DIE TRANSFUSION DES BLUTES IN PHYSIOLOGISCHER UND MEDICINISCHER BEZIEHUNG

By LADISLAO VON BELINA-SWIONTKOWSKI (1869)

A TRANSLATION OF PART FOUR (PAGES 101-125) OF THIS BOOK BY PHIL LEAROYD

'DIE TECHNIK DER TRANSFUSION' (The Technique of Transfusion)

A copy of 'The transfusion of blood in physiological and medical terms' by Ladislao von Belina-Swiontkowski, published in Heidelberg [by Carl Winter's Universitäts-buchhandlung] can be viewed of downloaded from the following sites:

https://wellcomecollection.org/works/xyaxdznu

https://books.google.co.uk/books/about/Die_Transfusion_des_Blutes_in_physiologi.html?id=8w0UxwEACAAJ&redir_esc=y

NOTE: The title page of this book gives the author's name as 'L. von Belina-Swiontkowski' and it is therefore this name that I have used in this translation. The author's surname has been given various interpretations in other texts, including Ladislao de Belina and L. Belina-Kwiatkowski, as well as the more frequently used Belina or von Belina.

NOTE: I have also translated the 'Historical Section' of this book (pages 3-18) into English – see separate document.

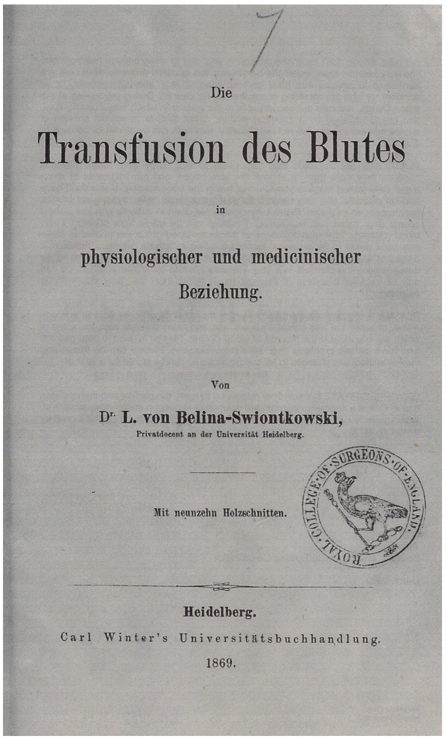
This book is essentially a review of blood transfusion up to 1869. The author starts with a section on the history of blood transfusion followed by a series of charts summarising the information for 155 blood transfusions that were published between 1819 and 1868 inclusive. These are broken down into three categories, i.e. transfusion given for uterine bleeding following childbirth (83 cases), for traumatic and neoplastic bleeding (21 cases) and for 'blood anomalies' (51 cases). Of these 155 collected cases he states that 75 had a good result, 3 had transitory good results, 5 were doubtful and 72 had no effect; in only 2 cases was animal blood used and these were both classed as 'doubtfully successful'.

As well as sections on the physiological basis for transfusion and the medical applications of transfusion the book also includes an extensive section (i.e. part four) on transfusion techniques. Belina describes and illustrates seventeen different blood transfusion devices developed and used by the people who performed the 155 cases of transfusion listed in the book. Although these include the direct transfusion device of von Graefe, the others include a large number of different types of syringes used for indirect blood transfusions, i.e. by von Graefe, Blundell, Martin, Demme, Eulenburg & Landois, Uterhart and Mosler, as well as the 'assisted pressure' devices of von Graefe, Mathieu, Moncoq-Mathieu and Richardson. The list also includes brief details of the 'newly published' items of equipment devised by Gesselius and Roussel.

Belina then identifies what he considers to be the necessary requirements of the 'ideal' blood transfusion apparatus and catalogues the difficulties in the design and applications of the syringes used for blood transfusion, which leads him into describing the indirect transfusion apparatus developed by him based on an idea by Dr Helmholtz that utilises compressed air (rather than a syringe plunder) to infuse defibrinated blood. Note: The arguments Belina uses against the 'simple syringe' are criticised by Oré in his book– see separate translation.

With regards to describing different types of equipment, this chapter is similar to that included in three other books of the same period, i.e. by Louis Jullien (1875), Joseph Roussel (1876) and Pierre Cyprien Oré (1876).

I have translated this section of Belina's book from the original German into English in the hope that the content may be appreciated by a wider audience. Whilst I am obviously aware that instantaneous computer-generated translation is possible, this process struggles with specialist terminology and also produces a 'colloquial style' not always representative of the original text. I have purposely produced this translation to be 'un-interpreted', in that I wanted to maintain the author's original meaning / wording as much as possible. As with any translation the wording may be purposely or inadvertently altered to 'make it read better' but in doing so there has to be an element of personal interpretation involving something on the lines of 'I believe that this is what the author is actually trying to say'. I wanted to avoid that as much as possible and try to present what the author actually wrote and as such the reader may find that the English text does not 'flow' as well as it could. Although I have taken great care not to misrepresent the author's original wording I cannot guarantee that this work does not contain 'translational errors' and the reader is recommended to check specific details against the original French text. I have in a small number of places included words or comments in square brackets to explain a particular term or word used by the author.



Die

Transfusion des Blutes

in

physiologischer und medicinischer

Beziehung.

Von

Dr. L. von Belina-Swiontkowski,

Privatdocent an der Universität Heidelberg.

Mit neunzehn Holzschnitten.

Heidelberg.

Carl Winter's Universitätsbuchhandlung.

1869.

Title page of Die Transfusion des Blutes by L. von Belina-Swiontkowski (1869)
(Image credit: Wellcome Collection)

THE TECHNIQUE OF TRANSFUSION

In the first attempts, when only immediate transfusion was applied, the apparatus consisted of silver tubes, which were used to try to connect the vessels of two individuals, who were brought as close as possible to each other.

In Libavius we find the first description of these tubes and the way in which they were used in the following words: “Assume that you have a strong, healthy young man rich in spiritual blood and a weak, thin, emaciated, barely breathing old man before you. If the doctor now wants to practice the art of rejuvenation on the latter, let him make silver tubes that fit one another; then open the artery of the healthy man, bring one tube into it, and fix it in it; then he opens the patient's artery and fastened the other female tube in it. These two tubes are now stuck into each other, and through this, the warm and spiritual arterial blood of the healthy overflows into the sick, and informs him of the source of life and drives away all weariness." (1)

Clarke and Henshaw only used one tube curved at both ends. (2)

De Graaf used two silver tubes that he connected to a piece of intestine. (3)

Lower and King connected the tubes to a prepared carotid or cervical artery of a horse or ox, with a third silver tube and quills. (4)

Denis and Emmerez used two rather fine tubes of silver, two inches long. One end of it is curved so that it can be easily inserted, shaped like the tip of a pen, and well polished. It also has small grooves around it to make it easier and safer to tie it in the vessel. The other end of each tube is straight and so constructed that it can be easily pushed into the opening of the other straight tube and fits exactly. Denis made the person sit on a low chair and put his elbow on the table. The animal that was placed on the table was stripped of the crural or carotid artery, and tied in two places, an inch apart, and loosely towards the heart, so that the ligature could be easily loosened. Between these ligatures the artery was opened with a lancet and a tube was tied so that the bent end was turned toward the heart. Now he opened the man's vein with the lancet as if he were performing a venesection, and let as much blood flow out as he wanted; then he took away the bandage that had been placed over the opening in the vein for the purpose of bloodletting, and put it back below the opening. Then Denis brought the curved end of the second tube into the vein, brought the animal closer to the man's arm, united the two tubes, and let the blood flow over into the person by loosening the ligature that was only loosely attached to the artery. To prevent the blood from clotting, Denis let the room warm up well.

Denis determined the amount of overflowing blood by weighing the animal before and after the operation, or by trying to determine how much blood can flow through the tubes in a given time. Six ounces flowed through the tubes in one minute in medium-sized dogs. (5) For the same purpose, after the tube was tied into the carotid of the animal, King and Lower allowed the blood to flow into a vessel for a minute, and then plugged the tube with a silver stopper. From the amount of blood, they believed they could estimate the amount of blood that was transfused in the following minutes. (6)

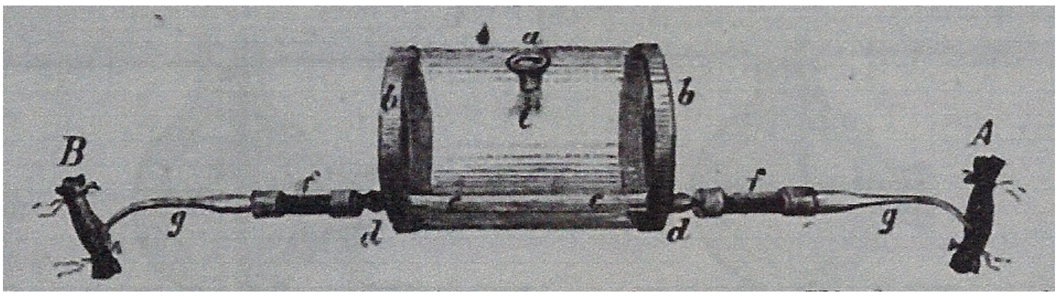


Fig. 1: von Graefe’s apparatus

C. von Graefe gave a complicated apparatus for immediate transfusion. It consists of a glass cylinder *C* (Fig. 1) with a brass frame *bb* and a tubule *a*. A glass tube *cc* runs through the middle of this cylindrical vessel. Their ends *dd* are united by elastic tubes *ff* and these again with silver tubes *gg*, the curved ends of which are tied into the corresponding vessels. Before the operation, the vessel is filled with hot water in order to maintain the temperature of the blood in the glass tube at the same level and to protect it from clotting. However, since the elastic tubes and the rather long silver cannulas are not heated and are very thin, the achievement of the desired purpose is illusory. (7)

Blundell's apparatus (8) consists of a syringe *A* (Fig. 2) which holds 11 drachms of liquid and is made of copper, taken from the reservoir *D*, for collecting the blood. This is triangular in order to prevent the blood from rotating when it flows in and is connected by means of a brass tube *klm* and a double-drilled tap *e*. The outflow tube *hfg*, made of leather, is connected to the tap by a screw thread and ends with a tube *I*, which is inserted into the vein. The construction of the stopcock is illustrated by Figures B and C; *adb* (Fig. B) shows the tube through which blood escapes from the syringe when tube *c* is closed; *adc* (Fig. C) denotes the tube through which the blood enters the syringe when tube *b* is closed.

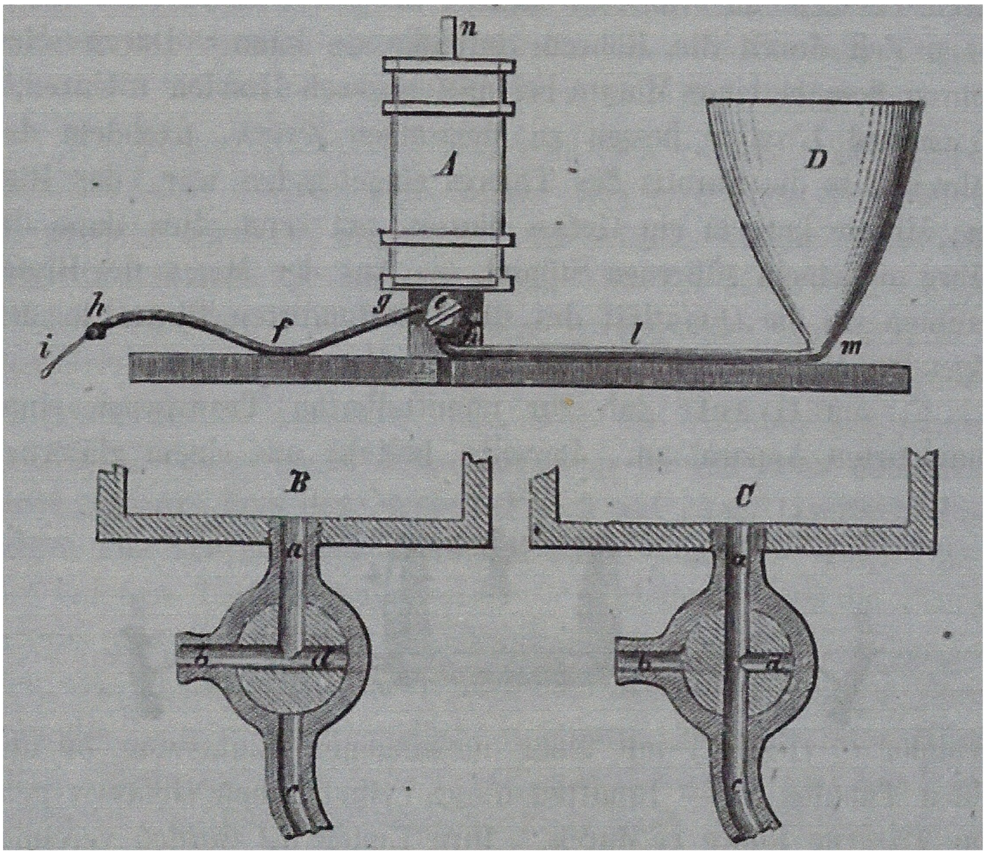


Fig. 2: Blundell’s apparatus

If one wants to use this apparatus, one first gives the patient a suitable position near the apparatus. After the blood from the healthy person has been collected in the reservoir *D*, the stopcock *e* is set in such a way that communication between the tube *klm* and the syringe is established and the syringe is now filled by pulling the plunger *n* upwards. Then the stopcock is set so that the earlier communication is closed and the syringe is only brought into contact with the leather tube *hfg*, and the blood is passed into the open vein of the patient through the end tube *i*, which is inserted into the vein towards the heart, by pressing the plunger down.

Blundell reported another device he called the Gravitator. This consists of a triangular reservoir for collecting the blood, which opens into an elastic tube that can be closed by means of a tap and can be screwed to a table by a movable support arm. The elastic tube ends in a narrower silver tube with a polished end. The blood is transferred here by its own weight according to hydraulic laws. (9)

C. von Graefe sought to improve Blundell's syringe apparatus. Fig. 3 illustrates the same; *ab* denotes the reservoir of strong, white, transparent glass. In this there is a glass funnel *cc* for holding the blood, as well as a suction and pressure pump *d*, the pump tube of which is also made of glass.

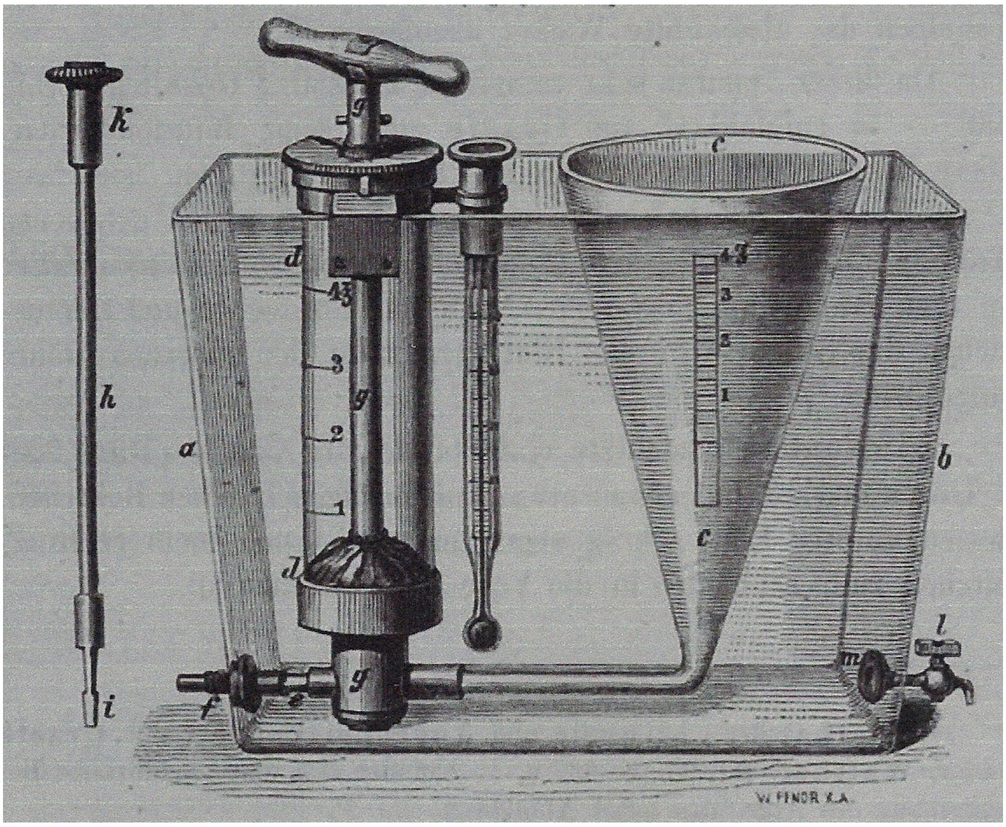


Fig. 3: von Graefe's apparatus

It communicates on its lower part and on one side with the glass funnel, on the other with the glass tube *e*, which opens out through an opening in the side wall of the reservoir at *f*. Before the operation, the reservoir is filled with hot water in order to keep the blood to be transfused at the necessary temperature. The reciprocal communication with the glass funnel and the tube *f* is accomplished by rotating the stamp *gg* and the shaft and its capsule located in it at the same time. The elastic, 4-inch long conduit tube *h* is inserted with its end *i* into the vein, with the other *k* on the other apparatus at *f*. Scales are attached to the funnel and the pump tube to indicate the content of these parts in ounces and drachms; there is also a thermometer in the glass reservoir. At *m* the reservoir has a tap *l* in order to drain the cooled water. (10)

Since this apparatus is very complicated and requires four assistants, C. von Graefe also recommended his infusion syringe. He had these made of silver for transfusion; it holds 1½ ounces. He also gave a special gently curved trocar with a silver tube and a pointed stylet and named it a Phlebotome. After the stylet has been pierced and withdrawn, the blood is injected through the silver tube. (11)

Dieffenbach used a syringe made of tin. This holds two ounces and is provided with a somewhat knee-shaped bent tube, the lower end of which is cut off at an angle and has several annular furrows for tying into the vein. (12)

The syringe from Blasius is made of glass with hard rubber attachments and hardly holds one ounce. The discharge tube fits into a slightly curved hard rubber tube two inches long.

Lloyd in London used a tinned brass syringe with a collecting funnel. The discharge pipe fits snugly into a winged tube. (13)

Sotteau (14) and Tietzel (15) gave insignificant modifications of Blundell's syringe device; Bougard tried in vain to improve Blundell's Gravitator. (16)

In 1853 Mathieu constructed his first transfusion machine – illustrated in Fig. 4. It consists of two vulcanized rubber balloons, which are connected with glass tubes and a corresponding ivory discharge tube. By virtue of their elasticity, the balloons can automatically take on their previous shape after being squeezed out, and so with appropriately designed ball valves they act as suction and pressure pumps. The valves, however, showed themselves to be very inadequate, stuck together, and since the apparatus could not be cleaned sufficiently, it can only be used for clystieren [sic – translates as clysing / clysts?]. (17)

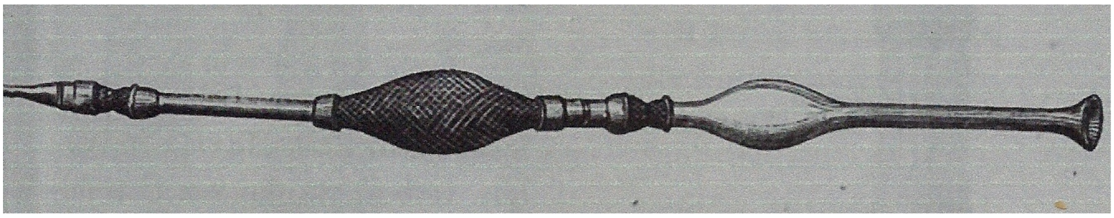


Fig. 4: Mathieu's first apparatus (1853)

Mathieu's second apparatus is a modification of Blundell's syringe apparatus that is similar to von Graefe's. This is (Fig. 5) a suction and pressure pump *B*, which is moved by means of the punch *A*. *D* is the receiving reservoir with its inlet opening *H*. *F* is the ivory discharge tube; *CC* is a glass cylinder that is filled with hot water. *G* denotes a thermometer that is fitted in a corresponding opening. In the cylinder are the glass tubes that connect the reservoir *D* to the pump and the pump to the discharge tube. (18)

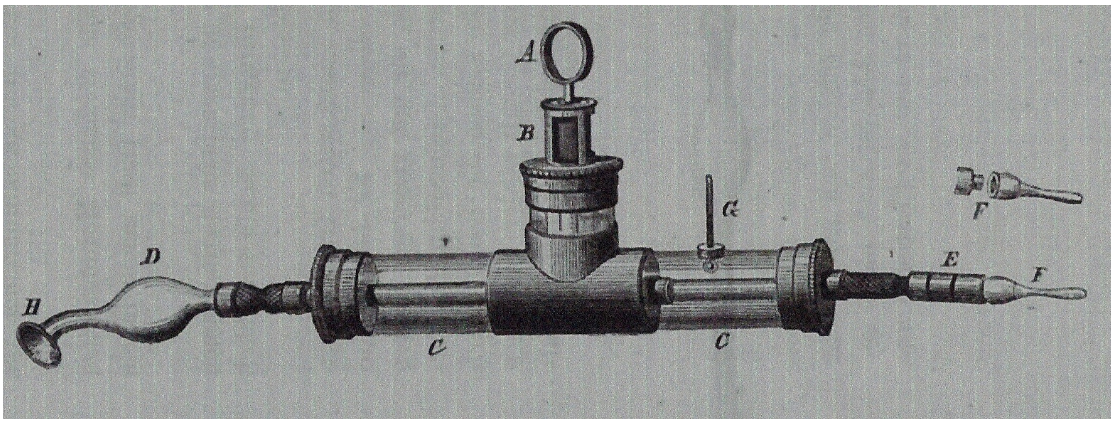


Fig. 5: Mathieu's second apparatus

My esteemed teacher, Professor Geh. Rath Martin in Berlin improved the von Graefe's transfusion syringe by swapping the silver syringe for a glass one. His apparatus consists of:

1. A syringe (Fig. 6) *1* made entirely of glass, 7 inches long. It holds a generous two ounces and has a glass embolus wrapped in cotton threads. Fresh cotton is always attached after use.

2. A smooth, moderately curved trocar at the tip for opening the exposed vein and for injecting the blood. It is 4½ inches long, 1½ inches wide from the tip, ¾ inches thick, casually curved in a 2 inch radius. The square-edged tip of the trocar protrudes 2 inches from the opening of the silver tube. The handle is 3 inches long. The silver tube has a funnel-shaped attachment on top that is wide enough to accommodate the tip of the syringe. This mouth is covered with a thin black rubber plate, partly to hold the syringe more firmly, partly to prevent regurgitation of the blood during the operation; *2* is the trocar's stylet; *3* the silver tube without the rubber plate; *4* the trocar. (19)

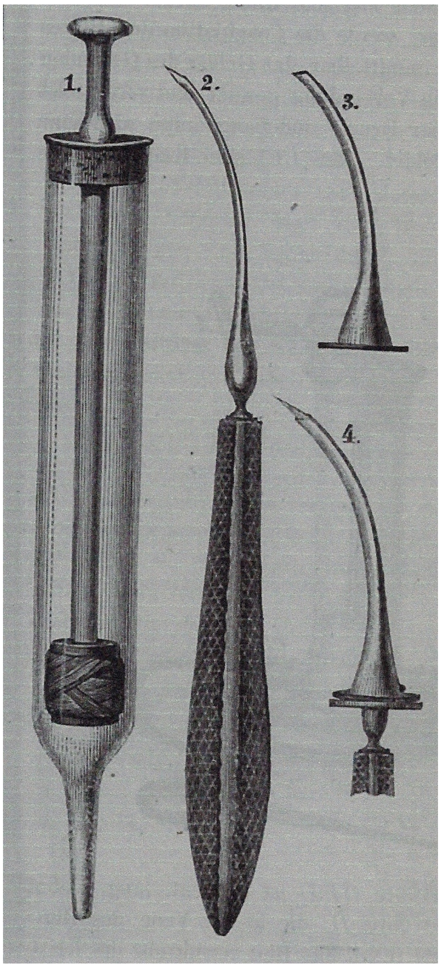


Fig. 6: Martin's apparatus

In 1862, Dr. Moncoq of Caen designed a new pump apparatus constructed by Mathieu – illustrated in Fig. 7. The rubber tubes are very narrow and thin, as is the discharge tube. This he believed would prevent the blood from coagulating. The vessel of the healthy person is directly connected to the vein of the patient and a kind of systole and diastole pressure is formed by the movement of the plunger and suction pump – with CC' flap valves attached. The capillary tube *CED* is ten centimetres long, ends in a small, straight silver tube *D*, which is inserted into the vein of the blood donor and leads the blood through valve *C* into the pump cylinder. Another similar tube, $C'E'D'$, carries the blood into the patient's vein. The silver end tube of this second tube - after all the air has been driven out of the apparatus by the blood - is connected with a trocar tube that has previously been brought into the patient's vein by means of a suitable stylet. The piston of the pump is moved by turning the handle *A*. (20)

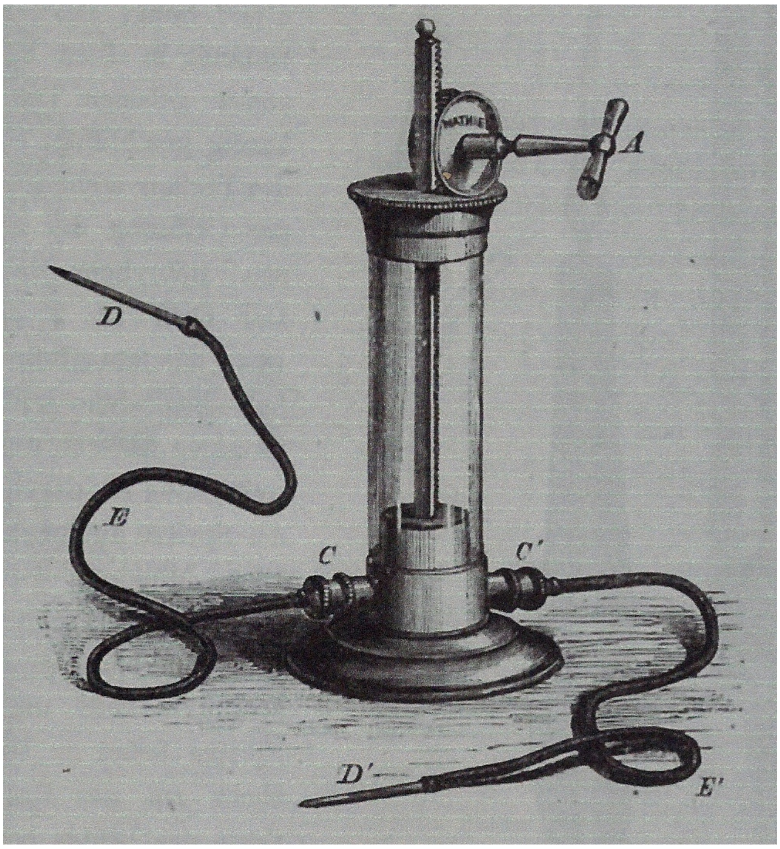


Fig. 7: Moncoq-Mathieu's apparatus

In 1864 Moncoq exchanged the trocar, as well as the discharge tube, with a needle, shown in Fig. 8, which is curved and hollowed at half its length and ends in a point at the front.

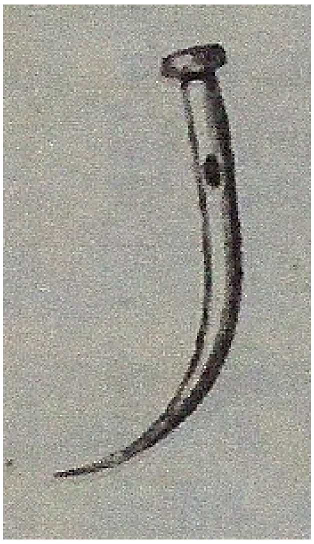


Fig. 8: Moncoq's needle

The canal running in it ends 15 millimetres from the pointed end with a lateral opening. In both healthy and sick people, a needle is pierced through the vein so that the lateral opening comes to lie straight into the lumen of the vein, directed towards the centre, and the blood can immediately be driven over and enter the vein by means of the hollow of the needle connected to the apparatus. (21)

My esteemed teacher, Prof. v. Nussbaum in Munich, uses a tin-like cyst syringe and an elastic tube for the transfusion. He describes (22) the performance of the operation in the following way: “The drawn blood is whisked and filtered through a piece of pure canvas and kept moderately warm. I put a bandage on the arm of the patient above and below the transfusion site, expose a swollen vein, open it with a fine scissor so that I get a very small transverse wound, and insert a small elastic cannula filled with distilled water, which is plugged with a cork stopper so that the water does not run out and no air can enter."

Fig. 9 shows the elastic cannula, the two ends of which, *a* and *b*, are made of silver. “The cannula is now held in place in the wound by an assistant. As the wound is very small, it is quite well plugged by the conical end *b*, and you do not have to tie up the vein with a thread.

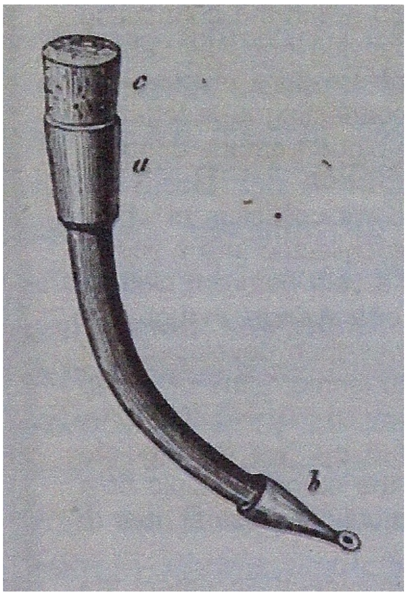


Fig. 9: Nussbaum’s cannula

Now I fill a good pure tin syringe with ½ pound of blood, taking care that no air remains in the syringe, take the cork stopper out of the cannula, insert the syringe and inject very slowly after I have opened both bandages. Convulsions often occur during the injection, which is why you have to hold the arm well. If you want to inject one pound, just fill the syringe a second time. The bandage dressing is like one for bloodletting."

Demme uses the system of syringe attachment that is customary for subcutaneous injection and with the same he opens the vein subcutaneously. His apparatus (23) is aligned with the French one and is constructed as follows: “A suction pump is connected to the pressure pump (Fig. 10), which keeps the dangerous space formed when the syringe is emptied continuously filled with blood, thereby preventing the entry of air and saves the need to remove and fill the syringe. The piston fits into a precisely calibrated glass tube holding 2–3 ounces, and its sufficiently large button can be pressed safely and evenly with the ball of the hand. At the lower end of the tube there is a brass attachment, which opens into two tube attachments of smaller calibre and can be unscrewed for cleaning. One of these approaches is intended for sucking up the blood, the other for flowing it out. The suction opening has an inward-looking cone valve, which lifts and lets the blood flow in the moment the plunger is lifted. A hermetically closing, elastic hose of short length that fits on the one hand to the suction opening and on the other hand dips under the blood level of the wooden collector, allows the blood to rise into the glass chamber of the syringe. The discharge approach of the syringe is attached to the trocar cannula. It contains a cone valve that opens outwards."

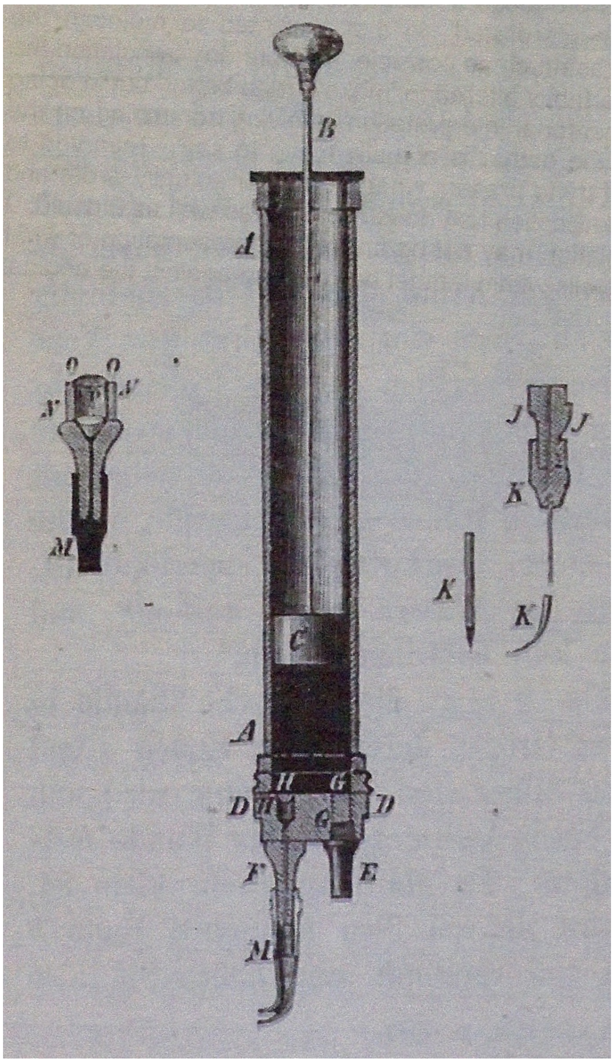


Fig. 10: Demme's syringe

"The syringe is drawn at the moment when the plunger is pulled up and the suction valve is open; the black space denotes the resulting filling with blood. The glass compartment of the syringe *A*, holding 2-3 ounces of blood; *B* the plunger; *C* the piston. *D* screwed brass attachment and from it, *E* unscrewable discharge attachment, *F* unscrewable suction attachment; *G* outward and *H* inward opening valve; *I* extension piece for attaching the lance cannula. *K* lance cannula in connection with the attachment, in side and front view. *M* elastic hose that fits to the suction attachment and creates the connection between the syringe and the blood collector; *N* the end of the tube (zinc or brass drum) immersed in the blood. *O* and *P* coarser and finer wire mesh to hold back clots. The first filling is best sacrificed completely before plugging in the syringe, because at the beginning the air contained in the elastic tube penetrates; further air entry is then impossible. An experimentally determined scale can be attached to the plunger."

In 1866 Mathieu presented his perfected apparatus to the Paris Academy, (24) which is illustrated by Fig. 11. *A* is a reservoir that opens into a pump tube by means of a flap valve. *HD* represents a plunger, which is pierced in its entire length and forms a canal that is connected to an elastic tube. This is provided with an end tube that is pushed into the trocar cannula. The blood is caught in the reservoir and by moving the plunger with the handle *B* the blood goes into the pump tube and is driven through the plunger channel into the elastic tube and vein of the patient. *G* denotes the mediating cannula provided with an obturator.

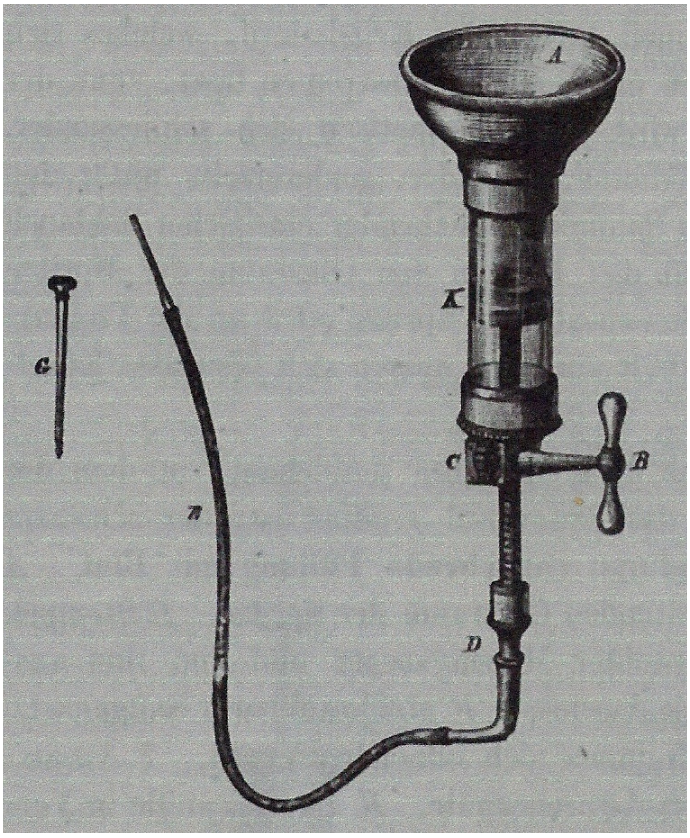


Fig. 11: Mathieu's apparatus

In the same year Eulenburg and Landois announced a new apparatus, the construction of which is aimed primarily at preventing air bubbles from entering the vein. It consists (25) of a syringe, an air trap and a cannula or trocar. The body of the syringe is made of glass. A cubic centimetre scale is etched into it.

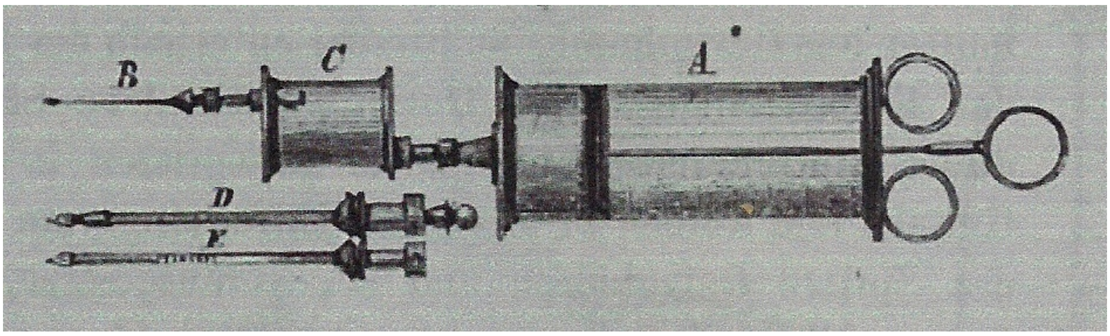


Fig. 12: Eulenburg and Landois' apparatus

The syringe itself *A* (Fig. 12) is provided with hard rubber attachments at the top and bottom, one of which carries the one inch long conical discharge tube to the attachment of the infusion cannula; the other guides the metal plunger rod in the central perforation point. The latter, as well as the plunger rod, are provided with rings on which the syringe can be held with the fingers of one hand during use. The interior of the syringe is able to hold 5-6 ounces of liquid.

Tube *B* of the cannula, attached to the outflow tube of the syringe, has a one millimetre diameter when exposed and has a rounded button at its end. The cannula is never inserted individually, but is always fitted to the filled syringe beforehand and filled with blood by moving the plunger. For subcutaneous transfusion, a special cannula *D* is recommended with a rounded button at the end, into which a stylet is inserted, and another stylet cannula *E*, modified according to Moncoq's needle, with a lateral opening.

The air trap *C* is a 1¼ inch long metal drum of elliptical cross-section. The height of the ellipse is 1 inch and its width ¾ of an inch. The syringe adapter and the discharge tube are attached to the two elliptical end faces in such a way that the former opens into the metal drum on one end faces hard on the upper edge of the ellipse, the latter on the other end faces hard on the lower edge of the ellipse into the metal drum. The discharge tube extends a little further into the interior of the drum, and there it is directed downwards in a concave curve, so that the inlet opening looks straight down. Before use, the entire cannula is filled with blood, and after it has been inserted into the venous opening, the syringe attachment is always held upwards. It is now clear that if air bubbles also get into the air trap through the syringe attachment with the injected blood, it will immediately enter under its upper ceiling, while the blood goes down. In this way the opening of the discharge tube will always lie under the blood and remain there, even if larger air bubbles have entered the air trap.

Uterhart simplified this apparatus by including the air trap in his syringe itself. (26) The glass syringe with a hard rubber frame is 15 centimetres long and 3 centimetres in diameter when exposed, it holds 4 ounces 6 drachms of water. At the end of the syringe, the extension tube is not in the middle, as with other syringes, but on the periphery of the end disk. Around the metal plunger rod, which moves through the socket of the syringe in a smooth tube, runs a narrow screw thread on which a flat screw nut made of hard rubber sits directly below the ring of the plunger rod. When this nut is in different positions, it is possible to hold the plunger at a greater distance from the bottom of the syringe and so, provided that the peripherally located tube is held down, to create a space that is completely identical to that of the syringe corresponds to separate Eulenburg air trap. Graduated lines on the plunger show the filling of the syringe to within half an ounce. Fig. 13 represents the syringe in average. [mid-point?]

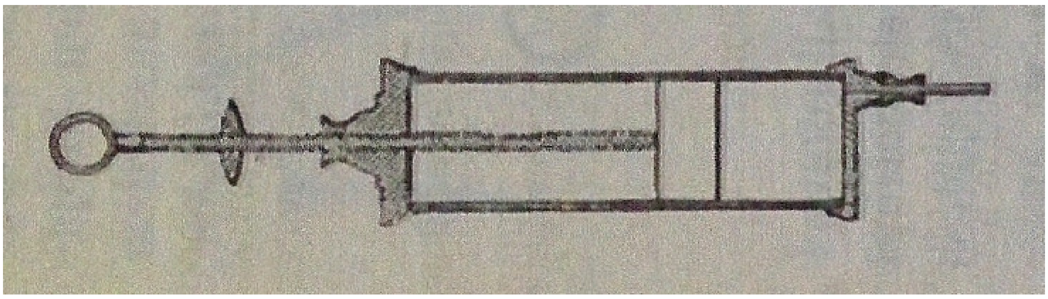


Fig. 13: Uterhart's apparatus

The Richardson apparatus (27) is illustrated by Fig. 14: *aa* is a graduated beaker that, for reasons of stability, is fused onto a broad glass base *ff*. This beaker has a glass extension piece at a/, which is intended to receive the cork *i* and the rubber tube *mmm*, several cubits [sic] long, with its moderately curved metal end tube *l*. A wire with two diametrically opposed eyelets is tied around the neck *h*. The neck is plugged by a pierced rubber stopper *c* which is held in place by springs *dd*, which are hooked into the eyelets of the neck wire, so that the rubber stopper is retained in the neck of the beaker. The pierced rubber stopper *c* carries a short metal tube *e* to which the pressure pump, *ppp′* is attached. Finally, at *b* one sees a small rubber ball that children have to play with, which has a small lead head *q* at one point, which forces the little ball in the same position everywhere in the liquid. If any quantity of blood or some other infusion liquid is poured into the beaker through the neck *h*, the same is closed by the rubber stopper *c* and secured in the closure by the wire spring *dd*, then when the liquid reaches the level *nn*, the air-containing rubber ball *b* floats on the water. If the wire clamp *k* is removed, the liquid will flow out through the metal end piece *l*. The speed of the outflow and the pressure with which the liquid emerges at *l* can be increased as required by the level difference between *nn* and *l*, which is the hydrostatic pressure height. If, however, the resistances in the veins or in the tube *mmm* becomes very large for some reason, and the infusion fluid cannot enter the body, then one need only set the elastic pressure pump *p′* in motion, which pumps air into the space above the liquid *nn*, which presses on the liquid like in an air chamber and drives it uniformly into the vein equal to any pressure. When so much liquid has been infused that the level *nn* sinks down against the constriction of the beaker *gg*, then naturally the ball *b* sinks down to *b′* and blocks the narrow opening. If the pressure pump is now also set in motion, the ball *b* will assume the shape *b′*, squeeze into the constriction *gg* and neither let liquid nor air pass through *l*.

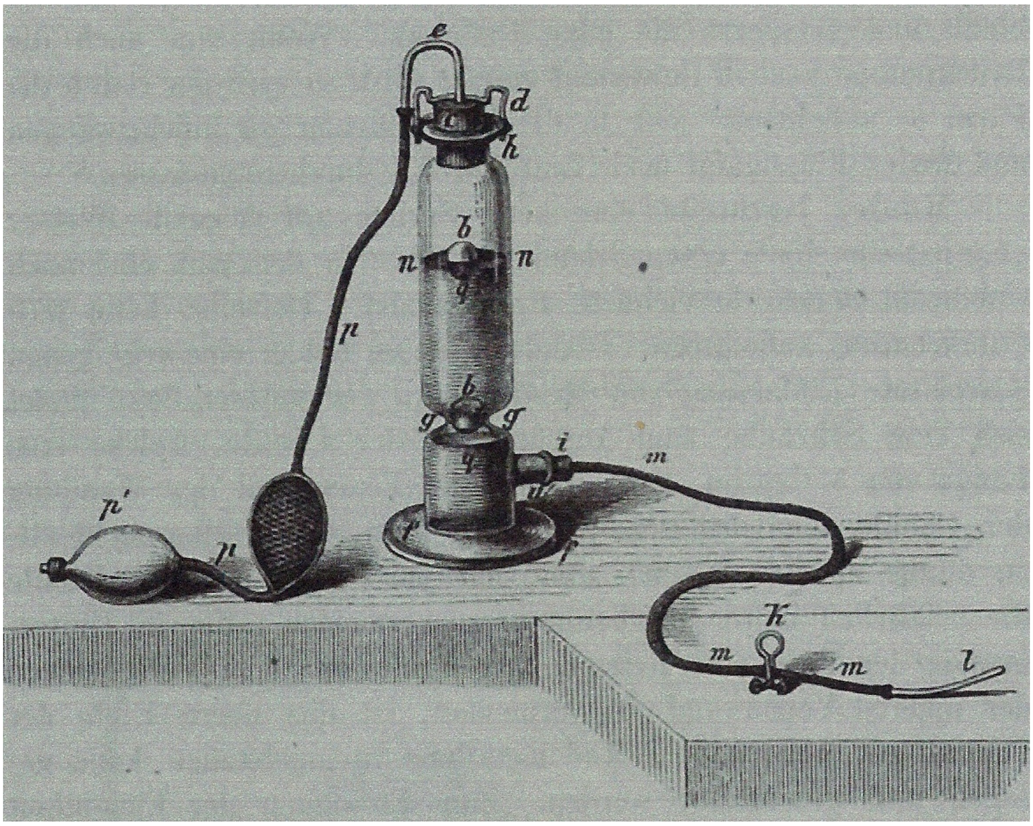


Fig. 14: Richardson’s apparatus

Mosler describes a new syringe in the following way: “It has a body made of glass (28) in which there is a scale marked according to cubic centimetres, which can take up to 270 cubic centimetres. Above and below it has a very precisely worked frame of brass. On the lower side there is a screw for screwing on the cannula, which is five centimetres long. In order for the vein wall to lie as close as possible to the wall of the cannula, I did not have it made too thin, especially since I consider any binding of the cannula to be dangerous, and I advise, to avoid causing irritation in the background of the vein. In order to avoid injuries to the inner vein wall, the upper end of the cannula is well rounded. The metal stamp rod can be pulled and screwed. To suck the liquid into the syringe, the plunger rod is drawn up slowly and carefully. After filling the syringe, the device located at the upper end is used. Two metal arms are fixed to each other by means of a hook so that the screw thread of the punch engages in the screw nut of these two arms. The disc at the upper end of the plunger rod is then carefully turned from left to right, the plunger and its piston sliding very gradually downward, and the liquid in front of it being injected in a steady stream from the cannula. Numerous experiments that I have made with filling and spraying my device have made me realize that this screw movement makes the flow rate of the outflow fairly uniform and that handling is also very simple. The round opening, which is located on the brass disc at the lower end of the glass body, is exactly in the middle and has a very small circumference. As a result, the air in the body is more difficult to expel when the syringe is held vertically. If I had intentionally left a lot of air in the syringe body in addition to the liquid, the air was only expelled when all the liquid had been drained when the syringe was held in this position. Since the main thing with a transfusion must always be to have a large amount of blood ready, I consider it better to push the plunger downwards only to the 30 cc scale mark. Then, if the syringe is held vertically, you have complete security that no air can enter the veins, and in my experience a specially designed air trap is not required for my syringe."

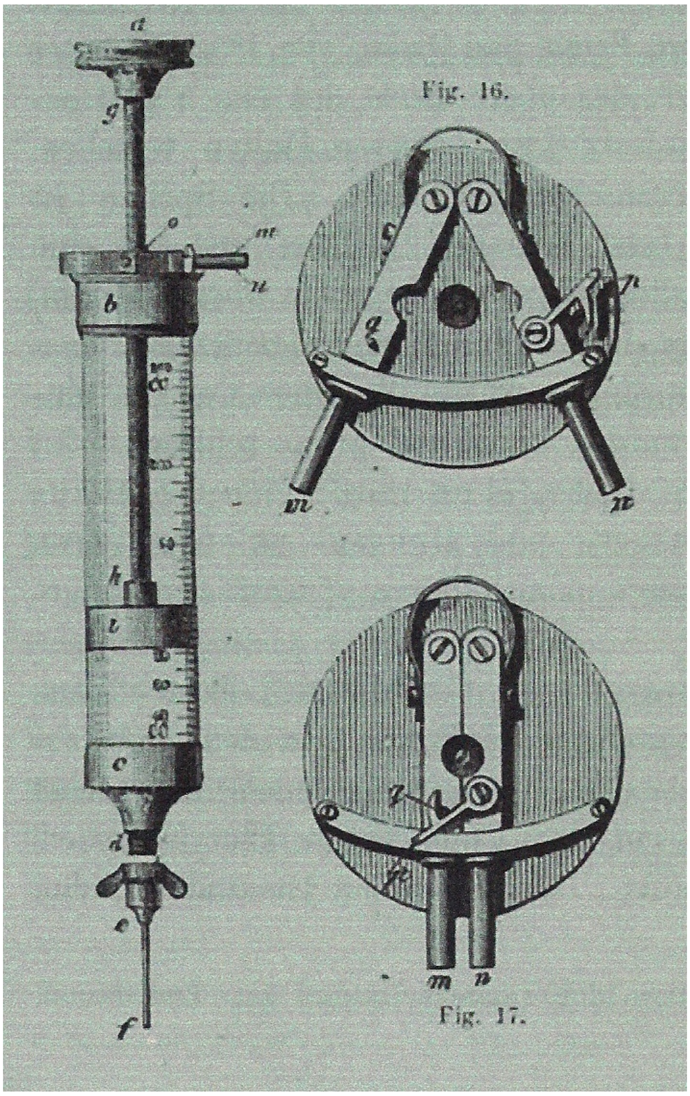


Fig. 15, 16, 17: Mosler's syringe

Fig. 15 shows the syringe as it is used during the transfusion: *a* the disk on the stamp rod, which is turned from left to right, *b-c* the glass body on which the cubic centimetre graduation is ground, which has a brass border at both *b* and *c*; *d* the screw for the cannula, which from *e-f* has a length of 6 centimetres and is made of steel; *g-h* the screw-threaded piston rod; *i* the leather-covered piston attached to it; *o* the opening of the screw nut into which the screw turns of the piston rod engage; *m* and *n* the two arms of the device, seen from the side, and described in more detail in Figs. 16 and 17, drawn in the open and closed states from above.

Fig. 16 shows in natural size the brass disc at the upper end of the syringe plunger, which forms part of the enclosure *b*; o the opening for the plunger rod *g-h*; *m* and *n* are two movable arms made of steel, which come closer to each other, then at *o* grasp the stamp rod firmly between them. To fix the two arms, the cock *p* is attached to the protruding pin *q*. Fig. 17 shows the same device with the movable arms *m* and *n* approached and the hook *p* attached to the projecting pin *q* to fix them.

For my first experiments on animals and humans I used Martin's apparatus which I modified. The difference is that the trocar cannula is only 3 centimetres long, i.e. so it is ⅓ shorter, very straight, at both ends of the same width and thickness, 1½ millimetres in diameter, the upper end is provided with a plate-shaped attachment for better holding. Figure 18 illustrates this. The syringe is made of glass, holds nearly two ounces, and has a silver discharge tube, a little over a millimetre in diameter, and is so constructed that it can be pushed one centimetre into the trocar cannula and closes exactly.

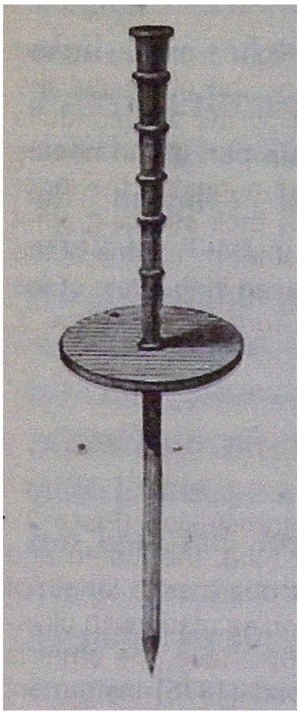


Fig. 18: Belina's modified cannula

In the course of that year, Gesellius in St. Petersburg and Roussel in Geneva announced new devices for immediate transfusion.

Gesellius's apparatus (29) consists of a glass cupping head in which an airtight cupping catch moves; on one side is an air pump, on the other a glass cylinder with a capacity of 150 cubic centimetre of blood. The latter is provided with glass taps at both ends. The cupping head as well as the cylinder are surrounded by a rubber jacket, which is designed to absorb water at 34°R. A stylus needle, like Moncoq's needle, is attached to the free end of the cylinder. The blood is taken from the capillaries of the blood-giving individual by means of the cupping head, and is collected by the perpendicularly hanging cylinder; from this the blood is then supposed to be driven by its own weight into the patient's vein according to hydraulic laws.

Roussel (30) describes a similar instrument. The blood is also drawn here by means of a cupping head, but from the arm vein, which is opened with an attached lancet instead of the cupping catch. To prevent the air bubbles from getting in, this adventurous vein section is done underwater. The glass cylinder that receives the blood is also filled with water before the operation and this is then be gradually displaced by the inflowing blood.

For successful use, a transfusion machine must meet the following requirements:

1. It must be able to be kept absolutely pure.
2. To hold the necessary amount of blood, be easy and safe to handle.
3. The blood must be kept in the apparatus in the appropriate temperature.
4. It must be impossible for air bubbles to get into the vein.

The longer time in the physiological institute under the direction of Prof. Geh. Rath Helmholtz experimentally dealing with the transfusion of blood, I have sufficiently convinced myself that the apparatuses used up to now are extremely inadequate to meet these requirements.

Apart from the great technical difficulties involved in grinding out a larger syringe body, it is also very difficult to unite the metal or hard rubber end pieces with the body so tightly that no gap remains between them. In use this gap fills with blood, cannot be cleaned afterwards, the blood decomposes, and the blood to be transfused may be infected with repeated use. The emboli, which mostly consist of leather caps and are smeared with fat, are very difficult to keep absolutely clean even in the long term. The leather always sucks in some blood, the grease goes rancid, small leather particles detach from the edge of the cap, and in this way the blood is only too easily contaminated.

As we have seen above, Prof. Martin, whose transfusion apparatus is relatively the best, tries to prevent this by making his syringe completely out of glass, the plunger also glass and the embolus from cotton that is freshly attached for each operation. However, this syringe can only be very small, not all the blood can be squeezed out of it and it has to be filled several times and brought into contact with the 4½ inch long trocar tube, since the tube with a funnel-shaped attachment rarely remains completely filled with blood, easily gets air bubbles in the vein. The vein is also very easily irritated when the syringe is pushed in and taken out and the plunger is handled, which is not easy to achieve evenly.

The French pump apparatus with its long and thin elastic tubes can be cleaned much less well, as can the ball with the leaden weight in the Richardson apparatus. Not all blood can be injected from the latter, and the blood from the narrowed point on the beaker to the discharge tube remains in the apparatus and this will probably be more than two ounces. It is also impossible to keep the blood in the long, elastic tubes at the necessary temperature; it mostly comes out of the discharge pipe completely cooled, and even if it is defibrinated, or not coagulated itself, it coagulates the blood in the vein and also causes shaking chills.

Prof. Go. Rath Helmholtz gave me excellent advice, instead of using plunger pressure, use air compression pressure to drive out the blood. In accordance with this principle, I have put together the following apparatus illustrated in Fig. 19.

It is an elongated, graduated, glass bottle holding 300 cubic centimetres. An air compression pump is attached to the opening of the tubule *b*. This consists of a rubber balloon *c* and a tin-plated brass attachment with two ball valves at *d* and *d'*. The balloon can easily be grasped by the hand; its diameter is approximately six centimetres. At *e*, the mouth of the two centimetre-long extension pipe of the pressure pump is covered with a double-folded dense gauze to keep the dust and organic germs out of the forced-in air. The neck of bottle *f* is on average half a centimetre thick and a six centimetres long rubber tube *ff'* connected to an infusion trocar designed by me. This consists of two interconnected silver tubes and a stylet. The two centimetres long tube opens into the other five centimetres long tube *hh'* at a right angle with a downward curve. The thickness of both tubes is a little over two millimetres. The stylet *ii'* fits exactly into the tube *hh'*. Its three-edged tip protrudes three millimetres from the opening of the silver tube. At *k*, a spring is attached which, when the stylet is pulled out to *n*, falls into a groove on the same, thus preventing the stylet from being pushed out further.

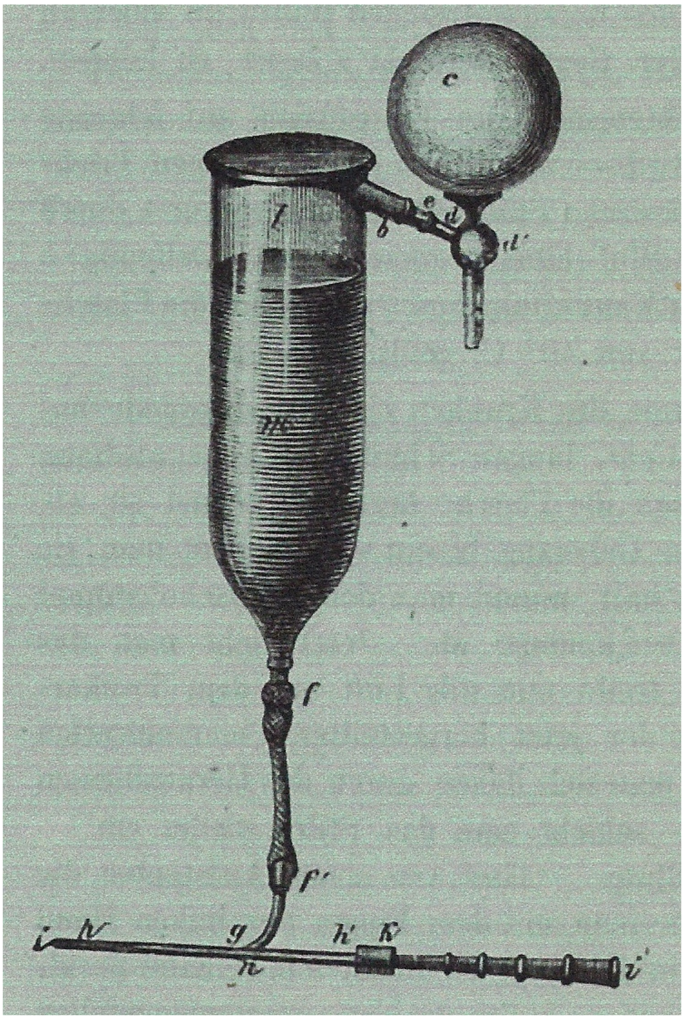


Fig. 19: Belina's apparatus

In order to keep the blood from a significant drop in temperature, the bottle has a woollen coating on which an incision is made to see the level of the blood and to be able to read the amount of blood that has leaked out on a centimetre scale located on the bottle.

In humans, the transfusion is carried out in the following way. The blood, defibrinated with a glass rod and filtered through a thick canvas, is poured into opening *b* by means of a glass funnel. The opening *b* is closed with a rubber stopper and the bottle is placed in a vessel filled with warm water at 40°C.

After putting a bloodletting bandage on the arm of the patient and with a one centimetre long incision has exposed the median vein, take out the bottle, dry it, push it into the woollen cover, and while holding it neck down, take out the rubber stopper and attach the pressure pump. The stylet is now pulled up to *n* and the blood now drives all air out of the trocar tube in the direction of the communication *fgh* that has now been established, and after having made sure of this by the flow of blood, the stylet is pushed back in. Clean the blood from the trocar; let an assistant hold the bottle and by fixing the vein with the finger of the left hand, the trocar is stabbed in it with the right in an almost parallel direction. Should the vein have collapsed, it is advisable to make a minimal incision in it, and, with the tip of the stylet lifting the wall of the vein, push the trocar into the latter. The bloodletting bandage is now loosened, the arm and the trocar are fixed by the assistant, the bottle is taken with the left and the elastic compression pump is handled with the right.

Each time you press the balloon, you get 40–50 cubic centimetres of air into room *l*, the air there is compressed and presses on the blood *m* as in an air chamber. By appropriate handling of the pressure pump and regulation by partial insertion of the stylet, which can be used here like a cock, one is able to let the blood flow safely and evenly into the vein.

This apparatus, which can easily be constructed anywhere with ease, meets all the requirements set out above, and also has the advantage that it is brought into direct contact with the vein, and the movements of the bottle when the compression pump is operated are reduced by the elasticity of the connecting tube, does not get passed on to the trocar and the vein wall is not irritated. The apparatus is easily portable, requires little assistance, and can also be used with advantage for infusions and histological injections. (31)

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