A CASE

OF

ANEURYSM OF THE ABDOMINAL AORTA TREATED BY THE INTRODUCTION OF SILVER WIRE

WITH A DESCRIPTION OF INSTRUMENTS INVENTED AND CONSTRUCTED BY MR. G. H. COLT TO FACILITATE THE INTRODUCTION OF WIRE INTO ANEURYSMS

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THE patient, a farrier, aged 29, was accustomed to perform heavy work in a stooping position. He had acquired syphilis at the age of seventeen, but had only been treated with mercury for a short time. Three and a half years ago he first noticed something beating in the right side of his abdomen, and since that time he had been continuously under treatment in some hospital or infirmary. On five occasions he received injections of gelatine in the gluteal region, but they had not produced any marked change in the swelling, which increased steadily in size.

On examination he was found to be a sallow, unhealthy, and anæmic man, addicted to morphia. His heart and lungs were reported to be normal. His pulse was regular, but poor in volume, and the radial arteries felt thickened. There was a throbbing area of skin in the epigastric and upper part of the umbilical region, which, at its highest point, seemed to be raised about three quarters of an inch above the level of the surrounding skin. The throbbing was expansile in character, and there was a well-marked bruit, which persisted when the patient was examined in the knee-elbow position. The pulse in the femoral arteries was equal and synchronous. The swelling was diagnosed as an abdominal aneurysm, and more probably an aneurysm of the cœliac axis or of one of the branches than of the abdominal aorta.

The sac of the aneurysm was very thin at one or two points, and as the life of the patient seemed to be in danger, it was decided to expose the sac, and either ligature the artery from which the aneurysm arose, or, if this were impracticable, fill the sac with silver wire.

When the operation had been decided upon my attention was drawn to the fact that Mr. G. H. Colt, one of my dressers in the Throat Department at St. Bartholomew's Hospital, had devised and made an instrument for this purpose. When I had seen the instrument I immediately decided to use it in preference to the more usual method.

I cut down upon the most prominent part of the swelling until an exposure of the sac showed that it would be hopeless to ligature the artery, as the sac was densely adherent to the surrounding structures. No coils of intestine lay between the parietal and visceral layers of the peritoneum in front of the aneurysm. I determined, therefore, to wire the sac, and eighty inches of silver wire, with a clotting surface of 3·7 square inches, were rapidly introduced into the aneurysm by means of the new instrument (described later as instrument No. 1). The needle was then withdrawn, the wire was divided, its end was bent up and it was pushed into the sac, the hole being easily closed with a few Lembert's sutures. The operation lasted thirty minutes from the time the patient was placed upon the operating table until he was removed. The actual introduction of the wire only took two and a half minutes, but even this time might be shortened on a future occasion. The pulse during the operation was 88 and the respirations 20. The operation was performed at 4 p.m., and the patient had a quiet night after a hypodermic injection of morphia at 10.30 p.m. On the following morning (January 21st) his abdomen was soft, his respirations were 18, and his pulse-rate was 136. He complained of abdominal pain over the aneurysm and of pain in his back. A second hypodermic injection of morphia was given at 10 a.m., and the patient then slept quietly for several hours. At 2 p.m. the pulse was 136—144, and at 7 p.m. it was 146. He was ordered two drachms of milk and water every hour, and he was kept under the influence of morphia. There was no evidence of gangrene, nor did he complain of any numbness or tingling in the legs. At 9 a.m. on January 22nd the patient was complaining of pain in his back, his pulse was 160, and his temperature was 101° F. The wound was dressed; it looked healthy. The abdomen was tender, resonant, and showed impaired movement. The right side of the aneurysmal swelling was hard, and did not pulsate, but there was distinct pulsation on the left side. The patient was now taking an ounce of milk and water every hour, and he was reported to have vomited twice, bringing up a small quantity of "coffee-ground" substance the first time, and half an ounce of bile-stained fluid on the second occasion. He still complained of pain in his back, his pulse increased to 170, and he gradually sank, dying at 6.20 p.m. on 22nd January, 1903, about fifty hours after the operation.

The post-mortem examination showed an aneurysm of the size and shape of a large orange projecting forwards from the abdominal aorta between the layers of the transverse mesocolon. The sac was somewhat compressed laterally, and was developed from the aorta itself, the dilated portion of the vessel being about three inches in length, and extending downwards from just below the diaphragm. The great omentum immediately below the greater curvature of the stomach had been torn through at the time of the operation to reach the anterior surface of the sac. On cutting across the aorta just above the diaphragm a loop of silver wire seven inches long was found projecting into the arch of the aorta, but the rest of the wire was irregularly coiled within the sac of the aneurysm. All the other abdominal organs were healthy; the lungs were normal, and the heart was free from disease, except that the pericardium was adherent in places. The aneurysm and aorta were hardened in formalin before a section was made.

There is nothing particularly new in the treatment of aneurysm by the introduction of wire, and I should not have ventured to bring this case before the Fellows of the Society unless I had thought that the apparatus invented by Mr. Colt was sufficiently novel and useful to make it worth while to draw special attention to it. Hitherto the surgeon has been content to puncture the aneurysm with a fine trocar and cannula; he has then withdrawn the trocar and forced the wire through the cannula, from which blood was often flowing with considerable force. The amount of wire introduced in this manner has varied with the time at which the occurrence of kinking arrested its further progress. For this reason it has sometimes only been possible to introduce a few inches when it was intended to have put in several feet. The introduction of wire through a cannula is open to the further objection that a great deal of handling is necessary both by the surgeon and his assistants, so that it is difficult to ensure that the wire last introduced shall be as sterile as that first used.

The factors in the construction of a new instrument were set out as follows:

(1) The instrument must be self-contained,—that is to

say, it must carry the wire on a reel, and have some form of fine cannula through which the wire is to pass.

(2) It must remove the wire from the reel and force it through the cannula, yet without permitting it to kink.

(3) It must not allow the wire to damage the sac or the surrounding tissues, although some force has to be used in the introduction of the wire; in other words, the wire must be made to coil up within the sac.

(4) It must be simple in construction, and so easy to work that no instrumental complication may occur during the actual operation, and it must necessarily be capable of withstanding prolonged boiling.

(5) It should, if possible, "snag,"—that is to say, knot or roughen the wire, as coagulation is likely to be promoted by such roughening.

INSTRUMENT I.—After a few preliminary experiments an instrument was constructed to meet these requirements. The instrument works on a principle which may be enun-

FIG. 1.

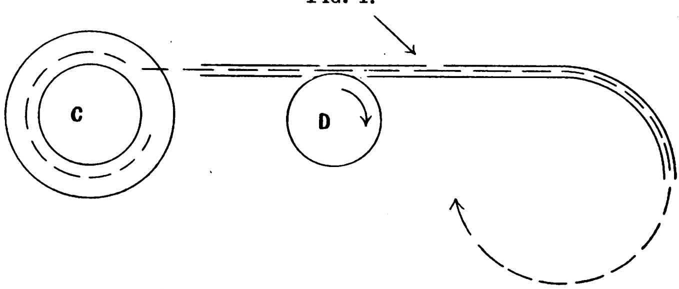


Diagram to illustrate the general principle of Instrument No. 1.
C. Reel.
D. Milling tool which rotates in the direction of its arrow.
The interrupted line indicates the wire passing from the reel through the needle.
The straight arrow points obliquely to the opening for the stilette.

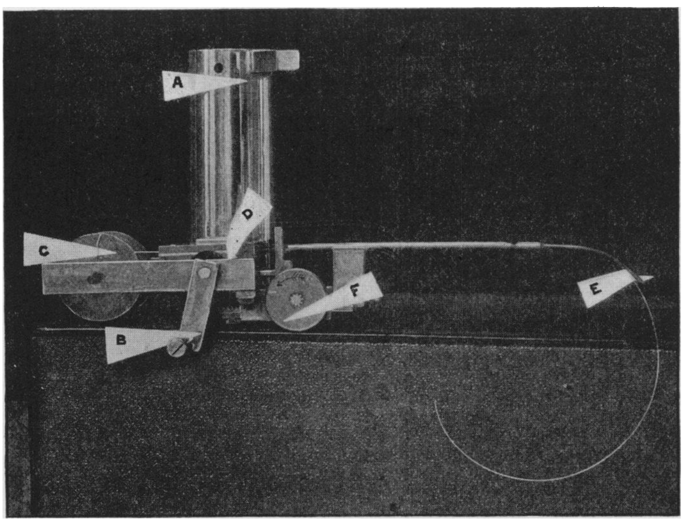
ciated in the following terms. If what is known to the mechanical engineer as a milling tool be made to revolve at a distance less than the diameter of the wire employed from the inner surface of the dorsal wall of a hollow needle, the ventral wall of which has been cut away, the milling tool will grip the wire between itself and the needle, and will wind it off a reel and drive it through the needle with a force only limited by the force at the disposal of the operator. It will at the same time "snag" or mill the wire (Instrument I, Fig. 1). To carry out this principle a quarter-curved tubular needle was embedded for about two inches of its length in the substance of a brass carrier. A semicircular incision was then made down to it through the brass, so that the lumen of the needle was exposed. A milling tool was introduced at this spot to compress the wire with a steady grip as it passed through the needle, the pressure being made between the milling tool and the dorsal wall of the needle, and care was taken that no space should exist in which the wire could kink. The mounting of the needle was then bolted to the mounting which carried the milling tool, which was so geared up as to give the operator room to use the instrument without getting his hands too near the wound. A second hole was made into the tubular needle distal to the milling tool, and along this a stilette is passed to block the point of the needle whilst it is being pushed into the sac of the aneurysm. The instrument is further provided with a handle by which to hold it, and with a second handle which, when turned, causes the milling tool to revolve.

The method of use is as follows:—The aneurysm is punctured on the right-hand side, the stilette is withdrawn, and blood flowing through the needle shows that the point is lying in the sac. The handle to which the milling tool is geared up is then turned in the direction of the arrow engraved upon it, and the wire is wound steadily and rapidly through the quarter-curved needle. The wire emerges into the aneurysm in a coil measuring one and five eighths inches in diameter, the coil increasing spirally from right to left so as to produce a loosely formed spring. The wire is milled as it passes under the milling tool on the axial surface of the spiral, the coils of which are parallel and one eighth of an inch apart. This arrangement of the coils is ensured by slightly curving the needle in a plane at right angles to its axis and to the plane of the quarter-curve. Five turns of the handle introduce two complete coils of the wire, the length of which is approximately ten inches, and the clotting surface at least 0·46 square inch. It is evident, therefore, that, although the point of the needle is out of sight, a fairly correct estimate can be made of what is happening within the sac of the aneurysm. When a sufficient quantity of wire has been introduced the needle is withdrawn, the wire is cut, is looped upon itself—to prevent the sharp end from injuring the sac,—and is pushed into the aneurysm. The hole in the sac is afterwards closed by a few point sutures.

The use of this instrument in the case narrated at the beginning of the paper shows that although it worked smoothly it did not quite fulfil all the requirements of the case, for it allowed a loop of the wire to travel out of the sac and seven inches up the aorta. An examination of the specimen shows that this diverticulum of wire was not carried into the aorta by the blood-stream, because it has gone upwards or against the direction of the blood-flow. The majority of the coils, too, are firmly implanted in blood-clot in the sac of the aneurysm. The real explanation seems to be that whilst the wire was being introduced into the sac some of the coils became hampered in their revolution, and the wire was driven out in a loop at one point. A further hampering then occurred, and the coils of wire no longer revolved, until the resistance to the further introduction of wire became so great that it could not be overcome by the milling tool, which then slipped upon the wire instead of biting it.

The best method of preventing such an accident on another occasion would be to introduce the wire so that the coils are not all in one piece. This can be done by dividing the wire into sets of coils, a method which has the further advantage of diminishing the ever-increasing resistance to its introduction. It does not seem possible to make one length of wire push the previous length through the needle into the sac, partly because the wire is too fine, partly because it does not exactly fill the needle when it has been milled, and partly because it is inconvenient to feed a needle with detached lengths of wire. As a matter of experiment, when such an attempt is made the two sections either jam in the needle or the hinder piece of wire kinks. The only alternative

FIG. 2.



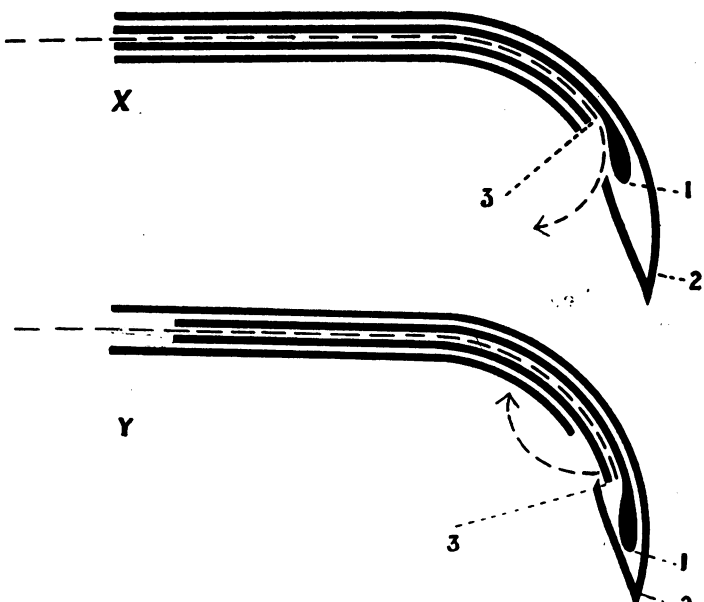
Flag labelled side view of instrument No. 2, about one third natural size. Enlarged from a photograph taken by Dr. E. H. Hunt.

A. Fixed handle for operator's left hand.
B. Moveable handle for operator's right hand.
C. Reel.
D. The arch is the situation of the milling tool.
E. Placed between the lateral eye of the outer needle and the coil of wire emitted. Near E the dorsal opening into the inner needle is seen.
F. Stud by means of which the outer needle is caused to slide over the inner needle. A portion of the rackwork with its stop is seen between F and B.

therefore, seems to be to cut the coils as they leave the eye of the needle, and this must be done without withdrawing the needle from the sac of the aneurysm. The wire can be divided in several ways, but the method now to be described seems to be the simplest and most practical.

INSTRUMENT II.—The second instrument (Fig. 2) differs in many important points from the first instrument.

FIG. 3.



Diagrams to show how the wire is severed at the lateral eye of the needle.

1. Inclined plane at the end of the inner needle.
2. Outer needle.
3. Cutting edge of inner needle.

In Fig. X the wire, represented by an interrupted line, after impinging on the inclined plane emerges as shown by the arrow.

In Fig. Y the outer needle has been retracted over the inner, and has severed the wire at 3.

There are no gear-wheels, and the milling tool is driven direct. The needle is sufficiently long to remove the mechanism to a distance from the wound. Lastly, the instrument is able to take a thinner wire, and a stilette is not required. The coils are divided by the following mechanism (Fig. 3) :—The hollow needle (Fig. 3, X) along which the wire travels is encased in a second needle (Fig. 3, X, 2), which exactly fits it. The end of the inner needle is completely blocked up by a minute inclined plane made of steel (Fig. 3, X, 1, and Y, 1), which is securely brazed in position, and is so arranged that it faces the oncoming wire. A lateral opening is made through both needles at their distal ends, and in such a manner that an eye is made with the depressed edges seen in the better kinds of Jacques' rubber catheters. When the two hollow needles are accurately adjusted (Fig. 3, X) the lateral opening is continuous from the inside of the inner needle to the outside of the outer needle, and through this opening the wire is directed by its impact on the inclined plane (Fig. 3, X, 1) which blocks the end of the inner needle. The tube of the inner needle is soft and flexible, except at the eye, where it is tempered. The outer needle is quarter-curved, tempered throughout, and pointed (Fig. 3, Y, 2). The inner needle adapts itself to the curve of the outer needle in all relative changes of position. The outer needle is attached to a rack and pinion placed close to the hand of the operator, and a movement of the pinion causes the outer needle to slide over the inner needle (Fig. 3, Y). The relation of the lateral eye of the outer tube to the lateral eye of the inner tube is thus altered, and by the position of a stop on the rackwork the operator knows the relative position of the two eyes, even when they are hidden from his view. The alteration in the two parts of the eye is sufficient to divide the wire, which may thus be guillotined wherever and as often as the operator chooses. The pinion is reversed when the wire has been divided until the stop is encountered, when a fresh series of coils can be introduced into the sac of the aneurysm.

The wire employed is No. 27 on the standard wire gauge, and is 0·0164 inch in diameter, or rather less than half a millimetre across. It is soft annealed silver wire, and is supplied by any large firm of wire-drawers at six shillings an ounce of about twenty-two yards. It is flattened by passing under the milling tool, and it is then 0·0215 inch in width and 0·0142 inch in thickness; and it has a slightly increased surface area, the surface area of the original wire being 5·152 square inches per length of 100 inches. It is exquisitely flexible after it has passed under the milling tool, and easily bends in the plane of the coil, though it is relatively rigid to stresses in any other plane. It is hardly possible to imagine it causing

FIG. 4.

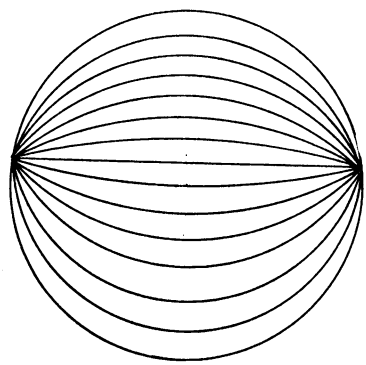


Diagram of ideal arrangement of expanding cage.

any damage inside an aneurysmal sac, and it is in the highest degree unlikely that it would pierce the wall. The diameter of a coil is three and a quarter inches, but a coil readily adapts itself to the wall of a cavity smaller than itself.

With this instrument ten turns of the handle introduce two complete coils of wire or a length of twenty inches. When the instrument is used to wire a large aneurysm five turns of the handle should be made before the wire is guillotined, for if fewer turns are made less than a coil is introduced, and when small pieces of wire are allowed to sink in the sac of an aneurysm there is a danger that they may be carried out into the general blood-stream with unsatisfactory results.

INSTRUMENT III.—Another method of wiring aneurysms consists in the introduction of one or more cages of steel wire. The cages can be compressed into a cylinder which can be easily passed through a fine cannula into the sac of an aneurysm, when they immediately expand in the manner shown in Fig. 5.

The model when compressed is five inches in length and one sixteenth of an inch in diameter. It consists

FIG. 5.

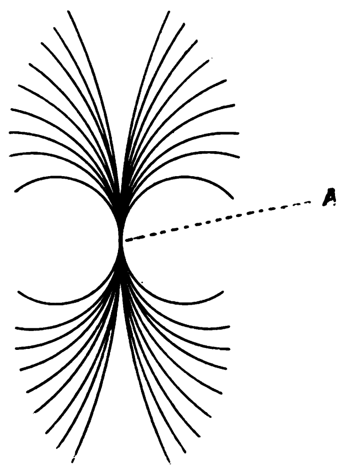


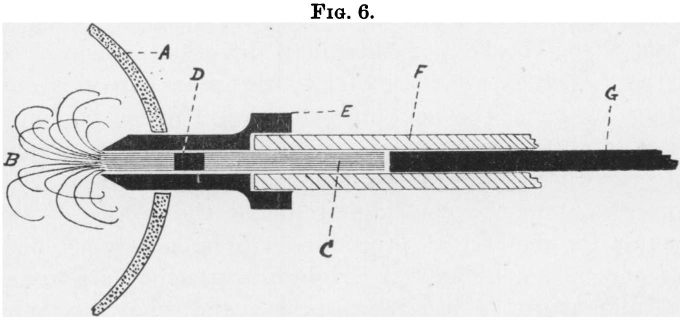
Diagram of actual arrangement of expanding cage. It can be compressed to its diameter at the central part (A), and after traversing a fine cannula will expand again.

of thirty wires, each measuring 0·008 inch in diameter and five inches in length. The cage when it is expanded fits a sphere three inches in diameter, but it can be made of any size. The total surface area of each cage is as nearly as possible two and a half square inches, which is almost equivalent to fifty inches of the silver wire used in Instrument II.

The cage is compressed when it is to be used, and is inserted into a cylindrical tube or cartridge which exactly fits a collar on the cannula employed to traverse the sac of the aneurysm. The cage is expelled from the cartridge through the cannula into the aneurysmal sac by pushing it home with a wire ramrod. More than one cage can be introduced if it is thought desirable to increase the clotting surface, but when a process of active clotting is once started in an aneurysm it is usually progressive, and there is some danger that the second cage may push the first one into an undesirable position.

An ideal wire cage of a spherical shape is shown in Fig. 4, but it is difficult to make and unsatisfactory in action. Fig. 5 is a diagram of the actual arrangement adopted, and Fig. 6 shows it in operation, but an objection

FIG. 6.



Diagrammatic section through Instrument III *in situ*.

A. Sac of the aneurysm.
B. The cage expanding.
C. The cage compressed.
D. Solder at the centre of the cage.
E. Collar on the cannula.
F. Cartridge.
G. Ramrod.

If C be considered absent, D to B would represent a "wisp" entering the sac.

to it is that the second half of the cage does not expand until it is completely freed,—that is to say, until the first half has moved onwards about two and a half inches from the end of the cannula. This might lead to forcible damage to the opposite wall of the sac by the half already introduced. It can be prevented by using only a half cage or "wisp," which, having completely expanded after traversing the cannula, is at once set free in the sac.

Experience may suggest different forms of wire cage, but for the present the wiring of aneurysms by means of a wisp appears to be the more satisfactory method. The chief reasons for this are that the apparatus required is exceedingly simple, and that this part of the operation can be accomplished in a very short time. In a suitable case it could be performed under cocaine, or without any anæsthetic, as in tapping a hydrocele. Thus in five seconds from the time of puncturing the sac a sterile foreign body presenting a clotting surface of relatively large value can be placed in position in the aneurysm with very slight risk of its injuring this structure, or of its moving about when once it is in position. Care is taken to make the puncture in a direction estimated, as far as possible, to be parallel to the plane of communication between the sac and the vessel from which it arises, and to arrange for closing the puncture wound before withdrawing the cannula. Thus it is clear that from the time the cartridge replaces the trocar of the cannula the method of procedure will be nearly a bloodless one, and not likely to frighten a patient only under the influence of a local anæsthetic; and what has been found to be one of the chief objections to performing the operation without an anæsthetic is to a great extent removed, and the procedure as a whole greatly facilitated.