CERTAIN ASPECTS OF TRANSFUSION UNDER PRESSURE

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Increased use is being made of positive pressure for blood replacement by the intravenous route. Not only is it a suitable means of transfusion where blood loss has resulted in venous collapse or spasm, but it is proving useful for rapid repletion of blood volume after severe haemorrhage during thoracic, and in particular cardiac and vascular, surgery. Coupled with this is the development of intra-arterial transfusion as an improved means of resuscitation.[1-3] A sure and safe method of avoiding air embolism is of prime importance. This has prompted the description of a simple piece of apparatus which is coming into common use for positive-pressure transfusion.

THE DANGER OF AIR EMBOLISM

The existing type of drip feed used in transfusion apparatus lends itself to the danger of rapidly fatal air embolism when positive pressure is applied to the transfusion bottle.[4, 5]

The commonest way in which air embolism has occurred is as a result of air being forced into the tubing after the level in the transfusion bottle has reached the level of the outlet tube. The precaution of keeping a continuous watch on the fluid level is not enough, for there is another less obvious means by which air embolism may result, which is demonstrated by the following case report.

Case Report. B.W. aged 54 years. Left pneumonectomy for extensive bronchiectasis. Because of considerable pleural adhesions, operating time was prolonged and blood loss necessitated the transfusion of 5 pints of blood, aided by positive pressure from a double bellows. A constant watch was kept on the transfusion bottle. When about 200 ml. of blood remained in the 5th bottle, it was noticed that a mixture of blood and air was entering the drip feed, despite the fact that the pressure in the bottle was restored to atmospheric level by disconnecting the bellows. The blood level in the dripper dropped completely. The tubing was immediately removed where it joined the intravenous needle, and a new transfusion set up. The patient suffered no untoward reaction.

On examining the apparatus it was found that, when it was allowed to flow, a short column of pure blood was followed by a mixture of air and blood. This mixture continued to flow despite the fact that the bottle was about half full and although no positive pressure was applied. When the 'wick' filter which had been continuously used for the previous 4 pints of blood and half of the 5th pint was examined, it was found that the mesh had been partially blocked with sediment. This caused the blood outside the 'wick' filter to dam up and the blood within the confines of the filter drained away and was replaced by air.

Dolten *et al*,[6] in 1945, reported on a similar occurrence, with a fatal result, due to this type of air embolism caused by a partially blocked filter. They pointed out that fatalities, in fact due to this type of air embolism, may in the past have been mistaken for status lymphaticus, acute cardiac failure, shock, and the like.

It must be stressed that this progressive blockage of the filter by sediment, with its attendant danger of air embolism, readily occurs when gravity alone is employed to transfuse blood. The danger may be avoided by regular renewal of the filter in the course of prolonged transfusion.

Apparatus

Fig. 1 illustrates the conventional transfusion apparatus designed so that positive pressure may be safely applied.

The glass drip-chamber is replaced by one which contains a float. The lower end of the float and the lower end of the drip-chamber are so ground as to create an airtight fitting when they come into contact with each other. The tubing and drip-chamber are filled in the same way as the ordinary apparatus. Details of this 'safety dripper' are illustrated in Fig. 3. The side tube allows for pressure equalization when the clip is opened. This permits the level of the float to be set at any desired height above its seating.

Fig. 2 indicates what occurs when the transfusion bottle empties. Air forced into the drip chamber causes the fluid level to drop. The float then sinks onto its seating, sealing the apparatus off from any further flow, and thus air embolism is prevented.

A screw cap, the top of which has been holed to allow passage of the glass inlet and outlet tubing is shown in Fig. 3. Figs. 1 and 2 show the purpose of this cap,

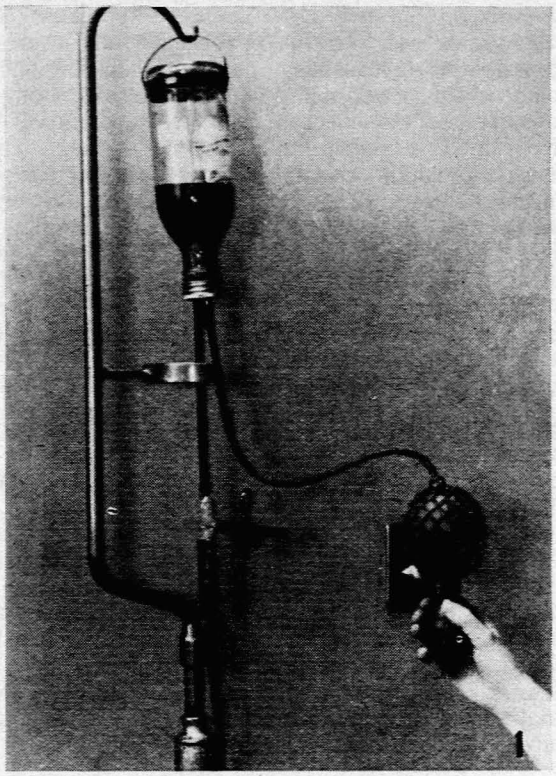

Fig. 1

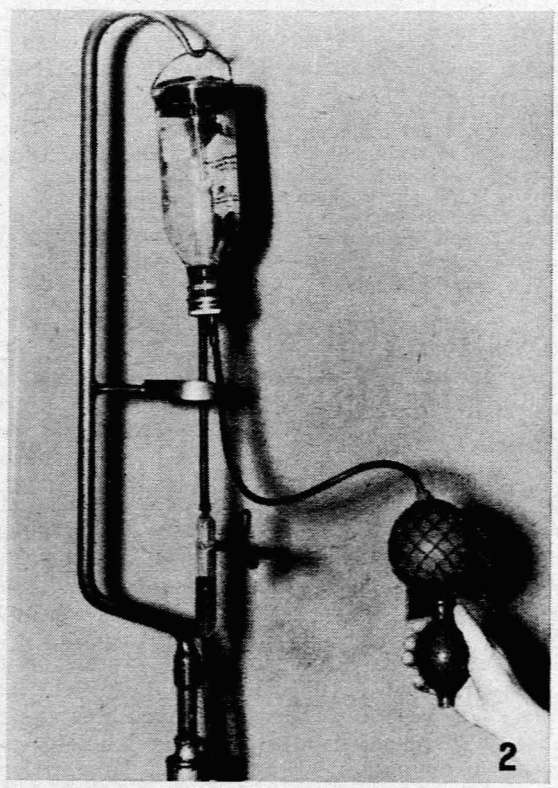

Fig. 2

which is to hold the rubber cork firmly in the rim of the bottle so that any excess of pressure will not blow cork, tubing and filter out of the transfusion bottle. This cap must be deeper than the usual screw cap, so as to accommodate the protruding part of the rubber cork and at the same time take a good grip of the rim of the bottle.

Positive pressure is obtained by the use of a double hand-bellows (Figs. 1 and 2), which allows an even and adequate head of pressure to be maintained. No other method, such as the employment of an oxygen cylinder, is advisable.

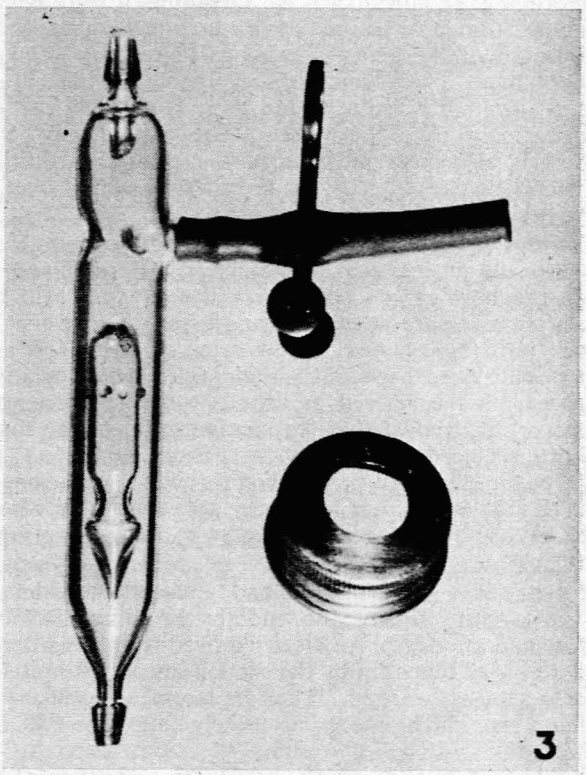

Fig. 3. Safety dripper and modified cap.

For intra-arterial transfusion all metal and rubber joints should be secured by wire. Also an 'aneroid' type of pressure gauge may be coupled (by a 'Y' tube) to the double bellows to indicate the pressure in the transfusion bottle.[7]

Testing of the Safety Dripper. In view of the less-known cause of air embolism (due to a partially clogged filter) we tested the reaction of the float mechanism when a mixture of blood and air entered the upper end of the drip chamber. The entry of such a mixture caused the float to fall with the receding fluid level in the drip-chamber. Any further flow was prevented as effectively as when air *alone* entered from the drained transfusion bottle.

In a further experiment carbon dioxide dissolved in saline at a pressure of 80 mm. of mercury was run through the apparatus. This solution immediately on reaching the drip-chamber again caused the float to

prevent any flow. Here the gas is released from solution and depresses the fluid level and the float with it.

OTHER ASPECTS

Rate of Blood Flow.[1-3] Jones [8] has recently emphasized that the size of the bore of the transfusion needle is the main factor limiting the volume transfused where gravity is the force employed. Where positive pressure is used a large-bore needle is just as important.

Instead of a large-bore needle, polythene tubing of 1·5 mm. bore may be used, in the following manner: The tubing is introduced by threading it through a suitable cannula. It is then passed up a few inches along the length of the vein, allowing it to reach a vein of wider lumen. The advantages are obvious. Little splinting of the limb is required and there is minimal risk of dislodgement from the vessel. The use of polythene tubing is also most satisfactory where large quantities of blood or packed cells are to be administered over a long period.

Venous spasm or collapse is commonly encountered as a result of massive haemorrhage. Here, however wide the bore of the needle, positive pressure will be essential to assure adequate transfusion, if irreversible shock is to be avoided. Flow rates of 75 to 350 ml. per minute have been safely maintained under positive pressure *via* the arterial or venous route. Experience, however, has shown that for maximum safety the total volume replaced in this way should not be more than 70% of the estimated volume lost through haemorrhage. Where jugular tracings have been taken in these cases, they have shown no undue increase in venous pressure.

Where surgical procedures are undertaken which involve sudden grave loss of blood, a reasonable estimate of the quantity lost may be made by weighing all swabs before and after use. All clots removed from the wound and all blood taken up by the suction apparatus must of course also be weighed. Thus replacement volume for volume is much more accurately and beneficially achieved.

Intra-arterial Transfusion. Those contemplating the use of intra-arterial transfusion must be fully aware of the possible complications (apart from air embolism) which beset this newer method of resuscitation. Complications include the effect on the myocardium of the excessive plasma potassium in stored blood. Then there is the possibility of small blood-cell emboli reaching the arterial system. There is also the risk of ischaemia of the member distal to the site of arterial cannulation.

Seeley and Nelson [2] and Melrose and Wilson [3] have exhaustively discussed this subject; Devitt and Wigderow [9] report on a successful case of intra-aortic transfusion. These reports are well worth careful study.

SUMMARY

Attention is drawn to the danger of partially clogged blood-transfusion filters which may allow a mixture of blood and air to enter the patient's circulation and cause fatal air embolism.

A description is given of a simple apparatus for safe positive-pressure transfusion. The apparatus was tested under different conditions to prove its efficacy.

Means of achieving a satisfactory rate of flow, and the quantities transfused under positive pressure, are discussed.

A warning is given of the possible dangers of intra-arterial transfusion. These may be avoided if the literature available on the subject is studied.

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