, and when there
is hypotonus I have considered that voluntary effort to bring
about detrusor activity, which initiated a series of
contractions, was evidence of normal bladder function".

A normal cystometrogram is shown in Fig. 10.

From cystometry much valuable information can be
obtained. A comparison of the measured residual urine with
bladder capacity forms an index of the degree of bladder
decompensation /
Fig. 10. - Normal cystometrogram.
decompensation, and reflects the function and efficiency of the organ as a whole. In this context, it is considered that decompensation is present when the residual urine is greater than 10 or 15 per cent of the capacity. The cystometrogram indicates the relationship between bladder sensation and detrusor activity; it gives an overall picture of bladder tonus and indicates with reasonable accuracy the summated detrusor force available for micturition whilst the overall pattern of the tracing allows for classification of the type of neurogenic disorder. Typical tracings from uninhibited, spinal reflex, autonomous and atonic types of neurogenic bladder disorder are shown in Figs. 11, 12, 13 and 14.

Ascending Cystography

The use of radio-opaque solution as the filling fluid for cystometry allows for cystography to be carried out on the diagnostic table without further urethral instrumentation or handling of the patient. Furthermore, it makes it possible for radiographs to be taken during or immediately after cystometry, so that the presence or absence of ureteric reflux can be correlated with the intravesical pressure. In the present series it was customary at the end of cystometry to allow further filling of the bladder with the radio-opaque fluid until a reasonable desire to void was again elicited, and a postero-anterior radiograph of the renal tract was then taken.
Fig. 11.- Cystometrogram of uninhibited neurogenic bladder.

Fig. 12.- Cystometrogram of spinal reflex neurogenic bladder.

Fig. 13.- Cystometrogram of autonomous neurogenic bladder.
Fig. 14. - Cystometrogram of atomic neurogenic bladder: (a) early; (b) late.
The patient was then rotated 45 degrees into the right oblique position, with the right hip flexed as far as possible and with the left hip fully extended. The X-ray tube was then centred over the symphysis pubis and the patient was requested to micturate. If a urinary stream was produced, the exposure of this oblique voiding film was postponed until the force of the stream was full or was just beginning to decline. In this way it was hoped to obtain either an adequate urethrogram or information as to which part of the sphincteric mechanism offered the highest resistance to urine flow or was responsible for the initial interruption of the urinary stream. When it became apparent that the patient was unable to void, he was instructed to strain as far as possible in an endeavour to produce a urinary stream, and the oblique exposure was made at the time of maximum exertion; this cystogram was then labelled "straining" as opposed to "voiding". Post-evacuation films were not taken routinely because it was considered that a residuum of urine after micturition under these circumstances could have no reliable significance.

The cystograms were subsequently compared with plain radiographs of the bladder region obtained as a preliminary to intravenous pyelography, and the following points were noted -

(1) The presence of calcification or calculi in the bladder and the condition of the bony architecture of the pelvis and lumbo-sacral spine.

(2)/
(2) The size, shape and contour of the bladder.
(3) The presence of ureteric reflux on either side and the degree of concomitant hydro-ureter or hydronephrosis.
(4) The presence of detrusor tonus as indicated by fine irregularity of the bladder vault.
(5) The presence of trabeculation, sacculation or diverticulum formation.
(6) The contour, width and function of the bladder neck.
(7) The calibre of the posterior urethra with particular reference to the level of the external urethral sphincter and the presence in male patients of reflux into the ejaculatory ducts.
(8) The anterior urethrogram and the localisation of any diverticulum formation or stricture.

Apart from excluding many of the complications of neurogenic bladder disorder, cystograms taken by this technique were valuable in providing information about the state of detrusor tonus, in localising increased urethral resistance to the bladder neck or external urethral sphincter, and in demonstrating whether ureteric reflux occurred during the filling or the voiding phase. A series of normal cystograms are shown in Figs. 15, 16, 17 and 18.

Cysto-urethroscopy /
Fig. 15. - P.A. view of normal male cystogram.

Fig. 16. - Right oblique voiding view of normal male cystogram.
Fig. 17.- P.A. view of normal female cystogram.

Fig. 18.- Right oblique voiding view of normal female cystogram.
Cysto-urethroscopy

This investigation was essential for the proper assessment of any patient who had had haematuria, but it was also desirable for a more accurate appraisal of the general condition of the bladder regarding infection, sacculuation, trabeculation and diverticulum formation than could be obtained from cystography. It gave specific information about the condition of the ureteric orifices and the presence of hypertrophy or contracture of the bladder neck to provide a visual confirmation of any proximal site of increased urethral resistance which could not be obtained with certainty from cystography. In male patients it revealed the extent of any concurrent prostatic encroachment and was sometimes necessary to allow for retrograde pyelography when the intravenous route had failed to outline the upper urinary tract adequately.

Ascending Urethrography with Sphincterometry

In selected cases an ascending urethrogram formed a useful supplement to the voiding cystogram and allowed for the resistance of the sphincteric mechanism to be measured. The method used in this series was described by Band (1956), and the necessary instruments are shown in Fig. 19. The two-way catheter was passed into the anterior urethra, and the /
Fig. 19.- Apparatus for ascending urethrography and sphincterometry.
the external urethral meatus around the catheter was occluded by the rubber urethral nozzle. One limb of the catheter was connected to a Wardill syringe containing 20 per cent "Hypaque" solution or a similar radio-opaque medium, whilst the other limb was connected through an antiseptic trap to a clock manometer with a luminous dial, as described by Yeates (1954). With the patient on an X-ray table the ascent of the opaque medium was observed on the fluorescent screen, and at the precise moment that the opaque agent was seen to enter the posterior urethra the pressure was read on the manometer and a radiograph was taken (Fig. 20). In the normal conscious individual there appeared to be wide variation in the tone of the sphincteric mechanism, but the average tone has been estimated at about 40 or 50 cm. of water. This investigation has been of most value in those cases of neurogenic bladder disorder in which the urethra was insensitive because it was otherwise accompanied by discomfort and even distress, with deliberate contraction of the sphincteric mechanism so that the recordings were unreliable. In suitable neurogenic cases, or with a fully co-operative patient, this investigation allowed for the difference between the voiding pressure as obtained by cystometry, and the sphincteric resistance as observed during sphincterometry, to be expressed in terms of centimetres of water.
Fig. 20. - Ascending male urethrogram during sphincterometry.
DISTURBANCES OF THE HIGHER CENTRE CONTROL OF MICTURITION

Urinary symptoms due to abnormal bladder function commonly feature in the response to stress of a normal personality and are frequently included in the symptom complex of definite personality disorders, psychoneurosis or the psychotic state. Such functional symptoms must obviously be distinguished carefully from those due to organic disease in the urinary tract or in the central nervous system. The ease with which emotion may interfere with micturition emphasises the caution which is required for the correct interpretation of the cystometrogram as a clinical method for the exclusion of organic pathology; the overall pattern of the normal tracing may vary considerably, though it should always contain definite evidence that the mechanism for normal micturition is intact. Accordingly, functional disorders of the bladder are included in this thesis because they feature so prominently in the differential diagnosis of neurogenic lesions.

The Effect of Emotion on Vesical Function

Emotional tension may produce urinary symptoms by its effect upon the endocrine and autonomic nervous systems to produce either sudden or prolonged changes in the content of urine excretion or in the sensitivity of the bladder plexus.
In individual cases it is usually easy to decide whether the symptoms are in normal proportion to the degree of emotional upset or have become so marked as to form a psychosomatic syndrome. Such exaggeration is most commonly encountered in female patients in whom the localisation of pain to the bladder and urethra, in addition to severe frequency of urination with urgency, has allowed "cystalgia" to emerge as a clinical entity. In an analysis of a series of such patients Chertok et al. (1953) noted the frequent absence of any organic illness and commented that where such illness existed it did not explain the severity of the symptoms. They further noted a coincidence between the onset of the urinary complaints and the presence of a crisis or conflict situation in the patient's life. Significantly, they found that the pain was usually of an unusual character, and of a unique expressive value, whilst either local or surgical treatment of the condition usually led to aggravation of the symptoms. These points are well illustrated in the following case.

**Case 1.** This 38-year-old, unmarried woman was pleasant and co-operative, but of rather inadequate personality. For some years she had complained of intermittent headache, vertigo and syncope, for which no organic cause could be found. Urinary symptoms first became prominent at the age of 36 years following hysterectomy, which had been carried out to relieve low back pain and menorrhagia. During mobilisation of the uterus, which was adherent to a large ovarian cyst, the bladder had been inadvertently opened through the posterior wall, but simple immediate closure was effected. Following operation she complained of intense frequency of micturition by day and night.
night. Physical examination was entirely negative and intravenous pyelography revealed no abnormality in the upper urinary tract. At cystoscopy under general anaesthesia, the bladder capacity was found to be reduced to 200 c.c., and though there was no trabeculation of the detrusor component or contracture of the bladder neck, it was noted that the mucosal lining was congested; retrograde pyelograms were normal. In view of the absence of any abnormality on urinalysis and urine culture it was accordingly suspected that this patient might have early interstitial cystitis. During three weeks of intensive treatment with Buscopan, Monodral, Probanthine and Prednisolone there was no clinical evidence that any relaxation of the bladder wall had been obtained, or that the bladder capacity was increasing. She continued to complain of suprapubic pain with a constant desire to void and intense diurnal and nocturnal frequency of micturition; though she remained completely continent, the volume of urine voided always varied between 30 and 50 c.c. At this stage further investigations were undertaken as follows:

Cystometrogram (Fig. 21).- Residual urine nil; resting pressure 5 cm. of water. The bladder pressure rose steadily with filling and showed slight intrinsic activity up to a pressure of 40 cm. of water at a capacity of 425 c.c. Throughout the recording a constant desire to void was experienced but definite suprapubic discomfort was superimposed after 75 c.c. of filling and at a pressure of 10 cm. of water. This unpleasant experience became exaggerated at a pressure of 20 cm. of water after 300 c.c. of filling. At maximal filling a voluntary contraction produced a peak pressure of 90 cm. of water with bypassing of the catheter.

Cystograms.- The P.A. film (Fig. 22) showed a large capacity bladder of regular shape and smooth contour without ureteric reflux. The right oblique voiding view showed adequate relaxation of the bladder neck and a normal urethrogram.

Repeat Cystoscopy.- Under general anaesthesia a further inspection of the bladder showed no intrinsic abnormality with a filling capacity of 300 c.c.

Comment.- Despite extensive medication with bladder relaxants and cystoscopic evidence of improvement of bladder capacity with the resolution of mucosal congestion, this patient's symptoms were completely unchanged. The cystometrogram was within normal limits and with good bladder tone. There was accordingly no evidence either of serious organic bladder disease or of support for the contention/
Fig. 21. - Case 1: cystometrogram.

Fig. 22. - Case 1: P.A. cystogram.
contention that the peripheral nerve supply of the bladder had been interrupted at the time of hysterectomy. The persistence of symptoms despite clinical evidence for a physical improvement in bladder function was thus probably psychogenic.

Occasionally, hypotonia is the essential feature of the bladder response to emotional factors and may culminate in urinary retention (Straub et al., 1949); it is accompanied by feelings of being overwhelmed or by hysterical reactions. Such patients may be extremely skilful in concealing their psychoneurotic tendencies from a urologist, but cannot easily withhold evidence of an intact mechanism for micturition from the cystometer if this investigation be completely novel to them, as in the following case.

Case 2. - A 27-year-old, unmarried nurse complained of severe dysmenorrhea, for which dilatation and cautery of the cervix had been carried out at the age of 22. Following this procedure she complained of backache and was found to have a urinary infection. During the succeeding five years she had three attacks of right-sided loin pain with variable frequency of micturition but with no haematuria. A persistent coliform infection eventually responded to Cycloserine therapy, and intravenous pyelography showed no evidence of abnormality in the upper urinary tract. She was admitted to hospital during the last occasion of recurrence of symptoms and developed sudden retention of urine when the Cycloserine therapy was begun. Occasional catheterisation and daily injections of Moryl were required to relieve the retention. She remarked that such treatment had not been necessary some years previously when urinary retention had occurred during the stress of qualifying examinations. Physical examination was entirely negative. At the time of urological examination she had not voided urine for eighteen hours, but admitted to only a mild desire to void.

Cystometrogram /
Cystometrogram (Fig. 23).—A two-way catheter was passed without difficulty and without undue reaction and drained a residuum of 550 c.c. of sterile urine. The resting bladder pressure was negligible and the bladder accepted 60 c.c. of fluid before the pressure rose even to 5 cm. of water. After 200 c.c. of filling a first desire to void was experienced with definite intrinsic activity raising the pressure to 10 cm. of water. A further slow rise in bladder pressure occurred to 15 cm. of water as filling progressed to 675 c.c. though a strong desire to void was experienced after 650 c.c. of filling. Voluntary contraction with straining at maximal filling produced a peak pressure of 32 cm. of water.

Cystograms.—The P.A. view outlined a large capacity bladder of smooth contour without ureteric reflux. The right oblique straining view (Fig. 24) showed the bladder neck to be closed and there was no evidence of detrusor activity or ureteric reflux.

Cystoscopy.—There was fine trabeculation of the vault and base of the bladder with very slight prominence of the posterior lip of the bladder neck. Bimanual examination by rectal palpation revealed no abnormality.

Comment.—Cystometry showed that in this patient the large capacity bladder had an intact reflex arc and projected proprioceptive sensory stimuli into consciousness at a normal stage of bladder filling. Cystoscopy confirmed the absence of any detrusor hypertrophy such as would have occurred in the presence of organic obstruction at the outlet of the bladder or in the urethra. It was almost certain that neurogenic or organic abnormality in the lower urinary tract could be excluded, and it was considered probable that her urinary retention was psychogenic.

Further questioning of this patient raised a strong suspicion of psycho-sexual disturbance and perhaps previous concealed pregnancy. When she was informed that a psychiatric opinion was to be sought, urinary retention spontaneously resolved and she was discharged home.

The cystometrogram of a female patient who presented very similar features to Case 2 is shown in Fig. 25; in this patient the threat of psychiatric assistance also led to an immediate resolution of the urological problem.

In /
Fig. 23. - Case 2: cystometrogram.

Fig. 24. - Case 2: R.O. cystogram.
Fig. 25.— Cystometrogram in patient with psychogenic urinary retention.
In their series of cases Straub et al. (1949) found that the more common psychological disturbances, such as general tension, anxiety and resentment were associated with hypertonicity of the bladder, presenting with symptoms of frequency, urgency and dysuria with some reduction of bladder capacity. In such circumstances the absence of urinary symptoms by night, a negative physical examination, normal urinalysis and normal pyelography and cystography by the excretion method constitute adequate clinical evidence that the urinary symptoms are of psychological origin. The occurrence of nocturnal enuresis in such patients demands that further investigations should be undertaken, because they are to be distinguished from the general group of persistent enuretics, and are frequently found to have either neurological or urological disease, as in the following case.

**Case 3**—Throughout his life this 40-year-old man had had urgency of micturition with urge incontinence, but without pain or haematuria or diminution of the urinary stream. Following partial gastrectomy for peptic ulceration at the age of 31 years, he began to complain of nocturnal frequency of micturition (up to six times each night) and was enuretic at least once weekly. There was no associated family history of urinary disturbance and he had shown no response to the restriction of his evening fluid intake or to various pills prescribed by his medical practitioner. He presented as a pleasant, co-operative but nervous individual and on physical examination was found to have a penile hypospadias as the only abnormality. Wassermann reaction and syphilitic flocculation reaction were both negative. His urine contained no abnormal constituents and was sterile on culture; intravenous pyelography outlined a normal upper urinary tract.

*Cystometrogram* /
Cystometrogram (Fig. 26).—Two-way catheter passed without difficulty and a residuum of 180 c.c. of sterile urine was withdrawn. The resting bladder pressure was 8 cm. of water, but after 250 c.c. of filling to a pressure of 30 cm. of water, there was a strong intrinsic bladder contraction which raised the pressure to 50 cm. of water. This tonic activity continued and produced reflux into the filling flask and bypassing of the filling catheter.

Cystograms.—The P.A. view (Fig. 27) showed that the bladder was trabeculated and sacculated whilst reflux of dye had occurred into the lower spindle of the left ureter. The right oblique straining view confirmed the presence of saculation but the bladder neck remained closed.

Cystoscopy.—Trabeculation and sacculcation of the bladder base were obvious and there was oedema of the bladder neck which made it difficult to assess whether any true contracture was present.

Ascending Urethrography with Sphincterometry.—The ascending urethrogram outlined dilatation of the distal urethra and suggested that there was resistance to ascending flow at the level of the external sphincter. However the sphincteric resistance was 50 cm. of water, and thus lay within the normal range.

Posterior Urethroscopy.—When the posterior urethra and bladder neck were viewed through the direct vision system of a Reed-Nesbit resectoscope it was apparent that the bladder neck, though smooth, was uniformly contracted. Five productive cuts were made so that the bladder neck was resected from 4 to 8 o'clock of its perimeter.

Progress.—Following transurethral resection, his convalescence was uneventful, and he quickly regained full urinary control. Though his residual urine was reduced to within normal limits, he still complained of moderate frequency of micturition by day and at night.

After discharge from hospital there was more rapid improvement aided by medication with Nonodral (12 mg. orally three times daily). When seen one year later, there had been no recurrence of the enuresis, and the nocturnal frequency of micturition had completely subsided.
Fig. 26. - Case 3: cystometrogram.

Fig. 27. - Case 3: P.A. cystogram.
Comment.- It is interesting to note that though this patient’s history of urinary disturbance could have justified a diagnosis of uninhibited neurogenic bladder, complete urological assessment indicated that though his bladder was hypertonic, the essential mechanism was that of detrusor hypertrophy secondary to bladder neck contracture.

This condition is referred to as congenital bladder neck obstruction and may present at any age and in either sex. It has been attributed to "achalasia" or neuromuscular inco-ordination of the bladder neck and to inflammation with squamous metaplasia of the adjacent mucous membrane and fibrous or cellular infiltration of the bladder neck itself (Mitchell and Andrews, 1953). It must be suspected and carefully excluded in all cases of uninhibited neurogenic bladder derangement, and particularly in cases of nocturnal enuresis when the patient has been known to have established normal urinary control during early life and to have become enuretic at a later age.

**Nocturnal Enuresis**

Before this term can be used to describe a disease rather than a symptom, it is necessary that in the individual cases organic neurological or urological pathology be excluded.

A selected series of such cases was studied by Stalker and Band in 1946. In their patients enuresis had persisted into adolescence and adult life, and from their study they were able to conclude that the enuresis syndrome is /
is not purely emotional in origin but has important physical components. They considered that the total personality was involved in its constitutional neurophysiological and emotional aspects.

In the present series eight similar cases were examined; five of them were males and three were females; their ages were between 16 and 28 years, and in each of them the enuresis dated from infancy. Seven of these patients had diurnal symptoms of frequency of micturition with urgency, with occasional urge incontinence in addition to their enuresis, and their histories alone justified a diagnosis of uninhibited neurogenic bladder. However, it was found that only three of these seven patients produced cystometrograms of the typical uninhibited type, and one of these is shown in Fig. 11. Of the remaining four, two had normal tracings (Fig. 28) and two had normal tracings with raised tonus (Fig. 29). The eighth patient was a male suffering from schizophrenia and his enuresis was not accompanied by diurnal symptoms; his cystometrogram was of the tonic normal variety. Each of the other four male patients had been brought up in an institution for the care of orphans and unwanted children, whilst of the females one was epileptic and another had a very unhappy home with a difficult father; the third female patient is described at length as Case 4.
Fig. 28. - Normal cystometrogram in enuresis.

Fig. 29. - Normal cystometrogram with raised tone of in enuresis.
In each of these cases it was thus possible to regard the enuresis as a reflection of an unbalanced personality; this concept has been repeatedly asserted by Michaels (1938, 1940, 1941, 1943), who noted the highest incidence of enuresis to occur amongst delinquents and psychopaths. It must be remembered that the enuresis itself may constitute an abnormal psychological stimulus which may be responsible for the perpetuation of the condition into adult life or form a resistant barrier to the success of treatment in the early stages. The type of bladder revealed by cystometry in this condition may have an important bearing upon the method and upon the success of treatment. It might be considered that the uninhibited neurogenic bladder in such patients represents an arrested stage of development from the physiologically normal spinal reflex bladder of the baby, and such arrested development might be related to traumatic events in mental development as elicited from these patients' histories. In the present series though an uninhibited type of bladder was sometimes suggested by the presence of diurnal urinary symptoms, its presence was not always confirmed by cystometry. In such patients attempts to re-educate by conditioning so that normal upper centre control of micturition subsequently prevails, may possibly fail, and it is suggested that patients with enuresis who are found to have a normal cystometrogram are more likely to be helped by more specialised /
specialised psychiatric treatment than by simple bladder drill and conditioning, as described below. Each of the above eight patients showed an early response to the following regime -

They were instructed to refrain from taking fluids after 6 p.m. in the evening, to micturate immediately before retiring and again on at least one occasion during the night when roused by an alarum clock. The time of wakening was adjusted according to the observed time at which enuresis most frequently occurred during a period of trial and error. In addition to this bladder drill, bladder relaxants were prescribed as either Monodral 25 mg. three times daily or Probanthine 15 mg. three times daily. When diurnal urinary symptoms were absent it was possible to restrict this medication to an evening dose which could be increased according to the patient's tolerance.

Though the response to this regime was early and satisfactory there was a very high incidence of relapse on treatment. The patients who were most responsive were those who were more intelligent and more co-operative but in none of them was it practicable to remove those factors which were possibly responsible for their disturbed psychological background. It was apparent that the type of cystometrogram, whether uninhibited, tonic normal or normal bore no relationship to the response to treatment, but the effect of the drug therapy requires further comment.

In /
In 1930 Parkhurst reported the successful use of ephedrine in the treatment of enuresis, but later reports by Stockwell and Smith (1940) did not confirm its therapeutic value. The use of sympathomimetic drugs in enuresis has some empirical basis when it is remembered that asthmatics taking ephedrine may not be able to urinate for many hours (Brookfield, 1937), but in any review of the neurophysiology of micturition there is little evidence to indicate that the sympathetic motor supply to the bladder is inhibitory to the detrusor musculature. Accordingly, the "bladder relaxants" with an atropine-like action such as Probanthine and Monodral might be expected to be more regularly efficacious and have been found to reduce tonic activity of the bladder musculature in neurogenic bladder disorders of the uninhibited (Penno and Dodson, 1953), the spinal reflex (Talbot, 1956) and the autonomous types (Swenson et al., 1956) due to definite neurological disease. However, in enuresis Leys (1956) found that Probanthine was of little use, and Mayon-White (1956) considered that any observed improvement in bed-wetting following the administration of this drug was due to some factor other than the Probanthine itself. It is thus apparent that from the clinical response of enuretics to the administration of anticholinergic drugs no deductions can be made which are relevant to any understanding of the neurophysiology of micturition. The present small series confirms the finding/
finding of Stalker and Band (1946) that persistent enuresis is frequently associated with an uninhibited type of neurogenic bladder as found on cystometry, but the complex nature of the disease, for such it is, frequently defies clinical analysis and symptoms may not correlate with the findings on cystometry and may persist or recur despite an established reduction in bladder tonus. The difficulties are well illustrated in Case 4.

Case 4.—This 28-year-old woman had been enuretic since infancy. She was of quiet disposition but intelligent and co-operative; there was no family history of enuresis but the patient was a heavy sleeper. Her enuresis had not responded to treatment with ephedrine and amphetamine. A psychiatrist could not find evidence of psychogenic instability and referred her for urological advice after her marriage, when the bed-wetting became a serious issue between herself and her husband.

Physical examination, urinalysis and urine culture revealed no abnormality.

Cystometrogram (Fig. 30).—A two-way catheter passed without difficulty. Residual urine nil; resting pressure 15 cm. of water. After 25 c.c. of filling intrinsic activity raised the bladder pressure to 26 cm. of water, and irregular intrinsic contractions occurred and were accompanied by a constant desire to void and a definite unpleasant feeling of fullness after 155 c.c. of filling. After 175 c.c. and at a pressure of 33 cm. of water a strong uninhibited contraction produced a peak pressure of 82 cm. of water and the catheter was extruded.

Cystoscopy showed that the mucosal lining of this small tonic bladder was normal, but marked detrusor activity presented as trabeculation at low filling. The bladder neck was contracted and both ureteric orifices were normally situated and were catheterised without difficulty to 30 cm.

Retrograde Pyelograms showed no abnormality in the upper urinary tract.

Bimanual /
Fig. 39. - Case 4: cystometrogram.
Bimanual pelvic examination was negative.

**Progress.**—This patient was instructed in the regime as outlined (p. 57) and Probanthine was prescribed (15 mg. twice daily, orally with an evening dose of 30 mg.) The initial response was not complete but was sufficient for the patient to be prognostically encouraged. A normal full-term pregnancy was later held responsible for serious relapse, but after the puerperium a return to the regime and the bladder relaxants had only a transient effect. It transpired that her husband was most unco-operative and showed particular objection to being wakened by an alarm clock whilst his wife was enuretic in a deep sleep, regardless of a nightly dose of amphetamine sulphate (25 mg.) in addition to the Probanthine tablets. She was accordingly re-admitted to hospital for re-assessment.

**Repeat Cystometrogram (Fig. 31).**—Residual urine nil; resting bladder pressure nil. The pressure rose to 5 cm. of water after 50 c.c. of filling and the first desire to void was experienced after 125 c.c. of filling at the same pressure. Slight intrinsic activity occurred after 250 c.c. of filling at a pressure of 8 cm. of water and was accompanied by a strong desire to void. The pressure then slowly rose to 10 cm. of water with 400 c.c. of filling, after which a voluntary contraction produced a peak pressure of 85 cm. of water.

**Cystograms.**—The F.A. view (Fig. 32) and the straining view showed a large capacity bladder with smooth contour and regular shape without ureteric reflux.

**Cystoscopy.**—The normal capacity bladder presented evidence of catarrhal trigonitis, but there was no evidence of trabeculation of the bladder vault or contracture of the bladder neck.

**Progress.**—Following these investigations all bladder relaxants were discontinued and from a period of observation in hospital it was apparent that there was no organic derangement of micturition and that enuresis was occurring shortly after sleep began. In view of the increasing domestic difficulties, this patient was recommended for supportive psychiatric treatment.

**Comment.**—In this enuretic patient an uninhibited neurogenic bladder responded to anticholinergic drugs with a considerable loss of tonus and a concurrent increase in capacity, but her enuresis persisted and was still accompanied by diurnal symptoms of frequency, urgency of micturition...
Fig. 31.- Case 4: repeat cystometrogram after Probanthine medication.

Fig. 32.- Case 4: P.A. cystogram.
micturition and occasional urge incontinence. It was apparent that the enuresis itself was causing psychological trauma by way of marital upset.

A male patient with a similar clinical history was dramatically cured when his psychiatrist prescribed a portable urinal.

**Neurogenic Bladder Disorders in Parkinsonism**

There is not yet universal agreement about the essential lesion in Parkinsonism. According to Walshe (1947) there are always degenerative changes of a senile order in the cells and the fibre tracts of the corpus striatum and substantia nigra. In the affected areas there is considerable loss or alteration of ganglion cells, and though neither generalised nor local cerebral atheromatous changes are characteristic of this disease, it is probable that it represents a local incidence in the brain of what is essentially equivalent to a senile degeneration. However, a similar condition may present in the younger age groups and may follow carbon monoxide poisoning, head injury, the inflammatory lesions of epidemic encephalitis and, less rarely, those of vascular degeneration and of neurosyphilis. It is probable that paralysis agitans owes its clinical individuality to the situation rather than to the nature of the disease process. In Parkinsonism a combination of tremor and rigidity with progressive /
progressive loss of power in the limbs are characteristic features.

After the onset of the syndrome, the patient's mental faculties may remain unimpaired for many years but there may be eventual slight deterioration which is manifest as difficulty in sustaining thought and conversation. The fixity of facial expression which is a feature of the condition, tends to obscure the patient's emotional reaction to his disability or to his environment, but it is generally recognised that fatigue, emotional disturbance, physical discomfort or pain, or the knowledge that he is being observed will lead to an aggravation of the characteristic tremor.

In a sensitive but otherwise normal subject, many of these factors will lead to disturbances of bladder function, but in the standard textbook descriptions of Parkinsonism, reference is not usually made to any concomitant urinary symptoms. However, in 1907 Minkowski noted occasional tonic incontinence in Parkinsonism, and in 1917 Gaulk and Greditzer mentioned that relaxation of the bladder sphincters may occur in paralysis agitans. Schwarz (1926) reported that dysuria was associated with injury to the corpus striatum, whilst Lichtenstern and Marburg (1933) found that retention of urine, associated with hypertonicity of the external urethral sphincter, sometimes followed injury to the globus pallidus. In 1938 Langworthy reported /
reported that urinary symptoms were present in 31 of 211 patients with Parkinsonism. Cystometry was carried out in 17 cases of this reported series using the method described by Lewis et al. (1935) with filling increments of 50 c.c. Langworthy noted that the resting pressure was usually high and the bladder capacity small. He found that the external sphincter often offered unusual resistance to the passage of the catheter, and considered that the increased height of the final contraction pressure recorded from these bladders could be related to the hypertonicity of the external urethral sphincter.

In the present series the patients had been admitted to hospital for consideration of surgical treatment of Parkinsonism, as reviewed and described by Gillingham and his colleagues in 1960. According to Gillingham (1960), serious disorders of bladder function do not feature prominently in the neurosurgical management of Parkinsonism, and it was the impression that any persistent urinary symptoms were associated with definite urological disease, such as calculus formation or benign prostatic hypertrophy. However, three female patients were referred for urological opinion following stereotaxic surgical treatment of this condition. Two of these were mentally difficult and rather unco-operative and at cystometry were found to be in a state of chronic urinary retention associated with large insensitive atonic bladders. There was no certain evidence that /
that either their mental attitudes or their bladder derangements were simply post-operative complications. These findings were in sharp contrast to the third patient who had complained of urgency and frequency of micturition for one year prior to stereotaxic surgery for Parkinsonism of 10 years' duration. Following operation she continued to complain of urgency of micturition with occasional incontinence and cystometry showed that she had a typical uninhibited neurogenic bladder without evidence of organic urological disease. Accordingly it was thought desirable that cystometry and cystography be included in the pre- and post-operative investigations of these patients in addition to the psychometry and full neurological assessment already carried out.

**Pre-operative Urological Findings in Parkinsonism**

Twenty-nine patients were available for urological review - 18 of these were male and 11 were female - but by coincidence, and regardless of sex, 18 had no urinary symptoms whilst some disturbance of bladder function presented in 11.

Eight patients had complained of frequency of micturition generally accompanied by urgency of micturition and occasionally by urge incontinence. Four of these 8 patients were found, on cystometry, to have uninhibited types of neurogenic bladder; in one the tracing was hypotonic /
hypotonic and in the remaining 3 the tracings were normal. Two patients presented with symptoms of hesitancy and difficulty of micturition but their cystometrograms were within the normal range. A third patient with these symptoms had experienced intermittent urinary retention and he was found to have a typical uninhibited neurogenic bladder.

When urinalysis, urine culture or cystography or the symptoms themselves raised any suspicion of organic urological disease then cystourethroscopy and pyelography were carried out. One of the patients with both symptoms and a normal cystometrogram was then found to have calculi in both kidneys and in his left ureter, and underwent urological surgical treatment prior to neurosurgical treatment. In the remaining patients with symptoms it was considered that organic urological disease had been excluded with reasonable certainty.

Of the 18 patients who were free from urinary symptoms, 11 had normal findings on cystometry, 2 had uninhibited types of neurogenic bladder, 2 had hypotonia of the bladder, one had an atonic bladder, one presented an atypical tracing, whilst in the eighteenth patient the catheter was obstructed at the level of the external sphincter and the investigation could not be completed.

Uninhibited /
Uninhibited Neurogenic Bladder Disorders in Parkinsonism

It was thus found that 7 out of 28 patients (25 per cent) presented uninhibited types of neurogenic bladder disturbance on cystometry, and in 5 of these 7 patients urinary symptoms were present. The duration of such symptoms varied from a few months to 5 years, but bore no relationship to the sex, age or duration of the syndrome or to the presence of either tremor or rigidity as its most obvious manifestation. The distribution of the cystometric findings according to age and duration of Parkinsonism as found in 21 cases in which these features were unequivocal is shown in Fig. 33. It was considered reasonable to exclude emotional stress as the cause of the marked elevation of bladder tonus in this group of cases, largely because during psychometry any emotional instability should have become obvious and would have been noted. Furthermore, it was explained to these patients that the urological investigations were being carried out as part of their general assessment and were thus to their advantage, though they were given the opportunity to refuse to undergo these urological procedures; any patients who became uncooperative subsequently were deliberately excluded from this series for the purpose of follow-up. The presence of urinary symptoms in a high proportion of this select group strongly suggested that though the uninhibited activity of these /
Fig. 33.- Distribution of the cystometric findings in Parkinsonism according to age and duration of the syndrome.
these bladders might possibly be associated with the emotional reaction to the Parkinsonism it was not directly related to the urological procedures themselves. It was interesting to note that hypertonicity of the bladder was present in many patients despite prolonged medication with either Artane, Kemadrin, Cogentin, Disipal or Lysivane.

Only one of the 7 patients with uninhibited neurogenic bladder disturbance before stereotaxic surgery showed evidence on the voiding cystogram of increased urethral resistance at the level of the external sphincter; 3 other patients produced normal voiding cystograms, whilst in the remaining 3 voiding was not possible and only straining cystograms were obtained. Though ascending urethrography and sphincterometry were not attempted in these patients, who were shortly to undergo multiple neurosurgical procedures under local anaesthesia, it did seem probable that in most of them hypertonicity of the bladder was not directly related to increased tonus of the striated musculature around the urethra.

Voiding cystograms were obtained in 10 patients in whom bladder tonus was either normal or slightly reduced, but in only 2 of these was there evidence of increased urethral resistance at the level of the external urethral sphincter.

An ascending urethrogram (Fig. 3b) was taken on the male patient in whom the catheter was held up at the external sphincter but cystometry was impossible and his bladder tonus was not recorded.
Fig. 3L.- Ascending urethrogram in male patient with Parkinsonism; there is increased torus of the external urethral sphincter.
The Localisation of the Stereotaxic Brain Lesion

The plotting of the site and the extent of the lesion on stereotaxic anatomical charts of Schaltenbrand and Bailey (1959) was completed by the surgeon and radiologist concerned (Gillingham et al., 1960). The individual cases were discussed with them, so that it was decided to what extent the lesion involved the ventrolateral nucleus of the thalamus (thalamotomy), the globus pallidus (pallidotomy) or the adjacent posterior limb of the internal capsule (capsulotomy). The results of post-operative neurological assessment and psychometric studies were also available for comparison with the follow-up urological findings.

Results of the Post-operative Studies

Before the post-operative cystometrogram and cystograms were compared with the pre-operative investigations and related to the stereotaxic brain lesion, several cases were rejected as unsuitable for this critical analysis on the following grounds. In one case it transpired that unilateral thalamotomy had been carried out ineffectively 2 years previously; in 2 female patients the urine obtained at repeat cystometry was found to be slightly infected; another female patient with marked hypotonia of the bladder both before and after stereotaxic surgery was found to have hypoplasia of one kidney, with malrotation of both /
both kidneys and further admitted to a long history of recurrent pyelonephritis, whilst in the last 2 patients studied, the stereotaxic charts were unavailable. Complete studies were thus only possible in 11 patients; in each of them any change in cystometrogram pattern, any alteration of bladder tone or bladder sensation and the peripheral response to stereotaxic surgery were related to the unilateral or bilateral distribution of the syndrome, its predominant somatic manifestations and the stereotaxic brain lesion induced. Four of these 11 cases will be presented in detail.

Case 5.— This 53-year-old man had kyphoscoliosis. Parkinsonism had developed with tremor of his right limbs 8 years previously, but there had been involvement of his left limbs with both tremor and rigidity for 2 years. He had been taking Artane 12 mg. and Disipal tablets 2 daily for several months but had no urinary symptoms.

Physical examination confirmed the extent of his kyphoscoliosis, but showed no evidence of cord or root involvement by the orthopaedic deformity.

Cystometrogram (Fig. 35).— Two-way catheter passed without difficulty. Negligible residuum of bladder urine withdrawn. Resting pressure 3 cm. of water. The bladder pressure slowly rose to 12 cm. of water with 175 c.c. of filling and the first desire to void was then experienced. The pressure then rose more steeply with a strong desire to void at 17 cm. of water after 225 c.c. of filling. An uninhibited contraction then raised the pressure to 50 cm. of water and a voluntary contraction then produced a peak pressure of 87 cm. of water.

Cystograms.— The P.A. view showed a small bladder with slight trabeculation but without ureteric reflux. On the right oblique straining view evidence of marked detrusor activity was present but there was no ureteric reflux and the bladder neck remained closed.
Fig. 35.—Case 5: pre-operative cystometrogram.
The bladder was thus tonic at slightly reduced volume, but the overall pattern of activity was within normal limits.

**Stereotaxic Brain Lesion.** - Charting indicated that this lesion was almost entirely within the left thalamus, as shown in the sagittal and horizontal planes in Figs. 56 and 57.

**Post-operative Assessment.** - Following operation there was still some residual rigidity in the right upper limb but tremor had been abolished. He had neither motor nor sensory deficits, and micturition remained normal. On the fifth post-operative day urological re-assessment was carried out.

**Cystometrogram (Fig. 38).** - Two-way catheter passed without difficulty. Residual urine negligible. (Contaminant organisms only were cultured from this urine sample.) Resting bladder pressure 8 cm. of water. With 75 c.c. of filling the bladder pressure rose to 12 cm. of water, and the first desire to void was then experienced and strong uninhibited contraction raised the bladder pressure to 80 cm. of water with intensification of the desire to void. Further peaks of intrinsic activity occurred up to 80 cm. of water pressure with 100 c.c. of filling, and the patient became emotionally disturbed. He was re-assured and became composed and the bladder pressure declined to 25 cm. of water and accepted 200 c.c. of filling. He then experienced a strong desire to void without any apparent further emotional disturbance but with a concomitant feeling of fullness and a forceful intrinsic contraction which raised the pressure to 90 cm. of water.

**Cystogram.** - The P.A. view demonstrated a small capacity bladder showing detrusor activity; the urethra was not clearly outlined, but was probably of normal contour. The right oblique straining view again showed marked detrusor activity in the bladder, but its neck remained closed and there was no ureteric reflux.

**Comment.** - Following the stereotaxic induction of an entirely left thalamic lesion, the pattern of the cystometrogram changed from a tonic normal to a classical uninhibited type with intensification of bladder sensation. The intensity of the initial reaction to filling and the subsequent response to reassurance with further uninhibited contractions, made it unlikely that the extreme tonic activity was associated with emotion. During the recording of the second tracing the emotional disturbance quite definitely followed and did not precede the intense desire to void which accompanied the uninhibited contractions.

**Case 6.** - /
Fig. 36.- Case 5: lesion in the thalamus plotted on a sagittal section 16 mm. from the mid line.

Fig. 37.- Case 5: lesion in the thalamus plotted on a horizontal section.
Fig. 38.- Case 5: post-operative cystometrogram.
Case 6.- This 52-year-old man had had Parkinsonism for 15 years; his disability began with tremor in his right hand and arm accompanied one year later by rigidity of his right leg. He had received prolonged and continuous treatment with Artane. For one year he had had frequency with urgency of micturition, terminal dribbling, urge incontinence and emesis. Physical examination revealed neither general nor neurological abnormality in addition to the rigidity and tremor involving the right side of the body but psychometry showed that there was a moderate degree of psychological deterioration.

Cystometrogram (Fig. 39).- Two-way catheter passed without difficulty. Residual urine negligible and sterile. Resting bladder pressure 15 cm. of water. After 25 c.c. of filling there was a first desire to void with intrinsic activity which raised the bladder pressure to 24 cm. of water. With 60 c.c. of filling a strong desire to void was experienced and the bladder pressure rose suddenly to 60 cm. of water to produce bypassing of the catheter. There was a decline in pressure as the catheter slipped forwards in the urethra but after the catheter had been reintroduced into the bladder filling eventually occurred to 200 c.c. of water at a pressure of 15 cm. of water. At maximal filling a brisk intrinsic uninhibited contraction raised the pressure to 60 cm. of water.

Cystograms.- The P.A. view showed that the bladder wall had good tonus but there was no ureteric reflux. The desire to void became so intense that the patient was allowed to micturate in the supine position and the P.A. voiding view (Fig. 40) showed that the bladder neck and posterior urethra were widely relaxed and there was still no ureteric reflux.

Stereotaxic Brain Lesion.- The sagittal chart of the induced lesion in this patient (Fig. 41) showed that it involved the left internal capsule. Horizontal plotting of the lesion on the chart showed that there was some destruction of the adjacent globus pallidus and confirmed that the capsular destruction had been placed more laterally in the posterior limb than was usual; this lateral siting of the lesion was done deliberately at operation because cerebral atrophy and mild associated hydrocephalus were demonstrated on ventriculography.

Post-operative Assessment.- Following operation he had a mild right hemiparesis with a right extensor plantar response. Immediately following operation he had been incontinent of urine for two days but had then regained full urinary control without urgency but with occasional nocturia. On the ninth post-operative day urological re-assessment was carried out.
**Fig. 39.** - Case 6: pre-operative cystometrogram.

**Fig. 40.** - Case 6: pre-operative P.A. cystogram.
Fig. 41.- Case 6: lesion in the internal capsule plotted on a sagittal section 23 mm. from the mid line.
Cystometrogram (Fig. 42).- Two-way catheter passed without difficulty. Negligible residuum of sterile urine withdrawn. Resting bladder pressure nil. Completely atonic filling occurred to 170 c.c. and the first desire to void was then experienced with a rise in bladder pressure to 13 cm. of water. A further slow rise of bladder pressure occurred to 20 cm. of water with 500 c.c. of filling, and a strong desire to void was experienced at 15 cm. of water pressure after 300 and later 400 c.c. of filling. At maximal filling a voluntary contraction produced a slight rise in pressure and was followed by an involuntary contraction which raised the peak pressure to 60 cm. of water with bypassing of the catheter.

Cystograms.- Voiding occurred during both the P.A. (Fig. 43) and the oblique exposures. Both these films showed a large capacity bladder with slight detrusor tonus, but with regular contour and without ureteric reflux. The urethrogram in both views was within normal limits.

Comment.- Following the induction of a predominantly left capsular lesion by stereotaxic surgery, the bladder was no longer uninhibited and the overall pattern approximated to normal with intact sensation. The marked reduction in bladder tonus and the increase in bladder capacity was also apparent from a comparison of the P.A. voiding cystograms as shown in Figs. 40 and 43.

Case 7.- This 52-year-old man presented with a complicated clinical history. He had had Parkinsonism since the age of 24 with rigidity and tremor involving chiefly his legs. One year prior to the present assessment he was found to have tuberculosis of the lymph glands of the left side of his neck, and had received antitubercular chemotherapy for a period of 6 months. Eight months later he fell and sustained a fracture of the left acetabulum, and whilst still convalescent from this injury, he developed a volvulus of his pelvic colon with perforation and faeculent peritonitis. A colostomy which was established at this time subsequently required operative refashioning on two separate occasions. Despite all these disabilities and misfortunes, he would admit to no urinary symptoms.

Cystometrogram (Fig. 44).- Two-way catheter passed without difficulty. Negligible residuum of sterile urine withdrawn. Resting bladder pressure 15 cm. of water. The first desire to void was experienced after 150 c.c. of filling at 20 cm. of water pressure. With further filling to 375 c.c. the bladder pressure rose to 25 cm. of water, and a strong desire to void was experienced. A voluntary contraction then produced a rise in pressure of only a few centimetres, /
Fig. 42.- Case 6: post-operative cystometrogram.

Fig. 43.- Case 6: post-operative P.A. cystogram.

Fig. 44.- Case 7: pre-operative cystometrogram.
centimetres, but after further filling to 400 c.c., an involuntary contraction produced a peak pressure of 88 cm. of water with reflux into the filling flask.

Cystograms. - The P.A. view showed slight trabeculation of the bladder which was otherwise of regular contour, and there was no ureteric reflux. Right oblique voiding view demonstrated prominence and thickening of the posterior bladder neck without resistance at the external sphincter level or ureteric reflux.

Stereotaxic Brain Lesion. - The charted lesion was localised to the posterior limb of the left internal capsule with slight involvement of both thalamus and globus pallidus, as shown in sagittal section in Fig. 45.

Post-operative Assessment. - Following stereotaxic surgery his convalescence was uneventful and his clinical response satisfactory. No urinary symptoms presented and further urological assessment was carried out on the sixth post-operative day.

Cystometrogram (Fig. 46). - Two-way catheter passed without difficulty. Negligible residuum of sterile urine withdrawn. Resting pressure nil. With 75 c.c. of filling the bladder pressure rose to 10 cm. of water. There was some intrinsic activity to a peak pressure of 18 cm. of water, but the bladder accepted 430 c.c. of fluid at a pressure of only 17 cm. of water. A voluntary contraction was ineffective, but a cough produced a peak pressure of 22 cm. of water. No sensation of fullness or desire to void was experienced throughout the recording.

Cystograms. - The P.A. view showed a bladder of smooth regular contour without ureteric reflux. Right oblique straining view - the bladder neck had relaxed but the posterior urethra was narrow. No ureteric reflux was present.

Comment. - Following the stereotaxic production of a mainly capsular lesion on the left side there was overall reduction in filling tonus of the bladder, and a complete absence of any normal peak voiding pressure at maximal filling. This lowering in tonus was associated with a loss of bladder sensation.

It is difficult to explain why this patient should admit to no urinary disturbance; he presumably had a normal desire to void but apparently did not experience any sensation of bladder filling during repeat cystometry.

Case 8. - This 59-year-old man who may have had encephalitis lethargica at the age of 31, had had Parkinsonism for 14 years with incapacitating tremor of the right hand but no rigidity. He had no urinary symptoms.
Fig. 45.—Case 7: lesion in the internal capsule and adjacent thalamus and globus pallidus plotted on a sagittal section 16 mm. from the mid line.

Fig. 46.—Case 7: post-operative cystometrogram.
On general physical examination he was found to be hypertensive but during hospitalisation it was appreciated that his blood pressure was labile and the highest recorded level was 200/120 mm.Hg. He had been maintained on lysivane for some time.

On neurological examination there was no clinical evidence of pyramidal tract involvement whilst no features of mental deterioration were found on psychometry.

**Cystometrogram** (Fig. 47).- Two-way catheter passed without difficulty. Negligible residuum of sterile urine withdrawn. Resting bladder pressure 10 cm. of water. When filling commenced, intrinsic bladder activity raised the pressure to 24 cm. of water with a first desire to void, and then suddenly to 57 cm. of water with bypassing of the catheter. After filling to 75 c.c. strong intrinsic activity was accompanied by a strong desire to void and raised the pressure to 62 cm. of water. With reassurance the patient was able to inhibit further contractions up to a filling of 225 c.c. when there was a recurrence of the strong desire to void with powerful uninhibited contractions which raised the pressure to 64 cm. of water with bypassing of the catheter. A voluntary contraction produced a further rise in peak pressure to 80 cm. of water.

**Cystogram.**- The P.A. view showed a small capacity bladder with increased tonus but without ureteric reflux. The right oblique straining view indicated that detrusor activity was present but the bladder neck remained closed and there was no ureteric reflux.

**Stereotaxic Brain Lesion.**- Charting of this lesion in the sagittal plane (Fig. 48) showed that it chiefly involved the left globus pallidus. There was some destruction of the adjacent posterior limb of the left internal capsule.

**Post-operative Assessment.**- Following operation he had mild inco-ordination of movements of his right leg, but this showed a progressive and rapid recovery. It was accompanied by transient frequency of micturition with some precipitancy. On the tenth post-operative day he had no urinary symptoms and urological re-assessment was carried out.

**Cystometrogram** /
**Fig. 47.** Case 8: Pre-operative cystometrogram.

**Fig. 48.** Case 8: Lesion in the globus pallidus and adjacent internal capsule plotted on a sagittal section 16 mm from the mid line.
Cystometrogram (Fig. 49).—Two-way catheter passed without difficulty. Residuum of sterile urine negligible. Resting pressure nil. Atonic filling occurred to 75 c.c., after which the bladder pressure rose to 12 cm. of water. With further filling the pressure slowly climbed and a first desire to void was experienced after 200 c.c. of filling at a pressure of 15 cm. of water. A strong desire to void was experienced at 18 cm. of water pressure after 300 c.c. of filling and was accompanied by an uninhibited contraction which raised the bladder pressure to 70 cm. of water despite bypassing of the catheter.

Cystograms.—The P.A. view showed good intrinsic bladder tonus to be present without ureteric reflux. Right oblique straining view— the bladder neck remained closed. No ureteric reflux.

Comment.—Following the induction of a left-sided lesion chiefly confined to the pallidum but with some involvement of the internal capsule, the pattern of the cystometrogram had changed from an uninhibited type to normal and bladder sensation remained intact.

The essential features of Cases 5, 6, 7 and 8 are included in the tabulated findings of the 11 selected cases, upon whom both pre- and post-operative studies were completed, as shown in Fig. 50. From this table a pattern emerges to suggest that—

(1) Stereotaxic lesions which chiefly involve the ventrolateral nucleus of the thalamus may lead to the development of typical uninhibited neurogenic bladder disturbance with intact sensation, the variable intensity of which is coincident with the strength of bladder contractions as generally found in this type of bladder derangement.

(2) Stereotaxic lesions in the posterior limb of the internal capsule may be associated with a fall in bladder tonus, so that the cystometrogram shows a shift to the right /
**Fig. 49.** Case 8: post-operative cystometrogram.

<table>
<thead>
<tr>
<th>UNILAT.</th>
<th>TREMOR</th>
<th>RIGIDITY</th>
<th>LESION</th>
<th>CYSTOMETROGRAM</th>
<th>BLADDER TONUS</th>
<th>SOMATIC RESPONSE</th>
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**Fig. 50.** Tabulated findings in 11 cases of Parkinsonism showing the peripheral manifestations and cystometric findings before and after stereotaxic brain surgery. (Cystometrogram: N = normal and U = uninhibited.)
right and a pre-operative uninhibited type may become normal. This fall in bladder tonus may be associated with a reduction in the intensity of bladder sensation. In some cases this reduced sensibility may have been due simply to the lowering of bladder tonus from the uninhibited range to the normal range, but in one case where the capsular lesion predominated sensation was almost completely abolished without concurrent bladder atony.

(3) When lesions of the globus pallidus are mixed with capsular lesions, their influence on the bladder is uncertain but when the capsular lesion does not seriously interfere with bladder sensation, it is suggested that pallidal lesions are associated with a reduction in bladder tonus.

(4) The more lateral capsular lesions show the least interference with bladder sensation.

It was interesting to compare these preliminary observations with the noted effect of lesions in the thalamus, capsule and pallidum as reported by Gillingham et al. (1960), who found that tremor was successfully abolished or greatly reduced in many more patients when thalamic lesions were induced in the ventrolateral nucleus adjacent to the capsule and 16 mm. from the midline. On the other hand, when rigidity predominated in the limbs, a lesion in the globus pallidus and adjacent capsule between its medial and lateral parts almost invariably gave good results. From their studies it appeared that the tremor and /
and rigidity were controlled most effectively by the strategic interruption of the thalamo-pallidal connections, essentially the ansa and fasciculus lenticularis. It is immediately apparent that somatic tremor does not correspond to visceral uninhibited activity in the bladder because the former is abolished by thalamotomy whilst the latter is either induced or is perpetuated if already present prior to stereotaxic surgery. It is interesting to note that in the first classic description of the thalamic syndrome by Dejerine and Egger (1903) vesical tenesmus and frequency of micturition were mentioned as two of the marked early symptoms; the findings in Case 5 strongly suggest that the thalamus in some way forms part of the normal inhibitory mechanism of the spinal centre for micturition because in this patient it was reasonably certain that the ventrolateral nucleus of the thalamus and not the adjacent internal capsule had been included in the lesion.

Lesions in the globus pallidus and adjacent capsule definitely produce a reduction in somatic tonus, and the cystometric studies suggest that they have the same effect upon bladder tonus. However, as already observed, lowered bladder tonus after stereotaxic surgery was associated with some reduction if not impairment of bladder sensation, and it is possible that the partial interruption of the ascending sensory pathways from the bladder by the capsular element of the induced lesions in such patients was responsible for the diminished tonus rather than the lesion/
lesion in the pallidum itself. The findings in Case 7 of apparent complete abolition of bladder sensation without very marked reduction in filling tonus of the bladder by a lesion which was almost entirely capsular do not necessarily conflict with this view; the post-operative cystometrogram in this patient (Fig. 46) shows a definite shift to the right, but may well present an incomplete picture. However, in the presence of reduced tonus and absent sensation, it was not considered safe to continue filling much beyond the capacity at which this bladder had previously been known to exhibit strong voiding contractions.
NEUROGENIC BLADDER DISORDERS AFTER ANTEROLATERAL CORDOTOMY

Derangement of bladder function is a well-recognised complication of the surgical division of the anterior and lateral spino-thalamic tracts on one or both sides. Urinary retention during the first post-operative week is so common that in many neurosurgical units catheter drainage is established as a routine precaution during this period. As a general rule, those patients who escape significant urinary complications after bilateral upper dorsal cordotomy are eventually found to have poor analgesic levels (Grant and Wood, 1958) and there is a significantly higher incidence of bladder complications after high cervical cordotomy, as compared with interruption of the pathways at a dorsal level (White and Sweet, 1955). In 210 patients who had undergone cordotomy at any level, White and Sweet (1955) found that the overall incidence of persistent bladder derangement was 13 per cent. The lowest incidence followed unilateral cordotomy (5 per cent); it was significantly higher after bilateral two stage procedures (16 per cent), and was highest after bilateral one stage procedures (29 per cent). These complications are related to the fact that the pathways of bladder sensibility lie in the dorsolateral portion of the anterior quadrants.
quadrants of the cord in close relation to the pain fibres from the sacral region (Nathan and Smith, 1951). This anatomical localisation is of the greatest surgical significance and underlies the fact that the deeper the cut of bilateral incisions into the cord in this region the greater will be the number of permanent bladder complications that ensue (Kahn and Peet, 1943). However, the division of the ascending tracts which convey the sensation of desire to void from the bladder to the higher centres does not necessarily seriously disturb the mechanism of micturition or its voluntary control; many of these patients may be quickly educated to make full use of the "substitute sensations" of imminent micturition (p.18) which travels through the posterior columns, a feeling of "bladder fullness" which travels via sympathetic pathways (p.111) or various peripheral autonomic effects associated with repletion of the bladder as described in paraplegic patients (p.112). Thus it is that extensive interruption of the ascending pathways, as described by Foerster and Gagel (1932), or the use of a more standard technique in tabetics (Hyndman and Jarvis, 1940) is not necessarily followed by permanent urinary retention.

It is thus suggested that prolonged bladder derangement after cordotomy may not be due entirely to the induced therapeutic neurological lesion; the general condition of the patient, the primary disease for which the procedure was carried out, the presence of other neurological /
neurological abnormalities or inadequate urological care in the immediate post-operative period may be other contributory factors.

In this series five female patients were referred for urological opinion because of severe disturbance of bladder function following bilateral two stage upper dorsal anterolateral cordotomies. In four of them the operative interference was undertaken for the relief of persistent lumbar or sacral root pain as a complication of previous laminectomy for intervertebral disc protrusion. The fifth patient had intractable left S.1 root pain associated with an inoperable carcinoma of the rectum. In two of the four patients who had undergone both disc surgery and cordotomy, the urinary symptoms were frequency, urgency, precipitancy of micturition and urge incontinence; the third patient complained of difficulty and hesitancy of micturition with diurnal incontinence, and though these symptoms had been present prior to bilateral upper dorsal cordotomy, they had become more marked after operation because the usual desire to void had been replaced by a vague uncomfortable feeling of fullness in the lower abdomen. The fourth patient had persistent dribbling incontinence with complete loss of all sensation in the bladder and urethra.

In each of these four patients cystometry showed that the bladder had normal resting tonus but gave a tonic or uninhibited reaction to filling which bore no obvious relationship /
relationship to any disturbance of bladder sensation. This hyperactive reaction to filling was noted by White and Sweet (1955) and was in sharp contrast to the motor paralytic type of bladders referred to by Grant and Wood (1958). The lack of relationship between bladder tonus and sensation as found in these patients did not allow the cystometrograms to be classified into any of the four recognised groups already described. The difficulties are well illustrated in the following patient.

Case 9.- At the age of 14 this 30-year-old woman fell backwards and struck her lumbar spine on an ice-skate. For four weeks after this injury she was confined to bed with severe continuous backache. Thereafter she remained subject to intermittent attacks of central lumbar pain of sudden onset which became more frequent and more prolonged. Her symptoms were exaggerated after dilatation of the cervix and curettage of the uterus at the age of 30 years.

At this time she was found to have slight depression of sensation in the left S.1 dermatome with diminution of the left ankle jerk, whilst left S.1 pain and right S.2 pain could be evoked by straight leg-raising. X-rays of the lumbar spine showed considerable narrowing of the lumbosacral disc space.

There was no response to conservative orthopaedic treatment and so laminectomy was undertaken and a sequestrated disc protrusion removed from the left side of the L4 - 5 space. Her post-operative progress was unsatisfactory and she complained of severe persistent left sciatic pain. One month later the lumbosacral interval was re-explored and the left S.1 root which was fixed and constricted by epidural fibrosis was freed and surrounding scar tissue excised.

This second operation was followed by incomplete relief of symptoms which were now accompanied by wasting and weakness of the left quadriceps group of muscles. The left ankle jerk was now absent and the left knee jerk showed a diminished response; she had sensory blunting of her left S.1 dermatome and a moderate weakness of plantar flexion of the left foot.
One year after the original laminectomy there was blunting of sensory appreciation to pin-prick of the left L.5 – S.2 dermatomes and of the right S.1 dermatome suggestive of more extensive root involvement. At this stage it was considered that she had a progressive arachnoiditis and was unlikely to derive further symptomatic relief from a third laminectomy. Intrathecal injections of phenol were effective in relieving her pain in the legs and back, but such relief was only temporary, and she further complained of severe pain in the distribution of the upper dorsal segments.

At the age of 31 years a right upper dorsal anterolateral cordotomy was carried out with an effective left-sided skin analgesic level at D.7. Two years later she had a total hysterectomy to terminate her third pregnancy, therapeutic abortion having been carried out on two previous occasions. She remained comparatively well for one further year and then again complained of right sciatica with clinical evidence of involvement of the right L.5 root. A left upper dorsal anterolateral cordotomy was then carried out at D.4 level and produced right-sided analgesia below the D.8 dermatomes.

Despite this long history of much suffering and many procedures she would not admit to any urinary symptoms at this time. However, three weeks after the second cordotomy she again complained of low back pain with left sciatica accompanied by frequency of micturition with urgency, urge incontinence and enuresis. These symptoms persisted for five months and were present at the time of urological investigation.

**Cystometrogram (Fig. 51).** - Two-way catheter passed without difficulty. Residual urine negligible and sterile. Resting pressure 7 cm. of water. With 100 c.c. of filling the pressure rose to 12 cm. of water and the first desire to void was experienced. Intrinsic activity then raised the pressure steeply to 40 cm. of water with a strong desire to void and to 57 cm. of water with bypassing of the catheter.

**Cystograms.** - The P.A. view (Fig. 52) showed a small spastic bladder of regular contour and with early trabeculation but without ureteric reflux. The voiding view showed strong detrusor activity to be present without ureteric reflux and with a normal urethrogram.

**Cystoscopy.** - /
Fig. 51.- Case 9: cystometrogram before third cordotomy.

Fig. 52.- Case 9: P.A. cystogram.
Cystoscopy.—With 200 c.c. of filling the bladder showed fine trabeculation of the vault and base but no contracture at the bladder neck.

Bimanual examination by rectal palpation revealed no pelvic abnormality; it was noted that the anal sphincter tonus was good but the ano-cutaneous reflex was not elicited.

Comment.—It was considered that the clinical symptoms and findings supported a diagnosis of uninhibited neurogenic bladder disorder. A period of bladder drill with regular micturition (hourly by day and two-hourly by night) was instituted and Probanthine was prescribed (15 mg. three times daily, with an increased night dose to 30 mg.)

Progress.—There was a dramatic symptomatic response within a few days; the bladder sensation became less intense and she developed full urinary control. However, there was intense recurrence of left lower lumbar pain with return of cutaneous pain sensibility and a repeat right upper dorsal cordotomy was accordingly carried out with further abolition of pain and temperature sensation up to the D.7 left dermatome.

Following this operation she was completely devoid of all bladder sensation and became incontinent of urine despite the continuation of the prescribed regime and bladder relaxants. The Probanthine was accordingly discontinued, and during the succeeding four days, though incontinence prevailed, she was found to have a residual urine of 130 c.c. The following urological investigations were repeated.

Cystometrogram (Fig. 53).—Two-way catheter passed without difficulty. Residual urine negligible and sterile. Resting pressure 5 cm. of water. After 100 c.c. of filling brisk intrinsic activity occurred and the bladder pressure rose to 45 cm. of water. A slight and bizarre sensation of bladder fullness was then experienced and the tonic reaction to filling continued up to a pressure of 45 cm. of water with bypassing of the catheter. At 150 c.c. of filling a voluntary contraction produced a peak pressure of 48 cm. of water.

Cystograms.—Both the P.A. and right oblique voiding views were similar to the previous films.

Comment.—/
Fig. 55.- Case 9: cystometrogram after third cordotomy.
Comment.- The striking similarity of the bladder response to filling as shown before and after repeat cordotomy tends to invalidate a pre-operative diagnosis of uninhibited neurogenic bladder. On the other hand, the resting pressure in each of the tracings was normal, and since it was a high dorsal cord section that finally abolished bladder sensation, this bladder could not be classified as autonomous in type. The coincidence of neurological signs and symptoms both before and after cordotomy, and the patient's general demeanour, made it extremely unlikely that any emotional factors could be implicated as the cause of the tonic bladder activity, and it was considered probable that there was sacral motor root irritation in association with spreading arachnoiditis.

A similar pathological explanation was applicable to the tonic bladder activity in the other three female patients who presented with very similar histories, and in one of them the voiding cystogram suggested that there was increased urethral resistance at the level of the external sphincter. This patient was completely devoid of bladder sensation, and though as in the other three patients it was possible to reduce bladder tonus by the use of Monodral and Probanthine, her incontinence has so far persisted and it seems likely that she will require some form of urinary diversion.

These four cases illustrate the value of cystometry in the investigation of post-cordotomy bladder disturbance with or without loss of bladder sensation; tonic activity may thereby be revealed, and simple and satisfactory treatment with bladder relaxants may produce a reduction in bladder tonus and an increase in bladder capacity with marked symptomatic relief.
The fifth patient upon whom bilateral upper dorsal cordotomy had been carried out for the relief of pain from inoperable malignancy presented a different aspect of the problem as follows.

Case 10.-- This elderly woman had had diverticulitis, appendix abscess and a pelvic floor repair four years, three years and two years prior to presenting with an inoperable carcinoma of the rectum for which a left iliac colostomy was established as a palliative measure. Six weeks later she developed severe pain in the left hip and thigh and over the lateral aspect of the left foot. These symptoms increased in severity and when admitted to hospital eighteen months later she complained of severe left S.1 root pain and was found to be anaesthetic over the distribution of the 3rd, 4th and 5th left sacral dermatomes, with depression of her left ankle jerk. A one stage bilateral upper dorsal cordotomy was carried out with an eventual bilateral analgesic level at D.8. She admitted that bladder sensation had been poor before the cordotomies but was markedly impaired immediately after operation; there was associated intermittent urinary retention with a persistent and high bladder residuum; she had a mixed urinary infection with Ps. pyocyanea and enterococci. Urological investigations were carried out as follows.

Cystometrogram (Fig. 54).-- Two-way catheter passed without difficulty. Residual urine gross and infected. Resting pressure 5 cm. of water. The bladder pressure slowly rose to 20 cm. of water with 600 c.c. of filling. A first desire to void was experienced after 450 c.c. of filling at a pressure of 14 cm. of water, and a strong desire to void with a feeling of fullness was felt at 20 cm. of water and at maximal filling. A voluntary contraction then produced a peak pressure of 35 cm. of water.

Cystograms. -- The P.A. view showed a large capacity bladder of smooth contour without ureteric reflux. The right oblique voiding view (Fig. 55) showed some elevation of the posterior bladder neck without significant detrusor tonus and with no ureteric reflux.

Cystourethroscopy.-- With filling to capacity the interior of the bladder was healthy in appearance and there was no trabeculation, but there was slight elevation of the posterior bladder neck with median bar formation.

Bimanual /
Fig. 51: Case 10: cystometrogram after bilateral upper dorsal cordotomy.

Fig. 55: Case 10: voiding cystogram.
Bimanual pelvic examination revealed no laxity of the pelvic floor; on rectal palpation it was found that the upper rectum was obliterated by tumour with obvious extension into the pouch of Douglas.

**Comment.** - The overall picture was that of a hypotonic bladder with a mixed infection but the ultimate detrusor force available on voluntary contraction was approximately normal at maximal filling. Bladder sensation was experienced only during the later stages of filling and it appeared unlikely that the intrinsic bladder tonus would increase unless the high residual urine and the urinary infection were simultaneously alleviated.

**Progress.** - Intermittent drainage through an indwelling urethral catheter was instituted for several days with the administration of chloramphenicol 250 mg. six-hourly. On removal of the catheter the patient passed only 50 c.c. of urine with abdominal straining; after the intramuscular injection of 1 c.c. of Moryl 240 c.c. were voided to leave a true residuum on catheterisation of 90 c.c. Unfortunately, there were marked side effects from the administration of the bladder stimulant, and it was therefore considered necessary to reduce the urethral resistance at the level of the bladder neck by transurethral resection. Following this procedure her convalescence was uneventful, urinary control was considerably improved and the residual urine markedly reduced.

**Comment.** - In this patient it is probable that the part played by bilateral cordotomy in the aetiology of the bladder derangement was quite non-specific. In debilitated patients of this age group, partly bed-ridden and with pain, chronic urinary retention with overflow and infection often occurs and may be precipitated by any surgical procedure not necessarily of a neurological nature. In this patient it is also possible that the urethral resistance was slightly increased as a result of the previous repair of the pelvic floor.

When cordotomy is indicated for the relief of pain due to involvement of either the sacral roots or their peripheral distribution, it is possible that the sacral centre for micturition may be persistently bombarded with abnormal or noxious stimuli to produce a motor disturbance of /
of bladder function. Alternatively, as the bladder nears repletion, the normal afferent stimuli from the stretch receptors in the bladder may reach a sufficient intensity to be referred as an exacerbation of pain or paraesthesia when such abnormal sensations are already present from some other cause (Nathan, 1956). Any clinical distinction between cause and effect in such sacral centre disturbance is not forthcoming from observations made upon patients after cordotomy, but it might explain the atypical tonic bladder activity which has already been described in association with root adherence, arachnoiditis or root compression following the surgical treatment of intervertebral disc protrusions and which may persist after bilateral upper dorsal cordotomy. This relationship between bladder tumours and peripheral pain is a definite entity and was demonstrated in the following case.

Case 11.- At the age of 33 this man underwent two stage colectomy with ileostomy for the relief of familial intestinal polyposis. One of the rectal polyps had already undergone malignant change at the time of surgical treatment and in his late convalescence the patient began to complain of left-sided sciatica with motor weakness of the left leg associated with tumour invasion of the left lumbosacral plexus. This pain was progressive and two years after colectomy he underwent right upper dorsal anterolateral cordotomy which produced a left-sided D2 level without sacral sparing and without urinary symptoms. Within four months he had developed right-sided sciatica and though he had no urinary symptoms urological investigations were undertaken to assess his suitability for treatment by left-sided cordotomy in view of the fact that there was already an established ileostomy.

**Cystometrogram**
Cystometrogram (Fig. 56).- Two-way catheter passed without difficulty. Residual urine negligible (contaminants were cultured from this specimen). Resting bladder pressure 10 cm. of water. As filling progressed there was slight intrinsic activity and the first desire to void was experienced at 23 cm. water pressure after 175 c.c. of filling. With further filling to 225 c.c. the bladder pressure rose to 30 cm. of water. He then complained of severe right sciatica coincident with brisker intrinsic bladder activity, though this was voluntarily inhibited up to 320 c.c. of filling. A strong desire to void was experienced after 290 c.c. of filling at a pressure of 35 cm. of water, and at maximal filling a voluntary contraction produced strong intrinsic activity which raised the pressure to a peak of 85 cm. of water with bypassing of the catheter and particular intensification of his right sciatica.

Cystogram.- The P.A. view (Fig. 57) showed obvious detrusor activity without ureteric reflux; the bladder was displaced to the right side of the pelvis which contained fractures of the superior and inferior left pubic rami with destruction of the bony architecture of the left ischial spine. The patient voided in the supine position and the bladder neck was seen to be well relaxed but the urethral stream was thin.

Comment.- The cystometrogram in this patient was within normal limits though tonic. There was a definite association between increased intrinsic contractility, high voiding tonus and progressive intensification of the sciatic pain associated with tumour invasion of the lumbosacral plexus and bony pelvis.
Fig. 56.- Case 11: cystometrogram.

Fig. 57.- Case 11: P.A. cystogram.
NEUROGENIC BLADDER DISORDERS IN TRAUMATIC LESIONS
OF THE SPINAL CORD AND NERVE ROOTS

Much information has been obtained from clinical studies of patients with traumatic lesions of the spinal cord and cauda equina (Denny-Brown and Robertson, 1933), and has been applied to the development of more physiological methods of management of these patients on a clinical basis. However, advances in treatment have not always been abreast of advances in surgical physiology because technical development has been comparatively slow and it is only recently that such factors as the size, shape and construction of urethral catheters have been re-appraised and redesigned (Gibbon, 1958).

Though considerable progress has been made in all aspects of management of the paraplegic patient in specialist units, the urinary tract is still responsible for a considerable proportion of the mortality and morbidity in these patients. In 1956 Damanski and Gibbon reported that urological complications were responsible for 64 per cent of the overall mortality (23 per cent) occurring in 116 patients. The relatively long-term surveys carried out by Talbot and Bunts (1949), Talbot and Lyons (1950) and Hutch and Bunts (1951) indicated that infection, upper urinary tract dilatation and calculus formation reached their maximum incidence within the first two years of the paraplegic state, whilst /
whilst failure in renal function became progressively more common after the third year. In 1955 Comarr reported an overall incidence of bladder calculi and renal calculi of 28 per cent and 6.8 per cent respectively in 1,104 patients.

The results of long-term surveys of large numbers of paraplegic patients may have uncertain significance with regard to any desirable alteration of the method of urological management, because many changes in urological thought and practice may have occurred during the survey periods. Moreover, the bladder derangement in any paraplegic patient presents a particular problem which requires individual consideration and it is possible that statistical reviews may allow the general principles implied in a particular regime of urological care to obscure the more particular methods of treatment required by individual cases.

In the present series an analysis of 35 patients with neurogenic bladder disorders following traumatic cord and nerve root injuries was carried out to evaluate the efficacy of different forms of treatment at different stages of the neurological disturbance with particular reference to prophylaxis against serious complications.

These 35 patients (2 females and 33 males) were either reviewed or treated in the Spinal Injuries Unit at Edenhall Hospital. Twelve of them (11 males and one female) had received their initial neurosurgical and urological treatment at other centres but detailed records of /
of their early management were obtained and their re-
assessment and further surveyance were carried out in the
unit. Though the remaining 23 patients did not receive
their initial treatment in the unit itself, they were
transferred, at an early date, from regional hospitals
where they had been seen by the specialist staff of the
paraplegic unit and had been generally managed along unit
lines. The urological management of patients in these two
groups will be considered according to the different phases
of traumatic paraplegia as follows:

(1) The initial phase.
(2) The phase of recovery and rehabilitation.
(3) The phase of complications.
(4) The phase of home management.

The prominent physiological features of the traumatic
cord bladder as related to the method of urological
treatment will be discussed phase by phase and illustrated
by cases from the series.

Neurogenic Bladder Disorders Immediately following
the Onset of Traumatic Paraplegia

Following injury to the spinal cord it is generally
accepted that there may be complete arrest of neurological
activity distal to the level of injury, and for over a
century the term "spinal shock" has been used to describe
this loss of segmental reflex cord function. Many workers
have reported that during this stage the urinary bladder is
in /
in an atonic state (Fernside, 1917; Walker, 1917; Holmes, 1933; Munro and Hahn, 1935; Riches, 1943) in association with transection, contusion, concussion or oedema of the spinal cord. However, experimental work by Kolb (1940) indicated that section of the spinal cord or of the sacral nerve roots did not produce an immediate stretching of the bladder detrusor muscle, and in human subjects Nesbit and Lapides (1948) reported that complete chemical blockade of the sympathetic and parasympathetic ganglia did not affect the tonicity of the bladder or its ability to maintain an approximately constant intravesical pressure with varying volumes of fluid. It is characteristic of smooth muscle that it will maintain much of its tension or resistance to extension under conditions of complete denervation (Evans, 1926), and it is therefore doubtful whether flaccidity or atonicity of the bladder in the stage of spinal shock can be directly attributed to its dissociation from extrinsic nerves or spinal reflexes. Nesbit and Lapides (1948) analysed the clinical studies of this problem which were reported after the first World War, and concluded that the patients then investigated had been examined days or weeks after their spinal cord injury. It was apparent that these patients had not been catheterised immediately after injury, so that retention of urine with overdistension of the bladder had prevailed for several days before urinary drainage was established. In one of their own patients (a 60-year-old man with a compression fracture of the first lumbar vertebra) Nesbit and Lapides carried out /
out cystometry seven hours after the onset of spinal shock and found that the bladder then had normal tone and accommodation; it was five weeks before reflex activity was apparent in this patient.

These observations suggest that bladder atony is probably an unusual response to a spinal cord lesion (Yeates, 1956) and is more frequently the direct result of overdistension of a denervated bladder during the few hours immediately after cord injury. Such overstretch would seriously interfere with the full recovery of bladder function if the cord lesion should prove to be incomplete or transient, whilst with complete cord section it would lead to serious difficulties in bladder rehabilitation. The avoidance of overdistension of the bladder therefore recommends itself urgently in the first aid treatment of spinal cord injuries, but the hazards of introducing infection into a retained insensitive bladder are so dangerous that many forms of management have been advocated as desirable alternatives to urethral catheterisation at this stage.

Manual (Credé) Expression of the Bladder

Those urologists who subscribe to the theory that the bladder atony is a manifestation of spinal shock per se are generally at a loss to explain why the bladder neck should in many cases remain closed and spastic. Denny-Brown and Robertson (1933) obtained evidence that in the human subject the /
the opening and closure of the internal sphincter were related to the ascent and decline of vesical waves of detrusor contraction, and noted that the internal sphincter did not show rhythmical activity which was unrelated to the contraction of the detrusor itself. They noted that though strong passive pressure on the lower abdomen may cause a drop of fluid to pass the internal sphincter it did not secure wide opening of the sphincter or produce an adequate urinary stream unless the rise in bladder pressure was sustained by detrusor contraction after the manual compression had been released. It thus follows that in the stage of spinal shock manual compression of the bladder could not be expected to produce adequate emptying of the organ even if it be admitted that the complete loss of intrinsic bladder tonus is due to overdistension rather than to sudden denervation of the viscus.

From the practical point of view it is reasonably certain that manual expression of the bladder is not effective in most cases (Holmes, 1933) of spinal shock; it is important to remark that adequate evacuation of the bladder by this method can be proved only by estimation of the true bladder residuum following catheterisation whereby the purpose of the method is defeated. Riches (1943) considered that this method was too hazardous and uncertain to be advised for general use.

In one patient of the present series it was decided to assess the efficacy of this method under controlled conditions, as follows.

Case 12.- /
Case 12.—This 39-year-old man sustained a wedge compression fracture of the body of the 12th dorsal vertebra in a pit accident. There was immediate flaccid paraplegia with complete sensory loss below the D₁₀ dermatomes without sacral sparing. Lumbar puncture was carried out and showed a complete subarachnoid block and the cerebrospinal fluid was heavily blood-stained. Urinary retention occurred immediately after injury, and had been treated by continuous free drainage through a Gibbon catheter which was removed on the fifth day after injury when the urine was sterile on culture and his neurological state had not changed. No spontaneous voiding occurred and manual expression of the bladder was carried out two hours after removal of the catheter, and was repeated at two-hourly intervals thereafter. It was considered to be very effective, because a good urinary stream could be obtained and variable quantities up to 300 c.c. were expressed on each occasion. On the fifth day an attempt at manual expression produced only 2 c.c. of urine but 360 c.c. were voided spontaneously after an injection of Moryl. Two hours later 120 c.c. were expressed from the bladder and cystometry was then carried out.

**Cystometrogram (Fig. 58).—** Two-way catheter passed without difficulty to drain a true residuum of 60 c.c. of urine. Resting pressure nil. Atonic filling occurred up to 125 c.c. when the bladder pressure rose suddenly to 20 cm. of water. Definite intrinsic activity then accompanied a progressive rise in pressure to 35 cm. of water with 225 c.c. of filling. The pressure then again rose suddenly to 80 cm. of water and tonic filling continued to 275 c.c. After 240 c.c. of filling a voluntary contraction produced a peak pressure of 90 cm. of water and manual expression at maximal filling produced a peak of over 110 cm. of water.

**Cystogram.—** A.P.A. view of the urinary tract was taken immediately after manual expression and is shown in Fig. 59. It demonstrated a gross residuum of urine in the bladder with bilateral ureteric reflux, mild bilateral hydronephrosis and moderate hydro-ureter. A further right oblique voiding view demonstrated detrusor activity in the bladder vault but the bladder neck was closed.

**Comment.—** Though in this patient there was no neurological evidence of recovering activity in the autonomous portion of the spinal cord below the level of section, bladder filling produced a definite detrusor response which was tonic and inco-ordinate. The combination of cystometry and cystography demonstrated that manual expression could evacuate a large volume of urine in this patient but an unsafe residuum of urine remained; the bladder compression produced a very high intravesical pressure, which was associated with bilateral ureteric reflux/
Fig. 58.- Case 12: cystometrogram.

Fig. 59.- Case 12: a radiograph (a) of the urinary tract after manual expression of the bladder during cystography; the extent of bilateral ureteric reflux is outlined in the tracing (b).
reflux and early dilatation in the upper urinary tract. The level of vertebral injury in this patient could obviously have been associated with extensive destruction of the conus medullaris and cauda equina. It might therefore be argued that the prevailing flaccidity of his lower limbs did not necessarily indicate that he was still in a state of spinal shock at the time of urological examination. The cystometric findings would then indicate that the bladder had quickly established autonomous activity. In either event the ineffectiveness and dangers of manual expression of the bladder at an early stage of traumatic paraplegia were clearly demonstrated. At the time of review for the purpose of the thesis three months had elapsed since the spinal injury but the neurological state had not changed, and catheter drainage was being continued because of deterioration in his general condition; recurrent attacks of fever had occurred with transient jaundice.

It is therefore difficult to justify a non-drainage programme for early bladder management in paraplegia because overdistension of the viscus may occur and vesico-ureteral reflux may be associated with manual expression and lead to the development of dilatation in the upper urinary tract.

Suprapubic Cystostomy in the Initial Phase of Treatment

Suprapubic catheter drainage has been recommended by Riches (1943) when it is considered unlikely that adequate nursing and medical supervision will be available to ensure that overdistension of the bladder will not occur in a paraplegic patient with or without urethral catheterisation during any proposed casualty evacuation or hospital transfer over a long distance. The drainage should be established through a high stab incision with the insertion of a narrow calibre tube through an oblique track. Such a procedure has many advantages under difficult circumstances but it upsets /
upsets the anatomical and physiological state of the bladder (Hardy, 1956). Though suprapubic drainage does not necessarily prevent the ultimate restoration of bladder function, the optimum time for it to be discontinued cannot be determined easily and trial periods without the drainage tube may lead to urinary leakage; in this respect Donovan (1947) found that cystometry was of little help.

Suprapubic cystostomy had been carried out as the initial urological treatment in three cases in the present series. In one of them it was discontinued uneventfully after a few months and reflex micturition was eventually established below a complete cord lesion at C5. In the other two patients the suprapubic cystostomy was closed after five years and eighteen months respectively but in both these patients urological management was difficult and prolonged; their histories are summarised in Cases 13 and 14.

Case 13.—At the age of 25 this 35-year-old man had sustained a fracture dislocation of D12 - L1 vertebrae in a pit accident and immediately became completely paraplegic below the D10 level. Suprapubic cystostomy drainage was instituted shortly after admission to hospital and the patient was nursed in a plaster shell. Within a few weeks heavy coliform urinary infection was present and suprapubic leakage persisted despite urethral catheterisation and tidal lavage; sacral bedsores developed. This patient further complained of severe pain over the fracture site and down the inner aspects of the right thigh and in the left groin but below these levels he had no sensation and neither voluntary nor involuntary movement was present. Following a period of indwelling urethral catheter drainage, epididymo-orchitis and gross urethritis developed with periurethral abscess formation at the peno-scrotal junction; Ps. pyocyanea and B. proteus were cultured from the urine. The scrotal abscess discharged and the urinary infection improved
improved following the restoration of suprapubic cystostomy drainage. Bilateral upper dorsal cordotomy was then carried out with complete loss of pain up to and including the right D5 dermatome and the left D10 dermatome. Following the abolition of his pain the patient's general condition improved though urological assessment (one year after injury) showed that his bladder was atonic, and there was some deterioration of renal function. At this stage external urethrotomy and urethroplasty were carried out, but the patient eventually required a resection of the bladder neck and operative closure of the suprapubic track. Following these procedures urinary incontinence prevailed for a further year before bladder control improved and he was able to urinate at will by abdominal straining; a urethral diverticulum developed, probably as the result of using a penile clamp. During the next six years this patient required multiple plastic surgical procedures because of sacral and trochanteric trophic sores.

When re-assessed nine years after injury he was found to have a heavy urinary infection with B. proteus and though there was some recent diminution in the urinary stream he was able to void by abdominal straining at regular intervals and without any bladder sensation. Intravenous pyelograms at this stage showed satisfactory function from both kidneys without calculus formation, but with hydronephrosis. The following investigations were undertaken.

**Cystometrogram (Fig. 60).**—The urethra required dilatation with Hinman bougies prior to the introduction of a two-way catheter which drained a residuum of 200 c.c. of urine from which B. proteus and enterococci were cultured. The resting bladder pressure was 5 cm. of water. The bladder accepted 300 c.c. of fluid with a gradual rise in pressure to 15 cm. of water and a voluntary contraction then produced a peak pressure of 40 cm. of water. Bladder sensation was absent.

**Cystograms.**—The P.A. view (Fig. 61) showed gross trabeculation of the bladder with sacculuation and extensive bilateral ureteric reflux with bilateral hydronephrosis and hydro-ureter. The right oblique voiding view (Fig. 62) showed relaxation of the bladder neck with slight dilatation of the posterior urethra; the urethral calibre was reasonable after instrumentation, but there was an obvious large diverticulum in the penile portion.

**Cystoscopy.**—The bladder vault was scarred and there was marked trabeculation of the vault and base. Both ureteric orifices were gaping and retracted backwards but there was no obvious contracture at the bladder neck.

**Comment.**—/
Fig. 60.- Case 13: cystometrogram.

Fig. 61.- Case 13: P.A. cystogram.
Fig. 62.— Case 13: voiding cystogram.
Comment.- After multiple urological, neurological and plastic surgical procedures this patient ultimately became rehabilitated and stable. On the occasion of his last review he was found to have a persistent *E. coli* urinary infection and there was some tightening of his urethral stricture which responded to dilatation. The stricture probably constituted an important element in the urethral resistance which allowed him to remain continent. The low level of the neurological lesion had left him with sufficient abdominal muscular power to enable him to void adequately by straining. In view of the persistent urinary infection and bilateral ureteric reflux, he was instructed to practise a regime of double micturition, i.e. 15 minutes after producing a good flow of urine and having emptied his bladder as far as possible he was then to repeat micturition by abdominal straining so that some of the urine which had refluxed into the upper urinary tract would have drained into the bladder and would then be voided.

Case 14.- At the age of 29 this 44-year-old man sustained a gunshot wound of his spine with complete paraplegia below L.2. Suprapubic cystostomy drainage was established shortly after injury and had been continued for four and a half years during which time the tube had been released hourly by day and two-hourly by night. He occasionally complained of severe pain in both loins when the tube was occluded. Following operative closure of the suprapubic track this patient developed an atypical sensation of bladder fullness and was able to start micturition by straining, though he always required to maintain abdominal pressure throughout the urinary flow. Three years later the suprapubic wound broke down on five occasions and urine leakage occurred; further excision and repair of the suprapubic track was carried out.

When assessed 10 years after the onset of his paraplegia it was found that his neurological level had not changed and though there was no cutaneous sensation below the L.2 left dermatome and the L.3 right dermatome he experienced a feeling of bladder fullness as a sensation of "pressure in the groins" and claimed that definite urethral sensation was present on voiding. Cystoscopy showed that the bladder was heavily trabeculated and both ureteric orifices were gaping and wide.

Cystogram.- After voiding 10 oz. of clear urine without residuum, cystography outlined a small capacity bladder with gross bilateral hydronephrosis and hydro-ureter associated with bilateral ureteric reflux (Fig. 63). The P.A. voiding view (Fig. 64) showed that the bladder neck was wide and relaxed and that the urethral calibre was adequate; the dilatation of the bulbous portion of the urethra corresponded to the site of a previous urethral fistula.

At
Fig. 63.—Case 14: ascending pyelograms obtained during cystography in the presence of vesicoureteral reflux.

Fig. 64.—Case 14: P.A. voiding cystogram.
At this time he was found to have a heavy urinary infection with B. proteus and urea clearance studies showed some impairment of total renal function to be present. During the next five years he was reviewed at regular intervals and his blood urea nitrogen level was always within normal range, but he developed a small left renal calculus and there was a persistent mixed urinary infection with B. proteus and coliform organisms.

Fifteen years after the onset of his paraplegia intravenous pyelograms still showed evidence of function from both kidneys, but cystography confirmed the persistence of easy reflux from a small capacity bladder into grossly dilated ureters with bilateral hydronephrosis. The voiding view (Fig. 65) showed an adequate urethral stream with a small urethral diverticulum, reflux with bilateral hydro-ureter, and a small diverticulum in the fundus of the bladder that was adherent to the suprapubic scar which became inflamed at intervals. A lateral voiding view (Fig. 66) demonstrated the gross degree of dilatation that was present in the upper urinary tract.

Comment.—Despite the advanced structural changes in his urinary tract, this patient still experienced an atypical sensation of bladder fullness; this sensation was localised to both loins and groins, and probably represented pain referred from the bilateral hydronephrosis. It was interesting to note that his residual urine was negligible, and it was thus probable that with good abdominal straining he was able to empty both his small capacity bladder and his dilated upper urinary tract. It was therefore considered that any surgical treatment would not improve his renal function which was already impaired but which had shown no serious deterioration during five years of careful follow-up.

It would be easy to condemn suprapubic cystostomy as a method of initial urological treatment after a simple consideration of the X-ray findings in these two patients. However, it must be remembered that they were both stable and were leading active lives 10 and 15 years, respectively, after the onset of their paraplegic state. Their long survival must be considered in the light of much suffering, prolonged morbidity, multiple operations and their being at great /
Fig. 65. - Case 14: right oblique voiding cystogram taken 15 years after the onset of paraplegia.

Fig. 66. - Case 14: lateral voiding cystogram taken 15 years after the onset of paraplegia.
great risk from any sudden culminating urinary infection which might occur at any time. It must also be remembered that it is possible that neither of them would have developed a reflex type of neurogenic bladder if they had been treated in any other way, and it is possible that suprapubic cystostomy in each of them had been responsible for their long survival because it had produced bladder atony which enabled micturition to be more safely accomplished by abdominal straining.

Suprapubic needle aspiration of the distended bladder has been suggested as an alternative to either urethral catheterisation or suprapubic cystostomy drainage. This procedure is possibly dangerous unless the bladder is allowed to distend before being aspirated; in practice it is not always easy to do, is time-consuming and is not altogether devoid of the risk of infection; for these reasons it cannot be considered as an established method for the treatment of the paralysed bladder.

**Urethral Catheterisation in the Initial Phase of Treatment**

Infection is the great hazard which accompanies any form of urethral instrumentation but it is particularly dangerous in the denervated bladder containing a residuum of urine. The risk of infection can be reduced considerably if the most suitable form of catheter is passed gently with a careful aseptic technique. Traumatisation of the urethra by /
by too large or rigid an instrument must be avoided, and chemical irritation by the sulphur content of red rubber catheters is obviously undesirable. If each of these adverse factors can be eliminated or reduced to a minimum, then urethral catheter drainage offers the simplest and most generally applicable method of initial urological management in traumatic paraplegia.

The catheter designed and described by Gibbon (1958) is the nearest approach to the ideal instrument currently available (Fig. 67). It is supplied in a sterile packet and partly enclosed in a sterile sheath to facilitate its introduction by a no-touch technique after the removal of the obturating filament. The wings of Portex sheeting which are cemented to the catheter enable it to be fixed in situ easily (Fig. 68), whilst the non-irritant and resilient nature of the polyvinyl chloride tubing from which it is made, allow it to be left indwelling in the urethra for prolonged periods without any serious incidence of urethritis. If such a catheter is available, it should be passed at the earliest opportunity after spinal cord injury when it is apparent that voluntary micturition has been seriously deranged. A 14 F. Latex rubber catheter of the Foley type is the most desirable alternative instrument, but the Gibbon catheter has the further advantage that its long length allows it to be connected directly to either a disposable plastic bag receptacle or a Mayo urinal bottle (Fig. 69). In this way closed continuous aseptic urinary drainage /
Fig. 67.- The Gibbon urethral catheter.

Fig. 68.- Method of fixation of the Gibbon catheter in the male.
Fig. 62.—Disposable plastic receptacle bag and Mayo urinal bottle.
drainage can be instituted even as a first aid measure, but the detailed management of this drainage assembly, as described by Miller et al. (1960) must be attended to.

It is undesirable that any other type of catheter should be left indwelling in the urethra of the paraplegic patient, and in the interim period before either a Gibbon or a Foley catheter is obtained the patient is probably at least risk of either overstretch of the bladder or infection if a careful programme of intermittent catheterisation is carried out.

_Urological Management of the Paraplegic Patient in the Phase of Recovery and Rehabilitation_

The duration of this phase varies considerably from patient to patient, and depends upon the nature of the neurological damage sustained. In transient or incomplete neurological lesions it may be very short, but in complete cord section it may be very prolonged and inseparable from the phase of complications. The aim of urological management during this time is to ensure urinary drainage in such a way that overstretch of the bladder musculature is avoided and the incidence of urinary infection is reduced to the lowest possible incidence.

The following regime was used in the management of the patients in this series.

When /
When continuous bladder drainage had already been established through an indwelling Gibbon or Foley urethral catheter during the initial stages of treatment then it was continued. Each patient was encouraged to increase fluid intake to such a level that at least three litres of urine were excreted daily; acidifying agents were administered by mouth; urinalysis, urine culture, estimations of blood urea nitrogen, serum calcium, serum phosphorus and serum alkaline phosphatase levels were checked at weekly intervals and intravenous pyelography was carried out as soon as the patient could be handled with safety.

The purpose of these measures was to control and reduce the incidence of infection, hypercalciuria and calculus formation in the urinary tract whilst the bladder was kept at rest until recovery of its function had occurred even to a limited extent. Each patient was maintained in a high nutritional state and received constant nursing attention to the skin and physiotherapy to the paralysed limbs in order to prevent the development of pressure sores, spastic muscles and joint contractures and to spare the spinal centre for micturition from any interference by noxious stimuli from peripheral nerves which enter the autonomous portion of the spinal cord below the level of injury.

The duration of the period of catheter drainage was not prescribed and fixed. It depended upon the patient's general condition, upon the stability or further progress of /
of the neurological or orthopaedic condition of the cord and spine and was a matter for careful clinical consideration in the individual patient. When there was any early evidence of neurological recovery the catheter was clipped and the bladder was allowed to fill gently; if it was then obvious that bladder sensation had returned, the catheter was removed for a trial period of two hours. Any urine passed by the patient during this two-hour period was collected and measured and then a suitable dose of a cholinergic bladder stimulant, such as Moryl, was given by intramuscular injection; any urine voided in the twenty minute period after injection was likewise collected and measured. The catheter was then replaced and the bladder was emptied so that a measure of the true residuum was obtained. By a comparison of these three measured volumes, it was decided whether the bladder was normally compensated, compensated after Moryl injection or decompensated. A similar trial was also carried out at an early stage of management in patients with complete section of the spinal cord who presented evidence of recovery of spinal reflex activity without any recovery of bladder sensation; the regular testing of the deep tendon reflexes and the bulbo-cavernosus and ano-cutaneous reflexes provided the early signs of recovery.

In the remaining patients the first trial without the catheter was usually postponed until their orthopaedic condition was stable enough for them to be nursed in an ordinary /
ordinary bed so that they were able to exert a greater voiding force by abdominal straining.

Despite evidence of recovery of compensated function it was considered unsafe to discard the catheter suddenly, and at the conclusion of even a favourable test the catheter was left in situ and later removed for progressively increased periods of time, day by day, and finally discarded when the residuum in the bladder after a twenty-four hour trial period (with or without Moryl) was less than 10 per cent of the bladder capacity.

Treatment of Urinary Infection

The mere presence of micro-organisms in the urine at any stage of this catheter treatment was not considered to be an indication for any change in the regime because bacteriuria may develop within seventy-two hours of the introduction of any indwelling urethral catheter (Anderson, 1954). However when bacteriuria developed attempts to reduce the bacterial population in the urine were intensified by further diuresis, more careful urinary acidification and by the administration of urinary antiseptics, such as mandelic acid or hexamine. In view of the risk of developing drug-resistant strains of organisms, the administration of antibiotics and chemotherapeutic agents was withheld until there was definite clinical evidence of established urinary infection with such signs as pyuria, fever, epididymitis, prostatitis or renal tenderness.
In the treatment of established urinary infection it was considered important to prescribe a full course of the appropriate agent (as indicated by laboratory sensitivity studies) and in full dosage. In this respect it was found that those agents which are usually excreted in a high concentration in the urine gave a rapid clinical response even when the presence of drug-resistant strains of organisms was indicated by laboratory studies.

It was found in practice that the Gibbon narrow channel catheter was easily blocked by debris when active infection occurred and freer drainage was then usually obtained by replacing the Gibbon catheter by a 14 or 16 F. Foley catheter with only 5 c.c. of fluid injected into the retaining bag. The catheter drainage was continuous during the acute phase of any infection, but was changed to intermittent hourly or two-hourly drainage during the recovery period; it was found that an uninfected though paralysed bladder would retain its resilience and tone if kept empty for a prolonged period, but if an infected bladder was treated in the same way then there was an increasing risk of the development of bladder contracture at a later stage.

Bladder lavage was used only for certain specific purposes. Debris and collections of mucus were removed by intermittent irrigation with sterile normal saline or weak aqueous solutions of sodium bicarbonate. Twice daily irrigations with a \( \frac{1}{2} \) per cent aqueous solution of acetic acid /
acid were carried out for a few days after litholapaxy or when phosphatic encrustation was troublesome; such encrustation readily occurred if the Foley catheter was not changed at weekly intervals. Tidal irrigation was never used.

The maintenance of adequate bladder tonus by this regime of continuous and subsequent intermittent drainage by indwelling urethral catheter in the presence of infection was shown in the following patient.

Case 15.—This 57-year-old man who suffered from Parkinsonism and manifested a mild degree of myelopathy in association with cervical spondylosis, had tripped, fell forwards and sustained an immediate spastic tetraparesis with complete loss of sensation below the C.7 dermatomes. X-rays of his cervical spine showed no evidence of fracture or dislocation but myelograms outlined anterior osteophyte projection at the C.4 - 5, C.5 - 6 and C.6 - 7 intervertebral spaces. It was considered that he had sustained an acute hyperextension injury of his cervical spine with severe cord damage but no neurological improvement followed an extensive cervical laminectomy from C.3 to C.7 vertebrae; the initial urological treatment comprised continuous indwelling Gibbon catheter drainage. During the succeeding four months his general management became extremely difficult; his neck wound became infected and disrupted and required resuture; he developed a bronchopneumonia for which tracheostomy was required; there was recurrent paralytic ileus and subsequently deep jaundice accompanied acute cholecystitis. As his general condition improved he was subject to severe peripheral flexor spasms which seriously interfered with any attempt at urological rehabilitation. Trials without catheter drainage showed persistent urinary retention without bladder sensation, and it was anticipated that his bladder was atonic.

A cystometrogram taken at this stage is shown in Fig. 70. The resting bladder pressure was negligible and hypotonic filling occurred to 375 c.c. of filling with a pressure of only 5 cm. of water. A vague feeling of lower abdominal fullness was then experienced and was accompanied by a sharp rise in intrinsic pressure to 35 cm. of water. The feeling became slightly more intense with further filling to 475 c.c. and some tonic activity was recorded.
Fig. 70.—Case 15: Cystometrogram four months after the onset of paraplegia.
He had a mixed urinary infection with *Ps. pyocyanea* and coliform organisms and a careful regime of intermittent drainage through an indwelling Foley catheter was instituted two-hourly; on three occasions each day Moryl injections preceded the release of the catheter clip and Furadantin was prescribed (100 mg. orally six-hourly) for one week. Before any further trial without catheter was attempted he had attacks of acute gastric dilatation and paralytic ileus and so the regime of intermittent drainage down the catheter was continued for a further five months until his general condition was again sufficiently stable to suggest that rehabilitation of the bladder might again be tried.

The cystometrogram obtained at this time is shown in Fig. 71. The resting pressure was 7 cm. of water but the filling pressure slowly rose to 25 cm. of water with 200 c.c. A feeling of fullness was then experienced in the lower abdomen and was accompanied by a peripheral flexor spasm and by a rise in bladder pressure to 45 cm. of water. Further filling to 400 c.c. occurred at a pressure of 35 cm. of water, after which a voluntary contraction produced a peak pressure of 50 cm. of water.

Comment. - Despite major pulmonary and abdominal complications in a tetraplegic patient with Parkinsonism, bladder tone was maintained at a very satisfactory level by a careful regime of indwelling urethral catheter drainage over a period of nine months.

**Bladder Training and Atypical Bladder Sensation**

In some patients clinical signs of infection never presented despite the persistence of a mixed growth of organisms in the urine. In such patients it was nevertheless customary to change from continuous drainage to intermittent drainage by indwelling urethral Foley catheter as soon as the tests of voiding and residuum showed that recovery of bladder function was beginning.

At /
Fig. 71.- Case 15: cystometrogram nine months after the onset of paraplegia.
At the time of change-over the patient was carefully instructed to concentrate on any vague sensation, however bizarre, which might accompany the filling of his bladder to a physiological degree when the catheter had been clipped. It was always recommended that the patients should be their own time-keepers in this respect, because it was considered important that they should learn to regularise any reflex bladder activity by controlling their fluid intake so that their rate of urine excretion offered a regular stretch stimulus to the bladder coincident with the time for voiding "by the clock".

The presence of a poorly localised abdominal sensation associated with repletion of the bladder has been observed in patients with a complete division of the spinal cord by Balint and Benedict (1906), Riddoch (1921), Denny-Brown and Robertson (1933), Voris and Landes (1940), Donovan (1947) and Kuhn (1950); in patients with total lesions of the cauda equina by Kocher (1896) and Denny-Brown and Robertson (1933); and in patients with division of the lateral part of the spino-thalamic tract by Nathan and Smith (1951). These references are quoted from a review by Nathan (1956) in which he remarked that the sensation is poorly localised and may be difficult to define. From his own observations and from those reported by Beck (1949) and by Kuhn (1950), Nathan concluded that when this sensation is present in patients with complete cord section it must be transmitted through afferent sympathetic /
sympathetic nerves which reach the spinal cord at a level cranial to the 4th thoracic segment.

In some patients with complete cord section various peripheral autonomic responses to bladder filling may occur. It was noted by Head and Riddoch (1917) that in low cervical cord lesions distension of the bladder produced profuse sweating of the face, neck and arms. In 1947 Guttmann and Whitteridge reported investigations of these autonomic responses to bladder distension in a number of patients with severe injuries of the spinal cord; the responses were found to be related to bladder pressure rather than to bladder volume. These autonomic responses were considered to be an adaptive mechanism and to represent alarm symptoms indicative of abnormal activity of a viscus in the anaesthetic area below the level of the lesion.

In the present series some form of sensation of bladder fullness was present in 11 of 19 patients who had developed reflex types of bladder function following complete cord section at various levels. In 6 of these 11 patients the sensation was that of "fullness" vaguely localised to the abdomen, whilst in the remaining 5 the sensations were due to associated autonomic activity, as already described.

Of these 5 patients 4 had cervical lesions and in 2 of them the appreciation of bladder fullness was experienced as a bizarre sensation over the upper part of one or other trapezius muscle with the onset of a prickly sensation in the upper cervical and occipital regions; in the other 2 cervical /
cervical lesions the bladder fullness was associated with flushing and perspiration of the face. Similar vasomotor changes were present in the fifth patient, who had a complete cord lesion at the D₁₂ segmental level. Thus in 5 patients with complete cord section bladder fullness was associated with peripheral autonomic responses, and it is interesting to note that in 3 of these patients these peripheral manifestations were maximal when the urinary stream was actually passing.

From careful questioning of these patients with unusual sensations of bladder fullness it was realised that the sensations were not only variable but might also be transient, and were thus not altogether reliable as an indication of when reflex micturition was either imminent or indicated. The majority of those patients who had been fully co-operative during the development of micturition "by the clock" found that their bladder control was more satisfactory over a period of months when such associated sensations were ignored and when their training routine of balanced fluid intake and regular micturition was followed. This regular habit was also found to be more desirable during the early stages of treatment when the patients with spinal reflex bladder function were being educated to locate and use "trigger spots" to initiate reflex voiding. There was an impression that when the reflex bladder was allowed to fill to that stage at which atypical sensations of fullness were experienced, then it was more difficult to induce reflex voiding by peripheral stimulation.
Of the 19 patients in this series who developed reflex type of bladder function after complete cord lesions, 5 of the 8 patients without any associated awareness of fullness induced reflex voiding by abdominal straining, whilst in 3 percussion of the suprapubic region was used. Of the 11 patients who had some awareness of bladder fullness micturition was initiated by straining in 5 and by suprapubic percussion in six. When reflex voiding was initiated by abdominal straining, it was almost invariable that if the straining was continued after the moment that voiding began then the urinary stream was intermittent and unsatisfactory.

An autonomous type of neurogenic bladder developed in only two patients of the present series. Neither of them experienced any atypical sensation of bladder fullness and they both induced voiding "by the clock" by strong abdominal straining which had to be continued in order to maintain the urinary stream; their management is discussed further on p. 127.

Cystometry in the Phase of Recovery of Bladder Function

From cystometric studies in patients who had sustained traumatic cord injuries, Munro (1952) considered that the early stage of bladder recovery after cord section was characterised by the development of ineffective abortive emptying contractions which occurred at a rather low level of basic tonus, and were insufficient to produce adequate voiding.
voiding. He further noted that such bladders would regress
to an atonic condition if allowed to become overdistended
or infected, or if the general condition of the patient was
allowed to deteriorate. If such adverse influences were
avoided, then the bladder usually passed through a
hypertonic stage of recovery and was more typical of the
classical autonomous type of neurogenic bladder disorder.

In the management of traumatic paraplegia it is
obviously undesirable to continue indwelling urethral
catheter drainage in any patient for longer than proves
necessary to restore bladder balance. It is also important
to postpone active measures to hasten the recovery of
bladder function simply because clinical evidence has been
obtained of recovery of reflex cord activity. A deliberate
reduction in urethral resistance by various urological
procedures at too early a stage of bladder rehabilitation
might well be followed by urinary incontinence at a later
stage after further natural improvement in detrusor tonus
or in the power of abdominal straining has occurred as the
patient becomes more mobile.

In the present series of patients cystometry was
carried out in those patients in whom recovery in bladder
function was considered to be slow, and the cystometric
findings were correlated with the general and neurological
state of the patient. In this way it was possible to
decide whether the bladder had reached an end point in
recovery and required more active treatment in order to
restore /
restore balanced function, or was simply slow to recover and required a further period of indwelling urethral catheter drainage.

Figs. 72 and 73 show the cystometrograms taken in a 33-year-old woman who had sustained a compression fracture of D.6 - 7 with complete paraplegia below the D.10 level. The recordings were taken five weeks and thirteen weeks respectively after the onset of paraplegia, and show the conversion of a hypotonic recovery phase bladder with decompensation to a compensated reflex bladder after a further eight-week period of intermittent drainage through an indwelling urethral catheter.

Figs. 74 and 75 show the cystometrograms taken in a 40-year-old man with complete section of the cervical portion of the spinal cord following traumatic dislocation of C.5 - 6. The first tracing (Fig. 74) was taken one year after the onset of tetraplegia and it suggested that the bladder was still in a tonic recovery phase. After a further period of indwelling urethral catheter drainage, compensated reflex bladder function was restored as shown in the second cystometrogram (Fig. 75) taken eight months later when he attended for full urological review.

When cystometry was used to indicate the ideal period of indwelling urethral catheter drainage required by individual patients, it was found that many patients of the whole group responded to the regime of urological management as already described; they recovered either normal reflex or otherwise compensated bladder function within a few weeks from the time of injury without further clinical investigation or more active treatment.
Fig. 72

Fig. 73

Figs. 72 and 73. - Cystometrograms in a patient 5 and 13 weeks after the onset of paraplegia (D.10).

Fig. 74

Fig. 75

Figs. 74 and 75. - Cystometrograms in a patient 12 and 18 months after the onset of paraplegia (C.8).
The Incidence of Early Urological Complications following Indwelling Urethral Catheter Drainage

Of the 23 patients who received their main urological management in the Spinal Injuries Unit, 18 were catheter-free at the time of analysis, and many of these were entering their third year of follow-up. Twelve of these 18 patients had sustained complete cord section, whilst 6 had had either incomplete or transient neurological lesions. Only one patient out of the entire group of 18 patients maintained sterile urine throughout the period of catheter drainage; in his case the catheter was indwelling for only a few days during a period of spinal concussion.

In the remaining 17 patients mixed infections were present, though it was sometimes four weeks after the initial catheterisation before the infection became established. The predominant organisms were *P. pyocyanea*, *B. proteus* and *B. coli*.

In the patients with complete cord lesions the duration of catheter drainage varied from 8 to 70 weeks, but only four patients were drained for periods longer than 20 weeks, whilst the shortest period of drainage was 4 weeks. In the incomplete cord lesions the period of catheter drainage varied from a few days to 13 weeks, though the majority were drained for a period less than 10 weeks.

Despite /
Despite an almost universal incidence of mixed urinary infection with organisms which are notoriously difficult to eradicate, 6 of the 18 patients were subsequently found to have no obvious urinary infection during the early phases of follow-up within the first two years after injury. Furthermore, only 4 of these 18 patients developed epididymitis, and in only one of them was urethritis definitely established, though in this patient it progressed to peri-urethral abscess formation with urethral fistula. Two patients developed small bladder calculi; one of the patients who developed epididymitis (Case 16) had been drained by catheter for 70 weeks but his urine eventually became sterile during the second year of follow-up.

None of these 18 patients had shown any radiological evidence of calculus disease in the upper urinary tract. In each of them intravenous pyelography had demonstrated satisfactory function in both kidneys without any evidence of hydronephrosis or hydro-ureter.

These findings suggest that if the regime advocated for the management of the paraplegic patient by indwelling urethral catheter drainage is strictly applied, then it must still be anticipated that urinary infection will be almost universal. However, such infection did not necessarily interfere with rehabilitation of the bladder and the period of catheter drainage required in most patients even with complete cord lesions was comparatively short. The incidence of epididymitis and bladder calculus formation is of doubtful significance in such a small group of patients but did not constitute a major problem.
Urological Management of the Paraplegic Patient in the Phase of Complications

In considering the urological management of the paraplegic patient during the third phase, the term "complications" is not used with reference to the incidence of urinary infection, epididymitis or bladder calculus formation, as already described during the early stages of management. It is used specifically to refer to the investigation and treatment of the bladder which had failed to show an early response to efforts of rehabilitation.

In this context, the urological management of individual cases was considered to be complicated when cystometry showed that the bladder activity had either stabilised atypically, as compared with the general condition of the patient and the extent and site of neurological injury, or when the bladder could be classified as reflex, autonomous or atonic in type but remained decompensated. Persistent urinary infection, further calculus formation and upper urinary tract dilatation, with or without vesico-ureteric reflux, could at this stage usually be attributed to a failure in bladder rehabilitation and in the present series were not often themselves considered to be the direct cause of serious delay in recovery of bladder function. These complicated cases were classified as follows:

(1) /
(1) The spastic reflex bladder.
(2) The tonic autonomous bladder.
(3) The atonic bladder.
(4) The atypical neurogenic bladder.

The Spastic Reflex Bladder

In some patients minor trophic lesions of the skin, reflex muscle spasms of no great orthopaedic significance, or intractable low grade epididymo-orchitis appeared to be responsible for interference in the co-ordination of the sacral reflex arc of the bladder by diffusion of noxious afferent stimuli in the autonomous portion of the cord below the level of section. This neurological mechanism has already been referred to in relation to cordotomy (p. 87) and has been more fully described in paraplegia by Hutch (1958); it may then be responsible for hyperactive though co-ordinated activity of the detrusor musculature which becomes hypertrophic, trabeculated and sacculated; it is usually associated with dribbling incontinence and irregular voiding, but the trigone and bladder neck may share in the muscular hypertrophy so that some residual urine is persistent. In other patients it is associated with ureteric reflux and a rapid development of dilatation in the upper urinary tract, on one or both sides. Hutch considered that the upper tract dilatation was not due simply to the raised intravesical pressure, but was associated with saccule formation in the region of one or other /
other ureteric orifices so that the valvular action of the
intravesical ureter was destroyed and the intramural portion
of the ureter migrated outwards to form a functional
obstruction to ureteric drainage. He applied the term
"hydroflux" to this local disturbance of the ureterovesical
junction and devised a plastic operation for its correction,
as illustrated in Fig. 76.

A spastic reflex bladder developed in one patient in
the present series as follows.

Case 16.—This 37-year-old man fell from a height and
sustained a fractured spine with immediate paraplegia below
D.10. Continuous urethral catheter drainage was
instituted shortly after injury, and though his general
condition and progress were entirely satisfactory, complete
urinary retention prevailed three months after his injury.
The cystometrogram taken at this time is shown in Fig. 77.
It indicated that the bladder had good tonus, but was
partly under the influence of peripheral flexor spasms which
were not in fact very marked and were not interfering with
his rehabilitation from the orthopaedic point of view.
Intermittent bladder drainage through an indwelling
urethral catheter was continued for a further eight weeks
and then a further cystometrogram was taken which is shown
in Fig. 78. The resting pressure had increased to 18 cm.
of water and after only 25 c.c. of filling a peripheral
flexor spasm occurred and the bladder pressure rose to
110 cm. of water. Plateau filling at 55 cm. of water
pressure then continued to 100 c.c. of filling, when again
peripheral flexor spasms raised the pressure intermittently
to 87 cm. of water.

Cystoscopy.—At cystoscopy the bladder was seen to be
mildly trabeculated and there was definite hypertrophy of
the bladder neck. A transurethral resection was carried out
and though the immediate convalescence was entirely
satisfactory, urinary retention prevailed. Six months from
the date of injury ascending urethrography and
sphincterometry indicated that the external sphincteric
resistance was 65 cm. of water, but this investigation was
followed by recurrent attacks of epididymitis and persistent
mixed urinary infection with B. proteus, Pa. pyocyanea,
enterococci and coliform organisms.

One /
Fig. 76. Diagrammatic representation of the mechanism (a, b) and surgical treatment (c) of "hydroflux". (Hutch, 1958.)

Fig. 77. Case 16: Cystometrogram three months after the onset of paraplegia.

Fig. 78. Case 16: Cystometrogram five months after the onset of paraplegia.
One year after injury and after further prolonged urethral catheter drainage, his urinary infection was under control and urological re-assessment was undertaken.

On cystoscopy the bladder still showed mild trabeculation, but the bladder neck was now wide, though lined with granulation tissue.

A voiding cystogram suggested that there was increased resistance at the level of the external urethral sphincter, but there was no response to bilateral pudendal nerve block with 1 per cent lignocaine though the bulbo-cavernosus and ano-cutaneous reflexes were completely abolished.

These procedures were followed by a recurrence of his urinary infection but when this subsided urinary retention prevailed and further re-assessment was required.

Cystometrogram (Fig. 79).- Resting pressure 3 cm. of water. As filling began a strong intrinsic bladder contraction raised the pressure to 100 cm. of water, followed by plateau filling to 150 c.c. at 44 cm. of water pressure, when a further strong co-ordinated contraction occurred.

A voiding cystogram (Fig. 80) showed the bladder to be small and spastic with right ureteric reflux, but the bladder neck was adequately relaxed and the urethrogram was within normal limits.

It was only at this stage of management that the possibility of spastic reflex activity was fully appreciated and though intravenous pyelography showed no abnormality in the upper urinary tract (Fig. 81), more specific treatment was obviously indicated, if not already overdue.

On two consecutive days 200 mg. of lignocaine in 150 c.c. of sterile water were instilled into the bladder and retained for 15 minutes, but there was no therapeutic effect (see Comarr, 1959). Accordingly, the 2nd sacral nerve roots were injected bilaterally through the posterior sacral foramina with 1 per cent lignocaine. Following this procedure there was a definite improvement in bladder function; there was a more obvious response to prescribed bladder relaxants and a repeat cystometrogram showed (Fig. 82) that with a resting pressure of 15 cm. of water, the bladder accepted 200 c.c. at a pressure of 25 cm. of water before a strong co-ordinated contraction of the detrusor (initiated by a cough) raised the bladder pressure to 110 cm. of water.
Fig. 79: Case 16: Cystometrogram 15 months after the onset of paraplegia.

Fig. 80: Case 16: Voiding cystogram 18 months after the onset of paraplegia.
Fig. 81. - Case 16: intravenous pyelogram 18 months after the onset of paraplegia.

Fig. 82. - Case 16: cystometrogram after sacral root infiltration.
One month later he was continent up to three hours and began voiding by suprapubic percussion to produce a strong urinary stream though on occasion it was found necessary to withdraw bladder relaxants completely and to give injections of Moryl.

Eighteen months after the time of injury this patient had complete control of reflex bladder function. His residual urine was ½ oz. and intravenous pyelography showed good bilateral function with no evidence of abnormality in the upper urinary tract. When followed up two years after injury, improvement had been maintained and there was no evidence of urinary infection.

Comment.—The failure of bilateral pudendal nerve block and topical anaesthesia of the bladder mucosa to reduce the intensity of the reflex activity of this bladder even temporarily suggested that infection (in the posterior urethra, prostate or bladder) was not responsible for irritative stimulation of the spinal centre for micturition. The second sacral roots were selected for injection because of a clinical impression that plantar flexion of the ankle was the initial involuntary movement of the more generalised flexor spasms which occurred in this patient's lower limbs. Furthermore, it was considered desirable to leave the third sacral roots undisturbed at this stage, because they represent the main segmental outflow of the motor innervation of the bladder (Heirowsky et al., 1950), and because such simple local anaesthetics as procaine or lignocaine have occasionally been found to have a permanent rather than the expected temporary effect when injected around peripheral axons emerging from a previously damaged or deranged spinal cord (Tulloch, 1959). The prolonged effect of the sacral block carried out in this patient justified this precaution. As improved bladder control developed he became more active and mobile, so that it was difficult to assess the precise effect of the sacral root block upon the limb spasms themselves. In retrospect, it is possible that the unilateral vesico-ureteral reflux associated with spastic reflex activity in the bladder might have been prevented in this patient if the cystometrograms had been more correctly interpreted and the sacral root block had been carried out at an early stage.

In the management of a tonic or spastic reflex bladder difficulty is sometimes encountered in the localisation of any source of irritant afferent stimuli which may interfere with the spinal centre for micturition, and this problem may present /
present in patients in whom voluntary control of reflex bladder activity has begun to deteriorate some years after the onset of traumatic paraplegia. In one such patient in this series the most prominent feature was marked hypertrophy of the bladder neck; his case history was as follows.

Case 17.- At the age of 40 this 46-year-old man was involved in a pit accident and sustained a fracture dislocation of D.12 - L.1 with complete paraplegia below L.1. Operative reduction and plate fixation of his spinal fracture was carried out and his initial urological management was by urethral catheter drainage, as already described. He was referred to the Spinal Injuries Unit six years after injury with a long-standing complaint of dribbling incontinence of urine with recurrent episodes of urinary infection. Intravenous pyelograms demonstrated moderate right-sided hydronephrosis, but the ureters were not outlined. The following investigations were then undertaken:

Cystometrogram (Fig. 83).- Two-way catheter passed without difficulty to drain 60 c.c. of residual urine (enterococci cultured from this specimen). Resting pressure nil. With 50 c.c. of filling the pressure rose to 25 cm. of water and then more steeply to 55 cm. of water. Plateau filling to 60 c.c. occurred, but a voluntary contraction produced a peak pressure of 100 cm. of water whilst a peripheral flexor spasm was associated with a further brisk bladder contraction to a pressure of 110 cm. of water with bypassing of the catheter.

Cystogram.- A P.A. view (Fig. 84) showed a small capacity bladder with gross trabeculation and sacculation without ureteric reflux. A voiding film was not obtained.

Cystoscopy without general anaesthesia confirmed the reduced bladder capacity and the trabeculation and sacculation of the bladder vault; it further demonstrated gross hypertrophy of the bladder neck which prevented the taking of a retrograde pyelogram for the further elucidation of the right-sided hydronephrosis.

A transurethral section of the posterior quadrant of the bladder neck was accordingly carried out; it was followed by recurrent attacks of bilateral epididymitis and urinary infection for which prolonged intermittent drainage by indwelling urethral catheter was required.

Three /
Fig. 83. - Case 17: cystometrogram six years after the onset of paraplegia.

Fig. 84. - Case 17: P.A. cystogram six years after the onset of paraplegia.
Three months later the urinary infection was under control and further urological assessment was carried out as follows:

Cystometrogram (Fig. 85).— Two-way catheter passed without difficulty. Negligible residuum of clear urine withdrawn; resting pressure nil. The bladder accepted 115 c.c., with a rise in pressure to only 10 cm. of water; a strong co-ordinated intrinsic contraction then raised the pressure suddenly to 70 cm. of water and caused reflux into the filling flask. The pressure declined to 30 cm. of water after 150 c.c. of filling and a voluntary contraction then produced a peak pressure of 90 cm. of water; this voluntary contraction was immediately followed by an involuntary contraction of the same amplitude.

Cystogram.— A right oblique voiding view (Fig. 86) showed an increase in bladder capacity as compared with the previous film; though the trabeculation and sacculation remained as before, there was no ureteric reflux and the bladder neck was seen to be wide and the urethrogram of normal calibre.

Cystoscopy.— Following the transurethral resection of the bladder neck the right ureteric orifice was easily identified and was catheterised without difficulty to 30 cm. A right retrograde pyelogram was taken, but showed that the catheter had curled up in the lower spindle of the right ureter, which was markedly dilated. No dye had entered either the upper ureter or the right renal pelvis and it was therefore assumed that the right-sided hydronephrosis was associated with right hydro-ureter secondary to the hypertonic bladder state.

Progress.— Probanthine was prescribed in a dose of 15 mg. twice daily, and during the succeeding weeks his urinary control improved and he was continent up to one and a half hours with occasional dribbling. He found that he could initiate a good urinary stream by suprapubic percussion and was able to pass up to 250 c.c. at any one time. A further intravenous pyelogram showed definite diminution in the size of the right hydronephrosis and when seen six months after transurethral surgery it was noted that there had been a striking improvement in this patient's general condition, and it was elicited that his lower limbs had been much less spastic.

Comment.— It remains uncertain whether the hypertonicity of the bladder in this patient represented an exaggerated tonic response to bladder neck hypertrophy or spastic reflex bladder activity with a neurological basis.
Fig. 85. - Case 17: cystometrogram after transurethral resection of the bladder neck.

Fig. 86. - Case 17: voiding cystogram after transurethral resection of the bladder neck.
It is difficult to accept that a persistent discharge of motor stimuli from the sacral centre for micturition would produce hypertrophy of both the detrusor vault of the bladder and the bladder neck, because though the musculature of these two regions is in continuity, they are functionally opposed and have a separate motor innervation. The precise aetiology of bladder neck hypertrophy in neurogenic bladder remains obscure and though it is generally most marked in the autonomous type (dissociated from the sacral reflex arc), it has been seen to develop in patients with typical spinal reflex bladders without spastic hypertonus as shown in Figs. 87 and 88.

This patient had complete paraplegia following transection of the cervical portion of his spinal cord; he was markedly iodine-sensitive and the cystograms were taken with a sterile colloidal suspension of barium in normal saline (Steripaque). The cystometrograms taken in this patient prior to cystography are shown in Figs. 74 and 75.

The findings in Case 17 suggest that there is no particular risk of persistent urinary incontinence after transurethral resection of the bladder neck in patients whose cystometrograms have shown that the tonic activity of the bladder is reflex and co-ordinated. Furthermore, it is probable that in the tonic reflex bladder with hypertrophy of the bladder neck the lack of adequate urinary control is the combined result of tonic detrusor activity, increased urethral resistance, reduced bladder capacity and a rising residuum of urine. Transurethral surgery in these patients reduces /
Figs. 87 and 88.- Voiding cystograms in a patient 12 and 18 months after the onset of paraplegia (C.8); there has been progression of bladder neck hypertrophy (and urethral diverticulum formation).
reduces the urethral resistance and thereby the amount of residual urine but this direct attempt to restore bladder balance is also followed by a reduction in detrusor tonus which may well represent a local muscular response to the lowering of urethral resistance as occurs in the hypertrophied bladder after prostatectomy. There is no reason to suspect that such a fall in tonus in the neurogenic bladder requires the reflex arc of micturition to be intact, but it was interesting to find that in Case 17 transurethral resection of the bladder neck was followed by a more marked clinical response to anti-cholinergic agents such as Monodral and Probanthine. The lowered filling tonus of the bladder is desirable because it is accompanied by an increase in bladder capacity allowing prolongation of the intervals between co-ordinated reflex contractions with little risk of progressive dilatation in the upper urinary tract.

The Tonic Autonomous Bladder

When the spinal injury has led to destruction of the sacral segments containing the spinal centre for micturition or to division of the cauda equina, the bladder detrusor activity though tonic is inco-ordinate. In such patients urinary control is more difficult to achieve and may follow only prolonged training and careful management so that it is justifiable to consider the management of the autonomous type of neurogenic bladder in paraplegia in the phase of complications. The high tonus of the autonomous bladder /
bladder at both the resting and filling stages is frequently the cause of progressive dilatation in the upper urinary tract, whilst the absence of co-ordinated emptying may be responsible for persistence of a significant residuum of urine and a high incidence of urinary infection. During the phase of rehabilitation care must be taken to distinguish between the autonomous bladder which is permanent and that which is merely at a recovery phase and with proper management may develop into a reflex type. This distinction may be made only by repeated cystometry during a prolonged period of indwelling urethral catheter drainage. When it is apparent that the bladder has stabilised as an autonomous type of neurogenic disorder the amount of residual urine should be repeatedly checked, and if it is persistently found to be greater than 10 per cent of the bladder capacity then full urological assessment is required and active urological intervention is urgently needed.

Endoscopic suggestion of hypertrophy or contracture of the bladder neck may be confirmed by cystography. In such patients transurethral resection of the bladder neck should be carried out as recommended by Lammro (1948) and by Band (1956). If this procedure is used indiscriminately it may be followed by intractable urinary incontinence though this complication may be unavoidable in some patients in whom the urethral resistance has to be reduced to a very low level before the residual urine falls to a safe and negligible amount /
amount. When the autonomous type of neurogenic bladder occurs in incomplete lesions of the sacral cord and cauda equina it may then be associated with appreciable urethral resistance at the level of the external urethral sphincter. Such resistance may be responsible for adequate urinary control after resection of the bladder neck but it may also be raised to an abnormal level and be responsible for decompensation of the autonomous bladder. Under such circumstances the external sphincteric resistance can be reduced by pudendal neurectomy after a therapeutic trial of pudendal nerve block. The reduction of urethral resistance either by transurethral resection of the bladder neck or by interruption of the pudendal nerve supply to the external sphincter in cases of autonomous neurogenic bladder disorder will usually lead to some reduction in bladder tone and an increase in bladder capacity; since voiding is adequately accomplished only by abdominal straining, urinary incontinence will usually by aggravated and may occur with any rise in intra-abdominal pressure such as accompanies general activity by the patient as he becomes mobile and rehabilitated.

An autonomous type of neurogenic bladder disorder was found in only two patients of the present series of traumatic paraplegia. In each of them the neurological level was at D.10 but their paraplegia was complete. In one of them it was difficult to understand why reflex bladder function had not been restored. This patient presented some difficulties in management and will be described in detail.
Case 18. - This 32-year-old man fell from a height and sustained a fracture of his 11th dorsal vertebra and dislocation of D.10 - D.11 with complete flaccid paraplegia below D.10. This patient was left without catheter drainage for 24 hours immediately after injury and for two weeks thereafter was treated by four-hourly intermittent drainage through an indwelling urethral Foley catheter. Four months after injury there was clinical evidence of return of reflex function in the autonomous portion of his spinal cord, but urinary retention prevailed. A cystometrogram at this stage (Fig. 89) showed a negligible resting pressure without spontaneous contractions on filling to 400 c.c. though the pressure rose to 30 cm. of water. A voluntary contraction at maximal filling produced a peak pressure of 80 cm. of water. No sensation of bladder fullness was experienced. Cystoscopy at this time showed no evidence of infection or trabeculation of the bladder and there was no contracture of the bladder neck. Intermittent drainage through an indwelling urethral catheter was continued for two months and the cystometrogram was then repeated (Fig. 90). The tracing showed the same general pattern as previously, but the overall tonus had improved. Cystoscopy was again carried out and there was a suspicion of early hypertrophy of the bladder neck. During the succeeding weeks, trials without the catheter were accompanied by irregular dribbling incontinence to leave a residuum of 150 c.c. of urine after injections of Moryl. Further trials without the catheter showed little improvement, but this patient was now mobile in his wheelchair and became extremely unco-operative with regard to fluid intake and bladder training.

Eight months from the time of injury he was still without adequate urinary control and his residual urine was excessive. At this time the bulbocavernous and anocutaneous reflexes could be elicited easily, and it was suspected that the delay in return of reflex bladder activity was possibly due to the overdistension of his bladder which might have occurred during the first two weeks of management. Accordingly, cystograms were taken in order to localise the level of any increased urethral resistance which might be preventing adequate emptying of the bladder by abdominal straining; the previous cystometrograms had shown high peak pressures to be attained by voluntary contraction.

Cystograms. - /
Fig. 89.- Case 18: cystometrogram four months after the onset of paraplegia.

Fig. 90.- Case 18: cystometrogram six months after the onset of paraplegia.
Cystograms.- The P.A. view (Fig. 91) demonstrated a normal capacity bladder of smooth contour and without ureteric reflux. The left oblique voiding view (Fig. 92) showed some shelf formation on the posterior aspect of the relaxed bladder neck. There was dilatation of the prostatic urethra below the bladder neck down to the level of the external urethral sphincter.

Ascending Urethrogram and Sphincterometry (Fig. 93).- The external sphincteric resistance was measured at 180 cm. of water pressure.

Bilateral pudendal nerve block was carried out with 1 per cent lignocaine and the bulbo-cavernosus and ano-cutaneous reflexes were abolished. Following this procedure he voided urine with a variable stream and with intermittent incontinence, but his residual urine after injections of Moryl was negligible.

His condition remained unchanged for a further six weeks; he continued to be unco-operative and complained bitterly about the wearing of a portable urinal in the management of the incontinence. A further cystometrogram was accordingly carried out (Fig. 94). Though the resting pressure was negligible the bladder accepted 250 c.c. of fluid with a high tonic reaction and with a filling pressure after 100 c.c. of over 60 cm. of water. Irregular intrinsic activity raised the pressure at intervals to 70 cm. of water, whilst a voluntary contraction at maximal filling produced a peak pressure of 110 cm. of water. The pattern of the tracing was typical of autonomous neurogenic bladder disorder.

Eleven months after the onset of his paraplegia this patient obtained a satisfactory settlement of his compensation claim; he became more amenable to treatment and accepted the portable urinal as a necessary part of treatment. Though he could produce a good urinary stream with abdominal straining, urinary incontinence prevailed; his residual urine remained negligible after Moryl injections, and he was accordingly discharged from hospital with an understanding that he would continue bladder training and that Moryl injections would be given to him each evening.

He made satisfactory progress, as judged by interim review, for eight months and was then re-admitted to hospital with preputial ulcerations and urethritis. He then admitted that urinary control had been negligible for several weeks, and that the urinary incontinence had worsened. Urinary infection responded to chemotherapy and urethral Foley catheter drainage and further cystometry was carried out.
Fig. 91. Case 18: P.A. cystogram eight months after the onset of paraplegia.

Fig. 92. Case 18: Left oblique voiding cystogram eight months after the onset of paraplegia.
Fig. 95.- Case 18: ascending urethrogram during sphincterometry.

Fig. 96.- Case 18: cystometrogram 10 months after the onset of paraplegia.
Cystometrogram (Fig. 95).— showed a serious deterioration in bladder tonus. The resting pressure was now negligible and with filling to 325 c.c. the pressure slowly rose without intrinsic activity to only 17 cm. of water; a voluntary contraction then produced a peak pressure of 80 cm. of water.

This patient was eventually rehabilitated without urinary incontinence and with regular voiding by abdominal straining at two-hourly intervals. He remained completely devoid of bladder sensation and found that abdominal straining had to be maintained throughout the urinary stream.

Comment. — Though this patient was unco-operative and had perhaps experienced overdistension of the bladder at an early stage of treatment, prolonged urethral catheter drainage was followed by a stabilisation of his bladder as an autonomous type despite the presence of reflex cord activity below the level of section and an adequate degree of bladder compensation followed bilateral lignocaine pudendal nerve block. However, it is probable that this unco-operative patient had failed to practise adequate bladder drill; voiding was probably incomplete and in the presence of infection it was inevitable that bladder atony would occur. Subsequent review indicated that this lowered bladder tonus was compatible with adequate bladder function provided that voiding was carefully completed by strong abdominal straining.

The Atonic Bladder

Selective interruption of the afferent limb of the sacral reflex arc subservient to micturition is probably uncommon after spinal trauma, but may occur as the result of penetrating wounds. It could be argued that the bladder of spinal shock truely represents the typical atonic type of neurogenic bladder disorder, but in the phase of complications bladder atony usually represents the end result of some adverse influence or interference with the tonus of either an autonomous or a spinal reflex type of neurogenic bladder disorder. This loss of tonus may be
Fig. 95. - Case 18: cystometrogram
19 months after the onset of paraplegia.
the result of mis-management, whereby overdistension of the bladder has been allowed to occur, or it may follow serious and prolonged infection, not only in the urinary tract but in other systems of the body. This loss of tone may be desirable in some cases because it may allow for a more reasonable degree of voluntary control over voiding than would either an autonomous or a spastic reflex type of bladder. In this context, it is possible to justify the deliberate induction of bladder atony by sacral rhizotomy (Meirowsky et al., 1950; Brendler et al., 1953), by sacral neurectomy (Hutch, 1957), by subarachnoid alcohol injection (Shelden and Bors, 1948; Hutch, 1955), or by surgical removal of the comus medullaris (Hutch, 1957). The effect of these procedures is graphically represented in Fig. 96, but in this present series it has not, as yet, been found necessary to carry out the more radical of them in order to restore bladder balance. Occasionally intrathecal injections of either alcohol or phenol have been given for the relief of peripheral flexor spasms.

Subarachnoid injections of alcohol or phenol have acquired a reputation for producing atony of the bladder when they are used in the treatment of spasticity in paraplegia. However, in 1953, Stellar reported the cystometric findings in nine cases before and after subarachnoid injection of alcohol. In five cases hypertonia of the bladder was converted to mild or moderate hypotonia.
Fig. 26.—Diagrammatic representation of the effect of division of the central connections of the spastic type of reflex neurogenic bladder disorder.
hypotonia, but in no case did the bladder become completely atonic; in one case a hypotonic bladder became hypertonic. In one case of the present series loss of bladder tonus followed the intrathecal injection of phenol for peripheral spasms associated with traumatic paraplegia below a D.5 level.

Case 19.- This 63-year-old man sustained a fracture dislocation of the 5th dorsal vertebra with complete paraplegia. Satisfactory reflex bladder function was established within one year from the time of injury, but during the next 18 months he developed severe peripheral flexor spasms. A cystometrogram taken at this time (Fig. 97) demonstrated spinal reflex bladder activity with peak contractions up to 80 cm. of water which were associated with peripheral spasms during the recording.

Following the intrathecal injections of phenol, there was dribbling incontinence of urine, though the flexor spasms were considerably improved. A further cystometrogram (Fig. 98) was taken one month after the injections had been given; it showed that the resting pressure was high (22 cm. of water) and though no coordinated detrusor activity was present, definite low amplitude inco-ordinate contractions occurred as the pressure rose to 65 cm. of water with 500 c.c. of filling.

Though this cystometrogram could probably be classified as an autonomous type, further review two months later showed that the bladder had become completely atonic, and no evidence of contractility was apparent up to 450 c.c. of bladder filling. An ascending urethrogram with sphincterometry at this stage showed the sphincteric resistance to be 35 cm. of water. This patient now had no urinary control and his residual urine was 150 c.c. Accordingly, a transurethral resection of the bladder neck was carried out and after an uneventful convalescence the bladder was found to be compensated completely after Moryl injections.

When reviewed two years later this patient's urinary incontinence had deteriorated because there had been recurrence of his flexor spasms; he found it necessary to wear a portable urinal both day and night.

Comment.- /
**Fig. 97.** - Case 19: Cystometrogram before intrathecal injections of phenol.

**Fig. 98.** - Case 19: Cystometrogram one month after intrathecal injections of phenol.
Comment.- This patient illustrates the serious disadvantages that may result from atony of the bladder in traumatic paraplegia. In order to ensure adequate bladder drainage after reflex micturition had been abolished by intrathecal phenol injections it was found necessary to reduce drastically the urethral resistance by transurethral resection of the bladder neck so that incontinence of urine prevailed.

Comparison of the cystometrograms taken in this patient indicate that the bladder atony was not the direct result of the intrathecal injections of phenol. These injections were responsible for the conversion of the bladder from a classical reflex type to an autonomous type. Atony and decompensation of the bladder developed subsequently because of inadequate emptying and persistent infection. The resection of the bladder neck was not an extensive procedure, and urinary incontinence was not anticipated because the external sphincteric resistance was within the normal range. It is possible that urinary control may subsequently improve in this patient if any further neurological procedure is undertaken for more permanent relief of the peripheral flexor spasms.

The Atypical Neurogenic Bladder

Though cystometry was found to be valuable in the assessment and management of neurogenic bladder disorders in paraplegia, changes in the treatment programme and specific surgical interventions were not undertaken after a mere consideration of the cystometrogram alone. The information obtained from this isolated clinical investigation was always integrated with other clinical findings so that it was obvious when cystometry gave a false representation of bladder activity as related to the type and nature of neurogenic bladder disorder. Occasionally it was found that simple catheterisation of a paraplegic patient acted as a powerful stimulus to the sacral centre for micturition and caution was required in interpreting the significance of cystometrograms taken in such /
such circumstances. The point was illustrated in the following case.

Case 20.- At the age of 24 years this man fell from a height and sustained a wedge compression fracture of the 6th cervical vertebra without displacement. Complete flaccid paraplegia developed below T.3 with analgesia below C.8 and complete anaesthesia below T.3. His initial urological management had been carried out in another centre, where a urethral catheter had been passed shortly after injury and continuous urethral catheter drainage had been continued for eight weeks. It was then considered that he had developed a spinal reflex bladder and catheterisation was accordingly discontinued.

One year after injury he was admitted to the Spinal Injuries Unit for re-assessment. It was found that his neurological state was unchanged; he was found to have a urinary infection with B. proteus and coliform organisms. It was proposed to treat this patient in the first instance with chloramphenicol during a short period of continuous indwelling urethral catheter drainage. The passage of a Gibbon's catheter produced powerful and persistent peripheral flexor spasms accompanied by profuse sweating and flushing of the face. These reactions became so marked that it was found necessary to remove the catheter after three days of drainage. Probanthine was administered in a dose of 15 mg. three times daily by mouth, and during the succeeding week bladder drill became more effective and the patient quickly adapted himself to the routine of micturition "by the clock". A good urinary stream was initiated by suprapubic percussion, and though bladder fullness was inconstantly associated with peripheral autonomic manifestations they were not used as a substitute sensation to indicate when micturition was desirable. As reflex micturition became more regular it was found that the peripheral flexor spasms and the vasomotor changes became much less obvious. However, macroscopic haematuria occurred on one occasion and it was thought desirable to carry out further urological investigations.

Intravenous Pyelography showed no abnormality in the upper urinary tract.

Cystometrogram (Fig. 99).— Two-way catheter passed with difficulty because instrumentation was accompanied by peripheral flexor spasms. Resting pressure was 18 cm. of water. After filling to 75 c.c. the bladder pressure slowly rose to 30 cm. of water and brisk intrinsic activity then occurred and the pressure rose to 60 cm. of water /
Fig. 99. - Case 20: Cystometrogram one year after the onset of paraplegia.
water with 125 c.c. of filling. A further rise to 65 cm. of water occurred after 170 c.c. and attempts at voluntary contraction then produced a peripheral flexor spasm with a peak bladder pressure of 97 cm. of water. No sensation of any kind was experienced throughout this examination.

Cystoscopy.— Under general anaesthesia it was found impossible to pass a 21 F. cystoscope into the bladder; any attempt to negotiate the external urethral sphincter produced severe spasm of the lower limbs and the pelvic floor musculature, and there was brisk urethral haemorrhage.

Following further bladder drill and Probanthine medication this patient's bladder function stabilised and was typically reflex in type.

Comment.— There was no particular clinical indication for cystometry in this patient, but in view of the previous experience with Case 16 it was thought desirable to exclude a spastic reflex condition of the bladder before he was discharged from hospital. The cystometrogram which was obtained was more typical of an autonomous type of neurogenic bladder disorder, though there was no clinical doubt that compensated spinal reflex bladder function was present.

Urological Care of the Paraplegic Patient in the Phase of Home Management

No patient was recommended for discharge from the Spinal Injuries Unit until it was felt that he or she appreciated the importance of maintaining the strict bladder drill which had been established during the phase of rehabilitation. An increased fluid intake and urinary antiseptics were continued as part of the regime of general care. The majority of those patients who had developed reflex bladder activity were dissuaded from wearing either a penile clamp or a portable urinal appliance as a precaution against incontinence; it was felt that they might come to rely /
rely upon such apparatus and gradually neglect the reflex voiding habit.

In patients with urinary incontinence in association with compensated autonomous or hypotonic bladders it was preferred to adapt a condom type of urinal as recommended by Comarr (1959) in preference to the heavy and more rigid Stoke-Mandeville type of appliance, which was frequently the cause of abrasions and sores on the prepuce and the ventral aspect of the penis at the peno-scrotal junction. Moreover, there was a possibility of more serious complications when such a heavy type of urinal was used by tetraplegic patients who were unable to control the position of the urinal adequately whilst sedentary in a wheelchair; such patients preferred to wear a urinal even though continent because it made them independent of their attendants at the time of reflex voiding.

The cystometric studies carried out in the present series of patients with traumatic cord injuries showed a certain gradation in intensity of bladder activity according to the level of cord section. The most powerful detrusor contractions were recorded in patients with complete section of the cervical region of the spinal cord. In such patients it was occasionally found during cystometry that powerful co-ordinated detrusor contractions could maintain a high state of tonus against further filling, if bypassing of the catheter did not occur.

This /
This phenomenon is shown in the cystometrogram taken from a 20-year-old patient 18 months after the onset of traumatic tetraplegia with a C.5 level and illustrated in Fig. 100.

Such powerful detrusor activity working against resistance in the urethra from pressure at the peno-scrotal junction by a rigid urinal appliance might lead to the development of a urethral diverticulum (as shown in Figs. 87 and 88).

As far as possible urgent re-admission of paraplegic patients was arranged for the treatment of any severe urinary infection or for assessment of any undesirable change in bladder habit. They reported on an out-patient basis as far as possible at six-monthly intervals for intravenous pyelography, serum electrolyte and blood urea nitrogen estimations, urine culture and measurement of the bladder urine residuum.

The Results of Urological Management in 35 Patients with Neurogenic Bladder Disorders in Traumatic Paraplegia

The period of follow-up of these patients ranged from 4 months to 16 years, and though several of them were still within the first 2 years of surveillance, it was found that in the great majority of them urological management by indwelling urethral catheter drainage had been followed by compensated bladder function with adequate "voluntary" control. The period of catheter drainage required by these patients /
Fig. 100.—Cystometrogram in a patient 18 months after the onset of traumatic tetraplegia (C.5).
patients, as indicated on p. 117, was not unduly long, and though there was a high incidence of urinary infection during the stages of catheter treatment, several of these patients were found to be free from urinary infection during the phase of home management.

Severe urethritis developed in only one of those patients treated by indwelling urethral catheter drainage from the initial phase of paraplegia; the urethral fistula which subsequently formed did not require operative treatment and closed spontaneously after the administration of antibiotics.

Urological Procedures required to obtain Bladder Balance

In only four patients was transurethral resection of the bladder neck carried out, whilst in two others pudendal nerve block was required, and in one of these sacral root block was later performed. Closure of a suprapubic cystostomy track was required in two patients in whom this form of drainage had been instituted at other centres during the initial phase of treatment.

Incidence of Calculus Disease

Bladder calculi developed in 10 of these 35 patients but the stones were soft and small and were satisfactorily treated by transurethral litholapaxy.

In /
In 10 patients in whom the Gibbon catheter was the main instrument for bladder drainage, only two small bladder calculi developed, whilst in 20 patients drained by Foley catheter for prolonged periods, seven bladder calculi were found. One of the two patients who had had suprapubic drainage developed a bladder calculus and the other a small renal calculus. A small renal calculus also formed in a patient who developed a severe staphylococcal urinary infection during initial treatment by tidal bladder lavage in another centre. Neither of these renal calculi has as yet required surgical treatment.

The Incidence of Upper Urinary Tract Dilatation

Marked hydronephrosis and hydro-ureter developed in the two patients whose initial management had been by suprapubic cystostomy and was associated with vesico-ureteral reflux. In two of the patients treated by indwelling urethral catheter drainage, mild dilatation of the upper urinary tract was associated with spastic reflex bladder activity and in both of these patients the dilatation resolved after either transurethral resection or sacral root block.
When the involvement of the cord only partially destroys or interferes with ascending and descending pathways subservient to micturition then the urinary disturbance may be minimal. It might present as an uninhibited type of disorder and respond to the treatment prescribed for enuresis (p. 57).

If there is loss of bladder sensation hypotonia or atony of the bladder will develop but in the majority of such patients restoration of bladder balance will follow re-education in the voiding habit "by the clock", with abdominal straining and suprapubic manual pressure (Band, 1956). It may be necessary to encourage detrusor contractions by the administration of Moryl by injection or by mouth and voiding may be further facilitated by the transurethral resection of a limited amount of tissue from the posterior aspect of the bladder neck as described for persistent retention after cordotomy (p. 87), bladder atony in traumatic paraplegia (p. 134) and "primary" bladder atony (p. 172).

The urological investigation of patients with more extensive non-traumatic lesions of the spinal cord or nerve roots does not differ fundamentally from that carried out in patients /
patients with partial or complete cord section following trauma, as already discussed. However, many different pathological processes may cause neurological involvement and the method of urological management must be varied according to the prognosis of the primary disease.

When the progress of the disease has been arrested or is extremely slow so that the long-term prognosis is good, urological treatment must be definitive and directed towards complete rehabilitation with maximum preservation of renal function. If the primary disease is progressive and the overall prognosis is poor then urological treatment is justifiably restricted to the palliation of urinary incontinence or retention by measures of a severity adjusted to the patient's general condition.

When the neurological cord lesion is at a higher level than the sacral segments and the overall prognosis is good then the development and maintenance of reflex bladder activity is attempted as already discussed in traumatic paraplegia.

More difficult problems in long-term urological management usually arise in patients with incomplete paraplegia due to non-traumatic lesions of the conus medullaris and cauda equina. Such problems typically occur in patients with severe forms of spina bifida and will be discussed in detail.

Urological /
Urological Management in the Severe Forms of Spina Bifida

The severe forms of spina bifida will almost always affect the innervation of the bladder and rectum by interference with the 2nd, 3rd and 4th sacral nerve roots and the pelvic nerves. The more serious cases will thus have an autonomous type of neurogenic bladder disorder from an early age and usually accompanied by faecal incontinence. Obvious difficulties will arise in educating both the parents and the child to practise adequate bladder drill and there is a constant risk that the bladder will become decompensated and infected and be responsible for dilatation and infection in the upper urinary tract with a serious and permanent impairment of renal function.

Attempts to restore bladder balance at an early age present difficulties in the surgical approach because the size of the urethra may prohibit the use of a resectoscope, though this is sometimes possible after perineal urethrostomy.

If a transvesical approach to the bladder neck is used the suprapubic wound may be slow to heal and suprapubic leakage of urine prevail in addition to the urethral urinary incontinence. Attempts to obliterate the urethra are frequently unsatisfactory and under any circumstances necessitate the establishment of a semi-permanent suprapubic cystostomy which is difficult to manage, is associated with protracted /
protracted cystitis, and may seriously interfere with the further rehabilitation of the bladder in later life.

Psychological and social problems may arise when the child attends school or during adolescence, when physical stability is so important for the training of these patients in a suitable career. These problems of rehabilitation were extensively reviewed by Band (1960), who stressed the need for integration of urological management with social welfare, education, orthopaedic treatment and employment. He indicated that diversion of the urinary stream by uretero-ileostomy should receive urgent consideration when it became apparent that bladder drill and restricted urological procedures had failed to restore bladder balance, when there was progressive impairment of renal function, when urinary incontinence was associated with trophic skin lesions, social and psychological problems, or when the urological disturbance jeopardized or contra-indicated orthopaedic rehabilitation. Such problems presented in two cases of the present series.

Case 21.- This 15-year-old boy had been operated upon for spina bifida at the age of one month. Since infancy he had been incontinent of both urine and faeces by day and night and since childhood had experienced difficulty in walking. He was referred for urological assessment at the age of 5 years, and was then found to be intelligent and alert but below average height because of retarded development of his lower limbs.

Physical examination showed bilateral weakness of the posterior tibial groups of muscles and less marked involvement of the anterior tibial groups. The knee jerks were brisk and equal bilaterally but the ankle jerks were absent /
absent. Sensations of touch, pain and temperature were absent over the S.3 - 5 dermatomes and diminished over the S.1 and 2 dermatomes bilaterally. He had no sensation of bladder fullness, but was able to produce a forceful urinary stream by abdominal straining. Micturition was followed almost immediately by dribbling incontinence, but his residual urine was negligible and sterile on culture. His home management had included the wearing of a portable urinal by day and napkins at night, and there was associated excoriation of the glans penis, scrotum and thighs.

X-rays of the lumbosacral spine showed extensive fusion defects of the 4th and 5th lumbar vertebrae and the upper part of the sacrum.

**Cystometrogram (Fig. 101).** - Resting bladder pressure 5 cm. of water. With bladder filling to 270 c.c. the bladder tonus rose steeply to 55 cm. of water and there was marked inco-ordinate intrinsic activity. Bladder sensation was completely absent. The overall pattern was that of an autonomous type of neurogenic bladder disorder.

**Cystoscopy.** - With filling to 270 c.c. the bladder showed trabeculation and early contracture at the bladder neck with dilatation of the prostatic urethra, but there was no evidence of infection.

**Progress.** - In view of his young age and the possibility of further neurological disturbance occurring with growth, it was considered that this patient's urinary incontinence might best be controlled by suprapubic cystostomy drainage. This was accordingly instituted and he was returned to the care of the orthopaedic surgeons with a recommendation that he should be re-admitted at or about the time of puberty for full re-assessment and probable transurethral resection of the bladder neck.

Three months after operation he was referred back because of persistent cystitis with leakage around the suprapubic tube and urethral incontinence. It had been found impossible for him to attend school.

When the urinary infection was under control two attempts were made to obliterate the bladder neck so that suprapubic cystostomy drainage could be continued without urethral incontinence; these procedures failed and urethral dribbling of urine continued. It was not considered advisable to attempt further obliteration of the posterior urethra and it was decided to discontinue suprapubic cystostomy drainage and operative closure of the suprapubic track was successfully carried out.

**Urinary /**
Fig. 101.- Case 21: cystometrogram at the age of 5 years.
Urinary incontinence was managed during the next nine years by the wearing of a portable urinal and he was referred back at the age of 15 years for consideration of further urological treatment before becoming an apprentice tailor. During the years he had developed definite paralytic flatfoot but orthopaedic surgical treatment was not considered to be indicated. The following urological investigations were undertaken.

Cystometrogram (Fig. 102).—The external urethral meatus was slightly ulcerated and required dilatation before a two-way catheter could be passed to drain a residuum of 60 c.c. of urine from which no pathogenic organisms were cultured. Resting pressure — 10 cm. of water. The bladder pressure rose rather steeply to 60 cm. of water with 200 c.c. of filling. A feeling of fullness was experienced after 110 c.c. of filling at a pressure of 25 cm. of water, and was accompanied by an involuntary contraction which raised the pressure to a transient peak of 60 cm. of water.

Cystograms.—The P.A. view (Fig. 103) showed marked trabeculation of the bladder with early sacculation but without ureteric reflux and with wide relaxation of the bladder neck. Voiding occurred and there was apparent narrowing at the level of the external urethral sphincter. The right oblique voiding view (Fig. 104) confirmed the presence of sacculation and trabeculation without ureteric reflux and demonstrated wide relaxation of the bladder neck with increased urethral resistance at the level of the external sphincter and with reflux of dye into the prostatic ducts.

Intravenous Pyelograms showed satisfactory excretion from both kidneys and there was no demonstrable abnormality in the upper urinary tract.

From these investigations it was apparent that the autonomous type of neurogenic bladder had remained compensated since early childhood and there was a striking similarity between the two cystometrograms taken at the age of 5 and 15 years. Dribbling incontinence of urine had allowed the bladder to remain compensated and free from infection and had protected the upper urinary tract. However, the recent cystograms indicated that there was increased resistance to urine flow at the level of the external urethral sphincter accompanied by reflux into the prostatic ducts. It was felt that this bladder would eventually become decompensated and infected as this resistance progressed, and it was almost inevitable that pudendal neurectomy would be followed by more persistent urinary incontinence, though such incontinence had been responsible /
Fig. 102. - Case 21: cystometrogram at the age of 15 years.

Fig. 103. - Case 21: P.A. cystogram at the age of 15 years.

Fig. 104. - Case 21: voiding cystogram at the age of 15 years.
responsible for the prevention of more serious urological complications in this patient; it was nevertheless undesirable and had been responsible for serious interference with schooling and threatened the beginning of a satisfactory career. Cutaneous uretero-ileostomy was accordingly carried out so that the urine could be collected in a water-tight apparatus. His convalescence was uneventful and on discharge from hospital his serum electrolytes were within normal limits and his blood urea nitrogen was estimated at 11 mg. per 100 c.c.

Two years later he was gaining weight and in excellent general health; the ileostomy appliance was working satisfactorily and he had been accepted for full employment. A follow-up intravenous pyelogram (Fig. 105) showed excellent bilateral renal function with no evidence of hydronephrosis.

Case 22.- This 16-year-old male patient underwent operative treatment for a severe degree of lumbosacral spina bifida shortly after birth, but there was considerable residual disability in the form of flaccid paralysis of both lower limbs with complete loss of cutaneous sensation below the level of the pubis. He was continent of faeces but incontinent of urine. After the age of 12 years multiple orthopaedic procedures had been carried out in an attempt to stabilise the lower limbs, so that he could become ambulant with calipers and crutches. These procedures included bilateral triple arthrodesis of the feet, Schantz osteotomy of the right femur and left femoral shortening.

X-rays of the lumbosacral spine and pelvis showed congenital dislocation of the right hip with anomalies of L.V.2, 3, 4 and 5 and sacrum.

On neurological examination he was found to have only slight motor power in the right quadriceps and anterior tibial muscle groups. There was complete paralysis of the left leg and all the lower limb tendon reflexes were absent. Loss of sensation was complete on the left side below the L.1 dermatome and on the right side there was diminution of touch and pain sensation below the level of L.3. Proprioception was completely absent in the right lower limb.

After a recent operation for left femoral shortening, he had developed a high post-operative fever with marked renal tenderness and suprapubic tenderness. A catheter specimen of urine had produced a profuse growth of *Ps. pyocyanea* sensitive only to polymixin. When the acute phase of the urinary infection had subsided it was found that his blood urea nitrogen level was 4.9 mg. per 100 c.c., and /
Fig. 105. - Case 21: intravenous pyelograms two years after uretero-ileostomy.
and on intravenous pyelography no demonstrable concentration of the dye was seen in either kidney. He was transferred to the Urological Unit where continuous urethral catheter drainage was instituted until the blood urea nitrogen level had fallen to 22 mg. per 100 c.c. The following urological investigations were then carried out.

**Intravenous Pyelograms** showed poor concentration of the dye by both kidneys with bilateral hydronephrosis and hydro-ureter.

**Cystometrogram (Fig. 106).**—Two-way catheter passed without difficulty to drain 300 c.c. of residual urine from which a mixed growth of organisms was obtained. Resting pressure 20 cm. of water. With 275 c.c. of filling the pressure rose to 40 cm. of water and responded with a few irregular intrinsic contractions which did not coincide with peripheral involuntary spasm. A vague feeling of lower abdominal fullness was experienced after 250 c.c. of filling and a voluntary contraction at maximal filling elevated the bladder pressure to 75 cm. of water.

In view of the mixed urinary infection and the marked impairment of renal function, it was considered inadvisable to proceed to cystography. It was apparent that this patient had an autonomous neurogenic bladder with marked decompensation, chronic urinary retention, urinary infection and bilateral hydronephrosis, and it was thought desirable to carry out urinary diversion at the earliest possible opportunity to prevent further deterioration of renal function and to facilitate further orthopaedic procedures urgently required in rehabilitation. Since it was anticipated that any attempt to restore bladder balance by a deliberate reduction in urethral resistance might be followed by urinary incontinence without significant improvement in the condition of the upper urinary tract and seriously interfere with his orthopaedic care, cutaneous uretero-ileostomy was carried out. His immediate post-operative condition was satisfactory and the serum electrolytes eventually stabilised at approximately normal levels with a blood urea nitrogen of 32 mg.%. Intravenous pyelograms taken one month after uretero-ileostomy (Fig. 107) showed delayed excretion of the dye by both kidneys with moderate bilateral hydronephrosis but the dilatation in the upper urinary tract was less marked than on the pre-operative radiographs.

Before any further orthopaedic procedures were undertaken he fell from his wheelchair and sustained an oblique fracture of the lower third of the shaft of the left femur. Eight months after operation he was readmitted to hospital with an acute febrile illness thought to /
Fig. 106.- Case 22: cystometrogram at the age of 16 years.

Fig. 107.- Case 22: intravenous pyelograms one month after uretero-ileostomy.
to be due to a gastro-intestinal infection. Otherwise there had been progressive improvement in his general condition and the management of his urine-collecting apparatus had been satisfactory.

Comment for Cases 21 and 22.- These patients showed satisfactory response to urinary diversion for the relief of autonomous neurogenic bladder disorder at different stages in its natural history. In Case 21 the procedure was undertaken for the relief of urinary incontinence and as an essential part of his rehabilitation into full employment and in anticipation of deterioration of renal function from bladder decompensation due to further increase in urethral resistance at the level of the external sphincter.

In Case 22 the procedure was undertaken for the direct treatment of severely impaired renal function associated with infection and hydronephrosis secondary to decompensation of the autonomous neurogenic bladder disorder and to facilitate the urgent completion of an orthopaedic programme of rehabilitation, with a view to more adequate schooling and training in a suitable career.

Though urinary diversion by uretero-ileostomy may thus be beneficial to patients with an autonomous type of neurogenic bladder disorder associated with a severe form of spina bifida, there are less extensive surgical procedures that can be undertaken to divert the urinary stream and the certain need for an ileal conduit has not yet been established. Other methods of urinary diversion, their relative merits and the choice of method for individual patients are discussed more fully on p. 192.

Before any irrevocable decision is made regarding the long-term urological management of patients with severe spina bifida, it must be remembered that the neurological disturbance may be progressive because differential growth occurs between the vertebral column and the spinal cord and may /
may cause traction on sacral nerve roots which are not
directly involved in the congenital anomaly. Such
difficulties in urological management associated with
progression of the primary neurological disturbance are
more frequently encountered in patients with neurogenic
disorders of the bladder following neoplastic involvement
of the central nervous system.

**Urological Management in Neurogenic Disorders of the**
**Bladder following Neoplastic Involvement of the**
**Central Nervous System**

Progression of the neurological disturbance associated
with tumour invasion of the central nervous system may be
due to progression of the tumour, the unavoidable excision
of cord segments and roots during surgical treatment, or
the late effects of gliosis after irradiation therapy. In
this group of patients the prognosis is often uncertain and
it is generally unwise to carry out palliative procedures
such as suprapubic cystostomy before it is obvious that the
survival time will be short, or to undertake extensive
surgical treatment until it is appreciated that the survival
time will be long. When the prognosis is obviously a
matter of weeks, then simple palliation by urethral or
suprapubic catheter drainage may be necessary. Otherwise
a careful regime of urethral catheter drainage as described
for traumatic paraplegia should be continued throughout the
early /
early stages of neurosurgical treatment until the neurological condition has stabilised within reasonable limits and the overall prognosis can be more accurately assessed. Full urological investigation should then be undertaken including cystometry and cystography and serious attempts be made to restore bladder balance by restricted surgical intervention before any final decision is made regarding urinary diversion. These points are illustrated in the following three patients.

**Case 23.** - At the age of 53 years this woman underwent partial excision of an extradural haemangioblastoma arising from the body of the D.8 vertebra. Further spinal decompression was required two years later and was followed by complete paraplegia below the level of D.8 associated with complete urinary retention. No improvement occurred after a course of external irradiation therapy and continuous indwelling urethral catheter drainage was continued for three months during which time marked peripheral flexor spasms developed. Trials without the catheter showed that urinary retention prevailed even with injections of Moryl and further investigations were carried out.

**Cystometrogram (Fig. 108).** - Two-way catheter passed without difficulty to drain a gross residuum of infected urine. Resting pressure - 22 cm. of water. The bladder accepted 560 c.c. of filling with a progressive rise in pressure up to 50 cm. of water. Irregular intrinsic activity occurred and was associated with peripheral flexor spasms during the recording. A vague feeling of fullness was experienced at maximum filling when a peak pressure of 60 cm. of water was produced by a voluntary contraction.

This patient thus had an autonomous type of neurogenic bladder disorder under the influence of peripheral flexor spasms. It was recommended that indwelling urethral catheter drainage should be continued and further urological assessment was postponed until one month after she had undergone surgical section of the anterior spinal roots from D.10 downwards for the relief of peripheral spasticity; urinary retention persisted throughout her convalescence.

**Cystometrogram /**
Case 23: Cystometrogram after excision and irradiation of extradural haemangioblastoma.
Cystometrogram (Fig. 109).—Two-way catheter passed without difficulty to drain a gross residuum of urine from which a profuse growth of \textit{B. coli} was obtained. Resting pressure nil. With 650 c.c. of filling the bladder pressure slowly rose to 15 cm. of water. At maximal filling a slight feeling of abdominal fullness was experienced and a voluntary contraction produced a peak bladder pressure of only 20 cm. of water. There was little evidence of intrinsic bladder activity.

Cystoscopy.—At maximal filling the bladder showed slight generalized congestion with fine trabeculation of the bladder vault but no evidence of contracture of the bladder neck. Several small phosphatic calculi were lying free on the base of the bladder and these were crushed and evacuated.

These findings indicated that rhizotomy had been followed by bladder atony. A programme of bladder drill with injections of Moryl and regular abdominal compression was instituted but there was no response to this regime and the bladder remained seriously decompensated. Five months later further urological assessment was undertaken.

Cystometrogram (Fig. 110).—Two-way catheter passed without difficulty to drain a gross residuum of urine which produced a mixed growth of \textit{E. proteus}, \textit{P. pyocyanae} and \textit{B. coli}. Resting pressure — 5 cm. of water. There was a slow rise in bladder pressure to 12 cm. of water with 500 c.c. of filling, but no intrinsic bladder activity occurred; no sensation of bladder filling was experienced and a voluntary contraction at maximal filling produced a peak pressure of 30 cm. of water.

Cystograms.—The P.A. view showed a large capacity bladder of smooth contour without ureteric reflux. The right oblique straining view showed some relaxation of the bladder neck but no voiding occurred.

Cystoscopy.—At maximal filling the mucosal lining of the bladder was smooth and there was no evidence of trabeculation or bladder neck contracture. Both ureteric orifices were normally situated and were closed.

Bimanual examination by rectal palpation showed that the anal sphincter was atonic, but there was no pelvic abnormality.

Bladder drill was temporarily replaced by a period of continuous indwelling urethral catheter drainage and antibiotics were administered. One month later the urinary infection had considerably improved, but the bladder remained /
Fig. 109.—Case 23: cystometrogram one month after anterior rhizotomy.

Fig. 110.—Case 23: cystometrogram six months after anterior rhizotomy.
remained completely decompensated. The most recent urological investigations had suggested that some response might be expected from bilateral pudendal nerve block with 1 per cent lignocaine but this was done without effect.

The general condition of the patient remained good and the peripheral flexor spasms had been completely alleviated by rhizotomy; though the bladder was hypotonic and decompensated there was no urinary incontinence and the urinary infection was under control; an intravenous pyelogram showed satisfactory excretion from both kidneys and there was no demonstrable abnormality in the upper urinary tract. It was therefore decided to postpone any consideration of urinary diversion and treatment was continued by intermittent drainage through an indwelling urethral catheter; injections of Moryl were given three times daily. Trial without the catheter was carried out at weekly intervals and on the sixth occasion voiding of 100 c.c. of urine occurred after the injection of Moryl. Thereafter the catheter was left out for increasing periods of time day by day and within four weeks compensated bladder function had been restored without urinary incontinence; the patient was then discharged from hospital.

During home management voiding "by the clock" was accomplished by abdominal straining and manual compression aided by a nightly injection of Moryl. She was re-admitted to hospital eight months later with urinary infection associated with bladder calculus formation but there was a prompt response to litholapaxy and compensated bladder function quickly returned after a short period of urethral catheter drainage.

Comment.- Persistent conservative management in this patient was followed by the restoration of balanced bladder function so that home management was much easier than it might have been if some form of urinary diversion had been instituted at an early stage.

Case 24.- At the age of 30 years this man underwent partial excision of an ependymoma of the spinal cord, and after operation was found to be completely paraplegic below the D.4 level. Bladder decompensation was complete for 15 months, during which time urethral catheter drainage was continued. It was then apparent that his general condition had been well maintained and there was no clinical evidence of rapid recurrence of tumour growth. It was therefore decided to attempt complete urological rehabilitation.
There was no response to a short period of tidal bladder lavage and suprapubic cystostomy drainage was required to relieve obdurate cystitis with calculus formation. After transurethral resection of the bladder neck the suprapubic cystostomy healed and he was then able to void urine at regular intervals without intermittent incontinence; the urinary stream was initiated and maintained by abdominal straining. He reported for urological review eight years after the initial neurosurgical treatment because he had recently experienced an unpleasant "cold feeling" in the left upper quadrant of the abdomen and there had been intermittent pyuria. The following urological investigations were carried out.

**Intravenous Pyelograms (Fig. 111).** showed satisfactory function in both kidneys without demonstrable abnormality in the upper urinary tract.

**Cystometrogram (Fig. 112).** Two-way catheter passed without difficulty to drain a negligible residuum of urine from which *E. coli* and *B. proteus*, *B. coli* and enterococci were cultured. Resting bladder pressure was 6 cm. of water. The bladder pressure rose to 12 cm. of water with 200 c.c. of filling and a vague feeling of abdominal fullness was then experienced. It rose further to 20 cm. of water after 400 c.c. of filling and a peak pressure of 75 cm. of water was obtained by voluntary contraction.

**Cystograms.** The P.A. view (Fig. 113) showed a large capacity bladder with definite detrusor tonus but without ureteric reflux. The right oblique voiding view (Fig. 114) demonstrated wide relaxation of the bladder neck with funnelling of the posterior urethra. A good urinary stream was outlined in the urethra without obvious obstruction at the level of the external sphincter.

**Cystoscopy.** At maximal filling the bladder mucosa was scarred in the vault but otherwise healthy in appearance; the bladder vault and base showed fine trabeculation but the bladder neck was relaxed and both ureteric orifices were normally situated and were closed. The posterior urethra was healthy in appearance.

Bimanual examination by rectal palpation: the prostate was of uniform firm consistency and the anal sphincter was atonic.

**Comment.**
Fig. 111.- Case 24: intravenous pyelograms eight years after the onset of paraplegia.

Fig. 112.- Case 24: cystometrogram eight years after the onset of paraplegia.

Figs. 113 and 114.- P.A. and voiding cystograms eight years after the onset of paraplegia.
Comment.- Urological investigation thus confirmed the presence of compensated bladder function by abdominal straining and with no abnormality in the upper urinary tract eight years after the onset of paraplegia. The recent urinary infection responded to antibiotics and the heavy phosphatic urinary deposit was reduced by the oral administration of acidifying agents.

In retrospect, the decision to discontinue suprapubic cystostomy drainage and to restore balance of bladder function by transurethral resection of the bladder neck was fully justified, and throughout the years this patient has actively participated in the direction of a prosperous business.

Case 25.- This 28-year-old woman suffered from multiple neuro-fibromatosis. At the age of 24 years the left lower limb had been amputated at mid-thigh level for the relief of painful ulceration of the leg and foot. Severe pain subsequently developed in the amputation stump and was relieved by right-sided upper dorsal cordotomy. Three years later a left upper dorsal cordotomy was carried out to relieve severe pain in the right lower limb, and was followed by urinary incontinence. Continuous urethral catheter drainage was required for adequate nursing care; the catheter was bypassed when clipped for longer than one and a half hours.

On physical examination she was found to have multiple subcutaneous neuro-fibromata but her general condition was satisfactory despite a marked lumbar kypho-scoliosis. X-rays of the spine showed that this deformity was associated with partial destruction of the left side of the bodies of L.V., 2, 3 and 4, with lateral dislocation between L.V. 4 and 5. Urological assessment was carried out as follows.

Intravenous Pyelograms showed satisfactory function in both kidneys without demonstrable abnormality in the upper urinary tract.

Cystometrogram.- Two-way catheter passed without difficulty and drained a negligible residuum of urine from which B. proteus, B. coli and enterococci were cultured. Resting bladder pressure - 5 cm. of water. The bladder pressure rose to 20 cm. of water after 100 c.c. of filling, but throughout the recording there was persistent bypassing of the catheter so that the recording had no certain significance. No sensation was experienced in the bladder or urethra.

Cystoscopy.- /
Cystoscopy. - A view of the interior of the bladder was obtained during continuous bladder irrigation. There was trabeculation and sacculation of the bladder base with moderate infection and encrustation of the mucosa. The ureteric orifices were slightly relaxed but were not gaping and the bladder neck was congested and wide.

Bimanual examination by rectal palpation: the anal sphincter was atonic but no pelvic abnormality could be felt.

Progress. - In view of the patient’s good general condition the relatively long-term prognosis and the normal state of the upper urinary tract it was decided to divert the urinary stream by uretero-ileostomy.

Right-sided pyelonephritis complicated her convalescence but there was a prompt response to treatment with antibiotics; she was able to manage her ileostomy appliance satisfactorily and arrangements were made for her to be rehabilitated to the use of an artificial limb.

When reviewed three months after operation her general condition was excellent and her morale had improved considerably. An intravenous pyelogram (Fig. 115) showed satisfactory function in both kidneys without evidence of dilatation in the upper urinary tract. This patient died two months after review when she developed a widespread panarteritis of unknown aetiology and severe haemorrhage occurred from the external iliac artery which could not be surgically controlled.

Comment. - The clinical findings in this patient indicated that inco-ordinate tonic activity was present in the bladder despite marked infection. The laxity of the urethra contra-indicated any attempt to render the bladder atonic as part of the rehabilitation programme whilst it seemed certain that palliation by suprapubic cystostomy would be accompanied by urethral urinary incontinence.
Fig. 115. Case 25: intravenous pyelograms three months after uretero-ileostomy.
DERANGEMENT OF THE SOMATIC INNERVATION OF THE BLADDER SPHINCTERS AND POSTERIOR URETHRA

The various cases of neurogenic bladder disorder which have so far been described in this thesis illustrate that the accepted classification into uninhibited, spinal reflex, autonomous and atonic types may be clinically useful as a general guide to the choice of treatment, the expected therapeutic response and the prognosis of typical cases. However, this classification may impose too rigid a discipline over the management of individual patients many of whom cannot be classified into any of these four groups, although in any series of atypical cases full urological assessment may show a common basic derangement of the mechanism of micturition.

There were four patients in the present series who presented with disturbances of micturition subsequently found to be due to increased tonus of the external urethral sphincter. The primary conditions for which these four patients were admitted to hospital were extremely diverse, and their case records will be presented in detail.

Case 26.- This 29-year-old woman had had three children delivered by caesarean section because of contracted pelvis associated with a severe degree of spondylolisthesis. There was no history of back injury or of back pain, but three months after the first caesarean section she complained of dribbling incontinence of urine. Though she occasionally experienced a normal desire to void, she had no voluntary control over micturition.
These symptoms were progressive and were recently accompanied by an aching pain down the outer aspect of the left thigh. On physical examination it was found that she was unable to contract the pelvic floor musculature and external anal sphincter; there was early wasting of the small muscles of the feet and there was bilateral loss of all sensory modalities in the 2nd, 3rd, 4th and 5th sacral segments bilaterally; both ankle jerks were absent and there was some diminution of the right knee jerk as compared with the left. X-rays of her lumbosacral spine showed a severe degree of lumbosacral spondylolisthesis. The orthopaedic abnormality is illustrated in the P.A. and lateral views of her myelogram in Figs. 116 and 117, from which it can also be seen that the contrast medium was completely arrested opposite the body of the 5th lumbar vertebra.

Urological investigations were carried out as follows.

**Intravenous Pyelography** showed no abnormality in the upper urinary tract.

**Cystometrogram** (Fig. 118).— Two-way catheter passed without difficulty to drain a residuum of 300 c.c. of urine infected with B. coli. Resting pressure nil. The first desire to void was experienced after 75 c.c. of filling at a bladder pressure of 8 cm. of water. A strong desire to void was felt after 200 c.c. of filling at 12 cm. of water pressure. Thereafter, marked intrinsic activity raised the pressure to 35 cm. of water with 360 c.c. of filling and a voluntary contraction then produced a peak pressure of 70 cm. of water.

**Cystograms**.— The P.A. view (Fig. 119) showed that the bladder was truncated with mild saculation of the vault. The right oblique voiding view (Fig. 120) showed that the bladder neck was adequately relaxed and though the proximal urethra was of normal calibre, there was probably increased resistance at the external sphincter.

**Cystoscopy**.— During instrumentation without anaesthesia it was apparent that urethral sensation was intact. Inspection of the bladder showed that the mucosa was congested and there was active cystitis; the bladder fundus was finely trabeculated but there was no contracture of the bladder neck and the ureteric orifices were normally situated and healthy in appearance.

**Gynaecological Examination**.— Though there was a mild degree of cystocele formation the cervix was conical and of uniform firm consistence and it was considered that there was no gynaecological abnormality to account for her urinary symptoms.

Rectal /
Figs. 116 and 117. - Case 26: P.A. and lateral myelograms.

Fig. 118. - Case 26: Cystometrogram.
Fig. 119.- Case 26: P.A. cystogram.

Fig. 120.- Case 26: Voiding cystogram.
Rectal Palpation.- The anal sphincter had very poor tonus and could not be voluntarily contracted.

The urological findings indicated that bladder sensation and urethral sensation were intact. The bladder had extremely good tonus but was, nevertheless, almost completely decompensated; the cystographic appearances suggested that the decompensation was associated with increased tonus of the external urethral sphincter. The overall picture was that of an irritative lesion of the sacral roots.

Following a period of indwelling urethral catheter drainage and the administration of antibiotics the urinary infection subsided and one month later the patient was able to remain continent up to one and a half hours, though the bladder remained decompensated.

An exploratory laminectomy was carried out and it was then found that the cauda equina was severely compressed between the inferior margin of the lamina of L.5 and the posterosuperior margin of the body of S.1; the compression was relieved by partial removal of the laminae of L.5. Following operation there was a progressive improvement in the sensory deficit, so that after one month light touch sensation was present in the 2nd and 3rd sacral segments but was still absent in the 4th sacral segments. Urinary control was regained 18 days after operation and the residual urine was then 90 c.c. One week later this patient was able to void up to 330 c.c. with full control, to leave a residuum of only 60 c.c. She experienced a normal desire to void without urgency and the urine was macroscopically clear.

Comment.- From the duration of the spinal deformity and the neurological findings it was anticipated that the cauda equina roots had been stretched and it was thought unlikely that any operative treatment would lead to marked neurological improvement. However, the urological findings strongly suggested that the root pathology was irritative rather than paralytic as subsequently confirmed at operation, which was followed by complete recovery of urinary control and marked but incomplete recovery of cutaneous sensation.

Case 27.- /
Case 27.—This 33-year-old man had concussion at the age of 12 years and four years later developed progressive weakness of his right foot, which subsequently required triple arthrodesis on two occasions. For 10 years he had complained of intermittency of his urinary stream, complicated for 7 years by frequency of micturition with urinary incontinence and loss of bladder sensation. These symptoms persisted despite transurethral resection of the bladder neck and interim removal of bladder calculi. For two years he had had recurrent attacks of bilateral epididymitis.

Recent neurological review showed that he had bilateral loss of pain, temperature and touch sensation in the 4th and 5th sacral segments with depression of pain and touch sensation in both 3rd sacral segments and part of the 1st and 2nd sacral segments; the anal reflex and both ankle jerks were absent but all proprioceptive sensation was intact. There was loss of motor power involving the leg muscles which was worse on the left side.

Lumbar and sacral laminectomy were carried out and at operation an abnormal prolongation of the spinal cord was exposed down to the upper edge of the 3rd sacral vertebra. At this level the neural tissue was further spread out over lipomatous formation in the extradural space. Following operation he experienced a normal desire to void, but there was hesitancy of micturition with intermittency of the urinary stream and alternating urinary retention and incontinence. The bulbo-cavernosus reflex was intact.

Cystometrogram (Fig. 121).—A two-way catheter was passed without difficulty and drained a residuum of 200 c.c. of infected urine. The resting pressure was 12 cm. of water. The bladder pressure slowly rose to 16 cm. of water with 100 c.c. of filling. A first desire to void was then experienced and was followed by brisk intrinsic activity which raised the pressure to 30 cm. of water with 275 c.c. of filling. A strong desire to void was experienced after 200 c.c. of filling at a pressure of 25 cm. of water and a voluntary contraction at maximal filling produced a peak pressure of 70 cm. of water.

Cystograms.—The P.A. view (Fig. 122) showed the bladder to be of irregular shape with saculation. The bladder neck was wide; the posterior urethra was dilated and there was bilateral reflux into the ejaculatory ducts.

The right oblique voiding view (Fig. 123) confirmed the saculation of the bladder and showed diaphragmatic closure of the bladder neck with gross dilatation of the prostatic urethra and with reflux into the right ureter. There was apparent increased urethral resistance at the level of the external urethral sphincter.

Cystoscopy.—/
Fig. 121.— Case 27: cystometrogram after laminectomy.

Fig. 122.— Case 27: P.A. cystogram after laminectomy.
Fig. 123. - Case 27: voiding cystogram after laminectomy.
Cystoscopy.— At maximal filling there was generalised trabeculation and sacculcation with infection, but the ureteric orifices were closed. There was slight oedema and early contracture of the upper part of the bladder neck but no median bar formation or lateral pillar prominence.

On bimanual examination the prostate felt indurated and irregular around its periphery, but there was a large central cavity. The induration extended into both seminal vesicles.

There was bilateral firm, irregular enlargement of the epididymes; the left epididymis was adherent to skin and the right had formed a cutaneous fistula with a purulent exudate.

Comment.— From these investigations it was apparent that his urinary symptoms were associated with increased tonus of the external urinary sphincter. In the presence of widespread infection throughout the lower urinary and the genital tracts it was considered unwise to carry out ascending urethrography with sphincterometry.

This patient is at present receiving antibiotic treatment for the infection, and is on a clinical trial of Lisidonil in an attempt to produce pharmacological relaxation of the striated musculature of the external urethral sphincter.

The return of a normal desire to void in this patient following laminectomy suggested that the tonic, but otherwise normal activity of his bladder, as shown by cystometry, was the result of the decompressive procedure. However, the long history of persistent bilateral epididymitis and the finding of marked dilatation of the prostatic urethra with reflux of dye into the ejaculatory ducts indicated that before operation the main urological disability was due to increased resistance at the level of the external urethral sphincter. This assumption was further supported by the failure of the patient to regain compensated bladder function after transurethral resection of the bladder neck. The cystographic findings were of further interest because they showed a definite diaphragmatic closure of the bladder neck during voiding, despite previous resection and the failure to demonstrate any recurrence of contracture of the bladder neck at postoperative cystoscopy. This diaphragmatic closure coincident with detrusor activity probably represented the tonic contraction of the striated muscle fibres which extend from the external urethral sphincter into the bladder neck itself (p. 5). There was, therefore, much evidence /
evidence to suggest that increased tonus of the striated component of the urethral musculature had prevailed for some time; its possible association with the congenital anomaly of the sacral portion of the spinal cord was of the greatest significance with regard to the following case.

Case 28.- A 25-year-old married man who had two children was admitted to hospital with a three-month history of suprapubic and urethral pain associated with difficulty of micturition and intermittency of the urinary stream. These symptoms had also occurred over a seven-month period about two years previously, and were then relieved by the transvesical removal of a bladder calculus. From his past history it was established that he had been enuretic to the age of 12 years and throughout his life the urinary stream had been so poor as to require conscious straining, although there had never been diurnal incontinence.

Physical examination was negative. He experienced a normal sensation of desire to void before evacuating urine in quantities up to 600 c.c., but on occasion, after voiding only 200 c.c. of urine he was found to have a residuum of 400 c.c.

Biochemical Investigations.- Serum electrolyte levels were within normal limits; the blood urea nitrogen was 5 mg. per 100 c.c. and the serum alkaline phosphatase level was 8 King-Armstrong units.

Radiological Investigations.- A plain view of the renal tract (Fig. 124) demonstrated a possible large bladder calculus with several small areas of calcification in the region of the prostate gland.

Intravenous Pyelograms (Fig. 125) showed good bilateral renal function with bilateral hydronephrosis and hydroureter, more marked on the left side. The presence of bladder calculi was confirmed.

Cystogram.- The P.A. view (Fig. 126) showed a large capacity bladder with marked trabeculation and sacculation but without ureteric reflux. Small calculi were present in the dilated prostatic urethra below the widely relaxed bladder neck. During retrograde filling, reflux of the dye had occurred into the prostatic ducts.

The voiding view (Fig. 127) demonstrated a thin urethral stream with definite narrowing in the region of the external urethral sphincter; reflux of dye had occurred from the dilated posterior urethra into the seminal vesicles but there was no ureteric reflux.
Fig. 124.- Case 28: plain X-ray of the renal tract.

Fig. 125.- Case 28: intravenous pyelograms.
Fig. 126. - Case 28: P.A. cystogram.

Fig. 127. - Case 28: voiding cystogram.
Ascending Urethrography with Sphincterometry confirmed that the resistance of the external urethral sphincter was 60 cm. of water.

Cystometrogram (Fig. 128).-- Two-way catheter passed without difficulty to drain a gross residuum of urine from which a profuse growth of coliform organisms was obtained. Resting bladder pressure 10 cm. of water. When the bladder filled to 375 c.c. it showed a normal pattern of contractile response with intact sensation but rather high tone.

Cystoscopy.-- Under general anaesthesia a 21 F. cystoscope was passed and encountered resistance at the external sphincter. The bladder accepted 500 c.c. of fluid without difficulty and with less tone than on cystometry without anaesthesia. A large calculus lay over the trigone and obscured the view of the left ureteric orifice, although the right orifice was healthy, closed and normally situated. The bladder base and vault were trabeculated and sacculated and the bladder neck was widely relaxed. The inter-ureteric bar was not prominent. Several small calculi lay in the dilated prostatic urethra on each side of the healthy verumontanum.

Comment.-- The long clinical history with recurrent vesical calculus formation suggested a diagnosis of either primary atonic neurogenic bladder or congenital bladder neck obstruction. However, the cystometrogram showed good bladder tone associated with detrusor hypertrophy as noted on cystography and cystoscopy. This hypertrophy was presumably the response to the demonstrated increase in urethral resistance at the level of the external sphincter. This patient had had urinary symptoms throughout his life and it therefore seemed reasonable to exclude the calculi as the primary cause of posterior urethral irritation and the sphincteric spasm. Other neurological signs could not be demonstrated, and the exact etiology remained obscure; in view of the findings in Case 27, it is possible that this patient has a congenital anomaly of his sacral spinal cord.

This patient was treated by litholapaxy, and after a satisfactory but transient response had been obtained to bilateral pudendal nerve block with 1 per cent lignocaine, a left-sided pudendal neurectomy was carried out as shown in Fig. 129, using the method described by Bors (1952), Ross and Damanaki (1953) and Bors et al. (1954).

Following operation there was a marked improvement in urinary function. The urinary stream was increased in force /
Fig. 128. - Case 28: Cystometrogram.

Fig. 129. - Operation of pudendal neurectomy.
(Band, 1956.)
force and he maintained full urinary control.
Cystoscopic review was arranged at intervals so that small residual calculi in the bladder and prostatic urethra could be removed. Ten months after operation further litholapaxy was required, but when seen one year from the time of pudendal neurectomy the patient had no urinary symptoms and was passing clear urine with full control.

Case 29.—A diagnosis of disseminated sclerosis was established in this male patient at the age of 31 years. During the subsequent three years there was slow deterioration in the condition of his lower limbs with increasing spasticity, and for one month there had been difficulty with micturition which culminated in acute retention which he was admitted to hospital. There was no voiding response to an injection of Moryl and continuous indwelling urethral Gibbon catheter drainage was instituted. Three weeks later the following investigations were undertaken.

Cystometrogram (Fig. 130).—Two-way catheter passed without difficulty. Resting bladder pressure—5 cm. of water. The first desire to void was felt after 200 c.c. of filling at a pressure of 10 cm. of water and with an intrinsic rise in bladder pressure to 22 cm. of water. A strong desire to void was experienced after 275 c.c. of filling with elevation of the bladder pressure to 50 cm. of water, and a voluntary contraction then produced a peak pressure of 80 cm. of water.

Cystograms.—The P.A. view (Fig. 131) showed a normal capacity bladder with mild trabeculation of its contour but without ureteric reflux. The right oblique voiding view (Fig. 132) showed adequate relaxation of the bladder neck but there was narrowing of the urinary stream at the level of the external urethral sphincter. No ureteric reflux was present.

Cystoscopy.—With filling to a normal capacity the bladder showed generalised cystitis with mild trabeculation of the vault and base. There was no apparent contracture of the bladder neck.

Binomial examination by rectal palpation confirmed that the prostate was not enlarged and was of smooth and firm consistency.

The catheter urine sample from this patient grew a mixed growth of B. coli and B. proteus.

Comment.—/
**Fig. 130.** Case 29: cystometrogram.

**Fig. 131.** Case 29: P.A. cystogram.

**Fig. 132.** Case 29: voiding cystogram.
Comment.—The cystometrogram showed that the bladder had good tonus with intact sensation and its overall pattern was normal. The persistent retention was associated with decompensation due to increased tonus of the external urethral sphincter. It was interesting to find urological evidence that the deranged bladder function was not associated with any derangement of the motor control of the detrusor bladder mechanism, but was associated with selective damage (of an upper motor neurone type) of the somatic innervation of the external urethral sphincter and posterior urethra. It was proposed to carry out a therapeutic trial of pudendal nerve block in this patient, but while he was awaiting transfer to the urological unit there was a slight but natural remission of his neurological condition and normal bladder function was spontaneously restored.

These four cases were remarkable for their diversity of clinical presentation, causative pathology and duration of neurogenic bladder disorder which in each of them could be attributed only to selective involvement of the somatic innervation of the posterior urethra and the perineal striated musculature. They stress the urgent need for cystographic and urethrographic investigation of patients with deranged bladder function in whom no organic obstructive lesion can be demonstrated and in whom the cystometrogram pattern is within the tonic range of normal. Such cases are particularly amenable to treatment by surgical interruption of the pudendal nerve if exploration at a more central level is not otherwise indicated and if a transient response is obtained to anaesthetic infiltration of the pudendal nerves themselves.
ATONIC AND INTRINSIC NEUROGENIC BLADDER DISORDERS

Modern methods of treatment of syphilis and sub-acute combined degeneration of the spinal cord have reduced the incidence of the classical atonic type of neurogenic bladder disorder associated with clinical signs of sensory impairment. However, disturbances of micturition associated with loss of bladder tonus still present and in a large proportion of such patients the aetiology is obscure or unknown. In the present series a group of patients who were suspected to have an atonic type of neurogenic bladder disorder were found to have bladders of large capacity with good resting and filling tonus associated with dilatation in the upper urinary tract. To this selected group the term "intrins ic neurogenic bladder disorder" has been applied.

Atonic Neurogenic Bladder Disorders

This particular group of neurogenic bladder disorders is perhaps the least satisfactory from the point of view of adequate classification. It is generally accepted that the typical atonic type of neurogenic bladder disorder is the specific result of interruption of the afferent fibres of the reflex arc for micturition by lesions of the posterior /
posterior sacral roots or of the posterior spinal columns, and does not usually include bladder disorders produced by lesions of the nervous system at any other site and in which bladder atony has supervened. Interruption of the sensory pathways from the bladder to produce an atonic type of neurogenic bladder disorder may also occur in association with generalised peripheral neuropathy as found in diabetes mellitus.

**Neurogenic Bladder Disorder in Diabetes Mellitus**

A clinical study of 150 cases of diabetic neuropathy was reported by Martin in 1953. Cystometric studies were carried out in the more severe cases of his series and showed that the bladder derangement was characterised by an impaired or absent sense of filling, a low expulsive force and an increased bladder capacity, as previously reported by Rudy and Muellner (1941), Rundles (1945) and Foster and Bassett (1947). Two similar cases were included in the present series and their cystometrograms are shown in Fig. 14. In neither of these patients was any sensation of fullness or desire to void experienced during cystometry. Though careful neurological examination produced evidence of widespread neuropathy it did not indicate the specific level of the neurological lesion which was responsible for the bladder derangement in these two patients so that no further information was obtained from them regarding any possible aetiological mechanism in this disease.
It has been suggested by Woltman and Wilder (1928) that the neuropathy of diabetes is associated with arteriosclerosis of the small nutrient vessels to the nerves especially in their peripheral portions. DeJong (1950) considered it probable that neither thiamine deficiency nor occlusive vascular disease is alone responsible for the nervous disorder. His further suggestion that the peripheral nerve changes result from abnormalities of metabolism, which are common in chronic unregulated diabetics, is supported by evidence obtained by Feldberg (1944) that concentrations of glucose of 0.2 per cent or above tend to inhibit the synthesis of acetyl choline by nerve tissue. The formation and breakdown of acetyl choline seem to be inseparably associated with the electrical events essential for the conduction of nervous impulses (Nachmansohn, 1947). In neither of the patients in the present series was there an adequate response to injections with Moryl, and it might therefore be suggested that even in the presence of peripheral neuropathy the final atonic state of the bladder was the result of prolonged overdistention subsequent to interruption of the sensory innervation of the organ rather than to interference with motor nerve supply. Such a mechanism obtains further support from the investigation of patients who developed chronic urinary retention after general surgical procedures.
Bladder Atony as a Post-operative Complication

Chronic retention of urine with overflow may develop insidiously after any type of surgical procedure but particularly in elderly female patients. It is not always associated with complete loss of bladder sensation but the degree of sensory impairment may have an important bearing upon the possible methods of treatment. These points are illustrated in the following two cases.

**Case 30.**- This 69-year-old woman tripped and fell and sustained a pertrochanteric fracture of the left femur, which was treated at operation by internal fixation. Some days after operation it was noted that she had stress incontinence of urine and the bladder was found to contain a residuum of 1 litre. No neurological or gynaecological abnormality was present on physical examination and the serological tests for syphilis were negative. The urine contained no abnormal constituents but a moderate growth of *E. coli* was obtained on culture.

Continuous indwelling urethral catheter drainage was instituted for a period of 10 days and was followed by intermittent drainage for a further week during which time injections of Moryl were given daily. The catheter was then removed for a period of trial but the residuum remained at 200 c.c. of urine after an injection of Moryl. The following investigations were undertaken two months after her accident.

**Cystometrogram (Fig. 133).** - Two-way catheter passed without difficulty. Resting bladder pressure - 3 cm. of water. The bladder pressure rose to 5 cm. of water with 250 c.c. of filling and the first desire to void was then experienced without any intrinsic bladder contractions. A strong desire to void was experienced at 5 cm. of water pressure after 350 c.c. of filling. The pressure then slowly rose to 8 cm. of water with 500 c.c. of filling and a voluntary contraction produced a peak pressure of 48 cm. of water with bypassing of the catheter.

**Cystograms.** - The P.A. view showed a large capacity bladder of smooth contour without ureteric reflux. The right oblique voiding view (Fig. 134) showed that the bladder neck was adequately relaxed and the urethrogram was normal. There was no evidence of detrusor activity.

**Cystoscopy.** -
Fig. 133. — Case 30: cystometrogram.

Fig. 134. — Case 30: voiding cystogram.
Cystoscopy.- After filling to 450 c.c. the bladder showed generalised congestion of the mucosa but there was no trabeculation and the bladder neck was not contracted.

Progress.- It was considered that decompensation of the bladder had been produced by overdistension which had occurred during the time of hospitalisation and surgical treatment after the accident. There was no evidence of lower urinary tract obstruction or neurological disease and cystometry had established that bladder sensation was present. For two weeks a regime of hourly micturition by day and two-hourly micturition by night (with an evening injection of Moryl after catheterisation) was instituted. There was a gradual increase in the intensity of the desire to void with recovery of full urinary control and reduction of the residual urine to a safe level.

Case 51.- This 57-year-old woman had a simple thymic tumour excised from her anterior mediastinum, and following operation she developed painless urinary retention without overflow. Physical examination was negative. Retention persisted despite intermittent catheterisation and oral Moryl tablets. The following urological investigations were undertaken three weeks after operation.

Cystometrogram (Fig. 135).- Two-way catheter passed without difficulty. Resting bladder pressure - 4 cm. of water. No intrinsic bladder activity was present but the bladder pressure slowly rose to 10 cm. of water with 650 c.c. of filling. A feeling of fullness was experienced after 375 c.c. of filling and a voluntary contraction produced a peak pressure of 50 cm. of water at maximal filling.

Cystograms.- The P.A. view showed a large capacity bladder of smooth contour without ureteric reflux. The right oblique straining view (Fig. 136) showed that the bladder neck was closed but there was no ureteric reflux and no evidence of detrusor activity.

Cystoscopy.- After filling to 650 c.c. the appearances of the interior of the bladder were healthy and there was neither trabeculation nor evidence of contracture of the bladder neck. Both ureteric orifices were normally situated and were closed.

Progress.- /
Fig. 135. Case 31: cystometrogram.

Fig. 136. Case 31: straining cystogram.
Progress.- In this patient bladder atony was associated with complete loss of the normal desire to void. This derangement was not associated with any neurological abnormality and could be attributed only to the over-distension of the bladder which had occurred after mediastinal surgery. There was no response to the regime of bladder management, as described for Case 30, and accordingly transurethral resection of the bladder neck was carried out on two occasions 8 and 10 weeks after the onset of urinary retention. When seen 9 months later this patient had some frequency of micturition with slight exertion incontinence, but her urinary control was definitely improving and there was no evidence of persistent urinary infection.

From a consideration of Cases 30 and 31, it is suggested that both loss of normal bladder sensation and bladder atony may be produced by chronic overstretch of the bladder musculature and stretch receptors. However, there are probably neurological factors implicated in the development of chronic urinary retention after operations in elderly patients. The possibility that senile degenerative changes in the central nervous system may be partly responsible for this unusual bladder disturbance in the aged was suggested by the clinical history of the following patient.

Case 32.- This 77-year-old woman presented with a history of difficulty of micturition of two months' duration and was admitted to hospital with chronic urinary retention with overflow incontinence. She further complained of difficulty in walking with a feeling of weakness and cramp in the lower limbs.

On physical examination it was found that the bladder was grossly distended; there was diminution of both knee and ankle jerks and though the muscle groups of the lower limbs were not wasted there was fasciculation in the right calf muscles and left peroneal muscles. No vibration sensation was present below D12 but all other forms of sensation /
sensation were normal; the right plantar response was extensor whilst the left was equivocal. Lumbar puncture was carried out with completely normal findings and it was the neurologist's opinion that this patient suffered from arteriosclerotic changes in the spinal cord. The following urological investigations were undertaken.

Cystometrogram (Fig. 137).—Two-way catheter passed without difficulty to drain a residuum of 1500 c.c. of urine which did not contain any significant organisms. Resting bladder pressure—nil. The bladder pressure slowly rose to 15 cm. of water with 1050 c.c. of filling. A feeling of fullness was experienced after 375 c.c. of filling at a pressure of 7 cm. of water. A strong desire to void was experienced after 500 c.c. of filling at a pressure of 8 cm. of water. At maximal filling a voluntary contraction produced a peak pressure of 50 cm. of water.

Cystoscopy.—At maximal filling the bladder appeared to be healthy apart from slight catarrhal cystitis. There was neither trabeculation of the vault nor contracture of the bladder neck.

Comment.—Retention of urine in this patient was thus associated with marked hypotonia of the bladder with intact proprioceptive sensation and with a moderate detrusor force available on abdominal straining. Following transurethral resection of the bladder neck she made excellent progress and with bladder drill and oral Moryl tablets compensated bladder function was restored and her final residuum was found to be 50 c.c.

It might be anticipated that more significant information regarding the development of bladder atony after peripheral interference with the parasympathetic motor and sensory innervation of the bladder would be forthcoming from a consideration of derangements of bladder function following extensive pelvic surgery.
Fig. 137.- Case 32: cystometrogram.
Neurogenic Bladder Disorders following 
Excision of the Rectum

In 1951 Watson reported that some degree of urinary retention occurs in just over 50 per cent of male patients following surgical excision of the rectum. He analysed the cause of such retention in 16 patients who were found to have a residuum of urine in excess of 150 c.c. on the tenth post-operative day. In seven patients he considered that benign prostatic hypertrophy was the cause of bladder decompensation; in five it was associated with poor general physique; in two patients there was postural difficulty with micturition which had been present before operation and in only two patients was it considered that major pelvic nerve injury had been sustained at operation. Williams (1951) suggested that after excision of the rectum the prostatic urethra falls backwards with the bladder to hinge on the fixed point of the perineal membrane so that the natural urethral curves are lost; in this way a minimal degree of prostatic encroachment at the bladder neck, which had not been responsible for urinary symptoms before operation, might well be responsible for urinary retention after excision of the rectum. Williams further described the sequence of events after major pelvic nerve injury: painless retention of urine progresses to overflow incontinence in the absence of any bladder detrusor activity, so that compensated bladder function ultimately relies upon abdominal straining. With
Cystometrogram (Fig. 138).- Two-way catheter passed without difficulty to drain a residuum of 150 c.c. of urine from which *E. coli* was cultured. Resting bladder pressure - 10 cm. of water. With 150 c.c. of filling the bladder pressure rose to 35 cm. of water and though there were slight changes in bladder tonus there was no brisk intrinsic activity. Filling continued to 300 c.c. at a pressure of 43 cm. of water and a voluntary contraction then produced a peak pressure of 90 cm. of water. No bladder sensation was experienced throughout the recording.

Cystograms.- The P.A. view (Fig. 139) showed some trabeculation of the bladder with early sacculation but without ureteric reflux. The bladder neck was relaxed.

The right oblique voiding view (Fig. 140) confirmed the relaxation of the bladder neck though there was a sharp incisura from its posterior aspect. There was narrowing of the urethral stream at the level of the external urethral sphincter.

Cystoscopy.- Instrumentation was difficult and the beak of the instrument had to be lifted over the posterior aspect of the bladder neck. The interior of the bladder showed trabeculation of the vault and though there was no encroachment at the bladder neck, its posterior aspect appeared unduly prominent because there was posterior sacculation of the prostatic urethra.

Comment.- Though this patient was devoid of bladder sensation it was found that there was good tonus with a hypertrophic detrusor response to increased urethral resistance at the level of the external sphincter. The findings in this patient suggest that if the urinary retention which may follow excision of the rectum is properly managed by catheter drainage then interference with the sensory innervation of the bladder through the pelvic nerves is not necessarily followed by bladder atony and there may in fact be a hypertrophic detrusor response to any concomitant increase in external sphincteric resistance. The sphincteric spasm in this patient was considered to be due to late involvement of the pudendal nerves in their intra-pelvic course through an organising haematoma.
Fig. 138.- Case 33: cystometrogram.

Fig. 139.- Case 33: P.A. cystogram.

Fig. 140.- Case 33: voiding cystogram.
Primary Atonic Bladder

In the present series no case of atonic bladder derangement presented without either signs of neurological disease or a history of the occurrence of overdistension of the bladder after general surgical procedures. Such cases of "primary atonic bladder" have been reported by Fish (1950) and their careful distinction from cases of bladder neck obstruction has been emphasised by Dillon (1941). It was suggested by Emmett (1940) that the bladder atony is not truly primary but may be associated with either slight impairment of conduction of sensory impulses or a mild degree of bladder neck obstruction. Slight but long-standing obstruction at the bladder neck should not be blamed for the dilatation and atony of the bladder unless a biopsy of the bladder provides histological evidence of muscular failure. Herrmann (1925) described histological changes which he thought were commonly associated with the syndrome of bladder failure; he found that there was thickening of the peri-muscular septa and replacement of the muscle fibres by new scar tissue, whilst the nuclei of the muscle cells showed vacuolation as an indication that degeneration of the muscle fibres formed the basis of the fibrotic process.

Intrinsic /
Intrinsic Neurogenic Bladder Disorders

Attention was diverted from a possible myogenic basis for primary bladder atony by the observations of Swenson et al. (1952) that dilatation of the bladder without loss of tonus may be associated with bilateral primary mega-ureter and with a demonstrable reduction in the number and size of ganglia, nerve cells and nerve bundles in the bladder wall. This combination of bladder dilatation with upper urinary tract dilatation in the absence of obvious neurological disease or organic urological obstruction has been termed the mega-ureter - megacystis syndrome.

The Mega-ureter - Megacystis Syndrome

This syndrome occurs in children of either sex and is characterised by marked bladder dilatation in association with bilateral mega-ureter into which there is gross urinary reflux through gaping ureteric orifices (Fig. 141) (Williams, 1958). The bladder itself is not thick-walled and trabeculation is either absent or minimal; there is no apparent abnormality of the bladder neck and bladder function is satisfactory in so far as its large content can be evacuated completely along the normal urethra and into the abnormal ureters. The finding of a deficiency of parasympathetic /
Fig. 144. -- Mega-ureter - megacystis syndrome; ascending cystogram in a 5-year-old girl presenting with a long history of general ill health, vomiting and nocturnal enuresis.
parasympathetic ganglia in the bladder wall suggests that this condition may be analogous to primary aganglionic mega-colon. An association of dilatation in both colon and bladder was found in the following case.

Case 34.- This 24-year-old woman had complained of chronic constipation since childhood with occasional attacks of abdominal pain. She had no urinary symptoms but commented that she was able to refrain from micturition for prolonged periods of time without experiencing any discomfort. On physical examination large masses of hard faeces could be palpated easily in the abdomen but the bladder was not distended and there was no other physical abnormality. Barium enema examination showed gross dilatation of the colon and rectum but the appearances were not typical of primary idiopathic mega-colon. However, it was thought that the distension of the rectum might indicate an aganglionic segment at the ano-rectal junction but a biopsy taken from this site contained definite ganglion cells. After colonic lavage sigmoidoscopy to 30 cm. showed an empty rectum and sigmoid colon without intrinsic pathology. An intravenous pylogram showed good excretion from both kidneys and there was no abnormality in the upper urinary tract.

Cystometrogram (Fig. 142).- Two-way catheter passed without difficulty to drain a negligible residuum of sterile urine. Resting bladder pressure - 2 cm. of water. After 175 c.c. of filling a feeling of fullness was experienced at a bladder pressure of 6 cm. of water. This feeling was transient but recurred after 425 c.c. of filling at a bladder pressure of only 8 cm. of water. A strong desire to void was experienced after 500 c.c. of filling at a pressure of 10 cm. of water but the bladder accepted 950 c.c. of fluid with a very slow rise in pressure to 16 cm. of water and a voluntary contraction then produced a peak pressure of 42 cm. of water.

Comment.- In the absence of any definite evidence for a diagnosis of aganglionic mega-colon and without dilatation in the upper urinary tract it was considered unjustifiable to make a urological diagnosis of mega-ureter-megacystis syndrome. However, the presence of dilatation in both the gastro-intestinal tract and the bladder suggested that these conditions were in some way related and the problem would not have been clarified by an assumption that the bladder condition was that of primary atony.
Fig. 142. Case 34: cystometrogram.
Gystometric studies were carried out in patients with mega-ureter - megacystis by Swenson and his colleagues and showed that bladder filling to a large capacity would occur with recorded pressure between 20 and 30 cm. of water, but without "emptying contractions".

This type of cystometrogram was recorded in the following patient of the present series.

**Case 35.** During routine medical examination for admission to the Armed Services this 19-year-old youth was found to have albuminuria. On admission to hospital he was symptom-free and physical examination was entirely negative. He was able to void 500 c.c. of urine with normal sensation and full control. His serum electrolyte levels were within normal limits and his blood urea nitrogen was estimated at 16 mg. per 100 c.c. He was found to have a maximum urea clearance of 51 per cent of average normal and a creatinine clearance of 75 litres per 24 hours. The following urological investigations were carried out.

**Intravenous Pyleograms (Fig. 143).** showed good concentration of dye by both kidneys but there was bilateral hydronephrosis and hydro-ureter.

**Cystometrogram (Fig. 144).** Two-way catheter passed without difficulty to drain a residuum of 40 c.c. of urine from which a moderate growth of coliform bacilli was obtained but no pus cells were present. Resting bladder pressure - nil. Atonic filling occurred to 115 c.c. and the bladder pressure then rose suddenly to 20 cm. of water. With 150 c.c. of filling a feeling of fullness was experienced at 22 cm. of water pressure. With further filling to 675 c.c. the bladder pressure slowly rose to 28 cm. of water. A strong desire to void was experienced after 275 c.c. of filling at a pressure of 22 cm. of water. A voluntary contraction after 560 c.c. of filling produced a peak pressure of 46 cm. of water and a further voluntary contraction after 660 c.c. of filling produced a peak pressure of 85 cm. of water.

**Cystograms.**
Fig. 143. - Case 35: intravenous pyelograms.

Fig. 144. - Case 35: cystometrogram.
Cystograms.— The P.A. view showed the bladder to be of smooth contour without ureteric reflux. The right oblique straining view (Fig. 145) showed no detrusor activity, and though the bladder neck remained closed there was no ureteric reflux.

Cystoscopy.— After filling with 300 c.c. of fluid the bladder was seen to be funnel-shaped and there was mild trabeculation of the bladder base without sacculum or diverticulum formation. The trigone was hypertrophic and raised as a prominent plateau with forward extension into the lateral pillars of the bladder neck to produce slight encroachment. Both ureteric orifices were normally situated but surmounted a thick inter-ureteric bar; they were closed but were catheterised without difficulty to 30 cm.

Retrograde Pyelograms were taken (Fig. 146) with cine-ureterography and the presence of bilateral hydronephrosis was confirmed. The ureters were strongly contractile in a normal direction from the renal pelvis down to the bladder and no hydro-ureter could be demonstrated. The cystoscopic findings indicated that the bladder derangement was probably based upon an overactive sympathetic innervation; the hypertrophy of the trigone thereby produced was apparently offering mechanical resistance to ureteric urine flow at the ureterovesical junctions and was responsible for the development of bilateral hydronephrosis and hydro-ureter with incipient renal failure.

Progress.— Pre-sacral neurectomy was carried out and the ureters were implanted into a new position in the bladder wall. At operation the bladder wall was healthy and a biopsy was taken and subsequently showed that no muscular hypertrophy, degeneration or fibrosis was present. Histological examination of the excised lower end of each ureter showed marked hypertrophy of the longitudinal, oblique and circular muscle fibres.

The patient's immediate post-operative convalescence was satisfactory and he continued to void urine with normal sensation and control to leave only a negligible residuum. When seen one month after operation he had a mild urinary infection, but he has defaulted from further attendance for two years and it is assumed that he has remained well.

Comment.— The finding of a large capacity bladder without a significant degree of hypertrophy and with a small residuum of urine suggested that this patient might represent the mega-ureter - megacystis syndrome at rather a /
Fig. 145.- Case 35: straining cystogram.

Fig. 146.- Case 35: retrograde pyelograms.
a late age. The acceptance of a large volume of fluid at relatively high pressure without detrusor activity, as shown on the cystometrogram, supported this suggestion, but the absence of ureteric reflux made such a diagnosis untenable.

This demonstration of hyperactive sympathetic innervation of a large capacity bladder with good filling tone was not strictly in accord with the observations of Swenson et al. (1952) that the deranged dynamics of megacystis are due to diminution of parasympathetic bladder innervation; it is interesting to note that Leibovitz (quoted by Williams, 1958) failed to obtain histological evidence of such deficiency in specimens of megacystis bladder. However, it cannot be inferred that overactive sympathetic activity may be responsible for the development of megacystis; Case 35 was not typical of the complete syndrome because no ureteric reflux was demonstrated. The dilatation of the ureters could have been due to the tonic contraction of the hypertrophied trigone around their intramural portions and it was not justifiable to make a diagnosis of bilateral primary mega-ureter as defined by Williams (1954). In this condition the dilatation of one or both ureters is not associated with any form of organic obstruction but may be related to the occurrence of retrograde ureteric contractions with an abnormality of muscular structure of the lower end of the ureter and ureterovesical junction (Murnaghan, 1958).

A clinical diagnosis of bilateral primary mega-ureter in association with a large capacity bladder was made in the following case.
Case 36. - This boy had had a hypospadias repaired at the age of 3 years. At the age of 11 years orchidectomy was carried out for clinical torsion of the left testis and subsequently the excision of a chronic sinus from the inguinal wound was required. At the age of 13 years he was admitted to hospital with a large, tender swelling of the right side of the scrotum which had been present for some weeks and was considered to be the result of torsion of the spermatic cord. At this time provisional arrangements had been made for the final stage of the hypospadias repair, but he was found to have pyuria with a staphylococcal urinary infection; he would admit to no urinary symptoms. The following urological investigations were carried out.

Intravenous Pyelograms (Fig. 147). - showed satisfactory excretion from both kidneys with bilateral hydrenephrosis and hydro-ureter, worse on the right side.

An attempt was made to carry out cystometry but the urethra was narrow and would not admit the standard-sized double-channel catheter. A 6 F. rubber catheter was passed without difficulty and the bladder was filled with 300 c.c. of radio-opaque dye; the patient then experienced a strong desire to void and a feeling of fullness.

Cystograms. - The P.A. view showed a large bladder of smooth contour without ureteric reflux.

The left oblique straining view (Fig. 148) showed neither detrusor activity nor ureteric reflux but there was some relaxation of the bladder neck.

Cystoscopy. - The urethra was dilated without difficulty to admit a 14 F. cystoscope. After filling to 300 c.c. the bladder presented no abnormal features. The lateral pillars and posterior lip of the bladder neck were well-defined but there was no apparent contracture. Both ureteric orifices were normally situated and though slightly prominent were catheterised without difficulty.

Retrograde Pyelograms (Fig. 149). - showed bilateral hydrenephrosis with hydro-ureter. With X-ray screening the left ureter was seen to be strongly contractile in a normal direction. No visible contractions were observed in the right ureter but at the lower end of both ureters supra-vesical narrow segments were demonstrated.
Fig. 147. - Case 36: intravenous pyelograms.

Fig. 148. - Case 36: left oblique straining cystogram.
Fig. 149. — Case 36: retrograde pyelograms.
A clinical diagnosis of bilateral idiopathic primary mega-ureter with supra-vesical narrow segments was made and bilateral neo-uretero-cystostomy was carried out with temporary suprapubic catheter drainage of the bladder.

The suprapubic wound was slow to heal but closed after prolonged urethral catheter drainage. Spontaneous micturition was eventually restored after repeated dilatation of the urethra. This patient's late convalescence was marked by recurrent episodes of fever with pain in the right loin and it was thought probable that reflux of infected urine was occurring from the bladder through the newly fashioned right uretero-vesical orifice. Urological re-assessment was carried out as follows.

**Cystometrogram (Fig. 150).**—An 8 F. double-channel Foley catheter was passed with difficulty. Resting bladder pressure - 7 cm. of water. The bladder pressure rose to 15 cm. of water with an atypical desire to void after 100 c.c. of filling. With further filling to 150 c.c. the bladder pressure rose to 20 cm. of water and suprapubic pain was experienced. The pressure then rose more steeply to 27 cm. of water and after filling to 175 c.c. a voluntary contraction produced a peak pressure of 32 cm. of water.

**Cystograms.**—A P.A. view taken at the time of voluntary contraction during cystometry showed reflux into the stump of his lower left ureter, but there was no obvious reflux into the re-implanted ureter on either side.

**Intravenous Pyelograms** taken one month after operation showed satisfactory function in both kidneys with bilateral hydrenephrosis and hydro-ureter (Fig. 151); the dilatation of the right ureter had decreased. Six months after operation this patient would admit to no urinary symptoms but there was persistent staphylococcal urinary infection with intermittent attacks of fever and transient abdominal pain.

**Comment.**—The absence of marked bladder detrusor hypertrophy with trabeculation made it unlikely that the dilatation in the upper urinary tract was simply the result of increased urethral resistance associated with previous surgical treatment of a hypospadias defect and a diagnosis of bilateral mega-ureter was justified. The supra-vesical limitation of a mega-ureter is recognised as a clinical variant of primary mega-ureter (Williams, 1958).

The
Case 36: intravenous pyelograms one month after bilateral neo-uretero-cystostomy.
The pre-operative cystograms and the post-operative cystometrogram approximated to the pattern of these findings in the classical megacystis syndrome. However, such a diagnosis was untenable because of the failure to demonstrate easy reflux into the bilateral mega-ureters.

Cases 35 and 36 thus presented features to suggest that a large capacity bladder with good tone (and without sufficient detrusor hypertrophy to indicate the presence of either organic or functional obstruction at the bladder neck or in the urethra) may be found with concurrent hydro-ureter or mega-ureter but in the absence of vesico-ureteral reflux. It might therefore be implied that the megacystis precedes and does not follow mega-ureter in the development of the combined syndrome. It is important to pursue the problem of dissociating megacystis and mega-ureter as two distinct entities in the same patient because such distinction may be relevant to the problems of vesico-ureteral reflux, the development of hydro-ureter and hydronephrosis and the indications for the early institution of ureteric urinary diversion in some cases of extrinsic neurogenic bladder disorder.

There is both clinical and experimental evidence to indicate that the functional relationship between the ureters and the bladder does not have a neurogenic basis. In 1919 Fullerton reported that ureteric peristalsis, normal movements of the ureteric orifice and competence of the uretero-vesical valve were all present in several patients investigated endoscopically shortly after they had sustained complete section of either the cervical or dorsal /
dorsal segments of the spinal cord. Learmonth (1931b) demonstrated that stimulation of the vesical sympathetic nerves produced simultaneous contraction of the trigone and closure of the ureteric orifices, but he considered that the control of these two structures was to some extent dissociated. Experimental evidence has indicated that the opening mechanism of the uretero-vesical junction may be inherent in the contraction of the longitudinal muscle fibres of the lower end of the ureter and is thus independent of the bladder and its nerve supply (Murnaghan, 1960). These reported studies strongly suggest that the relationship between mega-ureter and megacystis cannot have a neurogenic basis.

The occurrence of unilateral primary mega-ureter either with or without a supra-vesical narrow segment and without megacystis might indicate that mega-ureter forms the primary abnormality in the mega-ureter - megacystis syndrome. The dilatation of the bladder might develop as the result of reflux into a large mega-ureter at a late stage and might thus represent a physiological adaptation to rapid filling at low pressure as would occur when a mega-ureter emptied into the bladder immediately after voiding; it would thus contrast with the hypertrophic response of a bladder to a demand for greater detrusor force in the presence of urethral obstruction.

The /
The relationship between bladder tonus, urethral resistance and vesico-ureteral reflux was evaluated in the following patient.

Case 37.- This 26-year-old man was investigated because of recurrent attacks of urinary infection. He had pes calcaneovalgus but no other abnormality was detected on physical examination. The bulbo-cavernous and anocutaneous reflexes were present and the serological tests for syphilis were negative.

On cystoscopy the bladder was found to have a normal capacity and was not trabeculated; the ureteric orifices were small but normally situated and were catheterised without difficulty. Retrograde pyelograms showed that he had bilateral mega-ureter with calculus formation at the lower end of the right ureter.

At operation the right ureter was divided 5 cm. from its junction with the bladder and the calculus was removed. The lower end of the divided ureter was closed with catgut sutures and the upper end was implanted into the base of the bladder and the bladder was then closed. Two months after operation he was re-admitted to hospital complaining of severe right renal pain, exaggerated by micturition and accompanied by a discharge of infected urine from his abdominal wound. Full urological reassessment was carried out.

Intravenous Pyelograms (Fig. 152).—showed impaired function of the right kidney with hydronephrosis; dilatation of the lower spindle of the left ureter was seen on the bladder projection (Fig. 153).

Cystometrogram (Fig. 154).—A two-way catheter was passed without difficulty and drained 200 c.c. of residual urine from which a profuse growth of B. coli was obtained. Resting bladder pressure was 17 cm. of water. There was moderate intrinsic bladder activity with slow filling up to 250 c.c. with a peak pressure of 45 cm. of water. The first desire to void was experienced after 300 c.c. of filling at a pressure of 30 cm. of water. Further filling to 425 c.c. produced a peak pressure of 70 cm. of water with a strong desire to void and the sudden onset of severe pain in the right loin. After 450 c.c. of filling a voluntary contraction produced a peak pressure of 90 cm. of water.
Fig. 152. - Case 37: intravenous pyelograms.

Fig. 153. - Case 37: excretory ureterogram.
Fig. 15L - Case 37: cystometrogram.
Cystogram.- The P.A. view showed the bladder to have normal contour but demonstrated reflux of dye into the right ureter and renal pelvis. The right oblique voiding view (Fig. 155) showed no evidence of detrusor activity but there was marked reflux of dye into the right ureter and renal pelvis with gross hydro-ureter and hydronephrosis. The urinary stream was thin but the bladder neck was relaxed and there was a suggestion of obstruction in the region of the external urethral sphincter.

The urethra was calibrated with Hinman bougies but no stricture was demonstrable.

Ascending Urethrogram with Sphincterometry (Fig. 156).- The external urethral sphincteric resistance was found to be 45 cm. of water.

Cystoscopy.- After filling to 225 c.c. the bladder showed trabeculation and sacculation of its base; both ureteric orifices were normally situated but the interureteric bar was elevated, and the posterior aspect of the bladder neck was prominent. The site of re-implantation of the right ureter was healthy and was located high on the base of the bladder.

Right Ureterogram.- The stump of the lower right ureter was filled with radio-opaque dye and was shown to be dilated but without intrinsic pathology (Fig. 157).

Retrograde Pyelograms (Fig. 158).- showed hypertrophy of the left kidney with clubbing of its calyces and marked dilatation of the lower spindle of the left ureter. There was moderate dilatation of the right pelvi-calyceal system and marked dilatation of the lumbar spindle of the right ureter.

The results of these investigations indicated that this patient's symptoms were due to reflux of infected urine from a tonic bladder into the right-sided mega-ureter following re-implantation of this ureter into the base of the bladder after removal of a ureteric calculus. The absence of trabeculation and sacculation of the bladder at the time of initial cystoscopic examination made it unlikely that the ureteric dilatation was secondary to prolonged elevation of the intravesical pressure as the result of contracture or congenital obstruction at the bladder neck. It was therefore considered that hypertrophy of the bladder musculature had developed in the three-month interval between operation and urological reassessment. It appeared that this hypertrophy could be directly related to the reflux of urine from the bladder through the incompetent right uretero-vesical anastomosis. In view of the bilateral distribution of dilatation in the upper urinary tract it was not felt justifiable to remove the /
Fig. 155. - Case 37: voiding cystogram.

Fig. 156. - Case 37: ascending urethrogram during sphincterometry.
Fig. 157. - Case 37: right retrograde ureterogram.

Fig. 158. - Case 37: retrograde pyelograms.
the right kidney and ureter in order to obtain symptomatic relief and preference was given to an attempt to reduce the urethral resistance in order to improve bladder drainage in the hope that the urinary infection would then respond to antibiotics or chemotherapy. The bladder neck contracture was not marked and it was considered that fertility was less likely to be impaired after unilateral pudendal neurectomy than after transurethral resection of the bladder neck. Left-sided neurectomy was therefore carried out and was followed by easier micturition with a stronger urinary stream, but the amount of residual bladder urine remained high and eventually there was a recurrence of fever with pain in the right loin. It was thus necessary to carry out transurethral resection of the bladder neck. Through the resectoscope a "horse-collar" type of bladder neck encroachment was recognised and its posterior quadrant was resected. Subsequent histological examination of the resected tissue showed that it contained hypertrophic muscle fibres with cystic metaplasia of transitional cell mucosa, oedema and inflammatory cell infiltration.

Progress. - This patient reported for review at intervals; he had no further difficulty or frequency of micturition and maintained full urinary control with a normal desire to void; the residuum of bladder urine was found to be 60 c.c.

Intravenous pyelograms were taken 14 months after the transurethral resection and showed little change in the condition of the upper urinary tract, but repeated estimations of his serum electrolyte and urea nitrogen levels were within normal limits during 20 months of surveillance.

Further support for the suggestion that the bladder may offer a tonic and hypertrophic response to a urinary "escape route" which offers less resistance than the normal urethra, may be obtained from a consideration of some cases of bladder diverticulum. In 1849 Rokitansky taught that diverticula of the bladder result from urethral obstruction, and subsequent reports by Young (1918), Hinman (1935) and Kretschmer (1940) have tended to confirm this view. However, in some patients in whom bladder diverticulum formation has occurred it may be impossible to find any convincing /
convincing evidence of obstruction at the bladder outlet or in the urethra, and it is then customary to ascribe the diverticulum formation to some minimal degree of bladder neck hypertrophy or to label it "congenital". In such patients it is usually puzzling to find hypertrophy of the detrusor musculature with trabeculation out of all proportion to the degree of contracture of the bladder neck. It is then difficult categorically to dissociate the presence of detrusor hypertrophy from the altered hydro-dynamics of micturition whereby any rise in intravesical pressure causes urine to take the line of least resistance and to pass into and expand the diverticulum instead of passing into the urethra. This phenomenon has been described and illustrated many times since it was first noted by Ogier Ward in 1938.

From these considerations it appears probable that the bladder dilatation in the mega-ureter - megacystis syndrome is not secondary to the altered dynamics of micturition which are induced by free reflux of urine into the dilated ureters. The occurrence of "megacystis" without mega-ureter as described in the thesis suggests that an intrinsic neurogenic bladder disorder probably constitutes the primary abnormality in the complete syndrome. The maintenance of good bladder tonus with large capacity filling in such cases may not be a certain indication of impaired parasympathetic bladder innervation but might well result from an imbalance between the two divisions /
divisions of the autonomic supply, as described in Case 35. This concept would allow for the possibility that any sympathetic overaction would maintain increased tonus in the trigonal musculature around the uretero-vesical junction and would thus be complementary to the contention that the primary abnormality of mega-ureter lies at this junction, as indicated by experimental studies (Murnaghan, 1960).
When a careful regime of bladder rehabilitation and the skilful application of restricted urological procedures fail to restore balanced bladder function in a way that is compatible with comfort, social life and the preservation of renal function, consideration must be given to diversion of the urinary stream. The particular method chosen for the management of individual patients generally depends upon prognosis and general condition, as already discussed on p. 143, but the sex of the patient and the nature of the neurogenic bladder disorder are particularly relevant to this clinical problem. Concurrent loss of anal sphincter tonus usually excludes the possibility of urinary diversion by ureterocolic anastomosis.

**Suprapubic Cystostomy Drainage**

This procedure plays but a very small part in the satisfactory management of the decompensated neurogenic bladder. In the absence of organic urethral obstruction it is frequently accompanied by persistence of urethral urinary incontinence and is almost always complicated by infection with a high incidence of bladder calculus formation and leakage of urine around the suprapubic tube. The persistence of infection is almost inevitable because of the presence of the tube in the bladder as a foreign body.
body, and because the suprapubic route does not allow for dependent drainage. However, satisfactory suprapubic drainage has been established through a tubeless suprapubic cystostomy track in which the bladder mucosa is sutured directly to the skin (Blockson, 1957). This method has been applied successfully to the management of neurogenic bladder disorders in childhood by Carlson (1960). By this method the urine discharges directly from the cystostomy opening into a Ruten bag applied to the suprapubic region by a watertight adhesive patch, held in position by a metal ring and supporting belt as used for ileostomy drainage (Fig. 159). In most patients with suprapubic cystostomy drainage it is necessary to carry out careful obliteration of the urethra to prevent urethral incontinence. This complication is particularly troublesome in female patients because the short urethra offers little resistance to urine flow and incontinence may occur even in the presence of bladder neck hypertrophy or raised tonus in the external urethral sphincter. When the female urethra is patulous this complication may be avoided by transposing the urethra into the suprapubic region (Griffiths, 1960) where it behaves as a fistulous opening, but this method is not applicable when the neurogenic bladder disorder prevents the bladder and urethra from acting as a simple conduit; an unsatisfactory residuum of urine may then persist and upper urinary tract involvement may progress. When urinary /
Fig. 152. - Watertight flange and supporting belt used for ileostomy drainage.
urinary diversion is not required simply as a palliative measure for patients with a poor prognosis or in a debilitated state, its purpose will be more directly achieved if the diversion is carried out at a ureteric level.

Cutaneous Ureterostomy

Cutaneous ureterostomy is a well-established method of urinary diversion because it is known to carry a negligible mortality and is usually followed by the maintenance of renal function at a reasonable level. Its successful application to the management of neurogenic bladder disorders has been reported by Kennedy (1935) and Abeshouse (1948). Many modifications of technique have been introduced in order to overcome the disadvantages of two urinary fistulae and the common complications of stomal stenosis and leakage from the collecting apparatus. In thin patients it has been found possible to transpose one or other ureter across the posterior abdominal wall in the retroperitoneal space so that it may drain through an end-to-side anastomosis into the contralateral ureter which is delivered by an extra-peritoneal route to a single stoma on the abdominal wall (Tulloch, 1959). A technique for the elaboration of a double barrelled stoma for the satisfactory drainage of bilateral cutaneous ureterostomies into a single collecting bag has recently been described by Swenson and Smyth (1959). Their method does not involve the fashioning of skin tubes as described by Schinagel and /
and Sewell (1948); cutaneous pedicles do not necessarily prevent a stenosis at the ureterostomy stoma (DeVries, 1955) and when constructed in children they tend to tilt upwards as the patient grows, and are subject to infection and abrasion from the collecting appliance (Band, 1960).

These unsatisfactory features of cutaneous ureterostomy stimulated the application of uretero-ileostomy to the long-term management of complicated cases of neurogenic bladder disorder.

**Uretero-ileostomy**

It is a prolonged and extensive surgical procedure and has a mortality rate of 9 percent when carried out for the relief of urinary incontinence associated with congenital deformity (Wells, 1956). In other reported series of similar cases there has been either a high incidence of post-operative intestinal obstruction (Nash, 1956), or a tendency for stenosis to occur at the ileostomy stoma with accumulation of residual urine in a redundant ileal loop to produce electrolyte imbalance so that segmental resection of the ileum was required subsequently (Johnston and Rickham, 1958).

The establishment of uretero-ileostomy drainage in patients with extensive neurological involvement requires that particular attention be paid to certain technical considerations /
considerations. As far as possible the stoma should be sited on a flat surface and on sensitive skin; the collecting bag and supporting belt should be fitted before operation to ensure that the appliance will not interfere with the proper adjustment of the supporting straps of spinal braces, walking calipers or artificial limbs, if such be worn.

Urinary diversion in the management of neurogenic bladder disorders still presents many problems and no single technique is as yet available for safe and general application.
GENERAL DISCUSSION

The clinical cases presented in this thesis illustrate the extreme diversity of deranged bladder activity which may be associated with abnormalities in the central nervous system. This diversity confirms the intricacy of the normal mechanism of micturition whilst attempted classification of the cases into the accepted types of neurogenic bladder disorder emphasises the obscurity of the precise nature of higher centre voluntary control. The extraordinary way in which both willed and unwilled psychological factors may affect bladder function contrasts with the comparative simplicity of spinal reflex micturition after spinal cord section. It is apparent that without organic disease variation in the urgency or frequency of the need for micturition is essentially related to the fluctuations of psychological factors as emphasised by Denny-Brown and Robertson (1933). However, it has also been demonstrated that in the presence of nervous disease similar variation may be related to increased facilitation of the spinal bladder reflex by the presence of neuropathology in the conus medullaris or cauda equina or by the uncontrolled interplay of nervous activity in an autonomous portion of spinal cord below a level of cord section. The distinction between these /
these two groups is important not only from a physiological or diagnostic point of view but also for a proper appreciation of the problems of management of such conditions as persistent enuresis, post-cordotomy bladder disturbance and spastic bladder activity in paraplegia.

In enuresis though organic urological and neurological disease be excluded the demonstration of uninhibited activity of the bladder detrusor is not necessarily of any prognostic significance; longstanding or well-established disorders of personality are apparently capable of perpetuating deranged bladder function despite the restoration of a more normal tonic response to bladder filling by the administration of anticholinergic agents. This fact might suggest that the higher centre control of micturition may include definite stimulation of the spinal centre for micturition in addition to the release of inhibition which is generally thought to be the predominant mechanism for the willed initiation of the act. In this respect, the finding of a significant incidence of uninhibited neurogenic bladder disorder in Parkinsonism does perhaps indicate that the basal ganglia are directly concerned in the higher centre control. Tonic activity of the bladder in Parkinsonism was not found to be associated always with tonic rigidity of the striated urethral musculature, whilst the striking alterations produced in the cystometrograms by stereotaxic brain surgery showed a general correlation with the location of the stereotaxic lesion in the thalamus, pallidum or internal capsule /
capsule. There was a suggestion that thalamic lesions might induce uninhibited bladder activity, that pallidal lesions might lower bladder tonus, whilst capsular lesions might interfere with the higher perception of bladder filling. However, the number of cases considered suitable for critical analysis was small and it was impossible to make any positive conclusions regarding either motor function of the basal ganglia or the location of ascending and descending pathways in the internal capsule which are subservient to micturition. Up to the present time it has not been possible to carry out long-term urological follow-up of this group of patients and there is no evidence to indicate the permanency or otherwise of the changes produced in bladder activity by stereotaxic surgery in Parkinsonism. The post-operative urological assessments were generally carried out within a week of surgical treatment so that any apportioning of the changes in bladder activity between nervous destruction in the centre of the lesion and nervous irritation around the periphery of the lesion, (as might well be induced by diathermy coagulation) would be conjectural. A remarkable adaptability of cerebral control of visceral function after localised brain damage was noted by Pool (1954), so that it is possible that the alterations of bladder function produced by stereotaxic procedures might in any case be transient and have no clinical significance. In this context there was no constant correlation of symptoms of urgency and frequency of micturition in persistent enuresis or /
or Parkinsonism with the demonstration of uninhibited bladder activity by cystometry.

It was interesting to find symptoms and signs of such uninhibited disorder after cordotomy for the relief of root pain associated with post-laminectomy arachnoiditis, but a more critical analysis indicated that the bladder derangement in such cases was not due to faulty supranuclear control of the sacral reflex centre but was probably associated with interference with the centre itself or its nerve roots. Interference with the spinal centre for micturition by painful stimuli from peripheral nerves entering the same segments of the cord did not appear to disorganise the co-ordination of bladder detrusor activity completely, and it is therefore probable that arachnoiditis directly involves the motor roots of the bladder innervation. It follows that the spasticity of the bladder after surgical procedures for intervertebral disc protrusions is not analogous to the spastic reflex bladder in paraplegia, though the difference between these two types of spastic activity is not necessarily related to the nature and extent of any interruption of the spinal cord pathways.

The low incidence of such spastic reflex bladder activity in the present series of patients with complete traumatic section of the spinal cord could be attributed to their general management by careful specialist nursing and skilful physiotherapy. Such attention might also have been responsible for the unusual and high proportion of these /
these patients whose paraplegia stabilised at a segmental cord level above that which might otherwise have been expected from the level and nature of their vertebral injuries. These high level cord lesions allowed for rehabilitation of the bladder to compensated, reflex activity in many patients with injury to the dorso-lumbar region of the spine.

It would accordingly be unwise to attribute the successful urological management of the paraplegic group of patients with a low incidence of significant complications simply to the regime of urological care and to the use of indwelling urethral catheter drainage. Without careful general management and prompt mobilisation of these patients it is probable that the high incidence of urinary infection, associated with the catheter drainage, would have been more persistent and responsible for serious morbidity. However, the review of alternative methods of urological management indicated that either a non-drainage programme or suprapubic catheter drainage entailed many disadvantages and might prolong and complicate the period of rehabilitation.

From a review of published work and from the personal observations included in this thesis it was considered that during the stage of spinal shock the bladder is not completely atonic. Serious loss of tonus under any circumstances would appear to be due to overdistension of the bladder though interruption of the sensory innervation of the organ at any neurological level is probably the commonest /
commonest primary factor which allows such overdistension to develop insidiously. For this reason it is recommended that continuous urethral catheter drainage should be established as a first aid measure in any case of paraplegia of sudden onset and should be used prophylactically after extensive pelvic surgery, cordotomy or other major surgical procedures in elderly patients. If such drainage is competently instituted and properly managed it is unlikely to be followed by serious urinary infection when it is required for only a short time. Infection is almost inevitable when the period of drainage is prolonged, as in most cases of traumatic paraplegia, but the prevention of overstretch of the bladder musculature is of fundamental importance to the recovery or rehabilitation of the neurogenic bladder and as compensated function returns the urinary infection may completely resolve. The absence of upper urinary tract dilatation or other serious complications during the early years of follow-up of the series of patients with traumatic paraplegia included in this thesis fully justifies this method of urological management. Moreover, the recovery of balanced reflex bladder function in the great majority of these patients and its frequent association with atypical forms of bladder sensation after complete cord section indicate that any infection which occurs during the proper use of urethral catheter drainage does not usually become established deep in the bladder wall.
The advent of "substitute bladder sensation" in paraplegia was not found to be of any great value in the "voluntary" control of reflex voiding and the perpetuation of compensated bladder function was more certain if a regime of micturition "by the clock" was adhered to. The method used by these patients to initiate reflex detrusor contraction depended upon suprapubic percussion or upon a rise in bladder pressure induced by abdominal straining. On several occasions cystometry recorded evidence to indicate that this rise in pressure was followed by a strong co-ordinated detrusor contraction with simultaneous opening of the bladder sphincters and bypassing of the filling catheter. Any attempt to reinforce this reflex voiding by further straining was usually unsuccessful and if there was no indwelling catheter would be followed by intermittency and diminution of the urinary stream. These observations indicate that co-ordinated detrusor contraction is the stimulus for sphincteric relaxation and further suggest that, in man, supporting reflexes to the motor discharge from the sacral centre through the pelvic nerves do not arise as urine passes along the posterior urethra. The frequent absence of flaccidity in the internal vesical sphincter during spinal shock even after cord section above the segmental origin of sympathetic bladder innervation could be interpreted as evidence that the reciprocal action of detrusor muscle and the bladder neck is muscular and mechanical rather than nervous. Otherwise it is difficult to explain why tonus should be maintained in the smooth musculature /
musculature around the bladder neck when there is widespread suspension of nervous activity. The oblique looping of bundles of detrusor muscle fibres around the bladder neck may be in helical formation so that traction on them by passive distension of the bladder vault could lead to occlusion of the internal vesical orifice, whilst widening of the orifice could still result from active contraction of the muscle fibres themselves. It is difficult to ignore the definite motor sympathetic innervation of the internal sphincter in any consideration of this mechanism and a lack of proper understanding of the functional complexity of the bladder neck remains as a barrier to the proper initial urological management of paraplegia by a non-drainage programme.

Likewise there is no clear-cut neurophysiological explanation for the tonic behaviour of the autonomous type of neurogenic bladder, though the anatomical site of the neurological lesion responsible for this disorder would allow for a definite persistence of sympathetic innervation despite interruption of both afferent and efferent limbs of the micturition reflex arc. However, the hypertrophic and tonic state of both the detrusor and retentive forces of the autonomous bladder may lead to serious problems in urological management because of the attendant development of upper urinary tract dilatation with decompensated incoordinate bladder activity, urinary infection and persistent incontinence. Such problems may spontaneously resolve after the development of bladder muscular failure, but /
but it may be necessary to induce bladder atony deliberately or to divert the urinary stream in order to arrest deterioration of renal function.

In the management of neurogenic bladder disorders with atony it was found that a more satisfactory clinical approach could be obtained by a consideration of micturition as a delicate balance between a voiding force and urethral resistance. The voiding force should be adequate for bladder emptying to leave a negligible residuum of urine but, on the other hand, urethral resistance should maintain continence between acts of micturition, and yet be sufficiently low at the time of voiding, as compared with the voiding force, to allow for the bladder to remain compensated. A combination of cystometry, cystography, cysto-urethroscopy and ascending urethrogramy with sphincterometry has proved adequate for the evaluation of these factors of the "micturition equation".

Surgical procedures to reduce the urethral resistance should be undertaken only after a period of indwelling urethral catheter drainage with "bladder drill" and the administration of cholinergic bladder stimulants. Continuous catheter drainage was first advocated for the treatment of bladder atony by John Hunter in 1818 and he reported that it could be used for "five months without any inconvenience". In the present series it was found that such conservative management was least effective in those patients who had complete loss of bladder sensation.
The choice of a more active procedure to restore bladder balance depends upon the clinical assessment of whether the smooth or the striated muscular components of the urethral resistance predominates. Though it might be inferred that a selection of either transurethral resection of the bladder neck or pudendal nerve interruption has a definite neuro-anatomical basis such is the case only when urological investigations show that there is hypertrophy or contracture of the bladder neck or spasticity of the external urethral sphincter. Caine and Edwards (1958) have shown that bilateral pudendal nerve block after the bladder neck has been rendered incompetent by prostatectomy, does not produce urinary incontinence. They considered that "passive continence", as maintained without active sphincteric contraction, is due essentially to the tone of the smooth muscle and elastic tissue in the subepithelial layer of the posterior urethra; it was distinguished from "active continence" which they considered as a mechanism brought into play when a voluntary effort is made to interrupt the act of micturition or voluntarily to prevent the unwanted escape of urine. None of the cases reported in this thesis presented any features to detract from the value of the concept of "active" and "passive" continence, and it formed the basis for careful assessment of those patients with neurogenic bladder disorder who had retained some degree of voluntary control of micturition.

Such /
Such cases may be more common than is generally suspected but may not be recognised because the bladder derangement may be the only presenting neurological abnormality. Cystometry and cystography should therefore be included in the urological assessment of patients with enuresis of late onset, recurrent urinary infection, bladder calculus formation or disturbance of bladder habit unrelated to definite organic pathology in the urinary tract.

The use of cystometry in the management of neurogenic bladder disorders, as described in this thesis, confirmed its value as a reliable method for the clinical investigation of the mechanism of micturition. When combined with cystography it allowed for a quick assessment of the type of bladder derangement and served as a direct guide to the most effective form of therapy. It proved to be particularly useful in the assessment of bladder recovery in traumatic paraplegia and in the differential diagnosis of atonic and intrinsic neurogenic disorders. Occasionally it proved to be the only source of useful clinical information in the evaluation of these patients but more often the cystometric findings were significant only when they were integrated with the clinical history, physical signs and the results of other neurological and urological investigations. Though the technique of cystometry was standardised and meticulous in its clinical application the actual method was not sufficiently controlled to justify any analysis of the entire series for /
for the purpose of physiological research. However it was considered that differences in the recordings obtained from selected groups of patients with the same clinical diagnosis had physiological significance when they were correlated with concurrent neurological signs or with the observed effects of neurosurgical procedures.

Such correlation is the present main source of information for the formulation of new physiological concepts and is an essential clinical exercise for the proper management of individual patients because there is as yet no form of therapy which can be generally applied. The establishment of adequate voluntary safe bladder function essentially depends upon the training of patients into a new mechanism empirically based upon an incomplete and imperfect knowledge of the physiology of micturition.
SUMMARY AND CONCLUSIONS

1. The embryology of the bladder forms the basis for a subdivision of its innervation into sympathetic, para-sympathetic and somatic components which have separate peripheral pathways. The sensory and motor functions of these nerves and their related spinal tracts are integrated into a mechanism for normal micturition which is subserved by cerebral, spinal and vesical neuronal centres.

2. A simplification of this mechanism is used to classify neurogenic bladder disorders into uninhibited, reflex, autonomous and atonic types according to the level of neuronal disturbance; the characteristic features of each type are briefly described.

3. The clinical material and prescribed drugs are listed and the methods of clinical investigation are presented in detail.

4. Disturbances of the higher centre control of micturition are discussed in relation to personality disorders and emotional upset, and are illustrated with cases of cystalgia, psychogenic urinary retention and persistent enuresis. It is suggested that active stimulation of the sacral reflex centre may feature in the higher centre control of micturition.

The /
The results of urological investigations in patients with Parkinsonism are presented and a high incidence of uninhibited neurogenic bladder disorder is reported. The changes in cystometrogram pattern following stereotaxic brain surgery are correlated with the peripheral manifestations of the syndrome and the location of the therapeutic brain lesion. A critical analysis of these factors showed a relationship between lesions of the thalamus or pallidum and tonic bladder activity to suggest participation of the extra-pyramidal system in the higher centre control of micturition.

5. The mechanism of deranged bladder function after anterolateral spinal cordotomy is reviewed and its management discussed. A neurological basis for tonic bladder activity in this condition is demonstrated in reported cases; interference with the sacral centre for micturition by abnormal stimuli from peripheral nerves of the same segmental level is introduced as a clinico-physiological problem.

6. The urological management of patients with traumatic lesions of the spinal cord is presented with particular reference to rehabilitation of the bladder to reflex activity. It is suggested that the relationship between bladder detrusor and bladder neck may be mechanical rather than neurological. The neuro-physiological basis of urological complications in paraplegia is illustrated by clinical /
clinical cases which also emphasise the value of cystometry in the proper application of indwelling urethral catheter drainage without serious morbidity.

In non-traumatic and incomplete paraplegia the method of management must be modified according to age and general prognosis, as illustrated in the care of patients with severe spina bifida or neoplastic involvement of the central nervous system.

Selective derangement of the somatic component of the mechanism of micturition is defined as a cause of neurogenic bladder disorder and clinical problems relating to its management are illustrated.

8. The relationship of bladder atony to over-distension and sensory denervation is considered relevant to the prophylaxis and treatment of chronic urinary retention.

Dilatation of the bladder without loss of tonus and its relationship to ureteric dilatation are evaluated and illustrated with reference to the natural history of the mega-ureter - megacystis syndrome and to imbalance of autonomic bladder innervation.

9. The value of cystometry in the classification and management of neurogenic bladder disorders is confirmed by the present studies, but the results of this technique must be integrated with other clinical information before they are interpreted as physiological features of the mechanism of micturition.
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