Transfusion or Injection

of

Blood and other fluids

with special reference to the injection of blood

with saline solution

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and

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Transfusion of Blood has been long thought of as a powerful means of treating certain forms of acute disease, and we cannot but think, and trust to show, that it has been justly so. It was not however always recognised as a legitimate method, and fully 200 years ago it was only permitted in France under such restrictions, that it absolutely became neglected for many years as a means — a potent means, of recalling patients from the very brink of the grave. Since the early part of this century however it has held a different position, and now "it is almost universally admitted in principle, that Transfusion in conditions of extreme anaemia is a legitimate resource — may in many cases it is imperatively required," and "if there is one thing more than another calculated to surprise us, it is not the number of failures, but the number of successes that have been achieved under the desperate circumstances for which the operation has been resorted" (Garrison's Cyclopaedia Vol. xvi p.476).

What weighed with me in choosing this as a suitable subject for a thesis, was, that while acting as resident surgeon in the Edinburgh Royal Infirmary during the summer and autumn months 1865, I had the great privilege of assisting at four, and of performing one, Transfusion of Blood, and as it seemed to me that I had had a rare experience for such a young graduate, my thoughts, naturally, I think, turned to this subject as a fit one for my careful study.

The case I operated on, may be epitomised as follows — Peter Monat, aged 16, from 13 Crown Street, Leith, was admitted to St. Vincent's Wards on August 31st 1865, having been recommended by a Leith surgeon. The history of his illness was, that he had got over heated at work one day, and next morning had a rigor, that the doctor when called in pronounced him to be suffering from pneumonia, which was followed a few days afterwards by effusion, which, from what the mother says, must have been purulent from the first, at least pus was drawn off by the first tapping which their own medical attendant performed. After this, a consultation with an Edinburgh physician was recommended, who again aspirated
getting off about 40 ounces of pus, and two days later, recommended
that an incision should be made, which was accordingly done and
a drainage tube put in; but this latter was allowed to come out
in a few days, and on admission to Ward XVIII, fourteen days
after the incision had been made, there was only a superficial
wound in the posterior axillary line on the right side. After
admission, Dr. Catheart, who had charge of the Wards in Dr. Duncan's
absence, made a new incision, a large quantity of pus came
away; he again inserted a drainage tube and left instructions
that the pleural cavity was to be washed out with an antiseptic
fluid, one or more times daily. This was done, but matters went
on slowly for some weeks, and meantime Dr. Duncan had
returned, and after considering the case, resolved to reset the
ribs on the affected side, as recommended in chronic Empyema.
This operation was performed on October 13th - piec of seven ribs
being taken away from one wound, no great amount of
bleeding occurring during the operation. During the afternoon
the wound required dressing on account of oozy of blood-
stained serum, and at this time I washed out the pleural
cavity, with a solution of Thymol (1 & 2000). At the evening
visit the discharge was not through the dressing, but when
going my round after midnight, the night nurse informed me
the discharge had again made its appearance through the Corrosive
Sublimate Woot with which it was dressed. The patient was pallid,
but as there had been considerable sickness and vomiting since
the chloroform, I attributed the pallor to that, seeing there was
comparatively little discharge through the dressings; as, in order
to disturb him as little as possible, I merely applied some
fresh dressing over the old. Brandy, &c. Water, and rice milk,
allowed to be given in small quantities frequently. The following
morning (6 A.M.) he had a fainting turn, and the night nurse,
on account of his appearance, thought it necessary to call the
staff nurse, who, having given him some Brandy, and he
having revived a little, did not think it needful to send for
me. When first seen by me during the forenoon (about 10.15 A.M.)
it was very evident that the lad was far from well. He had all the appearance of having been profoundly bled, but contenting myself with seeing that there was only very little discharge through the dressing, and attending to stimulants being given every short time, I left the case in order to let Dr. Duncan see the round. This he did about 11.30 A.M., when he dressed the patient, not washing out the cavity however as the lad was so weak. Champagne was ordered. Dr. Duncan again saw the patient, before leaving the Hospital (about 1.30 P.M.), whom he found decidedly worse, and he warned me that we might require to inject some fluid into the lad's veins. I gave a hypodermic injection of ether, 30 minims, and at 2.30 P.M. paw the patient in consultation with one of my co-residents. By this time the lad had taken a considerable quantity of Champagne, but was certainly weaker, he had had several fainting turns, was very blanched, the pulse hardly to be felt, respirations 36 per minute, extremities were cold, and sometimes he was speaking incoherently. We felt something more than stimulants was required to save the lad's life, and concluded transfusion of blood was the only thing likely to be attended with success, although my colleague expressed his opinion to the effect, that I might transfuse or not "the lad will die". I at once endeavoured to get Dr. Duncan, but finding he was from home, returned to the Hospital and with my colleague's assistance proceeded to operate. Everything being ready, I first dissected out a vein at the elbow, (the patient hardly feeling the operation) and passed two ligatures under it, tying the distal one. Covering the wound with a sponge washed out of Corrosive Sublimate lotion, my colleague opened a vein of my left arm, and we allowed six ounces of Blood to flow into a solution of Phosphate of Soda. Getting my arm rapidly bandaged, I next opened the patient's vein and inserted the canula; the part of the operation which I found most difficulty with; I then slowly injected the mixture of Blood and Saline solution by means of a glass syringe. Several times during the operation I asked the patient if he felt any discomfort, and he
assured me he did not. Shortly after the Transfusion, the pulse had improved, the breathing was slower and quieter, the tendency to vomit had greatly diminished, and the lips were a much better colour. He had no rigor. I gave him a ¼ of a grain morphia suppository, and he fell into a nice sleep. Temperature at night registered 100·6° F. Without going into particulars, let me just notice that, previous to the operation, the lad was getting worse and worse, after it, he immediately began to improve, and when Dr. Duncan saw him the same evening, he was greatly pleased with his condition. Yet that the lad was out of danger yet, for the pulse rate kept high (about 120 & 130) and the temperature the two following days remained above normal (100° and 101·5° F. respectively). This however Dr. Duncan attributes to the septic condition of the wound, which was apparently correct, as when the cavity was washed out, a great amount of very putrid discharge came away, and the temperature fell to, and remained at 99°F. He continued to get Champagne for some days, and on two occasions I gave him a subcutaneous injection of a 3/4° of a grain of Digitaline. But his progress from the time of the Transfusion was steadily onwards for the better, and on the third day after it, we considered him as comparatively out of danger.

Besides this operation, as resident surgeon, I assisted Dr. Duncan while he transfused three times in a case of Pernicious Anaemia under Dr. Brakenridge’s care; (It was done a fourth time while I was off duty). On another occasion, when Dr. Duncan performed a primary amputation above the Knee, and transfused, or more correctly reinjected the blood which the man would have lost, a case which he took as the subject of a paper read before the Medico-Chirurgical Society, 23rd December 1885, and published in the British Medical Journal of the 30th January 1886; in this case also I had the privilege of assisting Dr. Duncan.

The above cases then form my plea for taking up this subject as a suitable one for a Thesis, all of them I will refer to later on, as well as other cases, which, through the kindness of Professor Annandale and Mr. Miller, I have had an opportunity of examining.
congealed blood" and directions how to avert this; all these points are given in full detail. In the same volume at page 385, we have some suggestions by Mr Boyle so interesting and worthy of investigation; such as, whether an animal can be kept alive by transfusion alone—whether the disposition of an animal is changed by transfusion, and other similar propositions.

The French claim, apparently, quite too, the priority of having practiced Transfusion on a human subject. Denys in June 1667, assisted by Emmeret, transfused sheep's blood into a lad lying semiconscious from a fever, who, after a severe reaction was greatly benefited by the operation. It was then tried on cases (which were far from suitable for transfusion, and Denys having been brought before the law courts on account of a death caused, it was said, by transfusion) it was decided that Transfusion of Blood was not to be performed without the permission of the Faculty of Medicine in Paris; the operation in France by this means falling into disrepute and oblivion.

Dr. Cowper and King were the first to perform Transfusion on a human subject in this country, and they carried it out successfully at Arundel House on the 29th November 1667, on Arthur Coga (Obit. Engl. 1873 p. 292), after which it was repeated on a few occasions. But the blow it had received in France seemed to tell across the channel also, and Transfusion was not heard of in England till about one hundred and fifty years afterwards.

Riva and Mangredi are said to have operated in Italy in 1681 (Ranlet 1681 Vol. I p. 187), but having mentioned these names we may pass over a century, as only a stray case or two will be found recorded till we come to Blandelli's time (1849) when Transfusion got a decided impetus forward, the operation being put on a scientific basis.

Such is a very brief sketch of the historical part of my subject; but without further delay, I wish to pass to a more practical and useful part.

In order to form a thoroughly clear and accurate estimate of the value of Transfusion of Blood as a means of treatment—in certain grave conditions, it would be well to have a definite idea—from
records of experiments and clinical experience of possible — of the relative value of the different methods of transfusion or injection of blood or other fluids, and with this view I propose to treat the subject in the following manner — to consider

I Whether blood from a lower animal can be used with safety for transfusion into a human subject.

II Whether any other fluid can be substituted for blood.

III If human blood is to be used, which is the best method of operating?

(a) Direct or Immediate Transfusion

(b) Indirect or Mediate Transfusion of (a) pure blood

(b) defibrinated blood

(c) Blood with saline solution


It is to the last method (blood with saline solution) that I have especially directed my attention, and I trust the facts regarding it, which I have been enabled to bring forward may prove of some service.

Animal Blood. Can blood from a lower animal be used with safety for transfusion into a human subject?

The use of blood of a lower animal for the purpose of transfusion is now looked upon with great disfavour by many, if not all, surgeons both in this country and abroad.

As already mentioned, it was the custom, read by Denys and Commery in France, and Lower and King in this country, in the seventeenth century, and during the eighteenth century it was occasionally, though rarely heard of. (See Lower 1875, vol. p. 162; Med. Transact. of St. R. Brit. vol. xiv. p. 67). Prescot and Demarras however, so far back as 1821 came to the conclusion it should never be used. (Demarras' Cyclo. vol. xvi. p. 154), and Blundell, in his "Researches Physiological and Pathological," published in 1824, records experiments, in which he tried over and over again to restore depleted dogs by means of human blood but always without success. His conclusion is "as it is clear from the preceding experiments that the blood of one sort of
animal cannot with impunity be substituted indifferently, and in large quantities, for that of another animal, it follows of course, that in performing the operation of transfusion on the human body, the human blood should alone be used" (p. 92 "Researches Physiological and Pathological"), and in support of this conclusion, he quotes experiments done by D. Learmonth of Barbados, who had transfused sheep's blood into depleted dogs, with results similar to his own (op. cit. p. 90).

But Landow's of Greifswald is the authority who has done most on this subject. He gives the results of his experiments in the Centralblatt f. d. medizinischen Wissenschaften 1873 pp. 885 and 897. By injecting blood from several different species of animals into the frog, and then watching the circulation in the web of the frog's foot, he found that the red corpuscles of the injected blood were rapidly broken down, when rabbit blood was injected, the solution took place in from 3 to 5 minutes, when calf's blood was used, 36 minutes, while the corpuscles of the dog took 60 minutes to dissolve. The corpuscles, he said, first became detacted, then globular and smaller, then pale and pale till nothing but stroma was left. He further experimented by mixing blood or serum of the frog with whole or defibrinated blood of mammals and watched the solution of the mammalian corpuscles under the microscope. By using such methods with various kinds of blood, he proved further, that the serum of one species of mammals dissolves the corpuscles of another species, the serum of the dog being very active, that of the rabbit very weak. (op. cit. p. 897). He also found a difference in the resistance which the corpuscles of some mammals showed to the serum of others — the rabbits being rapidly dissolved, those of the dog resisting the solvent action to a much greater degree (op. cit. p. 898). He then gives the conclusions he has arrived at, mine in all, the principle of which may be given as follows —

(a) The corpuscles of one species of mammals are dissolve
in the blood of another species, it making no difference whether
the blood injected be defibrinated or not.

1. The dissolved matter is partly excreted, by kidneys, intestines,
Uterus, Bronchi and serous cavities; but a certain quantity may
be assimilated. If the quantity transfused be small no blood
may be noticed in the excretion.

2. Transfused blood from a different species may sometimes
be beneficial by (a) supplying nutritive material to the receiver (b)
Oxygen from dissolved cells is given to the recipient, (c) it may
exert a good effect on the mechanical condition of the circulation.

3. Haemoglobin and Albumen are found in the urine in
about one hour and three quarters, and it remains for about
twelve hours or more.

4. Blood cells of recipient may also be broken down under
certain conditions.

5. Transfusion when followed by disintegration of corpuscles
may cause coagulation in the system and even death.

In the Centralblatt f. d. med. Wissen. 1875 p. 1 et seq. he explains
some of the results got after transfusion with animal blood.
From examining vessels in the mesentery of the fowl, he
affirms, that before the corpuscles break up they
begin together into glutinous masses which obstruct the capillaries.
If this occurs in the lungs, we get dyspnoea.
If in the intestines, increased peristalsis with colicky pains,
vomiting, purging, paralysis of bowel and distension of the
abdomen. In the urinary system, the capillary blocking will
cause Haematuria and Albuminuria; in the reproductive
system, abortion may be brought on; while the effects it produces
on the skin are coldness and loss of diffusion of heat, this
giving rise to internal temperature; while cutanea is common.
Rigidity of muscles is often seen; while in the nervous system,
there is observed first excitement and then paralysis and coma.
Landois thus strongly condemns its use.

Ponfick & Roeter did many experiments also, which go to prove
the danger of transfusing with animal blood. He shewed we set
a Haemoglobinuria, not a Haematuria, after its use, and he points out that the injection of the Haemoglobin after the solution of the corpuscles gives rise to an inflammatory condition of the kidney (seen at sepsis) which might even cause complete anuria. (Virchow's Archives B. 62 p. 332). When he injected a solution of Haemoglobin or blood of the same species of animals in which some Haemoglobin has been set free, he found he got Haemoglobinuria, just as when foreign blood had been used. (Stib, p. 327). He had also an opportunity of examining the blood of a woman who died soon after transfusion with lamb's blood had been practised on her, and he found yellowish bodies in the white corpuscles and serum, the appearance and chemical properties of which showed they were fragments of corpuscles of lamb's blood (Medical Times & Gazette 1874 Dec 2 p. 688).

Panum of Copenhagen adds his testimony, from experiments, to the danger of using animal blood for transfusion to man, giving a warning specially against the use of lamb or calf blood. (Virchow's Archives B. 63 p. 67). He found the same effects after its use as Landsoi and Ponfick had got (Virchow's Archive B. 67 p. 240, p. 1263, p. 12), and he concludes his articles by saying "animal blood (except perhaps cases) cannot be used for man, because it does not perform the functions of the Red Corpuscles." (Virchow Archive B. 63 p. 90)

Albertoni, (Arch. de Physiologie - normal et pathologique - Paris 1876 p. 831) after experiments, says, "Blood transfused into animals of a different species does not go to form living tissue. The corpuscles of the blood dissolve and their colouring matter is given off by the urine, whilst the stroma arrested in the capillaries obstructs them, causing serious accidents and even death."

Schäfer in his Report to the London Obstetrical Society (Obstet. Trans. 1879 p. 316 et seq.) expresses the opinion that "modern experiments and especially those of Panum and Landsoi have as conclusively established that the blood of an animal belonging to a different species, cannot be entirely substituted for the proper blood, as the fact that the blood of another animal of the same species can be substituted, was established by Lover." And in the conclusions he arrives at from his own
Animal Blood experiments and submits in the Report, he says: "Blood or serum of lower animals is highly detrimental, and in large quantities fatal, and ought never to be used for transfusion in the human subject. The only fluid which can be employed with any benefit for transfusion in the human subject, is the human blood, and this may be either in the normal or defibrinated condition."

With such an array of experimental evidence against its use the blood of a lower animal for transfusion in man might have been discarded altogether had it not been that Bierje of Virdu and Geissling of St. Petersburg, in 1873, reactivated it's use.

Geissling affirmed he could introduce into an undepleted animal, blood of a different species up to a twenty-fourth of the estimated amount of blood in the recipient animal without producing any bad symptoms, and he argued that what had produced the serious symptoms in Panum's cases, was that he had used defibrinated blood. (Virchow's Arch. Bd. 63 p.73). Panum, however, by further experiments showed conclusively, defibrination was not the cause of his results, and Gusto Landisio in support (Virchow's Arch. Bd. 63. pp.76-83). Labourel of St. Petersburg did some experiments, injecting defibrinated blood of one species into a depleted animal of another species, and thought he got beneficial effects (Ind. Times & Gazette 1874 Vol. III p.262).

Haeckel published 16 cases of transfusion which he had done with defibrinated human blood, and 15 cases in which he had used lamb's blood, and he claimed as good, if not better, results from the latter as from the former, and especially in phthisis did he think he got great benefit from transfusion with lamb's blood. Yet withal, he admitted the transfusion was always followed by a train of special symptoms, e.g. Dyspnea, rigors, sometimes vomiting, albuminuria and haemoglobinuria. (Obstet. Jour. Vol. II p.330. London Med. Record 1873 p.267).

Isolated cases, claimed as successful are also recorded e.g.
(a) one by Altman of Naples, where however a second transfusion with lamb's blood was followed by Peritonitis (Brit. Med. Jour. 1876 Vol. V p.43).
Another by Faber at the German Hospital, Dalston, which was thought at first to be a success, but soon afterwards the patient died (Lancet, 1874, Vol. II, p. 729), and (c) a case in the Practitioner, Vol. VIII, p. 439 where only two ounces were transfused.

We have already seen that Landus admits there may be some benefit derived from transfusion of small quantities of foreign blood, on account of the nutritive matter and oxygen in the blood given to recipient, as well as the mechanical effect on his circulation; and in the Centralblatt f. d. Medic. Wissen. 1875, p. 41, he expresses the opinion that in phthisis any good result got may be from the circulatory disturbance in the lungs setting up an inflammatory action, after which healing sets in.

Further, one of the patients whom Dr. Hesse claimed to have benefited, was a Dr. Reddel who suffered from phthisis. From a communication to the Medical Society of London, it appears that Dr. Reddel felt no change for the better except cessation of dysphagia. Physical examination was said to show a diminution of lung consolidation, but Dr. R. stated that three weeks after the operation, he felt himself gradually becoming worse, having received no material benefit. At the operation, dyspnoea began 30 seconds after the commencement of it, and became so intense after 90 seconds, that transfusion required to be stopped. He had pain in the loins lasting for some hours, a rigor in forty minutes followed by reaction with profuse perspiration, pulse 140, respiration 32 per minute; on the second day, albuminuria set in, and on the fifth day, he had a severe attack of Urticaria. (Lancet, 1874, Vol. II, p. 729).

This case certainly throws doubt on the good claimed by Hesse.

Dr. Champney (Obstet. Journ. Vol. VI, p. 645) refers to twelve cases of phthisis treated by lamb blood transfusion, which he had seen at Dresden. Dyspnoea, sometimes excessive, came on, in every case blood pigment appeared in the urine, frequently Urticaria showed itself. There was no death caused by it (Obstet. Trans., 1879, p. 347). See also case in Steinem's Handbook of Samuel Hirschfeld, Vol. II, p. 303. Fiedler and Bircher-Hirschfeld record six cases of phthisis.
in which they found no benefit, but rather an aggravation by the use of lamb's blood. (med. Times Gazette 1874 Vol II p 688)
Henselhoffer, Sieur of Fiederrath, Bridgeman of Cologne, Obhine of Dresden, and Küster, all think they got no permanent good in phthisis by lamb blood transfusion, and found blood and albumen were as a rule found in the urine after the operation (Lond. Med. Rec. 1874 p 624; and New York med. jour. 1875 Vol II p 600)
Roussel finds it is always followed by the gravest phenomena by the disturbance of the circulation produced immediately by the inordinate amount of blood which the violent action of the animal's heart diffuses; and that this is accompanied by equally serious secondary phenomena produced by the effect of the circulatory system to get rid of the blood at once, which, coming from a different species is unable to circulate and retain its vitality in the human body. (Transfusion by Roussel p 27)
Robert of Manchester thinks it only acts as a temporary stimulus, and that the blood of an animal is not in small quantities positively injurious, but simply useless (Brit. Med. jour. 1875 Vol II p 638)
After such a review of the subject, the conclusion one naturally arrives at is, that the corpuscles from an animal when transfused into one of a different species, at no times perform the functions of the red corpuscles of the recipient, but are dissolved. If the injection be small in amount, it will produce no serious symptoms, but if a large quantity be thrown into the system, grave symptoms are always produced, and we may even get a fatal issue.
Transfusion of lamb's blood to the human subject has been newly wholly used in chronic anemia, with what result we have already seen, and it has not been specially advocated in hemorrhage.
Still one of Hess's cases was an acute anemia and he claimed it as a success, and Allini's patient had also suffered from severe loss of blood, and appeared in the first instance to have been benefited, though afterwards fatal; while Arling failed by this means to restore a patient cut off by severe bleeding.

How then are we to regard transfusion of blood from a lower
Animal blood animal in regard to cases of acute haemorrhage?

Let us remember that if we use it, we inject a fluid which does not perform the functions of the blood of the animal receiving it, but which rather acts as a poison. The albumin and nutritive constituents of the blood (which Landau refers to) are not of much, if any, value in severe haemorrhages, but the oxygen which it contains, and the mechanical effect of the injection might assist in the crisis. But other fluids as we will see, may be used, having all the beneficial effects and none of the poisonous actions of blood from a lower animal; fluids too which will be more easily procured than blood from a lamb or other animal. In acute haemorrhages then, transfusion with blood from a lower animal should never be performed, since

1. It is injurious if used in quantity sufficient to benefit the patient, from a mechanical point of view or for the sake of the oxygen it contains; and may even in such quantities cause death; and

2. Other fluids having none of the merits of the medicinal effects of blood from a lower animal, and possessing any good property it may be thought to possess, can easily be found.

In chronic anaemias, clinical experience goes also to prove that it is injurious in large amount, and, to say the least, useless if used in small quantities.

With this we may dismiss the subject of transfusion with animal blood, and pass on to the second point: viz.

Can any other fluid be substituted for blood?

The difficulties which beset blood transfusion, led surgeons to consider whether there was no other fluid which might take the place of blood. Leaving out of account, serum, and pure water, which have seldom been used, we may consider two, both of which have been strongly advocated, viz. (a) milk, and (b) saline solution.
noticed the same increase, concluding it only occurred after the white corpuscles of the blood had eaten the milk globules.

As its use is always, or nearly so, followed by severe symptoms we find experiments recorded which show how these may be explained.

H. of New York (Fed. Times & Gaz. 1878 Vol. II. p.44) tried experiments on seven days — depleting them and injecting milk, and he found it always proved fatal, but Thomas ascertained he had used stale milk, and he got Dr. Dupuy to perform experiments similar to those of H. and he (Dupuy) ascertained, stale milk always proved fatal, while pure fresh milk was found innocuous.

Schefer (Arch. Inv. 1877 Vol. II. p.316 & 347), with undepleted animals, five out of six died, when he used ordinary milk for injection, and on microscopic examination, the blood corpuscles were seen to be extensively destroyed, and bacteria present in large numbers. Boiled or perfectly fresh milk he found to be harmless. In depleted animals he found the injection of milk was only followed by a temporary rise in blood pressure, and never did any permanent benefit follow — the animals always dying. Weigel (Arch. 1878 Vol. II. p.623) and Frecknanz (London Medical Record 1883 p.307) came to a similar conclusion.

Mr. Laparke (Brit. Med. Jour. 1879 Vol. I. p.358) by injecting milk into the lymph sac of the frog, and watching the circulation under the microscope, ascertained that he found fat globules soon appeared in the circulation, which circulated easily enough in the larger vessels, but got caught where the vessels branched or bent sharply, and this fat embolism he considered as the danger; this opinion being supported by Frecknanz who said the fat globules of milk must be kept back by careful filtration (ob. cit.)

But Vigeri of Pisa (Fed. Time's Gaz. 1883 p.505) on the other hand, while admitting that embolism is the danger, thought the emboli were formed of blood clots produced by the action of lactic and butyric acids in milk which was not neutral or alkaline, and he maintained the milk globules passed through the capillaries easily, while again Moutard Martin and Richel (Fed. Times Gazette)
In 1879 (Vol. II. p. 569) thought injection of Lactic Acid into the veins had no effect, except when in large quantities and then death ensued from Rubella Anæmia.

Wolfenberg at post-mortem found infarcts in Lungo (cf. cit.) and fatty infiltration of kidney has been often found. (Neußmann (cf. cit.) LANDOIS & StURLENS Physiologie)

Brown-Séquard in a paper read before the Société de Biologie (Quoted in Lancet 1878 Vol. II. p. 261) reports experiments he had tried as to transfusion with whole blood, defibrinated blood, and milk; and he was of opinion that he got similar results with all three, only he required to use more milk in order to get an equal result to what he got when he used blood. He drew 95 grammes of blood from a dog and replaced it with the same quantity of milk, and in 45 minutes there was no trace of milk globules in the blood, but an increase of white corpuscles as already said. The point that he required to use more milk is exceedingly interesting, as I think it points to the true good of milk injection, viz., its mechanical action—a point to be discussed under the injection of saline. Milk increases apparently the white corpuscles, a result which can be of little good in acute anaemia.

It has received its largest amount of clinical support from America. Hodges's two cases of cholera have already been referred to, but Galland & Thomas has done the most to bring it before the profession. In the British Medical Journal 1878 Vol. II. p. 261 he refers to twelve cases in which he had used it, and says he found the injection of milk is "safe, feasible and legitimate," and calls attention to the fact that the milk must be drawn within a few minutes of the operation; and in this he is supported by Dr. Brinnet & Brucelphia. (Medical Times Gazette Dec. 1878 p. 691)

Heldor of Dublin supports it very strongly. He writing in 1879, speaks of having used it twenty-five times, giving an account of twenty-six.

13 of Pithiosis, in which he was disappointed in only getting a temporary benefit—still life was probably prolonged.

1 of Pernicious Anaemia, which were cured.
Exhaustion from Haemorrhage—patient recovering.
Exhaustion from Leukemia—patient being benefited.

He argues that not more than six ounces of milk should be injected, and that the milk used should be alkaline (Brit. Med. Jour. 1879, Vol. III p. 349).

Magstaffe of St. Thomas' Hospital (Brit. Jour. Vol. III p. 549 et seq.) recommends a mixture of blood and milk, adding the milk on account of its being a heat-giving substance.

Other practitioners, however, depreciate its use. Howe of New York thought experiments had proved it was a dangerous operation, and not equaling blood transfusion. Human milk too, he found gave no better results, a conclusion supported by a case of Pernicious Anaemia in which Professor Amnandale injected human milk.

Prof. Pepper of Pennsylvania describes two cases very minutely:
(a) A case of anaemia—no organic disease—operation done thrice, the patient being improved.
(b) A case of Pernicious Anaemia—operation also done thrice, the patient died.

Professor Pepper thinks it should only be used when all other remedies fail, on account of the severe symptoms following its use.

McDonnell of Dublin records a case of Leukemia with profuse diarrhoea in which he tried it (Brit. Ind. Jour. 1879, Vol. I p. 165). He found a temporary strengthening of the pulse, and then a marked enfeeblement which continued two hours. He tried a second time on the same patient—sixteen days afterwards; three hours after the injection (4 ounces were injected) the patient was seized with tetrani convulsions and died.

While a student I had personal experience of one case—a railway aerial requiring amputation of one leg above the knee, and of the other at the lower part of the leg. About fourteen hours after the operation Dr. Duncan injected milk into the veins as the man was sinking, but no beneficial effect followed.

Clinical experience then shows:
(i) Injection of milk is very frequently, perhaps always, accom-
Panied by a good deal of constitutional disturbance; McDowell, Pepper, Howe and Higginson all speak of it as being very severe. Rigors, flushing of face, great difficulty of breathing, vomiting, are common occurrences, and in one of Pepper’s cases there was a sharp attack of Urticaria. In short, we find signs and symptoms very similar to those produced when animal blood is injected, and probably are to be explained as the result of small emboli, just as Landais explains the symptoms when blood from an animal of another species is used for injection (Central f. d. Mediz. Weissen. 1878).

(2) Clinical experience and experiments show that if used at all the milk must be fresh and alkaline, and not in too large a quantity, probably not more than six ounces.

On considering all these points it seems settled, that by the intravenous injection of milk we cause our patients to run considerable risks. "Ordinary milk is detrimental and ought never to be used" (Schifer op. cit.), while fresh milk or the boiled milk may seemingly be injected without so great risk of serious effects. When we come to think of it in practice it is not likely that we will be able to get milk perfectly fresh in a case of sudden emergency, and thus we might very frequently require, if we need milk, to fall back on the use of boiled milk. The dangers of sepsis, coagulation and emboli are by this means reduced to a minimum; but what of its real value. When discussing saline injections we will examine more fully wherein consists the value of a blood-transfusion; enough is stated at present that it seems to lie in the Red Corpuscles and Oxygen which it contains. Milk cannot supply these. True; fresh milk increases the white corpuscles, evidently by the palatin which it supplies to the white corpuscles already in the blood. (It is not stated whether boiled milk gives the same increase of white corpuscles). But before these white corpuscles can be transformed into Red Corpuscles (if they are so, for it is doubtful, see Landais & Sterling’s Text-Book of Physiology Vol I p 15)
some time must elapse to allow the blood forming glands and tissue to be stimulated to work, by having oxygenated blood supplied to them. This in acute anaemia is the difficulty; we wish red corpuscles and oxygen at once, milk, as we have said, does not supply these; therefore in acute anaemia we must look on milk as having merely a mechanical action, and in no way better than a saline solution. In chronic anaemia, e.g. Phthisis, it may be of more value by increasing the white corpuscles, for there may become transformed into red corpuscles by the blood glands, but this is a mere hypothesis, as no one will now think of maintaining that all white corpuscles are so transformed.

In acute anaemia however, a saline solution would, it seems to me, be of as much value as milk; it would probably be injected with less risk, and would certainly generally be more easily obtained.

Saline

(3) Reaching the question of the injection of saline solutions, it will be well to deal with several questions before going further with the subject of transfusion. The most important one is, it seems, what is the cause of death, when a patient is said to die “from haemorrhage”?

The idea has been advanced in recent years, that death is brought about by the disproportion between the speed in the vascular system and the amount of blood contained in it. Dr. B. Schwray is the great upholder of this view which was first expressed by Gotz in 1869.

Schwray in his “Über den Werth der injusion alkalischer Kochsalzlösung in das Gefäßsystem bei acute Anämie” Halle 1881, endeavours to show how, on this hypothesis, the symptoms of acute anaemia may be explained, as also the rapid recovery after injection into the vascular system. In consequence of the small amount of blood in the vessels a vicious circle of effects is supposed to be produced — the heart expels what small amount of blood is in its chambers, but this only enters the almost-
empty vessels and remains there; the heart continues to contract for some time, but has nothing to expel whereby to force on the blood already in the vessels, so that it (the blood) is not returned to the heart but remains in the vessels. The stagnant blood again does not give the necessary support to the vital organs (brain, heart, etc.), and this in turn reacts on the contractions of the heart, which cease, and the patient dies (Schwarz & Holtz) with sufficient blood in his body to carry on the vital functions could it only be set and kept in motion; which means, it would yield the necessary Faberum to the organs which require a constant supply.

Kronken and Landis (Berlin Klin. Wochenschrift, 1879, p. 762) had previously expressed a similar view, from experiments which they had performed on dogs. They took two dogs, bled one to 3/8th and the other to 1/2 of the estimated blood amount in body, and replaced the blood lost by a 0.6 per cent solution of sodium chloride, made alkaline by Hydrate of Soda; and they found the animals soon recovered.

Schwarz did many such experiments, and he concluded it was a perfectly harmless operation to replace blood by saline solution up to a 1/2 or even 3/5 of the estimated blood in an animal.

Dr. von Ott of St. Petersburg (Viehboer. Archiv, 1892, p. 159) supports this view, and at page 114 of same work, quotes some experiments of von Stein, in which he injected a solution of sodium chloride into frogs, at the same time letting blood flow from another vein, and he continued this for one or two hours, in fact, as long as there was any trace of redness noticeable in the fluid coming out from the vessel. If the frogs were kept he thought half of their number could be kept alive for two or three days; but this is now denied, for it has been found, that the blood of frogs cannot be wholly replaced, nor even to a high degree, without causing grave mischief (Martius, in Du Bois, Reymond's Archives for 1883).

the correctness of this view; and G. Gerton Jennings (London Hospital) in his "Transfusion of Blood and Saline Fluids" London 1863, adopted Schwart's theory, admitting however "that blood excels saline fluids for transfusion purposes, in respect of its corpuscles; but the dynamic effect of the operation being generally required to restore suspended animation in suitable cases, saline fluid will usually be found an efficient substitute for blood" (p.64).

The other view as to the cause of death by haemorrhage is that insufficient amount of oxygen and oxygen carriers in the blood is the cause of the dissolution.

Schäfer in his report (op. cit.) supports this view, considering that it is the deficiency in quality not quantity that brings about death; and Belina (Archives de Physiol. Paris 1872, p.47, et seq.) finds that it is "the red corpuscles saturated with oxygen" that are the resuscitating principles of the blood transfused.

Eulenberg and Landis consider the dyspnoea from a sudden loss of blood to be due to a diminution of oxygen, first overhauling and then paralyzing the respiratory centre (Central. J. Ind. Weiss. 1865, p.722), but they find that in severe anaemia a 0.6 per cent solution of sodium chloride cannot maintain life (Landis & Erdling's Text Book of Physiology Vol.1, p.306).

Brown-Leevand argues that it is by oxygen which it contains that red blood acts when it restores vital properties (Compte Rendus 1863).

Barnes takes a medium course, for while he considers the "rapid and laboured breathing is evidence of the craving of the system for oxidised blood" (Obstet. Journ. Vol.15, p.131), he does not lose sight of the fact that "the brain's circulatory system labours, not alone under the loss of the resuscitating element, but also under the purely mechanical difficulty of quantity" (Obstet. Operations 1876, p.579).

Playfair too considers that the action of transfused blood is probably twofold, (1) "an actual restitution of blood which has been lost" and (2) "a supply of a sufficient quantity of blood to stimulate the heart to contraction, and thus enable..."
the circulation to be carried on until fresh blood is formed” the
letter being of greater importance (Playfair’s Medicine Vol II p 246).
Le Page puts the question as forcibly and intelligently that
little excuse is required for giving an extract from his paper in
the British Medical Journal of April 1853 p 762. He says “in a
patent severely bled we notice, 1st a gasping for air. But what
is gasping? It is an indication that the respiratory centre in
the medulla oblongata is not duly stimulated, or that being
stimulated the force is not at hand for it to transmit. Let
us note that the natural stimulus of the respiratory centre
is Carbonic Acid, and that when it is in excess in the blood,
respiration is abnormally rapid, provided that the force is not
deficient, as in sleep, or almost entirely absent, as in the partial
stasis of profuse haemorrhage. No inspiration as an involuntary
act could take place in health were it not for the presence
of Carbonic Acid in the venous blood traversing the medulla.
How then does it come that this centre fails after haemorrhage?
In this way; the respiratory centre is the transmitter at
regular intervals of nerve force to the respiratory muscles,
but it is not the mechanism which transmits matter so as to
develop this force. Whilst Carbonic Acid is essential
to the inspiratory act, Oxygen is equally essential in the
generation of that force which the centre transmits. Well,
there is a deficiency of Oxygen because there is a deficiency
of blood, in the brain, and what there is, is in a state
approaching stasis. Propell more blood into the cerebral
vessels and what happens? Oxidation goes on, force is developed
which the inspiratory centre, stimulated by Carbonic Acid,
rhythmically discharges and respiration is established.”
2nd we notice “Absence of pulse after extreme haemorrhage.
Absence of pulse is the result of the heart’s dynamic inability
to work when deprived of that on which to expend its energy.
Give it blood to propel and propulsion will follow. “Half
the mischief arises from the heart and arteries having nothing
to contract upon.” Oxygen must be sent to the brain, Carbonic
Acid to the inspiratory centre in the medulla, and fluid to the heart. This it seems to me gives us a key-note to the whole question. In severe haemorrhage, the important thing required is to keep oxygen supplied to the brain, for if this fails, death occurs. Some say (Schwartz, principally) that if the blood left in the body could, by means of the injection of any innoxious fluid, be made to circulate, that alone would be sufficient to save life in most cases. It admits however, and Att and Jennings do so too, that there may be cases of extreme anaemia in which the necessary amount of oxygen would not be found in the blood left in the body, although they think the mechanical cause may kill before the lack of oxygen could have effect in such cases (Schwartz, Op. cit., p. 15). Others again (Schäfer principally) hold that the blood left after a severe haemorrhage is never sufficient to carry on oxidation.

This is the first point then, all allow that it is essential, is that oxygen be sent to the brain, and it is even admitted by the supporters of the mechanical theory, that sometimes the blood in the body, were it set in motion, would not be able to supply the amount required.

We may now proceed to consider whether we can by transfusion of blood supply this sine qua non; for it is evident the injection of saline cannot yield fresh oxygen.

Up to a recent date it was undoubtedly believed that transfused blood continued to carry on its functions, and therefore supplied oxygen, but recently doubt has been thrown on this point. Blundell (Researches Physiological and Pathological 1871) Panum (Archives Archivi Vol 63, p. 22) Lindius and Stirling (Text Book of Physiology Vol II, p. 199). Belina (Archives de Physiologie Paris 1870, p. 47 et seq.) Prevost and Dumas (Fluct Physiologie 1876, p. 2) all affirm, on experimental evidence, that transfused blood performs all the functions of the original blood of animal, carrying over oxygen to thedefect animal, see also Jameson's Handbook of General Therapeutics Vol II, p. 90.
Lately however (1883) Ott of St. Petersburg (Vinarv Archem 12.3 p146 et seq) has tried to throw doubt on the value of transfused blood. It will be necessary to consider his experiments and arguments at some length.

He did experiments with a 0.6 per cent solution of Sodium Chloride, serum, defibrinated blood, and whole blood, depleting animals and injecting a quantity of one or other of these fluids equal to the amount of blood lost. He argues

(a) that whichever of these fluids you use, you produce a hydraemia and you get similar results with them all, i.e. as good (or even better) results with a fluid containing no oxygen nor corpuscles, to one containing them.

(b) The greatest degree of hydraemia is produced more quickly with serum or sodium chloride solution, than with defibrinated or whole blood.

(c) While with whole or defibrinated blood, the hydraemia is not so strong, and does not reach its highest degree so quickly as it does with sodium chloride solution or serum, still full regeneration of the red corpuscles and albuminous constituents of the blood, takes place generally about twice as quickly after injection of solution of sodium chloride, or even still more quickly, than is the rule after blood injection or transfusion (Op. cit. p155).

(b) "Transfused blood is altogether expelled out of the individual to whom it has been given." (Op. cit. p156)

As whole and defibrinated blood do not produce so sudden nor so high a degree of hydraemia, he considers that in very severe cases of haemorrhage they may save life, while the injection of sodium chloride solution would not do so; whereas if not so severe a loss of blood had occurred, the patient would recover more quickly after sodium chloride solution than after blood had been injected (Op. cit. p.163). It is difficult to conceive, how, when a fluid (whole or defibrinated blood) is injected into the receiver, which he says, acts as a foreign body and is all expelled, it should more good in a more severe case, than
a solution (Sodium Chloride) which, he argues, does less harm in less severe cases. If correct, we might even be justified in maintaining that it can only be by the oxygen it contains that the good is achieved; for otherwise he asserts, the blood is all oxygen. But it is, however, that some of the corpuscles injected live, and thus the hydrenia must be too great? In proof of his assertion, Ott adds that he never lost a dog into which he injected the Sodium Chloride solution, provided it survived the first day or two; i.e. if it got over the period of greatest hydrenia, but the dogs into which he transfused blood were not well for several days, and occasionally died; sometimes at the time when the strongest hydrenia would be present.

His experiments show a great variation in their results, and on that account it is difficult to come to a very satisfactory conclusion from them.

Of his three trials with defibrinated blood; one dog had a severe abscess, another died, the third went on well.

With dog No I the lowest average of corpuscles (75%) was reached on the 5th day, and they were not restored to their normal number till the 10th day.

With dog No II the lowest average of corpuscles (45%) was reached on the 8th day, and afterwards the dog died.

With dog No III the lowest average of corpuscles (50%) was reached on the 10th day, and they were not restored to their normal number till the 15th day.

A experiment—No II, we notice, that although he injected almost a normal blood as he withdrew, still the day following, the number of corpuscles was less than half the normal. The corpuscles could not be expected to quickly as that, but what is the true explanation of the sudden diminution, we do not know. And what is there to explain the difference in the number of days (819-18) before the normal standard of corpuscles was reached in dogs No I and III, unless it be that the abscess caused the difference, if so, that would render the experiment useless.

Looking at his three experiments with direct transfusion, although he transfused a similar amount of blood to what he withdrew, yet in his three experiments he found,
with day 70, 1st day after the transfusion, the red corpuscles were 81%, were at their lowest (68%) on the 21st day, and did not rise to the normal standard, till the 27th day.

With day 77, 14th day after the transfusion, the red corpuscles were 117%, and gradually diminished till the dog's death on the 12th day.

With day 83, 1st day after the transfusion, the red corpuscles were 91%, were at their lowest (58%) on the 13th day, and did not rise to the normal standard, till the 34th day.

Thus we see in one dog (No. II) the normal number of corpuscles was expected on the first day after transfusion; while in another it was only 81% on the first day and did not rise to normal till the 27th day, and in the third, it was 91% on the first day, and normal standard was reached on the 34th day—a very marked difference in time.

A similar irregularity is seen to occur in the albuminous constituent, but the corpuscles were found to reach their normal numerical standard more quickly than the albuminous constituent.

There are cases recorded, however, in which the enumeration of the corpuscles gave different results from those of Oct,

25. A case of transfusion performed by Professor Behier, reported in the Medical Times and Gazette, 1874, p. 330, the patient being subject from prostrate menorrhagia. Behier operated with Moreau's apparatus modified by Mathieu, and injected 50 grammes (about three ounces) of undiluted blood. The enumeration of the corpuscles was as follows:

Before the operation, corpuscles were 850,000 per cubic millimeter, or about 16.5% per cent of normal.

Four hours after the operation, do 1,110,000 per c.mm. or 22.2% of normal
Eight hours after the operation, do 1,143,000 do 22.8% do
Fifteen days after the operation, corpuscles were 2,029,000 do 40% do

In this case there was a steady increase.

Still it might be argued, that a blood transfusion merely gets over an emergency from a sudden loss of blood, after which the blood glands take up and continue the increase of the corpuscles, and is
Saline

bring about an apparent gradual increase; in other words, it might be said, that after a transfusion it is not the blood corpuscles injected which give the gradual increase but the corpuscles formed by the blood glands, while the corpuscles which were injected are excrated. This may be so, but let us notice the fact that transfusion does great good in cases of Pernicious Anæmia, where the tendency is for the number of corpuscles gradually to become diminished. Several cases of this disease are recorded, see the Table of Dr. Crompton in the British Medical Journal t. Vol. I. p. 635, where cases are recorded in which deglutination had principally been used; and more recently there is Dr. Bockemüller's case, in which Dr. Duncan transfused four times, using blood mixed with saline. The enumeration of the corpuscles in this latter case, will be given in detail and remarked upon subsequently, certainly the patient was greatly improved by the transfusion. We must remember, however, that cases of recovery from Pernicious Anaemia are recorded after the intravenous injection of milk, as in Dr. Hudson's cases already alluded to.

Blundell in his Researches Physiological and Pathological, relates how, in order to prove that blood which had passed through a syringe could still be of use in the system and perform its natural function, he allowed an animal to bleed into his syringe, re-injecting the blood into another vein of the same animal, doing this for some hours, till he calculated all the blood in the animal must have passed through the syringe for several times, but the animal was none the worse. Were it not right, all the blood in these animals would have been wasted and only fit to be excreted.

Again, why should the transfusion of blood (whale or deglutinated) not produce so great a hydæmia, as the injection of saline or blood-serum, unless it be that some of the corpuscles live and perform their functions?

For these reasons, I am inclined to think that our cases too extreme a view regarding the joint of the excretion of the injected blood, and Panmure's opinion cannot be wholly disregarded.
"after many and varied experiments," he says it is proved, "that one can transplant blood corpuscles from one individual into another individual of the same kind, and that they continue their normal functions, i.e. carry oxygen from the lungs to the tissues." (Virchow's Arch. Vol 63, p 22).

What I say here, has reference especially to transfusion with whole or defibrinated blood. As regards blood mixed with a saline, it will be seen afterwards, that I was brought to the conclusion, that many of the corpuscles are so altered that they are useless.

The difficulty of coming to a perfectly correct idea of the value of a transfusion, lies, I think, in the fact that very small things make a vast difference in the results, and so it is not easy to know when an experiment has been fully successful. A too rapid injection, entrance of air, a clot, or septic matter, the transfused blood being heated or cooled too great an extent, any of these may make a transfusion inert or harmful.

III. We would wish to know, if these two actions (point d'appui for heart, and carrier of oxygen) are the only ones performed by transfused blood. (a) By some it is spoken of as a stimulant, and Prof. Vernes of Rochelle, speaks of this as its only action, and thinks that other subcutaneously would do just as well. (Med. Times 1852 Vol I p 56).

Professors König and Schade at the German Congress at Hanau, expressed a similar opinion. (Med. Times 1852 Vol II p 58).

Others, e.g. Martin of Berlin, admit it is a stimulant, but refuse to consider this as its only or most important action.

I do not think much can be made of its stimulant action; certainly Prof. Vernes's proposition is wrong, as any who have had experience of it in surgical cases, will, I am sure, be ready to admit. In my own case, after subcutaneously at Champagne, both failed and on account of their failure we thought of transfusion; and in Dr. Duncan's case of the primary amputation, which he read before the Medical-Chirurgical Society, the patient got other, but ether alone would never have brought the man round; I feel convinced of that. As further, when transfusion is done after a severe operation, the amount of shock from which the patient suffers, is found to be very much less, than what is
generally seen after such operations when the patient only gets stimulants.
Prof. Hageman has shown by experiments on depleted animals, 
that transfusion will do, what other stimulants cannot do 
in the way of restoring an animal (Med. Times Cyg. 1852 Vol II p. 794). 
What stimulant action it has, consists probably merely in 
it's supplying a fluid to the heart, which causes it to contract, 
and only in this light do I regard it as such, in short, 
only in the sense in which Schwann applies it.

(2) Can we consider transfused blood as a food?
Blundell kept a dog alive for three weeks by transfusion, 
alone. It however lost flesh to a great degree, although 
Blundell was convinced it did not lose weight so quickly as when 
he did not transfuse. (Researches Physiol. Pathol.)
McDermott of Dublin regards it as a food, founding his belief 
on a case of Jetanis. The patient, a girl, said she was dying 
of hunger, she could not take food, nor have even water 
diminshed, and McDermott transfused simply with the 
view of relieving the feeling of hunger if possible, and he 
found it did so. (Ibid. Jour. Vol VI p. 335)
Martin of Berlin lays great stress on its nutritive powers. 
(Med. Times Gazette 1861)
Prof. Giammugi on the other hand, found if two dogs were 
reduced equally by starvation, and transfusion of blood 
practised frequently on the one, and not on the other; 
the one on which repeated transfusion had been tried did 
first. (London Med. Record 1853 p. 308)
Lasse found that repeated injection into a healthy animal 
diminished its weight more quickly and more persistently 
than even the entire withdrawal of food. (Practitioner 
Vol XV p. 130)

When, therefore, we consider that animals kept alive 
by transfusion always lose flesh, and, if continued too 
long, will die, we cannot think that transfusion is 
advocable from the idea that it may take the place of food. As 
blood is the fluid which carries nourishment to the tissues, one
would conclude it must have a certain power in the direction, and the experience of McDonnell aids us in this idea; but then Gianmuzzi's experiments go directly against it; it must then lack a something which only food after digestion can supply.

(4) There is an action which can be claimed alike for saline, and the mixture of blood and saline, but not for the other method of transfusion; an action which has been overlooked in connection with this subject. In Macleod & Stirling's text book of Physiology Vol I p. 125 it is mentioned that Gaskell found saline solutions acted as tonics to the heart and arteries, causing them to contract. Dr. Matthew Hay found the same (Journal of Anatomy and Physiology Vol XVII p. 436). How in a case of severe hemorrhage, this action, it seems to me, would be of great importance. The vascular system is half empty and we put in fluid in order to fill up the vacuum, and if we can find a fluid which while helping to fill up the vacuum, will at the same time tend to lessen it, that certainly will be advantageous. Both saline solution alone, and saline solution and blood, will have this action, and it may be claimed as one of the advantages of either of these methods.

(5) A point worth noticing is the difference in the amount of saline solution injected, as compared with blood transfused, and their corresponding results.

Schwarz puts down as the minimum amount of saline solution to be injected into man, as 5 cubic centimetres (about 1/8 ounce). Now the average amount of blood to be transfused or injected, is mentioned by Playfair as from 1 to 6 ounces, by Martin & Berlin as 4 ounces, by Belina as 120 grammes (about 4 ounces), by Behris as 2½ ounces. There are however several cases recorded in which 2 ounces of blood have produced a decided and lasting beneficial effect—(see Cancer 1863 Vol II p. 266; Zimmerman's Handbuch der Therap. Vol II p. 382; and Martin's Table in his 'Transfusion bei Blutungen' p. 91), the last mentioned showing a case of hemorhaxis, in which a rapid recovery occurred after the injection of one ounce of blood.
So far as I can find, there is no case of recovery with anything like as small an amount of saline injection. Certainly in one of Kimmel's (Hamburg) cases, reported by Schwanz in the Berliner Klin. Wochenschr. 1862 p. 535, great improvement was seen after 160 grammes (about 57 ounces) of saline solution had been injected, but in the end the case was unsuccessful, the patient dying next day. The average amount injected in successful cases is fully a pint, and sometimes much more is used even up to four pints. When we try to explain to ourselves the cause of the difference in the amount of the two fluids, it suggests itself to us that when we inject blood, we inject a fluid, which the organism can make use of to some extent, as it contains oxygen and oxygen carriers, so that a much smaller amount of it suffices than when we use a fluid which contains no oxygen nor corpuscles, but merely acts in motion the blood already in the system, not itself however giving oxygen to the tissues.

We are now in a position to state briefly how transfusion acts. We may leave out of account the part it plays as a stimulant (if any) or as a food, and we find it acts as a point d'appui for the heart, which however is only of use, in that it causes the blood in the vessels, previously almost in a state of stasis, to be sent to the great nerve centres, to enable them to carry on the vital functions, and also to the blood forming glands and tissues, there to set going again the formation of the red corpuscles, which are required to take the place of those lost by haemorrhage. If the injection used be saline solution, or milk as previously stated, this is the only action of any great importance, whereas if whole or defibrinated blood be used, over and above this action, it will supply new blood to the depleted organism, with all the oxygenating functions of the blood already in the body, and if blood mixed with saline be injected, I conclude we get this latter action to some extent.
When we review the cases in which saline injection have been
used, along with the experiments done by Schwary, Ott,
Kroneker, and Sander, we can come to no other conclusion
than that in many cases it will prove most useful.
Injection of saline solution was first proposed in India
for the collapse of cholera, in the early part of this century,
but it has been thought, that in that disease, while it may
cause a temporary rallying of the vital powers, it will do
no permanent good. (Smith - Thiemann's Cyclop. Vol I p.460;
Johnson - Brit. Medical Jour. 1865 Vol II p.493; and Roger's
Report on Asiatic Cholera, 1849). In one patient, in whom
the heart had ceased to beat, it restored him for some hours.
(Jennings, Transfusion of Blood and Saline Fluids 2nd Ed. p.36). The
observations made in the recent (1854-5) epidemic of
Cholera in France, seem to show that it is of good service
in many cases (Lancet 1856 p.161).

In acute Anaemia, its use has been strongly advocated
in Germany, as already mentioned. Schwary, Ott, Kroneker
and Sander are its principal upholders there, and Jennings
of the London Hospital, its champion in this country.
Schwary records six cases in the Berlin Med.
Wochenbl. 1852 p.536, some of the patients being in a condition
that no permanent benefit could possibly be expected, still
the results of the injections were sufficiently good to
encourage him in its use. One of the cases was for
severe haemorrhage after amputation of the Cervix Uteri.
For Cancer, the patient receiving 1000 cubic centimetres
(1 pint=16 ounces) saline solution, and as far as the injection
went, the case did well, although the patient eventually died.
Schwary then quoted
(a) A case of Krukenberg's Tumor - double excision of ovaries,
1000 cubic centimetres of saline solution were injected
into the left radial artery of this patient, who rallied, only
however, for three quarters of an hour, and at the
Ecto, cancer of the peritoneum was found.
A case of Malaria & Burns — amputation at hip joint — for Sarcoma, followed by collapse; the patient getting 500 cubic centimetres (10 ounces) of saline fluid injected into the radial artery, followed by rapid recovery.

Kimmel of Hamburg — (1) After nephrectomy; 1000 cubic centimetres being injected into the Radial artery; the patient doing well at first, but succumbing from disease of other kidney.

(2) After resection of knee — 500 cubic centimetres being thrown into the radial artery, the saving the patient's life.

Bischoff's (Basel) case (Central. f. Chirurgieologie 1851 No 23) is also quoted by Salvany. It was for blood-loss after the removal of an adherent Placenta. 1250 cubic centimetres (about a pint and a quarter ounces) of saline solution were injected and followed by a good result.

Mackenzie of Cracow (Med. Times and Gazette 1852 Vol II p. 292) thinks transfusion of blood is now almost done away with; injection of saline having taken its place. In the American Journal of Medical Science (Vol 88, p. 509) a case of his, of wound of the Brachial artery is recorded, in which the injection of 600 cubic centimetres (more than a pint) of a saline solution gave splendid results, and other seventeen cases in which he had used it are referred to. Of these seventeen, eleven were followed by a very favourable result, while six failures could be explained by the seriousness of the cases.

Flemings in his little work on "Transfusion of Blood and Saline fluids" records a successful case of his, the injection being done on account of haemorrhage after Placenta Praevia. 10 ounces were injected (p. 25).

Cotes of London Hospital Maternity Charity (Einhart's 1852 Vol II p. 111, I) records a case of success after severe flooding in which salines were used; and at the same time, he mentions a severe case of secondary haemorrhage after delivery, in which he injected simply 22 ounces of warm water, and got a good recovery. Twenty-four
hours after injection there was no alteration of the corpuscles noticeable under the microscope.

Brown and Thorn—records a successful case of haemorrhage from a bad machinery accident, 760 cubic centimetres being injected, and a favourable result got.

Yet in reading over the cases of saline injection one cannot but notice how frequently the operation has only been followed by a temporary effect, and cases are recorded in which after trying saline fluids, the surgeon has had recourse to blood transfusion, sometimes without avail, however, the patient being too far gone. As examples we may take, (a) a case of post-partum haemorrhage, recorded by Dr. Henderson of Shanghai in the Lancet for 1874, Vol. p. 380, on which patient he first tried the injection of saline fluid, but finding its beneficial effects only lasted for 2 hours, he resorted to blood transfusion, using defibrinated blood, and found it completely successful. (b) Herrmann at the London Hospital Maternity Charity (Ibid. Times Gaz. 1873 Vol. p. 296) gives a case of placental polypus, in which severe bleeding occurred. He used intravenous saline injection (1 pint) but only with a very temporary benefit, whereupon he drew 16 ounces of blood from the husband's arm, with the intention of injecting it, but the patient died before the injection could be begun.
(c) He relates also a case of accidental antepartum haemorrhage in which the injection of twenty ounces of saline solution caused an improvement for three and a half hours, but then the patient appeared worse than before; twelve ounces of defibrinated blood and twelve ounces of saline solution were then mixed, and twenty ounces of the mixture injected, but this only helped the patient for about four hours. (c) Sometimes it fails to revive the patient at all, as seen in a case of Otto (Ibid. Lancet Record 1886 Feb. p. 76).

Taking them the whole of these cases into consideration, and accepting as I do the view that the good effects of a blood transfusion is due primarily to its blood corpuscles and oxygen, remembering that when a saline solution is injected
Saline

its only action is that it permits the blood already in the
body to be set in motion by the heart, whereas when blood is
transferred we add to the amount already in the vessels; and
considering that a saline solution can in no way be said to
have the same reviving power that blood has, it will be
seen that, while admitting saline solution often does great good
and is all that is required, I cannot countenance the view
that a saline injection is as beneficial as a blood transfusion.
Certainly the operation of injecting saline solutions is very
much easier, and seems to be seldom followed by consti-
tutional disturbance, than blood transfusion; this latter ques-
tion will however be again before us. And if blood cannot be
transferred by any of the different methods, most certainly
saline injection should be employed. I would even place it
as preferable to some of the methods of blood transfusion,
but at present, I content myself with affirming, that in
my opinion, ceteris paribus, a blood transfusion must be
of more lasting value than a saline injection.
Should we decide to use it in the case of an emergency,
a solution is easily made by taking a teaspoonful of
ordinary table salt, and adding it to a pint of water at
temperature of about 100°F. If pure Sodium Chloride is at
hand, so much the better, and some authors advise the
addition of Carbonate of Soda, so to the solution we might
add, if at hand, about half a teaspoonful or a little less
of Carbonate of Soda, as Barnes gives in his obetetic operation.
The solution frequently recommended is

6 per mille solution of Sodium Chloride with
1 per mille solution of Sodium Carbonate

Jennings advises (Transfusion of Blood - saline fluids 2nd edit. p 50)

Sodium Chloride 50 grams
Potassium Chloride 3 m-
Sodium Sulphate 2.5 m-
Sodium Carbonate 2.5 m-
Sodium Phosphate 2 m-
Water 1 pint

2 drachms of pure alcohol to be
added.
Little used in Cholera

Sodium Chloride 60 grains
Potassium Chloride 5 do.
Sodium Phosphate 3 do.
Sodium Carbonate 20 do.

Water 1 pint

Unless of course these mixtures are constantly carried in the form of powders, in the hurry in which one is likely to wish to use the injection, the simple teaspoonful of Sodium Chloride alone, or with the half teaspoonful of Sodium Carbonate, is likely to prove the most handy. Let us remember two that Dr. Bates of London on one occasion used an injection of warm water alone, followed by a complete recovery.

The fluid may be injected either by means of a syphon or simple syringe, and at least one pint should be made to enter the vessels.

Thus far the two questions we have considered are—Can the blood of a lower animal be used in transfusion to a human subject, and, Can any other fluid be substituted for blood? This latter including the consideration of milk and saline injections. But now we pass to the discussion of the third point, viz.

III. If human blood is to be used, which is the best method of operating?

There are two main divisions, under one of which the various methods may be classed, viz.

A) Direct or Immediate Transfusion
B) Indirect or Mediate Transfusion.

Under this latter we will take up

(a) Indirect—Transfusion with pure or whole blood
(b) do do do with defibrinated blood
(c) do do do with blood kept from coagulating by means of a saline solution.

A Direct or Immediate Transfusion.

Theoretically undoubtedy this is the best form of blood transfusion, and could it be easily and effectually put into practice, we could have no hesitation in saying that...
this form should always be used. But it is in its practical bearing that it falls short.

Aveling (Obstetrical Transactions Vol VI p.133), Roussel (in his monograph on Transfusion) and Le Page (Med. Times and Gazette 1852 Vol I p.65), have been the principal inventors of instruments for this operation; and they and Schäfer (Obstet. Transactions 1879) have been the chief upholders of this method. Schäfer advising simply the use of a short—flexible tube, having a glass cannula at each end, and depending on the force of the blood pressure in the blood donor, for the carrying over of the blood to the blood-receiver. Others again advise instruments which work on the same principle as the Stomach pump—a lateral and a terminal tube, one for drawing the blood into the syringe, the other for expelling; both ends being in the vessel at the same time (Schäfer—Brit. Med. Journ. 1874 Vol I p.33—J. Scott of Kewington Causeway; Obstet. Trans. 1866—in an article by Aveling)

Aveling claims as the advantages of his instrument, that

1. The chances of coagulation are small
2. The apparatus is effective, simple, and inexpensive
3. The operation is safe, easy, uninterrupted and a close imitation of nature (Obstet. Trans. Vol VI p.133)

Roussel says that by the use of his instrument, he has enabled a surgeon to cause the blood to be "conducted by an artificial vein and heart, hermetically closed, which are humid, warm and soft, just like the vessels themselves, far removed from contact with any spoiling substance. Neither has the blood undergone any modification, either in its fibrin or its globules, and it has lost neither its gases, its temperature nor its density" (Roussel on Transfusion p.69)

Le Page writes as if (1) no assistance would be required when using his instrument, (a statement one would be very doubtful of), and (2) it would be a sure protection against the entrance of air (op. cit.)

Schäfer's chief plea for his plan is its simplicity, and he thinks,
very urge of dissolution, and many an one, not used to
such sights, will become faint, especially after a small
amount of blood has been withdrawn, and thus their
blood flow becomes feeble, and the further operation requires
to be abandoned.

By using any of the above mentioned instruments, one would
require to have two or more skilled assistants, and these in
a case of emergency occurring in a general practice are not
always to be got; although in an hospital they may be easily
secured.

For the use of most of these instruments, the blood donor
requires to submit to a fairly severe operation on getting a
malleus fixed into his vein. Rinnel's apparatus does away
with this, but even the size of the round it makes is objected
to (Brit. Med. Jour. 1876 Vol II p. 800). Many an one will be
found ready to submit to having a few ounces of blood
withdrawn from them by a simple venesection, while they
would refuse to undergo the operation necessary for inserting
a malleus into a vein.

Having stated these objections to this method of operating as a whole,
it is hardly necessary to go into the objections raised against
each form of instrument; a few may be mentioned however.

Regarding Aveling's instrument, Schäfer says

1. The intervention of an elastic pump does not accelerate
   but may even completely stop the blood flow, owing to the
   thin placed wall of the vein being sucked against the
   mouth of the apparatus.

2. It may force small clots into the vein of the receiver.

3. There is a greater liability to septicaemia on account of the
   greater surface of instrument.

4. Suction is apt to make the vein of the donor collapse
   higher up, so hinder blood flow.

Rinnel's apparatus is

1. much too complicated

2. inefficient—in so far, that it has been found, the Least
does not enter the vein if it is given so easily as is anticipated, as the vein rolls the side, thus causing it to be necessary for a series of acts to be given before blood is drawn; greatly adding to the pain of the blood giver. (Chet. Journ. Vol. IV p. 261.)

38 The cup get fixed firmly by suction, and tends to prevent the flow of blood towards the wound, by the strong pressure of the brim of the cup.

Regarding Schäfer's plan of connecting the two veins by means of a simple tube, it seems only too likely I think, that the blood giver may become faint, and thus the necessary "blood pressure in the arteries" will be found to have "fallen to too slow a point," and so coagulation and blocking of the tube will occur. And as for transfusing from artery to artery direct, it is as Dr. Playfair remarks "too difficult for ordinary use," besides which, as Schäfer himself seems to feel, this would be much greater difficulty in getting a donor to allow an artery rather than a vein to be opened.

These objections then, along with what clinical experience has taught various surgeons, lead me to regard the use of the several methods of direct-transfusion, as not likely to become general. Certainly many cases are recorded in which they have proved most useful, and Roussel at the end of his monograph, gives a table of some fifty cases in which his instrument had been used; twenty six times with complete success, and fourteen times partially so. But such instruments seem never to prove of much service except in the hands of the inventors himself, and when we ask ourselves, why it should be so, the answer is to be found I think in the consideration that they alone have had the necessary practice to make them expert in the manipulation of the respective instruments.

Whichever plan is to be used, it must not be by some complicated and therefore expensive apparatus, an apparatus which a general practitioner is not likely to possess on account of its expense and liability to get out of working order;
But even did he possess it, an apparatus which would make the medical man almost loath to use it on account of his feeling it would very probably not fulfill the purpose he wished.

But on the other hand it must be for some plan, which is

1. Easy of carrying into execution, so that a general practitioner, although he has not time to give up to the study of particular branches, would yet be perfectly able and willing to operate, on the shortest notice, even without trained assistants, if required.

2. A plan not likely to be stopped while unfinished, on account of coagulation or some such hindrance.

3. A plan, necessitating only the use of an instrument which is portable, inexpensive, easily worked, and not likely to be found out of working order at the necessary moment.

Certainly the method of direct transfusion, by means of the instruments at present known, does not fulfill these requirements, and if asked to state how it is that direct transfusion has been so little used, my answer would be, that one or all of the above desiderata are not got when the instruments for direct transfusion are used.

Therefore while theoretically it is undoubtedly the best method, practically, as yet, it is not of much service, solely on account of the difficulties which beset the operation.

B Indirect or Indirect Transfusion
(a) With pure or whole blood.

This method of transfusion will not occupy our attention long as it has not been, and it seems to me, is not likely to be much practiced, although it certainly is advocated by several of our leading surgeons.

There are two ways in which the operation may be performed:

1. By using a simple glass or metal syringe allowing the blood either (a) to fall into the barrel of the syringe by removing the piston, as done by Dr. Blevins (Obstetrical Transactions Vol.VI p.136), or then (b) letting the blood flow into a vessel, drawing it up into the syringe as quickly as
it flows, stopping by mere pressure, the flow from the vein while a syringeful is being injected; as done by Lister (Glasgow Medical Journ. 1870. p. 129).

2. This method of transfusion may be performed by using a special apparatus, consisting of a funnel into which the blood flows, and through it, falls into a syringe, while a piston, elastic pump, or simply gravitation, forces the blood through the tube and nozle into the patient vein—innovators such as Blackwell used (Researches Physiol. Pathol.) or Collins (Med. Times & Gazette 1875 Vol. II p. 535) or Monroe's modified by Mathieu (Med. Times & Gazette 1867. Vol. II p. 84) or Higgins' (Reported Abstract 1857) or lastly Dr. Hamilton of Falkirk's (Edin. Med. Journal October 1862 p. 380), although many others have invented or modified instruments.

Hewitt (op. cit.) Lister (op. cit.) and Martin of Berlin (Uber die Transfusion bei Blutungen) feuwentzenden—Berlin 1887—all employed a simple glass syringe holding about two ounces, and have operated successfully. Lister injecting as much as ten ounces by this plan. The objections against this method are

1. That while a surgeon may have the operative expertise necessitated by the rapid coagulation of blood, not many general practitioners would have acquired it.

2. As is well shown in Lister's case, several (three) assistants are required, each to be set aside for a special duty; a difficulty which might easily be got over in an hospital, but in private practice, either impossible, or, at least, likely to cause delay.

3. The great risk of injecting clots, and if a clot of any size be introduced into a vein, the dangers are so great that medical men would hesitate to run such a risk of doing great harm.

The other mode, viz. that carried out by means of an instrument having a funnel to catch the blood as it flows, is followed by a great many inventors. Higgins of Liverpool, has published his experience, and this may be taken as an indication
Indirect Transfusion
(whole blood)

Of the probable success of this method of operating, this instrument is worked partly by gravitation and partly by the compression of a bulb; in one case he injected over twenty ounces. In his first attempt, though some of the patients died, yet they lived long enough to show that transfusion had been successfully performed (Rutland's Abstract Vol. XXV p. 268). While later, the successful cases out of Jaffrin are reported by him in the British Medical Journal (1874 Vol I p. 603).

A great many other instruments working on similar principles have been invented and used successfully too, but against them all there are the same objections,

1. They being bulky, expensive, not likely to be carried about and to be at hand, but probably out of working order, when required.
2. They requiring rapid manipulation, practice, and the aid of trained assistants; and
3. The great risk of coagulation occurring during the progress of the operation, causing the injection of clots.

In short, it seems to me, that, although comparatively safe in the hands of a skilled surgeon, or the inventor of the instrument, the risks run, when a general practitioner operates by this method, are too great, ever to allow of its becoming a method for general use.

The second method of indirect transfusion is that with defibrinated blood.

Proust and Dumas (1821) were the first to assert that defibrinated blood could restore an animal dying from haemorrhage, just as well as whole blood, and Flechonbauch confirmed this opinion, arriving at the conclusion that the red corpuscles contained the restituting principle (Virchow's Archives Vol. XXVII p. 243).

Brown-Segard has experimentally shown that defibrinated blood has the power of restoring muscular and nervous energy in just as high a degree as whole blood (Comptes Rendus 1858).

Panmini's experiments too go very strongly to show that it performs
all the functions of whole blood. He replaced the blood of an animal with defibrinated blood to the extent of 93 per cent in one case, and 94 per cent in another. (Virchow's Archive vol. XII p. 40) of the estimated amount of blood in the animal, yet they remained well. He showed also that either venous or arterial blood will do (Virchow's Archive vol. XII p. 70.) See articles by Panum, in Virchow's Archive vol. 63, p. 1, vol. 27, p. 240 et seq.

Kellina (Archives de Physiologie - Paris 1879 p. 227 et seq.) states clearly that defibrinated blood of a species transfused into an animal of the same species is able to revive the nervous system without loss of blood. It fulfills, he argues, from experiments, all the functions of the normal primitive blood, and is subject to all the physiological laws.

Dr. Hunt, "an eminent microscopist" states by Martin of Pennsylvania (Amer. Jour. of Med. Science 1874, in Brit. Med. Jour. 1877 vol. 1 p. 755) asserts that "in defibrinated blood there is not any appreciable loss of red blood corpuscles, neither is there any actual disturbance of the normal relative proportion of white and red, viz., about 1 white to 350 red. In no way whatever is there any evidence that the blood, after defibrination, suffers any degradation in its nutritive or therapeutic properties." Brown-Sequard and Dumas too, found there was no alteration of the corpuscles seen under the microscope, and thought they (the corpuscles) absorbed oxygen as readily after as before defibrination (Trav. Times 139, Nov. 17, 1855); an opinion come to also by Panum, from his own experiments, and which enabled him to contradict Gessellini's statement, that the corpuscles are "whipped to death." (Virchow's Archive vol. 63, pp. 55-70, or Ziemann's Cyclopaedia vol. XVII p. 580). This latter view being supported by Professor Babier of Paris (Compt. Rend. 1874 p. 70). Panum found the fibrin is soon all replaced; in one case only about 48 hours sleeping before it was up to normal (Virchow's Archive vol. 27 p. 291), and he maintained defibrination did not alter the excretion of Urea. In the same paper he showed defibrinated blood might be kept in ice, and heated up before
Indirect Transfusion

(Defibrinated blood)

being injected, and in many of his experiments he was preserved the blood for 24 hours, before using it.

For clinical support, M. Dornell of Dublin (Dublin Med. Journ. of Med. Science Nov. 1870 p. 680) and Morton of Pennsylvania (American Journ. of Med. Science 1874 p. 115) in Belina (Archives de Physiologie Paris 1870 p. 477) and Hunter of Freigewald (Brit. Journ. of Med. and Physical Sci. Rev. Vol 46 p. 272) along with others, all bring forward several cases of complete success. In Belina's table we find 47 cases recorded in which it had been used; 17 of these were successful, 3 favourable for a time, 1 doubtful, and 26 fatal, figures which, he remarks, appear to be against its use, but a scrutiny of the cases shows that that conclusion would be incorrect. In 2 cases of post-partum haemorrhage it was successful in 3, and the other 43 cases, were for alteration in the blood itself, e.g. Septicaemia. There are many noted cases recorded in the medical papers, I would only specially call attention to Dr. Henderson's (Shanghai) case, in which again injection failed, while defibrinated blood restored the patient as already mentioned (Hemat 1874. Oct. p. 387).

Of course this method of transfusion has its opponents, and there are cases recorded in which it failed to prove effective in restoring patients.

We find Rieckhoff (1838) had asserted that in transfusion, fibrin was the danger, and to be advocated defibrination; Venus's Archiv Vol 207 p. 34) but Magendie in his Lessons on the Brain (1834) asserts that the injection of defibrinated blood caused embolism, effusions, and a train of severe and even fatal symptoms. Pamun from his experiments gives a direct contradiction to this assertion of Magendie's, and Warm bull and others agree with Pamun that it does not produce effusions (Siemens's Cyclopaedia Vol 105 London Med. Record 1875 p. 820).

Morton of Pennsylvania, although he advocates it was from favourable results which he got in nine cases, records a case in which he had seen the use of defibrinated blood followed by purpura spots, great prostration, with bleeding.

But McDermott of Dublin in combating this opinion, asserts that "in no single instance where recovery took place, was there bloody urine or extravasation such as have been stated to occur; in no instances was there in fact, any alarming symptom to interfere with speedy convalescence" (Obstet. Jour. Vol. VII. p.376); whereas he thought that experiments had proved that both red and white corpuscles live in defibrinated blood (Obstet. Jour. Vol. VII. p.660 &c).

Madsen (Brit. Med. Jour. Jan'y 1874) while alluding to the fact that after transfusion with defibrinated blood, several cases have died of pyaemia, adds, "that no doubt it can be safely injected into veins as many cases have done well."

There is one danger however which must be referred to more fully, viz. the risk of coagulation in the system. Bergmann (Lond. Med. Recov. 1872, p.474) deprecates transfusion with defibrinated blood nearly solely on account of this, and quotes Cohnheim and Armin Köhler in support, the latter of whom, did experiments which caused him to bring forward his theory of "ferment poisoning." It is known as a physiological fact that defibrinated blood contains both fibrinoplasm and fibrin ferment, (Stokes' Physiology p.23) and the third factor (fibrinogen) which causes coagulation, being in solution in the blood already in the vessels, the union of these three, according to Schmidt, theory, cause coagulation. Bergmann affirms on the strength of Köhler's experiments, that extensive coagulation is found throughout the system, even after transfusion with defibrinated blood; the argument being founded on the above data. He apparently has made more of this danger of coagulation than other operators have found, and now we find that Ziemann goes the length of saying that "the investigations of Köhler in themselves have brought under consideration new and very interesting views which must be still further tested," but "that the application of defibrinated blood...
in transfusion does not appear seriously endangered by them" (Ziemssen's Handbook of General Therapeutics Vol ii. p. 287).

Foster too asserts emphatically that a general coagulation does not occur; "the coagulations which occur after transfusion of defibrinated blood are partial and uncertain" (Text-Book of Physiology p. 28). He then goes on to show that the system has a power to resist coagulation, and says that "a quantity of fibrin ferment injected into the system may be detected in the blood immediately afterwards (and is present there without causing coagulation) but quickly disappears" (op. cit. p. 25); and Schmidt shows that there is some ferment even in circulating blood (Sandius and Stirling's Physiology Vol ii. pp. 147; see also Lond. Med. Rec. 1875—p. 520). From this, above it would appear that Bergman's dread of injecting the fibrin ferment when injecting defibrinated blood is needless.

Perhaps an explanation of this result is not difficult to find, as there are many causes which might produce the signs and symptoms which he found, e.g.

(a) Schäfer has shown that although some kinds of blood be completely defibrinated, they will often yield a further coagulum (Arch. Intern. 1879). May this not have occurred in Köhler's experiments?

(b) But sudden death may be caused when too great force is used while injecting the fluid. At post-mortems in cases of heart-disease, where death has resulted from aortic incompetence, the ventricles and part of aorta are found filled with clots (see e.g. Balfour on the Heart, p. 95—101). The regurgitant blood from incompetent aortic cusps would have a very similar effect on the heart, to that caused by blood injected with too great a force; the heart fails to contract against it; death occurs, and at the heart and vessels are found filled with clots, just as when blood has regurgitated into the heart with too
great force owing to incompetent valves. The similarity of the
two cases seems to me to be very striking. Ponfick Dopke
found, that he could produce thrombi or not, just in
accordance with whether he injected the blood with little
or much force (Ziemssen's Handbook of Gen. Therap. Vol II p. 281)
(c)May coagulation must be caused by sepsis? Brady
as already said, found pyaemia occasionally followed the
use of defibrinated blood. It is well known too, that in
Septic Fevers, fibrin ferment is abundant, so that sponta-
naneous thrombosis sometimes occurs.

Bergmann further mentions that free Haemoglobin causes
coagulation in the blood, a fact first observed by Kann
1886 p. 157) Dr. Woodbridge of Guy's Hospital, did experiments which
go to show that it is not the injection of the free Haemoglobin
but of the thrombocy, that causes intravascular coagulation.

But whatever is the cause, observations by Panum, Behring,
Hunt, McDowell and others, throw great doubt on the
point as to whether either Haemoglobin or thrombocy are set free
by defibrination; from their researches we conclude they
are not; so that this cause of coagulation should not be
taken into account here.

So little does the fear of coagulation bulk in the minds of
some authorities, that Roberts of Manchester, mentions that-
defibrination is objected to, on account of it being likely
to retard coagulation, and so be worse than useless for
untreatable haemorrhage, or haemorrhage from recent wounds.

B. Jour. 1877 Vol II p. 256).

Martin of Berlin finds no better objection to the use of defibrinated
blood than (a) loss of time in preparation, and (b) that fibrin does
no harm, while Schlieph (med. Times Feb. 1874 Sep. p. 262) and others
think it unphysiological. Professor Behring quotes statistics of
Frarmier, in which two out of three patients, who were
transfused with defibrinated blood, died; while only one out of
three died, when whole blood was used.
On the whole, however, the objections to the use of defibrinated blood do not seem to be strongly held, and Playfair affirms that they are only "hypothetical," saying it is certain that the removal of the fibrin does not in any way deteriorate the blood for the purpose of transfusion (Lancet 1872 Vol I p.109). Finsen (Handbuch der Gen. Therap. Vol II pp. 277 & 279) asserts that "storing the blood for the purpose of removing the fibrin, does not to any extent impair the vitality of the Red Corpuscles," "in fact transfusion of human blood into human beings could never be attempted with safety and would never attain essential importance, if on any grounds the use of defibrinated blood were inadmissible." Roberts of Manchester says, "there is no evidence that blood by defibrination suffers any degradation in its nutritive or therapeutic properties" (Brit. Med. Jour. 1877 Vol II p. 259) and Zimmern in "Ziemssen's Cyclopedia of Med. Vol. XI p. 489, writes, "in man and in lower animals, defibrinated blood of the same species is fully equivalent in its essential physiological properties to blood not deprived of its fibrin." At the same time one cannot help noticing how that in several cases, it only received the patient for a short time (see Lancet 1873 Vol II p. 537; Lancet 1876 Vol II p. 6; Lancet 1877 Vol II p. 533; 40) and Roussel thought he noticed that the injection of defibrinated blood just produced a temporary effect, and never the excellent results which may be expected to ensue from a successful transfusion (Roussel in "Trauerman of Human Blood" p. 25). This is perhaps an extreme view, still the point is worth noticing.

The advantages claimed by its supporters, are that there is no danger from formation of clots. From what has gone before, it will be seen, that I conclude, the fear of coagulation has been brought forward too prominently by some, but still I think we cannot put it out of view altogether, on the grounds (1) of Schüfer's result, as to coagulation sometimes occurring after defibrination has been carried out, and (2) on consideration of the purpurae spots, ecchymoses, bleeding from the kidneys and urination, and...
Indirect Transfusion (Deoxygenated Blood)

being occasionally done; these having been very probably rendered by small emboli.

II. An advantage, mentioned by Panum, Roberts and others, is that venous blood becomes partly oxygenated by the whipping. This seems true; but may this advantage not be counteracted by the risk of septicity, which must follow a long exposure to the atmosphere? Hardy, as already said, speaks of several cases of pyaemia following its use. (Brit. Med. Jour. June 1876)

III. There is no hurry during the operation, such as occurs in direct transfusion.

IV. An advantage which can be claimed for all forms of transfusion save the direct, and indirect with whole blood is that it can be performed without bringing the blood given into the presence of the blood receiver.

V. The great benefit of this method, is I think the ease with which the operation may be performed. After having drawn and then whipped up the blood, preferably with a glass or silver whipper, but a perfectly clean instrument of any kind will do in an emergency, then proceeding to strain it through muslin; endeavouring to keep it at about the temperature of the body, by letting the cup it is received into stand in hot water; we have only to consider with what form of apparatus we will inject it. In an emergency any instrument at hand might be used, e.g. a Higginson’s syringe, or an ordinary glass or brass syringe. Some special instruments have been made however, e.g. McDonnell’s, which is a sort of large pipetter, holding about eight ounces, (Obset. Jour. Vol V. p. 548), or Belina’s, which acts on a somewhat similar principle (Archiv de Physiol. Paris 1876). Playfair uses a modified Belina’s syringe with values to regulate the direction of the flow; while most use a simple glass syringe.

Certainly the operation is easy, and with due precautions, safe, as McDonnell, Belina, Playfair and others have shown; an operation which it would be a duty to put into practice, if placed in circumstances requiring it.
The only other method of intravenous injection left for consideration is that, in which the blood is kept from coagulating by means of the addition of a saline solution. To this form I desire to call special attention.

So far back as 1664 Jean Daniel of Leipsig wrote about performing transfusion, by adding salts of Ammoniae to the blood in order to keep it fluid, but nothing more was heard of it. (Roman in Transfusion of Human Blood p. 9).

Deyay and Desgrange (Gazette Medical - Paris 1852 p. 299) mentioned the usefulness of salines in delaying coagulation, but they dreaded haemorrhage if used in transfusion, as the addition of the saline, they said, must tend to diminish the coagulability of the blood, and on this account they reject this method.

Richardson again in his Essay on Coagulation (p. 457) suggests that two minims of the strong Liqueur Ammoniae be added to the ounce of blood, and in the Medical Times and Gazette 1871 Vol II (p. 264) he refers to a solution of Phosphate and Carbonate of Soda being used. While Neudörfer (Archives de Physiologie - Paris 1870 p. 55) recommended two grammes of the Bicarbonate of Soda, with thirty to forty-five grammes of a solution of albumen or sugar for one hundred and twenty grammes of blood.


Egerton Jennings, although he strongly advocated the injection of the saline solution alone, felt the value would be greatly increased if blood were added, and he invented an instrument by which his saline mixture with two minims of Liqueur Ammoniae added to the point of solution, might be injected along with the blood taken directly from the blood donor (I am not the specific reference from 1889 Vol XIV p. 56).

Lastly Braxton Hicks (Guy's Hospital Reports Vol XIV p. 151-159) recommended on the strength of Dr. Pakey's advice, that a solution of Phosphate of Soda should be used. The strength he proposed
was three ounces to the pint of water, to be used in the
proportion of one part of solution to four parts of blood.
He used it of this strength in order to be near the specific
gravity of the blood. He said (looking at it from an obstetrician's
point of view) "the only point to be considered on the other
side is, whether by the addition of the salt, the natural
tendency of the blood (to coagulate) would be prevented in the
arterial sinuses, and thus the blood flow more readily from
the uterus. He was singularly unfortunate in the cases
which he published along with the description of the method.
They were four — 2 placenta praecox, 1 abortion, and
1 post-partum haemorrhage. All died, and Jennings
Dennison and others take this mortality as a strong
argument for objection to its use.
Braxton Hicks however is wrong in saying the only point
requiring to be considered is whether the injection alters the
coagulability of the blood in the vessels. This point appears
of little importance now that the injection of saline solution
alone has been shown to be of use, even in post-partum
haemorrhages; but the great objection felt regarding the
employment of this method is, the alteration the solution
effects on the red corpuscles of the blood drawn from the
blood donor. Schäfer (Obstet. Trans. 1879 p.347) dismisses the
consideration of this method by merely saying, the solution
must alter and kill the corpuscles, while Jennings after
telling "the unprejudiced reader" to place a drop of Braxton's
solution on the finger and then prick the finger through it, after
which he is to proceed to examine the corpuscles, when he will find
they rapidly "lose their biconcave outline, increase in size, and
become translucent" and, he goes on to say, "with the knowledge
afforded by the microscope, and considering the unstable relation
of Haemoglobin to the corpuscular stroma, as well as the free
solution of the former in Dr. Hicks solution, with the experience
derived from Poutejje's researches as to the highly phosphogous
action which Haemoglobin in plasma possesses on the Kidney,
and above all, with Dr. Hicks's series of cases before us, we are not justified in adopting this method of transfusion" (Jenning's on Transfusion of Blood vi. pp. 45-50). Notwithstanding this, Jenning has invented an instrument whereby a solution containing 60 grains of salines, and 10 minims of liquor ammoniac, are to be added to the blood. By the method advocated in the following pages only 0.75 grains of Phosphat of Soda, are injected at each transfusion.

The points regarding which I have endeavoured to come to a conclusion on, are;

1st. As to how far the red corpuscles are altered by the saline solution. For the settling of this point, two methods are open to us, viz.
(a) Examination, by means of the microscope, of the red corpuscles, taken from a mixture of blood and saline solution.
(b) Naked eye examination of the blood clot and serum from a mixture of blood and saline solution, as compared with those from blood alone.

2nd. As to whether the corpuscles become regenerated and perform the functions of normal corpuscles, after being mixed with the saline solution and injected into the system.

In all the succeeding experiments and cases, the strength of solution used was one ounce of Sodium Phosphate to three one pint of distilled water, one part of this solution being used to three parts of blood. This is very much weaker than what was recommended by Hicks, perhaps the fact may help to explain this failure.

1st. As to how far are the red corpuscles altered by the solution.
(a) Microscopic Examination of corpuscles in a mixture of blood and solution.

Rollet (Chicker's Human and Compar. Histology, Lydenham, vol. 1 p. 354) speaking of Sodium Chloride, Glauber's Salts, Ammonium Chloride and other similar salts, says, with moderately strong solution the corpuscles become less glutinous and extensible, their
Indirect Transfusion (Blood with Salts)

outline more distinct, their form curved, their surface wrinkled, and their borders dentate." (p. 39) We have seen already what Jennings says regarding the action of thick solution on the corpuscles. Not being satisfied with the method employed by Jennings, the one recommended by Harris of Birmingham, of merely placing a drop of solution on the finger, and pricking through it, for by this means one is never certain of the relative proportions of the two fluids, I took the pipette from a Haemoglobinometer, and measured 60 cubic millimetres of solution, and then drew 180 cubic millimetres of blood from my finger, thus getting the definite and proper proportion of one part of solution to three parts of blood. Mixing them thoroughly I at once made a preparation for the microscope, and examined it, and certainly found all the corpuscles separate and not running into rouleaux, slightly distended and therefore apparently paler. I continued however to make preparations every short time, and found that in about 10 minutes many of the corpuscles formed rouleaux as normally, and in the course of 20 minutes or so, the vast majority of the corpuscles had so compacted themselves, while a few remained isolated, distended, globular and pale.

Any one working at the subject can have no doubt that the vast majority of the corpuscles are not decoagulated. On one occasion this was very clearly proved to me. I had taken a mixture of 1 part of sheep's blood and 1 part of solution and allowed it to stand for 24 hours with a view to examine the serum. On this occasion I did not use the pipette for drawing it off, as I did subsequently, but merely poured it off carefully, and on examining it, I found it red coloured. But on again allowing it to stand for 24 hours, the serum was found clear, and a bright red deposit at the foot of the test tube. On examination by the microscope, this deposit was seen to be composed of red corpuscles, not much, if at all, different from corpuscles got by the same means, from blood not mixed with solutio
Thus, I found that corpuscles got in the serum rather roughly drawn off, retain their colour, yet the serum will be the part of the blood most intimately mixed with the saline solution, and therefore these corpuscles would have been more likely to be decolourised than the corpuscles in the clot. What the microscope reveals then with such a mixture of blood and solution of phosphate of soda, is that some of the corpuscles are distended and apparently pale, and do not run into rouleaux, while very many of them behave as normal corpuscles, their action being delayed however.

(a) Naked eye appearance of the clot from blood mixed with saline solution, and if the serum get from it.

(c) If we take 3 parts of sheep's blood and mix it with 1 part of solution as above, we find it acts normally in that it coagulates, this however being delayed, sometimes for a considerable length of time. The time of delay varies greatly, however, the variation being caused partly by the rate at which it flows from the animal, partly, whether it be the first or nearly last blood of the animal which is taken, partly by unknown differences in the blood of different animals, and lastly, partly by the mixing of the blood with the solution not being properly carried out. With sheep's blood, coagulation occasionally took place in 4 minutes, sometimes it had not come about in half an hour, while with rabbit's blood, coagulation occasionally occurred so rapidly as to cause a difficulty in carrying out a transfusion on the animal.

I am not aware of any satisfactory reason having yet been given as to how saline retard coagulation. Accepting Schmidt's theory, that coagulation consists in the union of fibrinogen and fibrinoplastin, brought about by the action of the fibrin ferment—(the two latter, it is thought, being derived from the destruction of the white corpuscles, and to a small extent of the red), may it not be the case, that the ferment is unable to act in a strongly
Indirect Saline Solution? In support of this idea, we know that if we take a mixture of blood and saline solution which has remained fluid on account of the strength of the saline solution used, and if we dilute this mixture with water coagulation will occur. Further, if a weak saline solution be used coagulation takes place, but it is delayed. During the delay, may we not safely conjecture that more ferment is being developed, and when this reaches a certain amount, an amount large enough to overcome the strength of saline present, then it is able to act, and cause the union of the fibrinogen and fibrinoplastin. If this view of the action of a saline in delaying coagulation be correct, then a mere retarding of coagulation need not be brought forward as an argument which is likely to militate against the use of a saline being added to blood about to be transfused.

The appearance of the clot too, is quite that of a normal one. In using a stronger saline solution I have noticed the clot sometimes appears pale at the upper part but this is simply due to the delay in coagulation allowing the red corpuscles time to fall towards the foot of the vessel. (see Carpenter on Landois & Stirling's Physiology)

(2) Examination of the Serum from blood mixed with saline solution.

Bonfiò's experiments already alluded to show that free Haemoglobin circulating in the blood is excreted by the Kidneys in which organ it sets up an inflammatory action. But he found it required a certain amount before this inflammation was brought about, the amount varying in the case of different animals; "small quantities too are capable of being oxidized in the system" (Ammerman - Ziemer's Cyclo. Vol. 3, p. 85)

Clearly then, if the solution of Phosphate of Soda dissolves out the Haemoglobin, at least to any considerable extent, the excretion of it will tend to cause a nephritic, and Jennings, as we have seen, urges this as an argument against the use of 

If dissolved out of the corpuscles, the Haemoglobin must—
necessarily be found in the serum, therefore what I proceeded to do was, to collect the serum from blood mixed with saline solution and compare it with the serum got from blood alone into 2 large test tubes I put 4 ounces of sheep blood alone into 1 of 2 I put 3 ounces of sheep blood and some of solution of phosphate of soda

Setting these aside where they could not be disturbed nor shaken, I allowed them to stand for 24 hours. I then proceeded to draw off the serum very carefully by means of a pipette, and placed the different serums in small test tubes

Here was less serum from the mixture of blood and solution than from blood alone. On comparing the two sets of serums, the one from the blood alone, were clearly a trifle darker than those from the blood with saline solution. As however in the one case, there had been no dilution, and in the other parts of blood were diluted with 1 part of solution, I next added distilled water equal to one third of its amount, to the serum from the blood alone. After this, on comparing the two serums, the one from the mixture of blood and solution, was found to be just a trifle darker in colour, the difference being very slight. Evidently

then, a very small amount of Haemoglobin is set free. Having thus concluded that the corpuscles are to some extent altered, and that a small amount of Haemoglobin is apparently dissolved out, I proceeded to examine the second point viz.

II As to whether the corpuscles may not be regenerated after they are injected into the vessels.

There are grounds for thinking they may be, as

(a) Corpuscles are found altered (as cremated) in healthy people at one time, and soon afterwards found to be normal. (Path. w. M. Wiltz.)

(b) Richardson showed that although the blood corpuscles circulating in a dog were so much altered by the inhalation of Ammonia Vapours, that on the fourth day of the experiment, not a perfect corpuscle could be found; and coagulation was fickle, and on the eleventh day, although the dog was weak, the blood corpuscles
were so much modified that it seemed a marvel how the animal could exist; still notwithstanding that the experiment was carried on for a month, in a week after its close the animal was as lively as ever; the corpuscles recovering their regular form in some weeks (Richardson on Coagulation pp. 156 & 121). It says further: "This, from demonstrative evidence, may be stated, that the corpuscles after undergoing a degree of change and partial dissolution from superalkalinity which would seem altogether incompatible with existence, will, on the withdrawal of the alkali, be renewed in the blood" (ibid. p. 383). This of course refers to circulating blood altered by alcalies.

(2) Blundell asserts that "deteriorated blood after it has been thrown into the vessels undergoes a passive change, by which it again becomes thoroughly congenial to the functions of the animal" (Researches p. 111).

These authorities give us ground for believing that the corpuscles, altered by the solution of Sodium Phosphate, are restored to normal after injection. Nothing however had been done on this subject, with regard to the phosphate of soda solution specially, and so to decide the point, I obtained permission to try a few experiments on rabbits. I tried to arrange these experiments in such a way, that one might be able to see at once the value of a transfusion by this method.

Thus I took 3 rabbits, estimated the probable amount of blood in their bodies (1/10 of body weight), examined their corpuscles and Haemoglobin; then bled them to a known quantity, and for some days afterwards enumerated the corpuscles, and noted the per centage of Haemoglobin.

Next I took other 3 rabbits, and carried out the preliminaries as in previous lot, but after the bleeding, I reinjected some of the animal's own blood with solution of Sodium Phosphate, and then again for some days, estimated the corpuscles and Haemoglobin.

By this means I hoped to show the difference between an animal which had been merely bled, and one into which some of the blood with
Saline solution had been re-injected.

The method I observed in operating was as follows:

1. To obtain the estimation of the corpuscles and haemoglobin, I transfused a vein of the ear, and by means of a Powers Haemocytometer and Haemoglobinometer, made the necessary calculation.

2. For transfusion—having placed the hair on the side of the neck, I cut down on a vein (external jugular?), cleared it from the surrounding tissue, passed an aneurym needle below it, and by this means placed two ligatures around the vessel; after which, I grasped the vessel with a pair of artery forceps, and made a transverse slit in it; an assistant being ready to catch the blood in a vessel containing the sodium phosphate solution. While the syringe was being filled, with the help of another assistant, I placed the cannula in the vessel, the artery forceps enabling us to know where exactly the opening was. After injection the two ligatures were tied, the wound sewn up, and covered with salicylic wool and a forcible collection.

The following were the results I got—(Graphical charts at end of thesis)

Bleeding alone

Rabbit (doe) weighing 4½ lbs. estimated the blood in the animal at about 40 drachms.

- March 15th: Corpuscles = 9,000,000. Haemoglobin 60 per cent.
- 18th: 10 5,000,000 10 5 60

Bled to about 5 drachms, i.e., about 1/8 th of estimated blood amount.

- March 19th: Corpuscles = 1,170,000. Haemoglobin 42 per cent.
  - 22nd: 10 4,240,000 10 16 6
  - 25th: 10 4,240,000 10 15 6

I made a calculation as to what the corpuscles and haemoglobin should have been, had the animal lost five drachms exactly, provided there were forty drachms of blood as estimated. I found the corpuscles should have been 4,180,000 and the haemoglobin 50%. Therefore possibly the animal lost a little more than I noted, it being difficult to count exactly, as to the amount lost by sweating.
(2) Rabbit (young buck) weighing 2½ lbs, estimated blood amount 24 drachms.
Feb 27th: Corpuscles 4,700,000. Haemoglobin 68 per cent.
       28th  4,680,000  68  68 per cent.
March 1st: Bled to 6 drachms, i.e. ¼ of estimated amount.
       2nd  Corpuscles 3,552,000  Haemoglobin 48 per cent.
       3rd  3,810,000  52  52 do.
       6th  4,310,000  52  52 do.

Little blood was lost during this experiment, making a calculation as in previous case, the corpuscles should have been 4,680,000, and Haemoglobin 51 per cent. The Haemoglobin in this animal seems higher than previous one; possibly the age might account for this.

(3) Rabbit (buck) weighing 4½ lbs, estimated blood at 40 drachms.
March 30th: Corpuscles 4,680,000  Haemoglobin 60 per cent.
       31st  Bled to about 6 drachms, i.e. ¼ of blood amount.
April 1st: Corpuscles 3,740,000  Haemoglobin 66 per cent.

(Animal killed at this date). Calculation as before, with result that the corpuscles would have been expected to be about 4,000,000 and Haemoglobin 57 per cent.

**Bleeding followed by reinjection**

Rabbit (Buck) 4½ lbs, estimated blood amount about 44 drachms.
March 12th: Corpuscles 5,270,000  Haemoglobin 70 per cent.
       13th  5,320,000  70  70 do.
Operation: Lost about 5 drachms of blood during the manipulation, but three (3) drachms with each solution were reinjected.
March 14th: Corpuscles 5,130,000  Haemoglobin 65 per cent.
       15th  5,010,000  62  62 do.
       16th  4,790,000  52  52 do.
       26th  5,060,000  59  59 do.

Suppose the animal had lost 5 drachms, calculating as in the previous experiment, the corpuscles would have been 4,680,000 and the Haemoglobin 62 per cent. The corpuscles are for the first two days therefore better than led the animal been merely bled. The Haemoglobin is also higher, but not co
high as we would have expected. On the day following the
Transfusion, I examined the corpuscles under the microscope,
and found many, pale, globular, finely granular corpuscles,
not running into rouleaux. On the third day, some, though
fewer of these were still found present.

(2) Rabbit (Buck) weighing 4 lbs. therefore blood estimated at 60 drachms.
March 30th. Corpuscles 6,780,000; Haemoglobin 70 per cent.
2° Bled animal to 3 drachms and reinjected it, with
one drachm solution. Lost only about half a drachm.

April 1st. Corpuscles 5,830,000; Haemoglobin 66 per cent.
- 32° 2° 5,060,000 2° 58 2°
° 4° 2° 5,170,000 2° 62 2°
7° 2° 5,700,000 2° 64 2°
9° 2° 5,890,000 2° 62 2°
Calculating, the animal & have lost 3 1/2 drachms, the
corpuscles should have been 5,770,000, and haemoglobin 63%.
The corpuscles were found higher in this case, but this
was likely due to an error in counting, as with such
numbers it is difficult to avoid making an error of
one or two in each square, while such a mistake
makes a considerable difference in the total.

The same pale granular corpuscles were seen in this case,
on the first, third, and a few on the sixth day after the
operation.

(3) Rabbit ( Doe) weighing 4 1/2 lbs. therefore amount of blood estimated at 60 drachms.
April 1st. Corpuscles 5,400,000; Haemoglobin 62 per cent.
- 3° Bled to 10 drachms (i.e. 1/4 of blood amount) and reinjected
2 drachms with one of solution.
- 1° Corpuscles 4,200,000; Haemoglobin 68 per cent.
- 7° 2° 3,800,000 2° 40 2°
- 9° 2° 4,110,000 2° 40 2°
Calculating as before, the corpuscles should have been about
5,050,000, and haemoglobin 60.5%. We evidently injected a small
clot in this case, for there was considerable dyspnoea after
the operation. Pale granular corpuscles seen on the first
Indirect Transfusion (Blood with Saline)

We had thus 3 Rabbits transfused, one having lost very little, (about half a dram) another about two drachms, and the third about seven or eight drachms.

The results got from these experiments are certainly not such as I expected. When we compare the Rabbits into which I re-injected blood, with those, where I only depleted the animals: we see there is a marked difference between the two. For the first day or two after the transfusion, the blood of the rabbit, which had the blood and solution re-injected, was found much richer in both corpuscles and Haemoglobin. But from the second & the fourth day, we find a marked diminution in all. The latter part of rabbit

In rabbit No. I from 5.130.000 to 4.790.000 (corpuscles) 6.7 per cent. to 5.4 per cent (Haemoglobin).

No. II 5.830.000 to 5.170.000 (corpuscles) 6.6 per cent. to 5.5 per cent (Haemoglobin).

No. III 4.200.000 to 3.800.000 (corpuscles) 4.6 per cent. to 3.0 per cent (Haemoglobin).

To make sure this diminution was not due simply to a falling off in the condition of the rabbit, from being kept in the laboratory, I took a rabbit, estimated its corpuscles and Haemoglobin, kept it for six days, under similar conditions to the others and found on April 2. Corpuscles were 5.760.000 and Haemoglobin 66 per cent.

9th 5.600.000 -- 66

showing a slight diminution in corpuscles, but not in Haemoglobin. Though nothing like the extent, as seen after a transfusion.

We notice in all the cases, both with and without re-injection, the amount of Haemoglobin is lower than we would have expected.

In all the three rabbits which I transfused, large, pale, globular, finely granular corpuscles were found, when the blood was examined directly, without mixing it with the Sulphate of Alum solution, necessary for estimating the number of corpuscles.

To see if these pale corpuscles were ones which I had re-injected, or merely corpuscles in the blood altered by the solution injected, I did the following.
Tried a rabbit, and bled it to about 3 ounces, and injected a drachm and a half of solution of Sodium Phosphate. The day following the injection, there were no pale granular corpuscles seen as in transfusion cases, and when I compared them with the corpuscles from a healthy rabbit, I found the two were very similar, only the corpuscles from the rabbit which had the injection, appeared to take longer to run into rouleaux than those of normal blood.

The only conclusion I can come to from the results just given is that very many of the corpuscles thus reinjected into a rabbit, seem to be excreted, perhaps all of them. This is in accordance with Ott's results, regarding transfusion of whole or defibrinated blood in the dog, and while my experiments seem to differ from Ott's, in that the animals commenced to regain corpuscles more quickly; they further agree with his, in that the corpuscles regain their numerical ratio more quickly than the Haemoglobin is restored. I did not continue to examine the animals till the normal was reached, as Ott did, for it was not required for the point I wished to settle.

Notwithstanding my conclusion regarding these transfusions on rabbits, I do not question the usefulness of the operation on the human subject, although I am now inclined to think that it cannot be quite so beneficial an operation, as it was at one time inclined to regard it. But we must remember 1st, that a rabbit's corpuscles are exceedingly easily destroyed, as already shown from Landolt's experiments, and so a true analogy between transfusion on a rabbit and on the human subject, is perhaps difficult to draw, from the simple fact, that rabbit corpuscles may be more extensively destroyed, than human corpuscles are.

2nd In all three rabbits transfused, for one or two days, the blood was evidently richer than it would have been had I merely bled the animal. Such an effect might be of great benefit in a case of haemorrhage; for as Ott would put it, there is not such a great hydramnia produced.
Indirect-Transfusion (Blood with Saline)

The rabbit seemed well and suffered no bad effect, except in the third case, where there was dyspnoea for some time, and we had evidently injected a small clot. Next day however the animal was quite likely.

And so there are several cases now, in which the operation has been performed, with undoubtedly great benefit following it; these cases I will now give in detail. For the report of the first case I am indebted to Dr. Braikenridge's resident-physician (Mr. MacAven); the other cases I examined myself.

1st. Clark's case from Bethnal Green, aged 33 admitted to Dr. Braikenridge's ward on June 19th 1886. A case of Pernicious Anaemia.

June 20th: Corpuscles 1,900,000. Haemoglobin 35 per cent. Ordered to get: Liquor Aemicus and Ferri et Quinina Citratus.

July 5th: Corpuscles 1,160,000. Haemoglobin 24 per cent.

Dr. Dunstan in consultation with Dr. Braikenridge had agreed as to the advisability of transfusing blood into the patient, and resolved to carry it out by the method referred to, Dr. Cotterill having recommended it. The operation was done on this date, and 7 hours after transfusion the corpuscles were 1,470,000. Haemoglobin 25 per cent. Slack rigor (temp. 101.2°). Liquor Aemicus continued. Urine no abnormal constituents.

<table>
<thead>
<tr>
<th>Day</th>
<th>Corpuscles</th>
<th>Haemoglobin</th>
</tr>
</thead>
<tbody>
<tr>
<td>6th</td>
<td>1,320,000</td>
<td>25</td>
</tr>
<tr>
<td>7th</td>
<td>1,600,000</td>
<td></td>
</tr>
<tr>
<td>8th</td>
<td>1,560,000</td>
<td>21</td>
</tr>
<tr>
<td>9th</td>
<td>1,240,000</td>
<td>26</td>
</tr>
<tr>
<td>10th</td>
<td>1,200,000</td>
<td>22</td>
</tr>
<tr>
<td>11th</td>
<td>1,280,000</td>
<td>23</td>
</tr>
<tr>
<td>12th</td>
<td>1,312,000</td>
<td></td>
</tr>
</tbody>
</table>

Transfusion of 6 ounces of Blood as before, no rigor.

<table>
<thead>
<tr>
<th>Day</th>
<th>Corpuscles</th>
<th>Haemoglobin</th>
</tr>
</thead>
<tbody>
<tr>
<td>12th</td>
<td>1,670,000</td>
<td>25</td>
</tr>
<tr>
<td>14th</td>
<td>1,850,000</td>
<td>26</td>
</tr>
<tr>
<td>16th</td>
<td>1,680,000</td>
<td>35</td>
</tr>
<tr>
<td>17th</td>
<td>1,980,000</td>
<td>40</td>
</tr>
</tbody>
</table>
Indirect transfusion
(Blood with Saline)

The corpuscles and Haemoglobin continued to tend to increase with slight ups and downs. Till the
July 26th Corpuscles 2,210,000. Haemoglobin 48 per cent.

Third transfusion 7 ounces of blood - no rigor.
(Evening) Corpuscles 2,820,000 Haemoglobin 50

- 27th - 2,460,000 - 50 -
- 28th - 2,110,000 - 50 -
- 29th - 2,630,000 - 50 -
- 30th - 2,570,000 - 50 -
- 31st - 2,380,000 - 50 -

August 2nd - 2,570,000 - 50 -

Previous to this, the temperature had tended to rise in
the evening, after this, it was never above normal.

1st Corpuscles 2,570,000 Haemoglobin 62 per cent.

- 2nd - 2,760,000 - 60 -
- 3rd - 2,490,000 - 60 -
- 4th - 2,575,000 - 62 -

6th transfusion - A one-in ten solution of Phosphates of Soda
used on this occasion instead of a one-in twenty one.
Only 3 ounces of mixture were injected. Bell, severe
pain in bowels and smell of bad, pulse greatly in-
creased in tension.

- 7th - Corpuscles 2,505,000 Haemoglobin 60%
- 8th - 2,750,250 - 60%
- 9th - 2,672,000 - 60%
- 10th - 2,523,000 - 62%
- 11th - 2,530,000 - 62%
- 12th - 2,607,000 - 60%
- 13th - 2,735,000 - 62%
- 14th - 2,492,500 - 62%
- 15th - 2,445,000 - 60%
- 16th - 2,520,000 - 62%
- 17th - 2,705,000 - 62%
- 18th - 3,340,000 - 58% (different estimation)
Indirect

Transfusion

(Blood with Saline)

 Enumeration continued, getting slight variations and on 
October 22nd Corpuscles were 3,412,000  Haemoglobin 60% 

\[ \frac{212}{2} - 2 \cdot 702 \cdot 000 = 60\% \]

On this last date, she went home, being discharged at her own
request. On admission there had been haemorrhage both
at the base of the heart and at the veins at the root of the
neck. When dismissed, these were gone. Colour too was very
much improved. On admission her weight was, 6 stone 3 lbs,
at discharge - 5 stone, 12 lbs; a slight decrease, although she
felt, and was, much stronger. She died at home on the
18th of November; her appetite gradually left her, and she
slowly lost ground. (see also Graphic chart at end of Thesis)

This case being one of Pernicious Anaemia, could not be considered
as a very hopeful one, yet by means of the transfusions, the
patients corpuscles were brought up from 1,160,000 to somewhere
about 3,000,000, and the Haemoglobin from 21 to fully 60-
per cent. I say, by transfusion, for although she got
Arsenic after the transfusion treatment had been begun, she
had got it before that, and yet it did her no good.

Examining this case closely, after the conclusion I arrived
at from my experiments, I found, that after the first transfusion
there was an improvement in the corpuscles for three days and
then a falling off; with the Haemoglobin, the improvement was
for two days, and then a diminution of it too.

After the second transfusion, there appears a slight falling off
of corpuscles after the second day, but a steady improvement in
the Haemoglobin.

After the third transfusion, a decided falling off in corpuscles
on the second day, and a falling off in the Haemoglobin, from
the previous day, although it never went below what it was
previous to the transfusion.

After the fourth transfusion, which was not quite as successfully
performed as the others, there was no increase of corpuscles got,
and a diminution in Haemoglobin.

The other points in this case, which I would like to be
Indirect- 

Transfusion 

(Blood with Saline)

...noted are, that there was a slight rigor (101.2°F) after the first transfusion, but not after the others. After more of the transfusions could the blood reaction be got in the urine.

2nd A case by Mr. Miller, referred to in the Edinburgh Medical Journal, February 1856 p. 721.

It was a case of uterine disease of several joints (both hips, one knee and one elbow), requiring amputation at one hip. The operation was done on 18th December 1855; the blood during the operation, being caught up and reinjected.

Unfortunately I was unwell at the operation, and I cannot give the estimate of the corpuscles before it, but I know the lad was "very weak and anaemic." Mr. Miller kindly allowed me to examine the patient's blood daily.

December 18th Operation

Data 19th  

Corpuscles | 6,400,000  

Hæmoglobin 68 percent

— 20th  

— 22nd  

— 24th  

— 25th  

1856  

27th  

January 1st  

— 11th  

— 16th  

February 2nd

Corpuscles | 6,380,000  

3,550,000  

4,240,000  

4,530,000  

4,310,000  

4,200,000  

4,500,000  

4,140,000

Mr. Miller states "there was slight Hæmaturia for two days." The facts are these—on Dec 19th the Guaiac and Ether test gave the blood reaction in the urine. I could find no corpuscles under the microscope; nor yet was the naked eye appearance of the urine, that of one which would be thought to contain blood, for it was by no means ambery, nor dark coloured. If any albumen were present, it was the merest trace.

On Dec 20th the Guaiac and Ether test again gave the blood reaction, but to a much less degree, and again a very slight trace of albumen was seen, got by Picric Acid, but not by Nitric Acid in the cold, nor yet by boiling after adding
a drop of acetic acid. No corpuscles seen under the microscope.

I again tested the urine, the day following and several times
afterwards, but never found any further trace of either blood or
albumen. The first point we must notice is, that the lad had
suffered from joint disease for a very long time. His right
hip had been affected for some 19 months, while his left hip,
left knee, and left elbow had troubled him for many months
also, and an abscess had formed in April 1885, at the right
hip and breast. Probably then his kidneys might be showing a
tendency to Waxy degeneration—a supposition which gains
support from the amount of urine he passed, which on one
occasion (2nd January) reached 84 ounces, and was frequently
above 70 ounces. No tube cast could be found. Next let us remember
that in the urine and ether test, it is the Haemoglobin that
gives the reaction. Suppose then, suppose some of the
corpuscles to become decolorised by the action of the saline
solution, and their Haemoglobin discharged; might it not be
the excretion of this, that caused the blood reaction, in other
words, may it not have been a Haemoglobinuria as found
by Ponfick, and not a Haematuria. In no other case, where
I have had an opportunity of examining the urine (in two cases)
has there been Haemoglobin found in the urine, but this lad
who, very probably had his kidneys in the early stage of
Waxy degeneration, had double the usual amount of blood
(11 ounces) and saline solution (4 ounces) injected, and who had
undergone one of the most severe operations the surgeon attempts,
in his case blood (?) was got. (I have submitted the preceding
for the clincher; he approves of what is said).

In this case, there was no rigor; and further the Urea was
not increased, the highest amount being 385 grains.

This case then shows how a patient, who, in his doctor's own words was
"very weak and anaemic", underwent the severe operation of amputa-
tion at the hip joint, "suffered from no shock whatever", and made
an "uninterrupted good recovery". Here also we see the corpuscles
kept up to a fair standard all through the time of his
recovery, except that on the 21st and 24th days, they were found to be down a little, but soon regained. (See Graph Chart—end of Thesis)

James Philip, under Professor Amandal's care. He had suffered from the effects of a dynamite explosion; acute pyaemia, sepsis; he had his leg amputated above the knee; reactionary haemorrhage occurred. Transfusion of 6 ounces of blood was performed through the night, followed the next forenoon by a second transfusion of 6 ounces. After this I saw the patient for the first time, and got Prof. Amandal's kind permission to examine the patient as required. After the second transfusion on January 15th the corpuscles were 1,600,000.

16th Transfusion of 6 ounces of Blood
17th Corpuscles 2,060,000
18th Do 1,480,000

Transfusion of 6 ounces of Blood
(evening) Corpuscles 1,730,000
19th Do 1,630,000
20th Do 1,750,000
21st Do 1,860,000
22nd Do 2,040,000
23rd Do 1,900,000
24th Do 1,930,000
25th Do 1,810,000
26th Do 1,740,000
27th Do 1,700,000

Large abscess which had formed in back was opened.

28th Corpuscles 1,970,000
30th Do 2,170,000

February 1st Do 1,990,000
3rd Do 2,200,000
9th Do 2,620,000
26th Do 3,490,000

April 8th Do 4,665,000. Haemoglobin 66.0%. I have this on record of the corpuscles after the two first transfusions, but after the third, there was a marked improvement.
only however of very short duration; largely due, possibly, to the great amount of sloshing which was going on. After the fourth transfusion, there was a permanent improvement going on with little interruption, to convalescence. After the two last transfusions, I examined the blood of the patient directly, under the microscope (i.e. unaltered by the preparation required for enumeration), and found there were present, many pale, sharply defined, globular, finely granular corpuscles. Their appearance reminded me distinctly of the appearance of the corpuscles, which are found to remain isolated, when the corpuscles, from a mixture of blood and saline solution, were examined.

After the first three transfusions, there was no rigor; after the fourth, a severe one occurred, (temp. 106°F.), but we must remember the patient suffered from acute tabes. I examined the urine after the 3rd and 4th transfusions, and got no blood reaction nor albumen. (See Graphic Chart—end of Thesis).

Mrs. Jane Robertson, Ward VIII Royal Infirmary, under Prof. Amundale's care, Fungioid lesions of Mamma, discharging very fetid pus, Patient cachetic and anaemic. Mamma and glands in axilla, were removed by Professor Amundale. By Prof. Amundale's kindness I found her corpuscles on—

January 20th

Corpuscles (before operation) 3,580,000.

Operation performed, at which about 2 ounces of blood were lost. 7 ounces of blood from a student, and 3 of solution, were injected into patient arm.

Corpuscles (after operation) 3,980,000.

January 26th

20 4,090,000

27 3,790,000

29 4,010,000

30 4,000,000

February 1st

30 4,280,000

8 4,640,000

9 4,200,000

20 4,290,000
There is shown in this case, an improvement which remained, all except a slight falling off on the second day, which I was inclined to think was due to the temperature (104°F) of the previous evening, caused by a spreading erythema of the arm; but, in the light of the experiment on rabbits, it may be otherwise. The same pale granular corpuscles were seen in this case, no Haemoglobin nor Albumen found in the urine. There was a slight rigor after operation. (See graphic chart end of Thesis)

5th Case of Thigh, under Dr. Duncan's care.

Amputation at middle third of thigh.

February 20th. Before operation - Corpuscles 4,830,000 Haemoglobin 74%

21st. After

Dv Dv Dv 4,760,000 Dv 66%

Lost several ounces of blood at the operation, as the tumour was very vascular. He had reinjected, 5 ounces of blood with 5 ounces of solution.

I was unable to get this case followed out any further, but the patient went on splendidly, without a scratch.

The points I noted were: there was little shock, there was no rigor, no Haemoglobin in urine. The pale granular corpuscles were seen on the 21st and 22nd February.

6th. Here is the case of Peter Howat, who had severe oozing, into the pleural cavity after the removal of portion of sever ribs. The case I operated on, and referred to at the beginning.

7th. The primary amputation, in which case Dr. Duncan reinjected the blood, which the patient would have lost. (Brit. Medical Journal - January 1876 p. 124)

8th. Colin Murray, under Dr. Annandale's care. A case of Acute Pyaemia. He was bled to 8 ounces, and had 6 ounces of blood and 2 of solution injected. Apparently there was no benefit. Patient died from sepsis.

In none of these last three cases, could I get the corpuscles enumerated, and for the facts regarding the last case I am indebted to Mr. Darling MB, CS. In the two former, the transfusion most decidedly helped the patient, and perhaps saved their lives, while in the last, transfusion seemed to fail.
These cases then, are, I think, quite sufficient to show, that this method of transfusion, is certainly useful. Still we see how to some extent— at least—they support the view I have taken as a result of my experiments, viz. that some of the corpuscles are excreted. In four of the cases (the only four I examined on this point, as I did not think of doing it, in the earlier cases) where I examined the blood the following day, to see if the pale, globular, corpuscles were to be found; in all of them, they were seen to be present.

To sum up then, I conclude, that a certain number of the corpuscles injected are destroyed and excreted, but it is difficult to come to even an approximate idea of the number which are so, although apparently there are not nearly so many in the human subject as in the rabbit.

This conclusion I arrive at for the following reasons,

(1) On account of the alterations seen in the corpuscles, which have been mixed with a saline solution, before injection.

(2) Because of the diminution in the corpuscles and Haemoglobin got in the experiments with rabbits; also seen, to some extent, in the cases recorded— after a transfusion.

(3) On account of the presence in the blood for some days after transfusion, of the pale, granular, globular corpuscles, in appearance very similar to corpuscles we see when we examine blood mixed with solution, prior to injection.

(4) Considering that Haemoglobinuria or Haematuria was got on one occasion.

But on the other hand, I conclude it is a useful operation,

(1) A great many corpuscles in the mixture of blood and solution, are seen & apparently not much altered.

(2) The Haemoglobin has been found in the urine in ten cases, out of eleven examined for it, and in the eleventh there was probably a diseased condition of the Kidneys present. Ponciotti's experiments have shown, that the danger of animal-blood transfusion lies in the fact, that the corpuscles are dissolved, and the excretion of the Haemoglobin.
sets up an inflammatory action in the kidneys. How if six ounces of animal blood be injected, the Haemoglobinuria is always got. Any argument then is, that six ounces of human blood mixed with solution, has not given Haemoglobinuria in any case (for in his killer's case, eleven ounces were reinject), therefore all the corpuscles cannot be dissolved and excreted. 

(3) For some days after the transfusion, a marked improvement is seen, both in experiments and cases.

(4) The appearance of a patient, after the blood has been transfused, if after a severe operation, the shock is seen to be markedly less than is generally seen after such. If after a haemorrhage, the colour of the lips, and the whole appearance is improved, and all the severe symptoms removed.

As I have previously stated, Dr. Hicks records 4 cases of transfusion by this method, all unsuccessful; and this point is brought forward as alone sufficient to condemn the method. Now however, I am enabled to cite 14 cases of transfusion done on 9 patients, and all of them can be claimed as completely successful, except the last one; a case of pyaemia. Dr. Hicks used a solution three times as strong as the one used in the above cases. This alone may have been the cause of his failure, as many more corpuscles might be destroyed, and more Haemoglobin dissolved out.

But surely the above results are quite enough to prove that the operation by this method is quite safe, and brought with great benefit to the patients. Still I feel it my right to add a warning against using either too strong or too much of a solution, or then transfusing too much. We know (a) that some corpuscles are destroyed, as they are seen to be so, under the microscope, either before or after transfusion, (b) the serum from a mixture of blood and solution is a tint darker than the serum from blood alone, (c) Haemoglobinuria was got in one case in which eleven ounces were injected, and (d) when a solution of
Double strength was used on one occasion (4% transfusion in Dr. Brakenridge's case), although less was injected, no improvement was got. Therefore, considering these points, we see that if we use too much we may get bad effects; but six ounces of blood and two of solution have been found in 12 cases to have no evil effects, but to be of great service to the patient. In 1 case no good seemed to follow.

The advantages which can be claimed for this method are many, and on comparing it with the other methods we find—

1st. It is never followed by the grave constitutional disturbance which is so constantly seen after blood from a lower animal or milk have been injected into the veins.

2nd. All the advantages which may be claimed for simple saline injections may be claimed for this method, plus the advantage of the addition of the blood. While on the other hand, the addition of the saline solution to the blood increases the bulk of the fluid, thus helping the "mechanical" difficulty after a severe hemorrhage, and further it will act as a tonic to the heart, and contract the blood vessels.

3rd. There is no complicated instrument required, such as are necessary in the direct method of transfusion. Nor is there any fear of coagulation, while all the preparations can be carried out away from the patient if required.

4th. There is no hurry, no risk of injecting coagula, such as occurs when pure blood is re-injected by the immediate method.

5th. There is no delay, such as occurs in defibrination, and there is also less exposure to the air, and so less chance of sepsis.

Further, the quantity of fluid is increased by the addition of the saline solution, not diminished as in defibrination.

The operation itself is simple. Having laid bare a vein in the patient's arm for about 1½ inches; an amunic needle is passed under it, and thus two ligatures are drawn below the vessel. The distal ligature may be tied. Next, resection on the donor's arm is performed. Two ounces of a solution of Phosphate of Soda (which I think is as well to be put into the syringe) is
Indirect Transfusion (Blood with Saline)

Slowly pour into a vessel graduated to eight ounces, which receives the blood as it flows from the donor's arm, and the blood and solution are mixed by gently stirring with a glass rod. When the proper amount is drawn off, the donor's arm must be attended to, and the glass basin, with the mixture of blood and saline, is placed in a larger basin of warm water (temp. 105° to 110°F) in order to keep it at the proper temperature. The receiver's vein is then to be opened, and this is best done by applying a firm, if catching up the vessel with a pair of artery forceps, and cutting it half across in an oblique manner. While this is being done, an assistant should be filling the syringe with the blood mixture, and then the syringe, with its cannula attached, is handed to the operator, who inserts the cannula into the vein, gets the assistant to tighten the ligature round it, and then proceeds slowly to inject the fluid, holding the syringe upright, in order to allow any air which may be present to rise to the top of the fluid. When the first syringeful is injected, the surgeon removes the syringe from the cannula, over which he places his finger so as not to allow blood to escape, and then either the same or another syringe is filled, or the contents slowly injected again. If thought necessary the blood in the syringe can be kept warm, by having pieces of lint or cotton out of hot water applied to the barrel. After all the fluid is injected the cannula is carefully pulled out, and the ligature tightened. Then a stitch is put into the wound and the dressing applied. A simple glass syringe holding 6 ounces does admirably, and it may be either provided with a paired cannula into which the nozzle slips, or then a glass cannula may be attached to it, by means of a piece of India rubber tubing.

Having thus reviewed all the forms of transfusion, and now judging of them in consideration of the three points—(a) beneficial effects on patient (b) risk run by patient (c) ease of operating; the different methods may be placed in the following order of usefulness:

1st. Injection of blood with saline solution
2nd. Injection of defibrinated blood
3rd. Injection of saline alone
4th. Transfusion of pure or whole blood by "middle" method
5th. Direct Transfusion
6th. Blood (boiled) only to be used if no other method can be employed
7th. Blood from a lower animal—never to be used.
There are several points in connection with the operation and the dangers and sequelae of transfusion, which, in order to give a completeness to our
resume of the subject, require to be mentioned.

I. The force with which the fluid should be injected.

No rule can be laid down regarding this, so far as I can find. It must be
left to the discretion of the operator, who will watch the symptoms and signs
of the patient, and thus regulate it. Bichat thinks a "short dry cough" as
the first sign that the patient has received "too sudden as too copious
an injection" (Hist. Tomes and Hist. p. 330). A difficulty in breathing
will point to the right; heart-labouring to contract against its
contents, and so it would be well to watch for this symptom.

But if the patient during the operation, admits feeling quite comfort-
able, and easy, we may safely continue with the force we are using.

One point Dr. Dunham has noticed is, that when injecting into a patient
who has lost a great deal of blood, it can be done much more
rapidly and without any bad effects, than when the operation is per-
formed on a patient who has not lost any blood, as in cases of
pernicious anaemia. In Dr. Breckinridge's case, Dr. Dunham on one
occasion injected the blood so rapidly, that it caused the patient to
have great discomfort, while in the case of the primary amputation
in which he re-injected the blood, which the man would have lost
he did it much more rapidly, and without any bad effects.

Graduation certainly would give a continuous steady flow, and it has
its advantages, but it becomes a degree more complicated and more apt to
go wrong than the simple syringe; while the force, when using the
latter, can easily be regulated by the operator, and experience has proved it
works well.

II. As to the temperature of the fluid injected.

Richardson showed that cold retarded, while heat accelerated coagulation
(see on Coagulation pp. 145 & 146). The point is therefore raised as to whether
this fact should not be taken advantage of in transfusion of blood.

In order to make use of it, for preventing coagulation while the operation
was proceeding, the blood would require to be kept at about 95° F. (for
Times Eng. p. 264). Without doing more than merely mentioning
the inconstancy of preventing coagulation by such a means,
which would be great, we pass on to notice some experiments by Cassel (Practitioner Vol. XV p. 129)

He did his experiments with defibrinated blood and found:

(a) If the blood employed be reduced to a low temperature (about 3°C or 37°F), the body temperature first falls and then rises, the more strongly the colder the blood which has been employed.

(b) If the blood employed be warmer than the animal, the temperature of the animal rises, but not to so great a height as when cold blood has been used.

(c) If the blood used be about equal to the temperature of the animal, the least change of temperature occurs. He got no ill effects from allowing the temperature to fall to that of the surrounding atmosphere.

"It is sudden changes of temperature which are to be avoided" (Ziemssen's Handbook of Gen. Surgery Vol. II p. 241).

On the strength of the above experiments, and considering that the nearer the temperature of the fluid injected, is to the temperature of the blood, the less will be the shock given to the patient, we may safely conclude, that the proper temperature at which either blood or saline fluids should be injected, is the temperature of the blood, i.e. 100°F.

III. Entrance of Air into Veins.

Certainly the less air admitted the better, alike from consideration of the mechanical difficulty which it causes to the heart, the danger of air-embolism in the pulmonary circulation, and the greater likelihood of septicity. But unless in considerably large quantity, the entrance of air into distant vessels, such as those on which transfusion is generally carried out, is not now considered as a danger.

Mr. Hutchinson (Med. Times & Gaz. 1850 Vol. I p. 165) says "the entrance of considerable quantities of air, is not nearly so fatal an accident as generally supposed." He tied a small tube into the jugular vein of a horse, and blew in air for some minutes with no bad effect. When however he put in a
large tube "a very large quantity of air having been blown in, the horse at length fell".


Senn asserts a dog will recover "if the quantity of air injected into the veins does not exceed one cubic centimetre of air to each pound of its weight" (Trans. of Am. Eng. Ass. Vol. III p. 264).

Bélain records two cases of death, from it, but in these, the transfusion was done into the jugular vein. If done in the veins of the extremities, the risk is reduced to a minimum (Senn of cit.) speaks of cases in which air was drawn into the Temporal and Long Saphena Veins), and the rate of injection in transfusion being very slow, it is really nil, especially if the syringe be held in an upright position while injecting in order to allow any air to rise to the surface of the fluid.

IV Entrance of Clots.

I need hardly stay to point out this risk. If a clot be injected, it is carried to the heart, and from thence to the lungs, and as its size will set up various degrees of mischief—dyspnoea, haemoptysis, and even sudden death—a danger which every surgeon takes great care to avoid.

V Phlebitis is often spoken of as a dangerous sequel. It seems to be of rare occurrence however, and when it does make its appearance, it very soon passes off, without producing any very serious results. (Bélain—Archives de Physiol. 1870. p. 470).
As to introducing septicid.
There can be no doubt this is a danger.
Lister, recorded at the British Medical Association meeting held at Cambridge (Brit. med. Journ. 1850 Vol. II. p. 316), some exceedingly interesting and instructive experiments bearing on this subject. He showed most clearly that "blood serum was not at all particularly disposed to septic alterations, and was not by any means a favourable field for the growth of organisms." He further pointed out that it made a considerable difference, when the septic media (he used drops of water) were introduced after coagulation instead of before it. If introduced after coagulation had occurred, the blood had not the same power of resistance to septicity, which it exhibited when the septic media were introduced before coagulation.

Bacteria, are said not to multiply unless at rest, and therefore not in circulating blood (Edin. med. Journ. July, 1856 p. 767).

But whether the blood be a favourable soil for the cultivation of bacteria or not, no surgeon would now think of operating without paying attention to have everything to be used scientifically clean. Every glass instrument used should be thoroughly soaked in a 1:1000 solution of corrosive sublimate, and just immediately prior to use, be rinsed out with boiled distilled water; the saline solution used should be made with distilled water, and boiled for a few minutes and then allowed to cool before being used, and all metal instruments soaked as usual in 1:20 carbolic solution.

Septicaemia and Pyaemia may be caused by transfusion. Madge mentions this specially with regard to the use of defibrinated blood, as already said; and Schäfer says "after defibrinated blood, a febrile condition almost invariably follows." (Pathetical Journ. of St. Brit. Vol VII p. 647). Perhaps it is sometimes the true cause of death when other things are assigned. If more frequent of occurrence when defibrinated blood is used, than with the other methods of transfusion, may the cause not...
Probably be found in the fact of its greater exposure to the air. Under the following head, the possible relation of septicity to the fever which occasionally follows transfusion will be noticed.

VII. Rigors and Fever following transfusion.

The fever which frequently accompanies transfusion is an exceedingly complicated and difficult question, and I am not prepared to say what is the true cause of it. As we have seen in the case under Dr. Brakenridge’s care, the first transfusion was followed by a rigor, with a temperature of 104.2° F. while the others were not. I am at a loss to know wherein this transfusion differed from the others. We note however, that it was the first one carried out on this principle which we had charge of and some little flaws may have been unnoticed by me. I can speak very confidently as to the perfect asepsis of all instruments, which I had special attention to, as well as to the sterility of the phosphate of soda solution, which I had boiled for several minutes for two or three nights previously, and kept it in a Florence flask plugged with salicylic wool. On this occasion however, and not on the others, the operation was carried out in the open side room connected with the wards of our Infirmary, and thus the patient was removed into the large ward. On the other occasion the transfusion was carried out in the side ward, and the patient kept in it. After the fourth transfusion on the man, who had suffered from the effects of a dynamite explosion, under Prof. Armandale’s care, there was a severe rigor (temp. 106° F.). We cannot lose sight of the fact however, that this patient had severe acute pyaemia, and his wounds were septic. This last transfusion was performed by Dr. Cuttill, and with his permission, I state that there was an unusual delay, after the canula had been inserted into the vein, on account of the difficulty of venesection on the donor’s arm. A clot might have formed in the canula during this delay. Lastly in the case in which Prof. Armandale removed the fungating cancer of the mamma, and afterwards transfused; there was a very slight rigor, which soon disappeared.
A rigor following transfusion is exceedingly common, so much so, that B. Burnett of Charing Cross Hospital, in relating a case in which he had transfused by means of Russell's instrument with success, (Lancet 1877 Vol I p.527 or Rousel on Transfusion of Human Blood) says, "rigors are constant after successful transfusion; and another practitioner (Sir. C. E. M. Dunshe) in recording a case, in which 5 to 6 ounces were injected, writes "after ten minutes, the characteristic rigor appeared" (Lancet 1878 Vol II p.116). Rousel (Transfusion p.87) says "rigors begin twenty minutes after the transfusion, they last thirty minutes, and are sometimes severe, but never excessive." "It is a kind of rigor ensuing on the digestion of the new blood as it were; being the action of the vasomotor system distributing throughout the whole organism the blood which has just distended the veins."

Lieberknecht of Liege (Med. Times Gaz. 1878 Vol I p.120) states, that whatever be the kind of blood used, there ensues a rise of temperature. He quotes the conclusions of Dr. Arndt of Revel as follows:

transfusion of a small quantity of blood (say 1/6 of whole blood volume) does not produce appreciable fever;
transfusion of a large quantity (say 1/4 to 3/4 of whole blood volume) always produces fever if preceded by previous bleeding.

The cause of the rise of temperature is attributed in both cases to the "reabsorption and oxidation of an increased amount of products of destructive tissue changes".

Further, he (Lieberknecht) refers to M. Montestruc and Stricher of Vienna, who let blood flow from the artery to vein of the same dog, and each time got fever. Liebrecht however failed to get it with the same experiments.

Lieberknecht himself experimented in the same way on 9 dogs, and he, in the first place, found if there was no fever within the first three hours, it was not likely to occur at all. In 4 of his experiments he got fever (2°C) and in the others no material change, and he could not come to any conclusion.
Why it occurred in some and not in others, as the experiments seemed to be the case. His suggestion is, that "pressure in the Vena Cava (Injury) and Hepatic System is increased by the injection," and he supposes a considerable amount of blood must accumulate in the portal system.

Landois again holds the opinion, that it is caused by the Vasomotor Centre in the Medulla being excited, this causing all the vessels of the body to contract; those of the skin included. (Central J. 1875 p.3. or Landois & Strong's Physical Vol. p.116.)

It will thus be seen, that great uncertainty and difference of opinion remains as to its cause.

Roussel's idea ("the digestion of the blood as it were") is unsatisfactory, as regards most severe ones too, are got after milk and "foreign blood" transfusion, and may occur after saline injections, none of which we consider as "digested."

Ries's idea (reabsorption and oxidation of an increased amount of products of destructive tissue changes) is objected to by Liebrecht, because the venous pressure is not diminished, but increased after a transfusion, so that, he argues, instead of a reabsorption into the vessels there should occur an exudation from them. This objection of Liebrecht certainly holds good, I think, when the transfusion has not been preceded by depletion, but if a severe haemorrhage has occurred, transfusion of blood will not raise the blood pressure to normal, and we might understand how the renewed circulation could cause a "reabsorption and oxidation" of waste products. But, unfortunately for Ries's theory, fever does occur even when no previous haemorrhage has occurred, (e.g. case of pernicious anaemia) when Liebrecht's objection is tenable.

Liebrecht's own theory (increased pressure in the portal system) seems unsatisfactory to me also. It is not necessary, as far as I can see, that an injection of blood into a vein of the arm should cause an increase of pressure in the portal system. (Ries's thinks it does (Practitioner Vol. p129).) But suppose this hepatic congestion does occur, we know the liver is a great-
source of animal heat; and the blood in the Hepatic Vein has a temperature of 105° (Prof. Rutherford's Lecture. see also Carpenter's Physiology 9th edit. p. 224); still we can hardly think, this increased Hepatic pressure, could give rise to so sudden and so great (often 5 to 7 degrees F.) a rise of temperature over the whole body. Further if it is from the backward pressure that the elevation of temperature occurs; why do we not get these rigoros and rise of temperature in cardiac disease with tranfusum regurgitatum? Further Liebreich would require to explain, how it occurs in some transfusum and not in others, and why the rigors are always more severe after blood from a lower animal or milk is used, less severe when human blood is used, and comparatively seldom got with saline injections; for with all these fluids the portal congestion should be the same.

Landois' theory (excitation of the vaso-motor centre) has it drawbacks too. Were it merely the vessels of the skin that were contracted we could understand, how the diminished loss of heat, might cause such a sudden and severe rise of temperature. But the vessels of the internal organs will also be contracted, so that while there is diminished loss, there will be diminished production of heat as well.

So far then a satisfactory reason has not yet been assigned, which will explain the occurrence of rigors so frequently after transfusion. Let us note the facts regarding the point. They are these — a rigor is always seen, and is very severe after transfusion with blood from a lower animal or with milk; it frequently accompanies, but is not as severe, after the use of whole or defibrinated blood; it is rarely though sometimes got (see case of Otto, with a temp. of 106°. Med. and Med. Record February 1886. p. 76) when saline injection is performed; and so far as my experience goes, is not often found after the use of blood mixed with saline. (found in 3 cases out of 13.) It does not seem to stand in any fixed relation to the amount of blood used, for a small quantity of blood from a lower animal will cause it, while with a much larger
amount of human blood it would not be found, and Riebrecht sometimes got a rigor, sometimes not, when he transfused the same quantity. As previously stated, Cassie, found the temperature of the injected fluid appears to influence the subsequent fever - but this does not explain the greater severity after the introduction of brute blood or milk, when carried out at the body temperature.

Further it has been ascertained that after a severe haemorrhage, the temperature at first falls, but rises again several tenths of a degree, and is usually accompanied by a shiver or slight rigor. (Landois & Stirling's Physiology, Vol. I. p. 446)

We know the sources of heat production in the body are, the glands, muscles, and nerve cells; the structure for loss of heat are principally, the skin, lungs and kidneys. Over and above it is probable there is a special (nervous) centre for regulating the temperature of body (Foster's Physiology p. 432 - see also Practitioner - January 1886 p. 1). The question to be answered is, which of these act on, when a transfusion is carried out?

Having stated these facts, and admitting I am unable to form a definite conclusion; I would throw out one suggestion, which has probably occurred to many before, although as far as I can find, not published; viz. May the rigor and fever not be of septic origin? A fact to be noticed certainly, but not of much value, is that McEwan of Glasgow, transfused blood in a case of haemorrhage after lithotomy, carrying out the transfusion under the spray. It was not followed by a rigor. (Glasgow Medical Journal 1869). In several of the cases I record there was no rigor; while in all of them antiseptic precautions were taken, although the spray was never used. If septic fluid be injected into the blood, it produces symptoms very quickly. Half a drachm of recent pus injected into a dog causes sudden death; (Callender in Holmes Surgery Ed. Vol I p. 271) "when smaller doses are used a febrile disturbance of limited duration is the only result" (Schickel - Vol I p. 935).
The symptoms of a lethal dose are described by Erichsen (op. cit.) as: first symptom, a slight shudder, vomiting, diarrhoea, and dyspnoea, temperature rising at first. These are symptoms, such as are sometimes got after a transfusion, especially of animal blood or milk, and the sudden and rapid onset is also observed. There is ground for supposing that sometimes, at all events, the severe symptoms, got after a transfusion, may be of a septic origin, and Bacterie have been found in blood after milk injection (Ehrlich).

Embolism may suggest itself as likely to account for the symptoms. Balfour (on the Heart 2nd edit. p. 376) says that pulmonary embolism may cause "a rapid rise in temperature which may rapidly disappear". Szent-Györgyi in Ziemssen's Cyclopedia (Vol. II. p. 257) writes, "A febrile movement may be set up, though not necessarily, after an embolism of the lung: but it allows several days to elapse after the embolism, before its occurrence; although he admits, it sometimes occurs soon (see Supplement to Ziemssen's Cyclop. p. 297). For my own part, I do not think the occurrence of the sharp febrile attack can be due to embolism, for the following reasons,

1st (remembering the embolus would be carried from the right heart to the lungs) Haemoptysis does not occur, whereas were pulmonary embolism common, haemoptysis would be frequently seen.

2nd Dyspnoea (although it is spoken of as occurring when blood from a lower animal or milk are used) did not occur in the three cases in which I had an opportunity of seeing the patients during the rigor. But Haemoptysis and Dyspnoea are the two prominent symptoms of pulmonary embolism: while a rapid rise in temperature is, by authorities on the subject, spoken of as a symptom of secondary importance.

For these reasons I reject an embolic theory; and on the whole, am inclined to favour the theory of septic production.
VIII. A point raised is, whether transfusion should be carried out, even although the haemorrhage has not ceased. Such an occasion rarely, if ever, occurs in the surgeon's sphere, but the obstetrician may meet with it.

Grailly Hewitt is of opinion, the haemorrhage (post-partum) should have ceased, before one attempts transfusion.

On the other hand, experiments have been done to show, that injections of weak saline, blood (whole or defibrinated), but especially blood serum, have a direct haemostatic effect (Haghen, Amer. Jour. of Ind. Science Vol 57, p. 557). Jermings records a case of partial placenta praevia, in which he injected sixteen ounces of his saline-alcoholic solution, after which labour went on "without any further operative interference." (On Transfusion p. 22). Martin of Berlin gives his support to the carrying out of transfusion early (Ind. Times Aug. 1861); while Belina, thinks that in traumatic haemorrhage, the bleeding should always be stopped before trying transfusion; but in post-partum cases it is well to transfuse before haemorrhage has ceased if necessary, as it often helps to cause the Uterus to contract, and he records two cases in which it had evidently done so. (Archives de Physiol. Paris. 1870).

Belina's is the ground I would be much inclined to take up, for while we may often be unable to control the haemorrhage from a post-partum case, transfusion seems to help in causing the Uterus to contract, and thus to bring about the object most desired. But in a surgical case, matters are entirely different. Here we generally are able to get at the source of bleeding, and it seems rational, first to stop the haemorrhage by ligature or otherwise, before we inject fresh fluid into the veins. Should it be the case, that we are unable to get at, and stop the haemorrhage (in a surgical case), I question very much, if transfusion will save the patient's life.

As mentioned already, critics thought his method of transfusion, would be objected to, on account of its tendency to delay coagulation. Haghen's experiments, and Jermings
experience, seems to show, that the injection of saline alone at least, have rather a haemostatic effect. Nothing has been done on this point, with regard to phosphate of Soda specially. I tried on two experiments—bleeding a rabbit, and noting how long the blood took to coagulate, then injecting solution of phosphate of Soda, equivalent to the blood lost, and allowing it to circulate for twenty minutes, and then drawing off some fresh blood, watching the time of delay in coagulation. The results were so varied I was unable to come to a conclusion on the point. The sources of fallacy in such experiments are many, but the great difficulty I experienced was, to get the blood to flow from the vein, at the same rate before and after the injection of the solution; for clearly, unless this point is attended to, no reliance can be put on the time the blood remains in the vessel taken to coagulate. I trust yet to be able to work out this point. Surely however, if saline solutions alone have been found not to delay, but rather cause coagulation in the system, then blood mixed with a saline solution can only have the same effect.

IX

All that I have previously written, has been in relation to injection or transfusion into a vein.

Hijlir of Greifswald, advocates that an artery should be the recipient vessel, as originally suggested by G. von Graefe (Central. f. med. Wissen. 1869 p. 387). He used defibrinated blood, injecting it into the distal end of a vessel, and had experience of it on eight occasions. He chose the Radial or Posterior Tibial Arteries, as being the most suitable, and the advantages he claims, are

1. The blood is by this means carried to the heart in a regular, slow stream.

2. Although a small quantity of air enters, it does no harm; the same with embolism. Air when injected into arteries, may however, as Laborde, Auron and Penn have shown, cause death by

(3) There is no risk of phlebitis.

As a drawback, is mentioned, the great amount of pressure required to overcome the resistance in the peripheral vessels. The same operation has been twice carried out successfully by Moses of Greifswald (Arch. Gen. Med., 1875, Vol. I, p. 586.) Salines have been injected in the same manner, by Bischoff of Basel, Kretschmer of Jena, and Kümmell of Hamburg, all previously mentioned, and in all the left radial artery was chosen. In one of Kümmell’s cases, gangrene of the hand set in from Thrombosis of the Ulnar Artery, and amputation was required, a most disagreeable result, although the patient recovered. Schäfer again advises, and has Landis support, that blood should be injected into the proximal end of the artery, thus forcing the injection against the blood stream, an opinion expressed by Blundell in his Researches Physiological and Pathological, as far back as 1825. Besides the advantages claimed by Hütten for his operation, Schäfer says by his method, the "blood is driven towards the aorta, and will tend to fill the whole arterial system, and assist in supplying the coronary arteries of the heart." (Ostet. Trans., 1869.) He thinks this form of transfusion may restore even when the heart has ceased to beat. He advises direct transfusion from an artery to artery, but I agree with Dr. Playfair, who in the discussion on the Report, said he thought this was too difficult for ordinary use, while Prof. Belcher says of it, that "its advantages are not worth the increased risk." (Lond. Med. Rec. 1874, p. 570), and even Schäfer himself acknowledges that difficulty may be experienced in getting a blood donor for such an operation.

Ordinarily, I think injection into a vein is all that is required, and is more easily carried out, but in an extreme case, e.g. where a patient has evidently expired, while preparations are being made, probably cutting down on the Radial Artery and injecting towards the heart, would give the greatest chance (small at
The suggestion has been made that the operator should endeavour to save the blood likely to be lost at a primary amputation, especially if there has been much previous bleeding; and reinject it into the system; and it is proposed that the same might be done at the amputation of a limb for disease. Lamesch and other surgeons before the invention of the tourniquet, used to deject the blood a patient lost, and reinject it (Ziemer's Handbook of Gen. Chirurg, Vol. I., p.364). M'Connell of Dublin, from consideration of a case of bad machinery accident, which ended fatally from loss of blood, advised the same plan. It has also been suggested to use the blood in a post-partum case, for the same reinjection (Santet. 1874, Vol. I., p.85). This latter suggestion does not seem feasible, but Dr. Duncan has again suggested (independently of the other writers) the catching up of the blood, when an amputation of a limb is required, whether from accident or disease. He has carried it out successfully on several occasions (see Brit. Med. Journ. 1886, p.194, also Edin. Med. Journ. Feb. 1886 p.721), keeping the blood fluid by means of the Phosphate of Soda solution. Further experience on the point is required, but it will be found, I think, to diminish greatly the shock, from which a patient after a severe operation is sure to suffer.

I would like to do little more than mention, intraperitoneal and subcutaneous injection of blood.

(a) Intraperitoneal. On account of the difficulties attending intravenous transfusion, Pouchet introduced the intraperitoneal method of blood injection. That such a method must be useless in acute haemorrhages, seems very plain, from consideration of the occurrence of haemorrhages into the peritoneal cavity in females. Such occur only too frequently, and if severe the patient quickly succumbs, with all the appearances of an acute external haemorrhage. Were intraperitoneal injection of blood to be of any use in acute haemorrhages, these effusions...
should not cause a fatal result, but we know death may be rapid, and it is only when a comparatively small amount of blood has been affected, that the patient recovers, and even then she has symptoms of anaemia for a considerable time.

In chronic anaemias, such a method may be useful. Ponzio, Bizzozero, Golgei (End. Ind. Rec. 1880, p. 12) Katsyrowich (End. Ind. Rec. 1881, p. 25) and Hayem (Soc. Med. Gen. Therap. 1875, p. 333) experience and experiments, would lead us to believe it is so. But it is not without its risks, and these very grave ones too, for this is apparent from cases, in which it has been followed by peritonitis and a fatal result (see Mosler & Rosso, London Ind. Rec. 1881, p. 326 and 1883, p. 20).

There are few surgeons who would not as readily open a vein and inject blood, as pass a trocar into the peritoneal cavity for the same purpose.

(2) Subcutaneous. If intraperitoneal injection be unable to save life in acute anaemia, much more will the subcutaneous method be so. Still it is proposed for such, a case in the London Medical Record, 1883, p. 26; where into a patient who had suffered from severe hemorrhage, 90 grammes (about 3 oz.) of blood were injected subcutaneously, the lose circular tissue of the abdomen being chosen.

If Golgei, Schwarz, Kromecker, Lande, and Ott are correct in their opinion, that the want of a fluid in the circulatory system has a great deal to do with death in acute anaemia, how are we to explain to ourselves the action either of the subcutaneous, or intraperitoneal injection, in cases where a large amount of blood has been lost. For acute hemorrhages than I think this method will never become to be generally used. In chronic anaemias it may be. Ziemessan reports two cases (Deutsch. Arch. f. Klin. Ind. Rec. 1887, Vol. XXXV, p. 269), Leiber von Reims also speaks in its favour (Arch. Gen. de l'Ind. Rec. 1884, Vol. III, p. 641), and two cases are recorded in the London Ind. Rec. for March 15th, 1886, p. 110.

A question however, if the carrying out of the operation
is in any way to be preferred to an intravenous transfusion or injection, while its beneficial effect cannot be so rapid.

Such then is a resume of Transfusion in all its forms. It has proved successful in the past, and statistic, if required, can be produced to show that it has been so (see Siemens's Cycle. Vol. xvi; Martin's Transfusion bei Blutungen. Neurethen, etc.). It has been in Acute Haemorrhages, undoubtedly, that the greatest benefits have been reaped from its employment; but its usefulness is not confined to these alone, for it has occasionally proved highly beneficial in Pyæmia, Phthisis, Pernicious Anaemia, Diphtheria Anaemia from Suppuration, Haemorrhage and Carbonic Oxide poisoning. It has however utterly failed and should not be tried I think in the like of Hydrophobia, Tetanus, Epilepsy, Diphtheria, Haemorrhagic Diathesis, in all of which it has been wholly unsuccessful in bringing about the desired end.

But when used in suitable cases, it will, I am convinced, continue in the future to prove a most powerful therapeutic measure, and practitioners should not hesitate to employ it when they deem such a proceeding necessary, as the operation is now one of comparative simplicity, and if called to a patient who is rapidly sinking, and friends and medical attendant alike feel as if he were about to slip from their grasp; to restore such an one, virtually to life again, is a duty, the pleasure of which can hardly be overestimated; for it is not an honourable feeling for one to cherish, that a life has been truly saved by him, it may have been by the yielding of his own blood; a feeling which will amply repay any anxiety or trouble a medical man may have had or taken.

Edward Garnish. 1843.
From these charts, we see at a glance that when the rabbit was only bled, the blood was at its lowest the day following the operation and gradually improved, whereas when a reinjection was carried out, although the blood for a day or two was comparatively rich (richer than it would have been had the animal been merely bled), still the corpuscles and haemoglobin both fell off for some days after the operation.