incision the ilio-inguinal nerve is liable to injury, and is sometimes followed by the appearance of a post-operative right inguinal hernia.

The paramedian incision with outward displacement of the rectus muscle has the advantage that it can be safely extended to any length; this is undoubtedly the best incision for general exploration of the abdominal cavity where the diagnosis is in doubt and good access is required. In many cases, however, this incision will be found to be at some distance from the site of infection and will necessitate very careful packing off of the small intestine to avoid the risk of soiling the general peritoneal cavity when an abscess is present. For these reasons there is much to be said in favour of a lateral incision.

In typical cases of acute appendicitis localized to the right iliac fossa and in young patients, Battle's pararectal incision with inward displacement of the rectus muscle is regarded as being very satisfactory. This incision gives adequate exposure in such cases with the minimum disturbance of the inflamed parts; and as the nerves can be seen and readily avoided it rarely leads to any subsequent weakness of the abdominal wall. No case of inguinal hernia following the use of Battle's incision during a number of years has so far been encountered.

REFERENCES

- ¹ Southam: *British Medical Journal*, 1924, i, 513.
- ² Roberts: *Lancet*, 1919, ii, 1169.
- ³ Griffiths: *Ibid.*, 1919, ii, 1026.
- ⁴ Romanis and Mitchiner: *Theory and Practice of Surgery*, 1930.

A METHOD OF BLOOD TRANSFUSION WITH SPECIAL REFERENCE TO CHILDREN

BY

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When a transfusion is given by an expert to an adult the best method is probably the direct transfer of unaltered blood,^{1 2} but this requires a sleight of hand that can only be acquired by constant practice, and a speed of flow that is dangerous to small recipients. Consequently, the indirect method described in this paper may be found useful both in transfusions given by the relatively inexpert, and in those given to children.

If I state the requirements of a satisfactory apparatus, it will be seen, without discussing other methods, why I have added a new one to their vast number. It should be capable of a very high pressure, but with complete control of every drop injected; it should be practically unbreakable and free from danger of spilling its contents. It should be easy to assemble, to transport, and to sterilize; and, most important of all, it should be workable by one man.

Physiological Dangers

Besides mechanical difficulties, however, there are physiological dangers in transfusion, and these should be outlined before the points of the technique can be assessed. The chief are:

1. Incompatibility of red cells and opposite serums—the most serious of all.^{3 4}
2. Incompatibility of white cells. A very interesting line of research, especially in regard to immunity.⁵
3. Sensitization of the recipient to the blood of a particular donor.⁶
4. Changes in the reactions of previously tested bloods. All these four dangers can be eliminated by direct cross matching, and by it alone.

5. Too large an injection. It is not easy to collect enough blood to harm an adult by overdosage, but it is very different with a child.⁷ The safe limit is about 10 c.cm. to the pound, and if this seems small it should be remembered that for the average man it would mean two and a half pints.

6. Too rapid an injection. The circulatory system has a marvellous power of varying its capacity to suit circumstances, but it cannot do this instantaneously, and an amount of blood that would be harmless were its injection spread over twenty minutes, may produce death from distension of the heart if injected in five. As there is no reason to suppose that a baby makes the necessary adjustments more quickly than an adult, a full injection should take the same time in any case, irrespective of the actual amount given; so that a five-pound baby receives its 50 c.cm. drop by drop during twenty minutes at least. Apart from mechanical considerations it is possible that biochemical adjustments to the foreign blood may occur and need time for their consummation. The work of Cruchet,⁸ even if we do not follow him to all his conclusions, is extraordinarily interesting in its suggestion that the rate of injection is the most important single factor in transfusion troubles. Finally, it is obvious that, should there be any incompatibility, the slower the injection the less the likelihood of getting in a dangerous dose before the signs of trouble declare themselves. The following notes on a child of 7 weeks illustrate this point:

August 8th, 1927: Admitted suffering from pyloric stenosis. Rammstedt's operation.

August 12th: After doing well, developed enteritis and became rapidly worse.

August 17th: Very collapsed and dehydrated. Blood transfusion by air pressure, and the whole dose of 60 c.cm. injected in about five minutes. Immediately afterwards the child died, the heart apparently stopping before the breathing. Post mortem, the heart was dilated and full of blood.

I have no doubt at all that in this case the cause of death was too rapid an inflow. Since then I have transfused many babies in just as weak a state, but I have made the injection far more slowly and have had no such trouble. I do not think that works on transfusion have given sufficient warning on this point. For instance, many advise a rate of transfer of 100 c.cm. a minute or more⁹ without any caution against applying this speed to small children. When one considers that this might mean, in a 5 lb. baby, the equivalent of giving an adult three pints in thirty seconds, it seems reasonable to moderate it. Carlton, also,¹⁰ when advocating Lindeman's¹¹ method, in which the blood is injected as fast as three workers can fill, empty, and clean syringes, advises that infants showing signs of cardiac distress should be put in a hot bath, while blood is withdrawn from the longitudinal sinus and adrenaline injected. Without pausing to discuss these restoratory measures, their mention does seem an admission that trouble in the very small is liable to occur.

7. Too cold an injection. A very common cause of reactions.^{12 13}

8. Products of digestion in the blood of the donor.¹⁴

9. Changes in the blood due to the time it remains outside the body.

10. Changes in the blood due to contact with foreign substances.¹⁵

11. Changes in the blood due to trauma to it.

12. Dried blood in the apparatus from previous use.

13. Unsuitable water in the citrate solution.¹⁶

14. Citrate poisoning. Many rather biased papers have been written both to prove that this occurs¹⁷ and to prove that it does not.¹⁸ My own opinion is that properly prepared citrate is quite harmless, and it should be remembered that before any one of the fourteen points given above can be proved responsible for a reaction, the other

thirteen must be definitely eliminated. Citrate has also been accused of spoiling the defensive powers of transfused blood,¹⁹ and defended against this charge.^{20 21} However, even if there should be a lessening of what is assumed to be the bactericidal power of the blood *in vitro*, it has yet to be proved that this persists *in vivo* after the citrate has been removed by the recipient's kidneys. In any case, it is clinically certain that citrated blood does transfer resistance to infection, whatever that may depend on.

15. Local damage to the recipient. Injection into the longitudinal sinus introduces an unnecessary risk of irremediable damage. I know of two cases of permanent damage to the Rolandic area caused by it. Injection into the peritoneal cavity can only be excused by the incapacity of the operator to put the blood into a vein.^{22 23}

16. Injection of air into a vein.

17. Infection of either party to the transfer.^{24 25}

I have purposely made the most of these dangers, but the list is more formidable in appearance than reality. To recognize most of the perils is to avoid them.

Testing the Bloods

A box fitted in the syringe case contains pipettes, test tubes, wooden sticks for stirring the blood, Hagedorn needles for pricking the skin, a white glazed tile on which to examine the bloods, a grease pencil for writing on it, a lens to magnify the reactions, a bottle of normal saline, and a bottle of spirit. The Moss grouping is a very useful indication of what the reactions of bloods are likely to be, but before every transfusion it should be determined what the reaction actually is. For this about 2 c.cm. of each blood is needed, and in many cases that

of the recipient can be obtained from an operation wound, an injury, or a placenta. Two drops are picked up with a pipette and blown into 5 c.cm. of saline, and the rest is allowed to clot or is centrifuged in order to separate the serum. Then a drop of each serum is mixed with each opposite solution of corpuscles on a patch of the tile that has been isolated and labelled by the grease pencil, and the mixture watched for any clumping of the red cells. The dilution of the donor's blood makes the reactions easy to interpret by preventing rouleau formation, and if agglutination occurs it results in a very characteristic "cayenne pepper" appearance of red granules in the clear serum. If possible, twenty minutes should be allowed to elapse before it is decided that the bloods are compatible, but it is usually possible to make out the result in the first five minutes after they are mixed.

TRANSFUSION

The apparatus consists of a metal syringe of a pint (600 c.cm.) capacity as described by Macintosh,²⁶ with the addition to the piston rod of a screw that can be thrown into or out of action by a small nut. When the syringe is full of incompressible fluid a slight forward

turn of the screw will produce a very high pressure inside it, which can be changed to zero, and then to a negative pressure by equally slight turns the other way. When fluid alone is in the barrel it will only be driven out while the screw is actually being turned; but the whole character of the action is changed by the admission of air, which can become compressed and continue forcing out the contents while the piston is still. Consequently care must be taken to prevent this. On the side of the syringe are two lugs, by means of which it can be fixed to its stand (Fig. 1). This stand is an essential part of the apparatus, and clamps to any table in such a way that it will hold the syringe either horizontally for the delivery of blood or vertically for the collection of it, with a steadiness and safety beyond the powers of the most careful assistant. Instead of the glass nozzle of the original Macintosh model, which was extremely fragile and gave no indication of the flow of blood, there is a metal nozzle on the detachable forward end of the syringe, with a recess in its base in which a small piece of gauze can be packed if it is thought necessary to filter the blood, and to the end of this a Lauries's dropper, which acts as an air-lock and sight feed, is connected by two inches of rubber tubing. This tubing is of a special sort, with a smooth bore of 2½ mm., and

walls almost as thick. Its small bore ensures that the flow of fluid through it is rapid, and so the risk of coagulation when drawing off the blood is lessened, while its thick walls minimize the loss of heat. Incidentally, it has the very useful quality of fitting the nozzle of a Record syringe, and though I have had the utmost difficulty in obtaining it, it is one of the most generally useful types of tubing I know. Another twelve inches of it lead from the

FIG. 1.—Injection of blood. The syringe can be on a separate table, or turned the other way.

Lauries's dropper to the introducing needle. This is either sharp, with a special short bevel for use when it is possible to thrust it into a vein through the skin, or carefully blunted at the end so as to be useful as a cannula when the vein has to be exposed. The ordinary intravenous cannula is far too large for a small child.

For withdrawing the blood I think the needle should have a "sclerectomy" point, with the walls bevelled inwards, and should certainly be no larger than size 14. It is connected to a foot of the special tubing, the other end of which is held by a small clip which screws on to the edge of the barrel of the syringe during withdrawal. The needle and tube should be rinsed through with citrate before use, and the flow of the blood through the small unchanging bore is so rapid that I have never had any trouble from clotting. The citrate is carried dry in sterilized ampoules of 2 grams each. One of these is broken into 100 c.cm. of freshly distilled water to give a 2 per cent. solution, 10 c.cm. of which is added to each 100 c.cm. of blood, and the remainder used for rinsing the tubes. If fresh distilled water cannot be got, boiled London tap water is perfectly satisfactory.

Withdrawal of the Blood

The stand is screwed on to a table over a sterile towel, as shown in Figure 4, and on to its hook the syringe (which has been thoroughly lubricated inside with liquid paraffin) is hung by whichever of its lugs leaves the top

FIG. 2.—Showing difference between the depth to which the point must penetrate to get the entire orifice of the needle within the vein. A, with opening down, and B, with opening up.

in the most convenient position. Its piston is fixed at a position corresponding to the amount of blood required, and a suitable amount of citrate is poured into it. The usual cause of failure to tap the blood is the transfixion of both walls of the vein, and the best guard against this, as can be found by experimenting on a thin piece of tubing, is to put in the needle with the opening downwards (Fig. 2). If the opening is downwards it is also

FIG. 4.—Withdrawal of blood.

less liable to be blocked by the collapse of the vein's walls (Fig. 3). As the blood flows it is gently stirred into the citrate with the wooden rod supplied, and when enough has been collected the top is screwed on to the syringe, which is then removed from the hook. After all air has been driven out by screwing in the piston the injection tubing and needle is attached, and the syringe is set horizontally on the stand, where it is kept warm by covering it with cloths wrung out of hot water till it is needed.

Injection of the Blood

I agree with Robertson²⁷ that the best place for this is the internal saphenous vein where it crosses the lower end of the tibia. The patient cannot watch the operation, and the great veins through which the injection must pass

FIG. 3.—Showing way in which the collapse of the superficial wall of the vein occludes the opening if this is upwards (A), but not if it is downwards (B).

act as a safeguard against flooding the right auricle. If a vein is punctured through the skin a negative pressure should be kept in the syringe when the needle is buried, and then blood will rise in the air-lock as soon as tapped.

Indications

The range of these is becoming much more widely admitted, but a short review of them may be of interest, together with brief notes on a few of the more uncommon cases I have met with.

In spite of the universal admission that transfusion is the best treatment for haemorrhage and shock, many lives are still being lost and many recoveries made unnecessarily difficult for lack of it. Before any severe operation (including childbirth) it is a useful precaution to have a donor ready. Apart from the saving of time there is a saving in mental stress to all concerned if the possibility of a transfusion has been discussed beforehand. Again, in the Army a man's blood group might join his religion as a possibly useful piece of information on his identity disc. It is uncomfortable to many of us to think of those of our friends who might have been alive to-day had we had to-day's knowledge sixteen years ago; and for use in the field I do not know of any method which I would prefer to the one here described.

In the leukaemias, myelogenous and lymphatic, it can only delay the inevitable end; but this delay may

be of great personal importance to the patient. In pernicious anaemia it may be of great use in strengthening the patient till he can take advantage of other treatment, while in haemophilia, though its aid is transient, it is the best remedy that can be given. Haemorrhage of the newly born may often be cured by the simpler method of injecting blood subcutaneously, but though this will end the bleeding it does not make good the loss already suffered. Transfusion does both, and should be used if the baby is in any danger of death. In acute secondary

anaemias²⁹ its results may be brilliant, as the following case will show:

D. R., female, aged 7, was quite healthy till ten days before admission, when she had what was apparently an acute tonsillitis with swelling of the cervical lymph glands. Her parents had noticed her to be very pale for three days. On admission she was very collapsed, and had a waxy pallor. The blood count showed red corpuscles 680,000 per c.mm., white corpuscles 33,000 per c.mm., polymorphs 75 per cent. A transfusion of 500 c.cm. was given. She made a steady recovery, was discharged fit three months later, and is now perfectly well, two years after the onset of the disease.

I am not sure that chronic infections do not provide the largest field for the use of transfusion. In low-grade septicaemias, empyemas, and similar conditions it may often make the difference between life and death, especially in children. However, it must be admitted that it is impossible to give absolute proof that the improvement seen after it would not have occurred without it.

In acute infections the general opinion seems against transfusion. I have had no experience of its action, and should welcome any information about it.

It often does very definite good in athrepsia and malnutrition of infants, as in the case given below.

G. G., male, aged 3 weeks. Admitted suffering from pyloric stenosis. Weight 5 lb., "big baby at birth," passing blood per rectum, and looking absolutely moribund. Transfusion 50 c.cm., Rammstedt's operation under local anaesthesia twelve hours later; uninterrupted recovery.

Transfusion seems the logical treatment for coal-gas poisoning, to replace the haemoglobin that has been put out of action by the CO, and in burns it helps both in the early shock and in the later toxæmia. Nephritis is usually given as a contraindication to it, but I have had two extremely interesting cases in which it seemed to avert certain death from uræmia. I give the histories without attempting to draw definite conclusions from them.

B. W., male, aged 10. September 6th: Admission, suffering from acute haemorrhagic nephritis. Blood and casts in urine, with large amount of albumin; blood urea 160 mg. to 100 c.cm. October 6th: Going downhill in spite of treatment; urinary output diminishing; vomiting; blood urea 250; transfusion 500 c.cm. October 10th: Much improved; passing more urine, with less blood and albumin in it; blood urea 140. October 31st: Blood urea 60. November 5th: Septic tonsils removed, as being probably the cause of the nephritis; "flare-up" of the nephritis, with blood urea rising to 120. January 1st, 1929: Sent out much improved; blood urea 40.

E. R., female, aged 7. May 2nd, 1927: Admission, suffering from acute haemorrhagic nephritis. Improved under treatment and was sent to country branch of hospital. August 9th: readmitted in uræmic coma; unconscious, dusky, and apparently dying; blood urea 122 mg. to 100 c.cm. Blood was withdrawn to the amount of 200 c.cm., and a transfusion of 500 c.cm. was performed. The effect was almost biblical, as she recovered consciousness on the operating table, and returned to the ward talking cheerfully. August 30th: blood urea 56. The patient was sent out much improved.

I have been able to find very little work on this subject,²⁸ and of course the action of the transfusion was not a simple dilution.

My thanks are due to the honorary staff of the Hospital for Sick Children, Great Ormond Street, for their encouragement in the work on which this paper is founded, and for permission to publish the cases described; and also to Dr. Aaron Signy for his advice and aid in the very important department of blood matching.

The instruments described have been made by Messrs. Down Bros., Ltd.

REFERENCES

- ¹ Unger, L. S.: *Journ. Amer. Med. Assoc.*, 1915, lxiv, 582.
- ² Blain, A. W.: *Annals of Surgery*, 1929, lxxxix, 917.
- ³ Guthrie, C. G., and Huck, J. G.: *Bull. Johns Hopkins Hosp.*, 1923, xxxiv, 37.
- ⁴ Sidbury, J. B.: *Journ. Amer. Med. Assoc.*, 1927, lxxxix, 855.
- ⁵ Doan, C. A.: *Ibid.*, 1926, lxxxvi, 1593.
- ⁶ Boughton, T. H.: *Journ. Lab. and Clin. Med.*, 1920, v, 597.
- ⁷ Cherry, T. H., and Langrock, E. G.: *Journ. Amer. Med. Assoc.*, 1916, lxvi, 626.
- ⁸ Cruchet, R.: *Journ. de physiol. et de path. gén.*, 1926, xxiii, 80.
- ⁹ Brines, O. A.: *Arch. of Surg.*, 1926, xii, 124.
- ¹⁰ Carlton, H.: *Lancet*, 1926, ii, 850.
- ¹¹ Lindeman, E.: *Amer. Journ. Dis. Child.*, 1913, vi, 38.
- ¹² Lindsay, J. W., Rice, E. C., and Selinger, M.A.: *Journ. Amer. Med. Assoc.*, 1929, xcii, 291.
- ¹³ Shera, G.: *British Medical Journal*, 1930, i, 903.
- ¹⁴ Brem, W. V., Zeiler, A. H., and Hammack, R. W.: *Amer. Journ. Med. Sci.*, 1928, clxxv, 96.
- ¹⁵ Busman, G. J.: *Journ. Lab. and Clin. Med.*, 1920, v, 693.
- ¹⁶ Seibert, F. B.: *Amer. Journ. Physiol.*, 1925, lxxi, 621.
- ¹⁷ Unger, G. J.: *Journ. Amer. Med. Assoc.*, 1921, lxxi, 207.
- ¹⁸ Lewisohn, R.: *Boston Med. and Surg. Journ.*, 1924, cxc, 733.
- ¹⁹ Colebrook, L., and Storer, E. G.: *Lancet*, 1923, ii, 1341.
- ²⁰ Mellon, R. R., Hastings, W. S., and Casey, G. V.: *Journ. Amer. Med. Assoc.*, 1922, lxxix, 1678.
- ²¹ Cheer, S. N.: *Journ. of Immunol.*, 1930, xviii, 187.
- ²² Floyd, M. L.: *Amer. Journ. Dis. Child.*, 1929, xxxvii, 1007.
- ²³ McKhann, C. F.: *Boston Med. and Surg. Journ.*, 1926, cxcv, 1241.
- ²⁴ Rosenthal, G.: *Bull. et Mém. Soc. Méd. de Paris*, 1929, xvi, 381.
- ²⁵ Aubertin, C., and Fleury, J.: *Bull. et Mém. Soc. Méd. des Hôp. de Paris*, 1930, liv, 69.
- ²⁶ Macintosh, R. R.: *Lancet*, 1927, ii, 22.
- ²⁷ Robertson, B.: *Toronto Arch. of Surg.*, 1924, ix, 1.
- ²⁸ Martin: *Siglo Méd.*, 1924, lxxiii, 615.
- ²⁹ Lazarus, S. D.: *Amer. Journ. Dis. Child.*, 1930, xl, 1063.

MECKEL'S DIVERTICULUM AS THE CAUSE OF ACUTE SYMPTOMS

BY

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During a series of 105 laparotomies, performed for various conditions during the three months June, July, and August, 1930, at the Stockport Infirmary, four cases were operated on by me which showed various forms of Meckel's diverticulum. In two of these, acute symptoms were caused, and in view of the comparative rarity of such cases some details may be of interest.

CASE I

A labourer, aged 52, was admitted at 11.55 p.m., on June 9th, with severe gnawing pain around the umbilicus. The onset had been sudden at 4 p.m. on the day of admission, but the man had remained at work for one and a half hours; since leaving it he had vomited three times. The bowels had moved at midday; they were usually regular. There was no pain in the back or shoulders, no urinary trouble, and no history of previous indigestion.

The patient was collapsed and covered with cold perspiration, his temperature being 97° F., and his pulse 80. The tongue was coated and dry. The abdomen was tender in the right hypochondrium and just below the umbilicus. Both recti were rigid. A rectal examination was negative.

An operation was performed at 1 a.m. on June 10th, a right rectus slide incision being made. Much free sanious fluid escaped, and coils of strangulated gut presented. On close inspection a Meckel's diverticulum, arising from the antemesenteric border of the gut, was found to be strangulated through a hole in the mesentery of another loop of gut. The portion of bowel bearing the diverticulum was tightly constricting a large loop of bowel, compressing its mesentery. This loop was drawn so tight that the strangulating bowel was only of the diameter of a pencil. The diverticulum was excised between clamps, but even then it was found impossible to reduce the strangulation until the constricting loop of bowel had been similarly divided. After reducing it the involved bowel was still blackened, and there was no sign of pulsation in its mesentery, into which considerable haemorrhagic effusion had taken place. Resection of three feet of intestine was therefore performed, with end-to-end anastomosis, and the abdomen was closed