ON THE
TORSION OF ARTERIES AS A MEANS
OF ARRESTING HÆMORRHAGE,
WITH EXPERIMENTS.

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ON the 16th of July, 1829, M. Amussat read before a meeting of the Académie Royale de Médecine a paper on his new method of arresting hæmorrhage from large blood-vessels without the aid of the ligature, the plan having been, as he tells us, suggested to his mind by the long recognised fact that "torn wounds do not bleed."

He supported his suggestions by relating the details of some experiments he had made upon animals, as well as upon the human subject, and quoted four cases of amputation of the thigh, and one of the arm, in which hæmorrhage had been readily and permanently arrested by simple torsion.

His practice was at once adopted in Paris by MM. Boyer, Dupuytren, Velpeau and Thierry: also by Lieber of Prussia, Fricke of Hamburg, and Schrader of Dresden. It received also the unqualified support of Majendie, who described it as one of the most brilliant discoveries in modern surgery.

In the periodicals of the day many cases are also related in which these surgeons had practised torsion of the arteries with immediate and permanent success, even to the divided extremities of large vessels; and amongst these are cases of disarticulation of the shoulder-joint, amputation of the thigh, leg, arm, and forearm; castration, extirpation of the breast, and other tumours.

The surgeons of this country, however, took little or no notice of the practice for some years; and it was not till the year 1834, five years after Amussat's paper had been published, that the subject was clearly brought before the notice of the profession: when Mr. W. B. Costello read before the Westminster Medical Society a paper "On the Torsion of Arteries for the purpose of arresting Hæmorrhage," which was subsequently published in the 'Lancet' of March 8th, 1834.

In this paper Mr. Costello gave the results of M. Amussat's practice, and detailed the particulars of five successful experiments which he had made upon dogs under that surgeon's direction.

The paper was well received, and some notice was taken of it at the time, but the practice was never followed, and, from that day to this, torsion, as a means of arresting hæmorrhage in large vessels, has never been practised, although for small ones it has been occasionally employed. An explanation of this apparent want of attention to this new method of arresting hæmorrhage may possibly be found in the fact that it was suggested before its time; that is, before the introduction of chloroform, by the use of which the surgeon is enabled to take up all vessels with care and precision, and there is no object in hurrying over any of his proceedings—a condition of things which can hardly be said to have existed under previous circumstances, when the surgeon's anxiety was to complete his operation as speedily as possible, and it was a source of satisfaction to know that a stout ligature was on the end of a large vessel.

Within the last few years, however, the attention of the profession has been much directed to the subject of hæmo-

statics ; and it would seem that many surgeons have become clearly dissatisfied with the practice generally adopted of ligaturing divided vessels, and of leaving the ends of the ligatures within a wound. It being stated, as a broad objection to their use, that they, by their presence, prevent a rapid or primary union of a wound ; that they keep up if they do not excite suppurative action within the parts, and thus add to the danger of an operation by postponing recovery and rendering a patient more prone to that fatal scourge pyæmia than he would be under other circumstances ; to these another objection may still be added, that the ligatures on their separation from the artery are apt to be followed by secondary hæmorrhage.

To Sir James Simpson unquestionably our thanks are due for having specially directed our attention to this subject, and for having suggested a plan of treatment which, to his own mind and that of others, aims at rendering more simple our mode of arresting hæmorrhage, and at the same time does away with some of the objections which have been adduced against the use of the ligature.

It is not my intention to inquire into this question on the present occasion. It has able advocates in the person of its distinguished author, and in Messrs. Keith and Pirrie ; it is, moreover, now under trial by the profession. It has doubtless advantages over the ligature, and disadvantages which have to be comparatively examined by the grand test of experience, by which it will stand or fall. I have practised it myself, and seen it practised in many ways, but regret to say that neither my observation nor experience have been of the most satisfactory kind.

It has, however, physiologically considered, one point of weakness which has some bearing on my present subject, for the value of the practice of acupressure rests on what has hitherto been looked upon, and what must still be described, as being a temporary mechanical obstruction to arterial hæmorrhage ; the permanent arrest of bleeding depending in this practice, as in others, on natural processes ; now, in acupressure the permanent arrest of hæmorrhage depends

entirely upon the clot which forms in the vessel, for no evidence has yet been adduced to show that any change occurs in the inner tunics of the vessels which have been subjected to the pressure of an acupressure needle, such as is well known to take place after the use of the ligature, and such as also occurs after the application of torsion in large vessels. In these last two forms of practice the two inner coats are divided, and subsequently unite, the permanent arrest of hæmorrhage depending materially on such a process; in acupressure there is no evidence whatever to show that any such union takes place between the two surfaces of the vessel which are brought in contact; as a consequence the permanent success of acupressure depends upon the coagulating power of the blood in the occluded vessel, the needle acting as a temporary mechanical obstruction to the flow of blood during the brief period of its presence.

Physiologically, therefore, acupressure is an uncertain process, and when contrasted with the ligature and torsion stands condemned; for its success depends only upon the temporary processes which nature adopts for the purpose of arresting hæmorrhage, and not upon the permanent hæmostatic changes which nature employs in other cases.

When Professor Syme, therefore, in a short note published in the 'Lancet' of January 4th, drew the attention of the profession back again to the subject of torsion, I must confess to feeling a sense of satisfaction, for it seemed tolerably clear that, if it could be practically proved that hæmorrhage from a divided artery could be safely and permanently controlled by such a method, we should have a means at our disposal which would be entirely free from all the objections which the strongest objectors to the use of the ligature could possibly adduce, and which in its simplicity and value would without doubt bear favorable comparison with acupressure as well as with the ligature.

It was under these circumstances that I was thus led to examine into the question, to try it in practice, and to prove it by experiment; and I now propose to lay the results of my inquiries before the Fellows of this Society, with the hope

that they will be induced to test the practice for themselves, and by the aid of experiment gauge its value.

I propose to relate seriatim the experiments I have made upon the dog, horse, and human subject to test the value of torsion, and to observe the process by which the vessels so treated become permanently sealed; having previously described the two methods by which torsion has been practised.

I shall pass on to describe the physiological changes which have taken place in the arteries which have been twisted; and draw attention to such special points as it seems necessary to attend to in the application of the practice. Some brief comparison will then be made between the value of torsion and the ligature, and some general deductions drawn up from the consideration of the subject as a whole.

I must add that in most of my experiments I have had the benefit of Mr. H. Howse's able assistance; that he has given me valuable aid in examining the vessels of the animals after death, and that the descriptions of the physiological conditions of the arteries are chiefly from his pen, receiving from me only such slight alterations as I deemed necessary. I am also indebted to him for the drawing of some of the preparations.

It would be well, however, *in limine*, to premise that there are two modes of applying torsion; one described by Amussat as "free" torsion, the other as "limited."

In *free torsion* the end of the artery should be fixed by a pair of clasp forceps and twisted freely.

In *limited torsion* the artery, having been drawn out of its sheath, should be fixed *transversely* about three quarters of an inch from its divided extremities by a pair of clasp forceps and held steadily; whilst with a second pair the free end of the vessel should be twisted freely as in the former, the object of the first pair of forceps being to fix a limit to the twisting of the vessel and prevent the artery being separated for any distance from its vascular attachments.

Experiments on the Dog.

EXP. 1.—February 4th, 1868.—I divided the left *femoral* artery of a dog just below Poupart's ligament, and twisted the cardiac end by "free" torsion *four* times with success. During this time the distal end was held by forceps, and when these were removed hæmorrhage occurred; the bleeding extremity was, however, seized by forceps and twisted *four* complete revolutions, all bleeding at once ceased, and by the seventh day the wound had united.

The dog was killed on the eleventh day after the operation.

EXP. 2.—February 8th, 1868.—I divided the right *femoral* artery of a dog and twisted its cardiac end *three* times by "free" torsion; hæmorrhage, however, at once occurred, the end was accordingly twisted *four* times more, when all bleeding ceased. *Four* twists to the distal end of the vessel at once succeeded. On the third day the dog appeared as if nothing had been done to him. The wound looked very healthy.

It must be noted that the blood from the lower part of the vessel came out quite black, like venous blood; the contrast between it and that from the cardiac extremity was very marked.¹

The dog was killed on the seventh day.

EXP. 3.—February 8th, 1868.—I divided the left *femoral* artery of a dog high up, and twisted its cardiac end *three* rotations with success, not a drop of blood escaping. The same treatment was also applied to the distal end, with a like result.

On the third day the dog was well, and the wound healing.

The dog was killed on the tenth day.

¹ This fact has been observed in the human subject, particularly by Guthrie, but is not generally recognised. It does not appear, however, to be constant.

Exp. 4.—February 11th, 1868.—I cut down upon and divided the right *common carotid* artery of a dog. I applied “free” torsion to its cardiac end, making *three* revolutions, without success, and accordingly seized the vessel again and twisted it four times more. Hæmorrhage was at once arrested. *Three* complete twists were then given to the distal end of the artery, and no bleeding followed.

On the second day the dog was quite well, he had taken his food as usual, and appeared in no way disturbed by the operation. On the following day the animal was destroyed.

It must be noticed that in this case, as in the second experiment, three rotations of the artery were not sufficient to arrest bleeding; four proved successful in both cases.

Both the distal and cardiac ends of this artery have been drawn (see Plate VIII, fig. 2).

Exp. 5.—February 11th, 1868.—Cut down upon and divided the right *common carotid* artery of a dog. Twisted the cardiac end *four* times, with immediate success, and likewise the distal end. Hardly a drop of blood was lost. On the second day the dog appeared to be as well as he was before the operation. On the fourth day the wound had nearly healed.

The animal was destroyed on the seventh day.

Exp. 6.—February 15th, 1868.—I cut down upon and divided the left *common carotid* artery of a dog. I applied free torsion to the cardiac end of the vessel, making *four* complete revolutions of the forceps; all hæmorrhage ceasing. The distal end was firmly pinched by a pair of forceps both at its free extremities as well as one inch up the artery; no bleeding took place.

The animal was killed on the third day.

Experiments on the Horse.

EXP. 7.—March 17th, 1868.—I cut down upon and divided the left *common carotid* artery of a horse ; applied two pairs of torsion forceps transversely to the vessel, and divided the artery midway between them, leaving an inch of artery on the distal side of each pair of forceps. With a third pair of torsion forceps I then seized the extremity of the artery at its cardiac end, and twisted it *seven* complete revolutions. I then removed the instrument that fixed the vessel, and not a drop of blood escaped ; the pulsations in the vessel were very strong. The same treatment was then applied to the distal end with a like result. It was certainly somewhat astonishing to see the great vessel fill out and pulsate after the operation without one drop of blood escaping ; and although the animal plunged somewhat during and after the operation, the success was most complete.

The animal was allowed to live for forty-eight hours, and then killed.

The condition of the vessel will be described in another page (see Plate VIII, fig. 3).

EXP. 8.—April 2, 1868.—I cut down upon and divided the left *common carotid* artery of a horse. I applied a *ligature* to the distal end, and *twisted* the cardiac, employing in this instance, for a definite object, a different method to that which I had used in the former experiment. In both, about one inch of the divided artery was left beyond the point at which the vessel was fixed by the forceps, which were applied transversely ; but in the former successful experiment the orifice of the vessel was alone seized before the torsion was applied ; in the latter, the extremity of the vessel was taken hold of nearly its whole length, the twisting of the artery being confined to the spot at which it was held ; in the one case about one eighth of an inch was allowed for the purposes of torsion, in the other half an inch. *Three* complete twists were alone given, but by those the external coat was so

twisted as to appear hardly larger than a crowquill, and I must confess to feeling somewhat alarmed lest I had ruptured the vessel. On removing the forceps that fixed the artery no bleeding took place, and I hoped all would have been well; within a minute, however, signs of bleeding occurred, and on opening the wound it was clear that blood escaped from a small laceration of the external coat at the point of twist, the twist having remained unaltered. It being apparent that the violence of the torsion had been too much concentrated at one spot, I accordingly seized the vessel lower down, cut off the injured end, and applied limited torsion as in the last experiment, holding the orifice of the artery alone, and giving *six* complete revolutions of the forceps to the free inch of the vessel. No bleeding followed the removal of the instrument, complete success having been secured.

The horse was killed on the fourth day—eighty-seven hours after the operation. No single bad symptom had shown itself. The animal had taken his food ravenously during the interval.¹

The appearances found on dissection will be described further on.

Mr. Towne has made a model of this preparation, showing the physiological changes which have taken place in the artery after the application of a ligature and torsion respectively.

The design for the model was shown when the paper was read, and a drawing from it (see Plate IX).

Effects of Torsion on the artery of a patient to whom it was applied during life.

I have only one observation to make bearing upon this point, but it is of value, for it well supports practically and physiologically the results of the experiments I have already given upon the horse and dog.

¹ In these experiments on the horse I had the kind and able assistance of Mr. Moss, M.R.C.V.S., of Vauxhall.

On January 13th, 1868, I applied "free" torsion to the brachial artery of a woman, æt. 68, for whom amputation was demanded in the upper third of the arm for a compound comminuted fracture of the elbow-joint, and extensive laceration of the soft parts. The artery was twisted *four* revolutions by "free" torsion, one blade of the forceps being introduced at least half an inch into the vessel, and no bleeding followed, although the pulsation of the artery was very strong. The patient died thirty-five hours after the operation from thoracic complications, and thus I had an opportunity of examining the changes which had taken place in the vessel. I should add that some bleeding took place from the stump twelve hours after the amputation had been performed, from a vessel which had not been seen at the time; and, to this, torsion was successfully applied by the House Surgeon, Mr. Morris, who stated that when the stump was opened, the brachial artery was seen to be pulsating powerfully, but not a drop of blood escaped.

The changes found in the vessel will be described with the other cases, and seen in a drawing (see Plate VIII, fig. 1).

A DESCRIPTION OF THE PHYSIOLOGICAL CONDITION OF THE ARTERIES WHICH HAD BEEN SUBJECTED TO TORSION, AS SEEN IN THE BRACHIAL ARTERY OF THE HUMAN SUBJECT, AND SEVEN FIRST EXPERIMENTS IN ANIMALS.

Mode of preparation.—The vessels were all hardened in spirit immediately after removal from the subject, and then longitudinal sections cut.

Condition of the human brachial artery.—The artery was removed from the innominate downwards. The aorta and innominate were very atheromatous, but this did not extend to any very marked degree to the brachial.

The diameter of the artery was about a quarter of an inch where the clot existed; of the cavity about one sixth of an inch; elsewhere not quite so much. The twist, which was quite local, though free torsion had been practised, was about an inch from the amputated extremity of the artery. The

distal end of the artery was empty. The *cardiac* end contained about two inches of clot; where this ceased a small artery came off. The middle and internal tunics of the artery had clearly ruptured and retracted, they also were completely *incurved* as seen in Plate VIII, fig. 1, meeting in the middle line of the artery; beyond this spot was a small quantity of firm defibrinated clot, which would serve to maintain the incurved tunics in position, and which was covered by the twisted external coat. At the *distal* end of the artery the middle coat was not incurved, the ends merely coming into contact in the middle line.

Experiments on the Dog.

To save repetition, it may be stated that in all this series of experiments, although free torsion was performed, the twist in the vessel was found to be localised to a spot a little beyond the bite of the forceps, never spreading up the artery as described by Amussat.

Exp. 1.—Left femoral artery examined on the eleventh day after the experiment.

The *cardiac* end was pervious to rather more than half an inch from the point operated on. The parietes of the pervious portion were thickened, as if the original, comparatively speaking, thin-walled artery had contracted down upon the cavity. The obstructed part had an ampulla-like appearance, was filled with firm fibrous clot, in which were one or two cavities, containing grumous matter, as if from the commencing softening of the centre of the clot. At the point of torsion, the divided middle coat was perfectly continuous with the other side, so that the cardiac end of the artery formed a perfect cul-de-sac containing fibrin. From the cul-de-sac two branch arteries were given off: one joined the main trunk again beyond the point of operation, the other ended in the surrounding muscles, both were perfectly obstructed by fibrin. Of that part of the cardiac end of the

artery actually seized by the forceps, no trace remained, it seemed to have all atrophied and become absorbed.

The *distal* end of the artery presented none of the appearances above described; it was thin-walled and pervious, nearly up to the point operated upon, where it was obstructed by a small clot which had become much shrivelled.

EXP. 2.—Right femoral artery examined on the seventh day.

The *distal* end was in every respect similar to that of the vessel just described. It was thin-walled, as if the parietes had contracted a little upon the cavity, and was obstructed by scarcely a quarter of an inch of clot.

The *cardiac* end was also like that just described; such complete contraction of the muscular parietes had not, however, taken place in the pervious part of the artery, the wall being thinner and the cavity larger.

The changes in the clot had not advanced so far in either end as in the last experiment; they were not decolorized, nor were there any spots in which it was breaking down.

The part of the artery actually seized by the forceps, although withering, was more distinct in the present case than in the last, but there was no indication of any sloughing of the part in either case.

EXP. 3.—Left femoral artery examined on the tenth day.

Nothing very distinct could be made out in the dissection of this artery, the occlusion and wasting of the vessel had proceeded too far; what remained of it seemed to agree with the other femorals.

EXP. 4.—Carotid artery examined on the fourth day.

The *cardiac* end of the artery was taken out from the innominate. It was obstructed with clot for an inch and a half. The end of the vessel, where the twist had taken place, was dilated into a kind of ampulla, but not nearly so markedly as in the *distal* end next to be described. The walls of the artery were rather thick, and remained so

to about one sixth of an inch from the twist, where they abruptly became thin from the sudden lessening in diameter of the middle coat, which ran forwards and was lost between the clot and tunica cellulosa or external coat, just at the point of torsion where the ends seemed to rest against a small decolorized plug of fibrin. The part of the artery actually seized by the forceps remained very distinct, though much contracted. The fibrin in the vessel was firm, and with the exception of one or two spots in the ampulla, was not decolorized. A small branch was given off from the ampulla, which was obstructed.

The *distal* end of the vessel was obstructed with clot for the space of three inches. The ampulla-like dilatation in this case was remarkably distinct for half an inch below the point of obstruction; its walls were thin, this being clearly due to the difference in thickness of the middle coat; and its cavity was double in diameter to the cavity of the remaining portion of the artery.

No distinct incurvation of the middle coat of the vessel could be traced.

Half an inch of old withered artery remained above the point where the obstruction commenced.

Both the cardiac and distal ends of this vessel have been drawn (see Plate VIII, fig. 2).

EXP. 5.—Right carotid artery examined on the seventh day.

The vessel seemed in every respect similar to that already described, although the clot was smaller, and the artery seemed more contracted and withered.

The *cardiac* end contained about two inches of clot; where it ceased a small artery came off. The middle and internal coats were completely *incurved*, meeting in the middle line of the artery; beyond this was a small quantity of firm defibrinated clot, which would serve to maintain the incurved tunics in position, and which was covered by the twisted external coat; and, finally, came the distal end of the artery, the middle coat of which was not incurved, the ends merely coming into contact in the middle line.

EXP. 6.—Left carotid artery examined on the third day.

Of the *distal* end of the vessel nothing need be said; it seemed in most respects similar to the others already described.

The *cardiac* end was as usual dilated into a kind of ampulla. The middle tunics seemed to have met and united, but it is somewhat difficult to distinguish them from the fibrin or lymph effused beyond the point of union. The external coat was, however, capable of being dissected from the middle, and there seemed to be some degree of incurvation. About three quarters of an inch of clot had formed in the ampulla and artery leading to it; this was partly decolorized.

Experiments on the Horse.

EXP. 7.—Left common carotid artery examined forty-eight hours after the operation.

Nearly six inches of the cardiac end of the artery were removed, and about two inches and a half of the distal end.

The diameter of the widest part of the *cardiac* end, close by the twist, when in a measure shrunken by spirit, was about three eighths of an inch, the cavity being proportionally large. From the point of torsion, the size gradually diminished towards the cardiac extremity. No branch was given off in the whole of the part taken out.

There was about four inches of continuous clot in the artery from the point of torsion, then came an empty space, and beyond this about three quarters of an inch of semi-detached clot. A piece of fibrin about two inches long, which existed in the middle of the continuous clot, had contracted no adhesion to the walls of the artery; thus it fell out on making the section (see part marked in Plate VIII, fig. 3).

The middle and internal tunics at the point of torsion are turned in and somewhat clubbed, the clubbed ends meeting. Beyond this point comes the twisted external coat; next, a *curious swelling* covered only by the external coat which is

twisted beyond it; and finally, the empty end of the artery where seized by the forceps. The middle coat at this point does not incurve, but merely meets, as in the distal portion of the human brachial artery before described.

The *swelling* already alluded to, which was covered only by the external coat, to the naked eye appeared to contain either defibrinated clot, or lymph; but examined microscopically, it was found to consist of distinct lamellæ of elastic tissue mingled with defibrinated clot. It appears likely, therefore, that it is the middle and internal coats of that part of the artery which had been actually seized with the forceps transversely—for it must be remembered that in this case “limited” torsion was practised—and which had rolled up in this form by their own natural elasticity, or by the twisting; some serum remaining and coagulating in the interstices.

The *distal* end of the artery contained about one inch and a half of clot. The middle coat was turned in and overlapped in the median line, otherwise there was nothing very remarkable in this point.

EXP. 8.—Left common carotid artery examined eighty-seven hours after the operation.

All the soft parts, from the angle of the jaw to the thorax, were removed including the trachea. Directly after their removal, a careful dissection was made, the following conditions being observed.

The *cardiac end* of the artery appeared to be quite empty, it contained only a little liquid blood. At its extremity, where it had been twisted, a mass of lymph existed which had to be dissected off. The twist in the vessel then became very clear. Its free end showed no evidence of having lost its vitality; below the twist a firm clot existed for about a quarter of an inch, and below this a large branch was given off from the vessel.

The *distal end* of the vessel to which a ligature had been applied showed nothing unusual. There was the usual linear division of the middle and inner coats. Both can be well seen in Plate IX, figs. 1 and 2.

On making a section of these parts subsequently it was observed that, in the *cardiac end* which had been twisted, the same changes had taken place as have been already described in other cases. The middle coat had been ruptured and had retracted, its free end having approximated above the small clot which had formed in the vessel. This clot was hardly larger than a pea; at its circumference it was partially decolorized. Below this clot a large branch was given off from the artery. Beyond the clot was the twisted vessel. It was a question whether the small clot in the artery was not placed between the divided inner and middle tunics; this splitting of the tunics taking place after torsion in some cases.

In this case it is tolerably clear that the twisted cellular or external coat must have been the chief obstacle to the arterial flow, the retraction and approximation of the divided inner tunics giving valuable aid. The clot was clearly too small to have much influence, unsupported by the other conditions of the vessel.

On making a section of the *distal end of the vessel* to which a ligature had been applied, it was clear that at the point of ligature ulceration had taken place, nearly separating the end; that the middle tunic of the vessel had been divided and had apparently united. No retraction of this tunic, however, had taken place, nor was any clot found in the vessel.

At the *distal* end of the ligature there was a small clot enclosed by the middle coat, and it will be observed that beyond this point the artery had again contracted, clearly by its own natural elasticity.

To explain the presence of this clot at the cardiac side of the ligature, it should be stated that the ligature was applied to the artery after it had been exposed, and that with my thumb and finger the blood was squeezed backwards before the vessel was fixed by the forceps applied transversely. The artery was then divided and twisted. This clot must have formed at this time, some portion of blood remaining near the ligature and being caught by the divided middle coat.

Experiments upon the arteries of the dead subject.

I have made a large number of experiments on the arteries of the dead subject, healthy and diseased, having generally selected the common iliac and external iliac vessels, and have found that in all the same changes have taken place as have been already described. In every instance the retraction and incurvation of the middle and inner tunics were well marked, and in some the latter was most remarkable; it appears also that in the atheromatous vessels this incurvation is equally well seen.

Indeed this incurvation of the inner tunics of an artery, to which torsion has been applied, appears to be a point of peculiar interest, and from a large number of experiments on the dead subject it may be stated to be a very general result of well-applied torsion.

The amount of incurvation in different instances will, however, be found to vary; in some it will show itself more as an irregular crowding together of the divided and retracted tunics; whilst in others it appears as a complete valvular incurvation of the divided coats, the incurved portions appearing within the vessel as nipple-like projections; under these circumstances, the incurved portions form the most perfect valves it is possible to conceive, being not unlike the semilunar valves of the heart and closing as perfectly. In some cases, again, the middle and inner coats appear to split, and thus to form an additional means for causing coagulation of the blood and obstruction to the artery.

This incurvation is clearly a physical act, and is due to the natural elasticity of the coats of the vessels; it may consequently be confidently expected to take place in all the larger vessels.

The preparations and drawings well demonstrate these points (see Plate X, figs. 1, 2, 3).

I have found also that when a vessel has been efficiently twisted, no legitimate force that can be employed with a syringe, introduced into the vessel above, will unfold the twist in the cellular coat, or undo the retraction and incurvation of

the inner tunics, although the artery will frequently rupture above the part which has been twisted; when the extremity of the vessel has been twisted off, leakage, however, frequently follows.

It should be stated that this incurvation of the inner tunics seems unknown after the ligature; indeed it should be stated that in a large number of experiments which I have made, in which a ligature has been applied to an artery, the only change that takes place in its coats is an imperfect and irregular division of its middle and inner coats; in rare cases this division is very complete, in many others it does not take place at all.

There is never any retraction worth mentioning, and no incurvation. I may refer to Dr. Jones's work on 'Hæmorrhage,' published in 1810, to further illustrate this point.

Résumé of the physiological effects of Torsion on the vessels.

The results of the experiments made upon animals, and the single observation I have had an opportunity of making on the human subject, singularly accord; for in the cardiac and distal ends of the arteries which had been treated by torsion, I found the middle and internal coats of the vessels had been divided; that these coats had retracted in the direction opposed to the blood stream, approximated and overlapped; that at the cardiac end in several instances the coats had become partially incurved, as shown in the preparations and drawings of the carotid of the horse, and the brachial of the human subject; and I found also that every vessel contained clot, from the giving off of the first branch to the point of contact of the two inner divided coats; that lymph or organizable blastema was poured out around the divided extremities of the coats, and between them and the external cellular coat; also that a second smaller clot often existed between the distal end of the two divided inner tunics, and that portion of the cellular coat which had been twisted.

I found, moreover, that the twist which the cellular coat had

sustained was clearly permanent, and that it did not untwist (this can be shown on the dead body). That in no single instance was there any evidence to indicate that the portion of vessel which had been twisted had lost, or was likely to lose, its vitality; or that the parts about the vessel had received any material injury.

That in most cases a kind of ampulla tends to form in the cardiac end of the artery, and sometimes in the distal end. The appearance which this presents varies in every case, and seems to depend on the rapidity with which coagulation takes place in the end of the artery, and upon the amount to which the artery, beyond the point where the clot forms, contracts. In those arteries, therefore, in which much muscular fibre exists, and in which it is healthy, it will be most apparent; thus it is scarcely visible in the brachial artery from probable atheroma, and in the carotid of the first horse which was an old worn-out creature.

It is not necessary, therefore, to suppose that the force of the heart actually dilates the end of the artery. The diameter of the ampulla is in fact something less than the original cavity of the artery. Fibrin forms here first and prevents that close contraction of the parietes which goes on in other parts, and thus an apparent dilatation is formed. The middle coat in the artery is always much thinner than that in the contracted part of the artery (see Plate VIII, fig. 2 B).

Thus the appearance of an ampulla is rather due to unequal contraction than to dilatation.

That though "free torsion" was practised in every case except in the horse, yet the twist in the vessel was local, not extending high up the artery.

That torsion when applied to large vessels immediately above the giving off of a large branch may be successful (see experiment No. 8, on the horse, and Plate IX); and that when applied to diseased vessels in old subjects it may likewise succeed (see torsion of brachial artery, Plate VIII, fig. 1; and preparations of vessels twisted after death, Plate X, figs. 1, 2, 3).

Remarks on the Experiments made on Living Animals.

It is to be noticed that in the experiments upon dogs "free torsion" was employed; in the two upon horses "limited torsion" was used. In all the operation was ultimately successful.

In several on the dog bleeding took place when the torsion had been imperfectly carried out; three revolutions of the vessel being clearly insufficient; in all, however, on the dog four revolutions at once succeeded.

But the arteries of dogs are not large, and although the experiments upon them, as far as they go, must be regarded as satisfactory, they would not be to my mind of sufficient value to prove the power of torsion unsupported by others of greater importance.

The experiments on the horse I cannot but refer to with unmixed satisfaction, for no one can look upon the dilated pulsating carotid artery of such an animal during life, without a feeling of astonishment that such a simple act as that of torsion should be found sufficient to arrest hæmorrhage from its divided extremity; and yet in both the cases related complete success followed the operation when it had been properly performed.

The temporary failure in the second case which followed upon the imperfect application of the practice must be looked upon with favour, for it went to prove what I confidently anticipated would have been the case—that torsion of the external coat when too much concentrated to one spot must end in its rupture, and consequently in failure: but the ultimate success of the torsion when carried out in an efficient manner was most satisfactory, for it tended to show that the means employed were such as could be relied on with some confidence.

The fact that torsion was successfully performed on the carotid of a horse, immediately above the giving off of a large branch is a point of great value, (see experiment 8); for if the permanent safety of torsion depended upon the mere

coagulation of the blood in the vessel, success could not have been thus acquired—for as the drawing, model, and preparation well show, there was no room for such an obstruction to the arterial flow to take place between the twist in the cellular coat, and the point at which the branch artery was given off.

It would thus appear that the twist in the cellular coat was the chief cause of the arrest of the arterial hæmorrhage in the experiment referred to, and that this twist with the adhesion of the split, *retracted*, and approximated middle tunic forms the true permanent occluding medium of a divided vessel; that upon such points the main safety of the practice of torsion really rests, the coagulation of the blood in the vessel acting a part of secondary importance.

As mere experiments, these operations on the horse must be looked upon with favour; for they prove practically that torsion of such a large artery as the carotid is to be relied on; and consequently it does not appear unfair to believe that the same practice applied to any smaller vessel would be equally successful. As physiological experiments, however, the observations I have been enabled to make must be regarded in a higher light, for they show that nature's well-known hæmostatic processes act at a far greater advantage when torsion has been applied, than they do after the use of the ligature; and, what is of far greater importance, they are allowed to go on undisturbed in their conservative action, for there is no foreign body to set up ulcerative action in the vessel in the seat of its occlusion; nothing to undo at a late period of the case what nature, assisted by art, has done at the beginning for the prevention of arterial hæmorrhage. The twist in the vessel remains permanent; the coagulation of the blood in the meshes of the retracted, approximated and incurved middle coat goes on undisturbed; and the whole becomes, subsequently, rapidly condensed into one homogeneous mass by the effusion of lymph from the exposed surfaces of the divided tunics.

In the application of torsion some care is needed, and as two methods have been described, the "free" and the

"limited," it may be well to point out as far as possible the conditions under which they should be employed.

"Free" torsion appears to be the more applicable to small vessels, and even to the large trunks of the extremities; the "limited" torsion to such arteries as are unsupported by muscles and loosely connected.

It will have been observed that in all my experiments upon dogs, in which both carotid and femoral arteries were treated by torsion, the "free method" was used; and in the single example I have quoted in which I adopted the practice in a large vessel on the human subject—amputation of the arm high up—free torsion was also employed; for in that case I passed one blade of my forceps into the humeral vessel for about half an inch, and, with the other outside, after four complete revolutions the operation was successfully performed. I have, since this paper was written, applied free torsion to the femoral artery of three adult patients with complete success. On the dead subject also this mode of torsion proves successful, particularly on the femoral, brachial, and carotid arteries. It should also be stated that Amussat in his last years employed the *limited* torsion in all except the very small vessels; whilst Thierry employed the *free* in every case.

Three or four revolutions of the artery are required for small arteries, five or six for large: when the vessels are atheromatous the former number (three or four) is amply sufficient under all circumstances.

The orifice of the artery alone should be held by the forceps which twist the vessel in both cases.

In no case does it appear necessary, or even prudent, to twist the vessel till the end is twisted off: for by so doing we do away with the chief safeguard against bleeding, we run the risk of breaking up the valvular incurvation of the inner tunics, and disturb the clot which forms between the retracted ends of the two inner tunics and the twisted cellular coat. In very small vessels this point is not of so much importance. It is probably due to this error of twisting off the ends of the vessels, that the practice of torsion has failed to hold its ground, for in the few cases in which

it has been employed, such a mode has been generally, if not universally, adopted.

It seems to be a good rule in every case of torsion, whether free or limited, to hold the end of the vessel for a second or two after the twists have been made, to allow of the parts becoming plugged with blood, and the divided tunics to retract and come in contact.

It appears also to be a matter of great importance in twisting large vessels that the whole orifice of the artery should be seized and firmly held; this cannot be well done with the forceps ordinarily sold, but can be by the forceps I have had made for the purpose by Mr. Millikin of Southwark Street, the ends of which are broad, and firmly hold the artery, and not having sharp ends do not tear it. The blades are closed by a simple catch. With a small pair of forceps the surgeon is very apt to tear out a piece of the end of the vessel and not twist it securely. I have proved this on many occasions on the dead body.

The forceps I have had made for holding the vessel are very simple, they fix it firmly with flat surfaces without injuring the external coat, which the sharply-teethed forceps are apt to do; they are also very well adapted for the twisting of vessels of moderate calibre.

Comparison between Torsion and the Ligature.

If we compare the effects of torsion on the arteries with those of the ligature, it appears that the changes the two inner coats of the artery undergo are in a measure similar under both circumstances; that the same plugging of the vessel by the temporary clot, and permanent sealing of the extremity of the vessel by the organization of effused lymph, take place in both—in the one case the twisted cellular or external coat mechanically arrests immediate hæmorrhage, and in the other the ligature. But between the two methods there is this great difference, that with the ligature we have a foreign body, applied only for a temporary purpose, which,

when it has served, can only be regarded as a source of irritation and of some danger; but with the torsion no such foreign body exists, for, when the extremity of the vessel has been once fairly twisted, it is twisted for ever, and what was at first only a temporary obstruction to the arterial flow becomes a permanent one.

In the second experiment on the horse which has been modelled (see drawing from model, Plate IX), all these changes may be seen, and from this it would, moreover, appear that the twisting of the vessel, together with the adhesion of the orifice of the two inner tunics, is amply sufficient of itself to be both a temporary and permanent obstruction to the arterial flow; the formation of a clot being of quite a secondary importance.

It should be stated, however, in this comparison that in the ligature there is no incurvation of the ruptured middle or inner tunics, and but little retraction. It would thus appear that when torsion has been thoroughly and efficiently performed, hæmorrhage from the small, and even from the largest vessels, may be arrested with some certainty; and that, what is of still greater importance, when this effect has been produced, the fear of secondary or any subsequent bleeding is apparently groundless: for when once the inner tunics of the arterial walls have been divided, and as a consequence have retracted, incurved, and approximated, and when the cellular coat has been completely twisted upon itself more than once, the knot formed by such a twist does not seem to be capable of unfolding, and there is no foreign body about the vessel, as there is when a ligature has been used, to set up a fresh inflammatory or ulcerating process to destroy the permanent sealing of the twisted or occluded artery, and thus give rise to secondary hæmorrhage.

It is in this point, I would respectfully suggest, lies one of the great advantages of torsion over the ligature, for when once bleeding has been successfully arrested by well-applied torsion, and no signs of hæmorrhage occur within a few seconds of its application, there need be little fear of a subsequent bleeding—in a healthy subject at least—or of a

secondary hæmorrhage, for there is nothing to interfere with the physiological processes which nature invariably adopts to seal permanently the divided vessel; there is no foreign body to set up ulcerative action, which must undo to a degree, and may undo altogether, the work that nature has performed to guard against bleeding.

In the use of the ligature no such certainty exists, for such ulcerative action must take place for the purpose of its liberation, and this ulceration, or sloughing of the ligatured extremity of a divided artery, is the most common cause of secondary hæmorrhage; we all know, also, too well how frequent and how serious secondary hæmorrhage from a large artery always is.

I might add that of all the cases recorded, in which torsion has been used, in none is secondary hæmorrhage mentioned to have taken place.

It may be objected, however, that torsion is not applicable in every case. I would perhaps grant the objection; but because a practice is not applicable in every case, there can be no objection to its use in such as it can be applied. I believe it will be found that the practice can be carried out in by far the majority of cases of divided vessels, if not in all, whether healthy or diseased; but that in the latter the number of twists required will be far smaller than in the healthy subject, for when arteries are diseased it is in the middle and inner tunics that the mischief is situated, and it will be found that these coats readily break under the influence of torsion, and as readily retract and approximate; the cellular coat is rarely involved in the disease, and may be twisted with care.

Again, should torsion fail it will fail at once, and the surgeon can then repeat the same or adopt other means of arresting bleeding; but should it succeed, it will probably succeed unto the end, for there is no local exciting cause to set up fresh action, there is no influence going on in the part to undo at a later period of the case what has sufficed to arrest the flow of blood at the beginning.

By way of summary the following conclusions may be drawn up.

1. That hæmorrhage may be arrested by torsion from even the largest vessels.

2. That it is a safe and judicious practice in all cases in which the vessels are small or of moderate calibre; and that, as far as experiments and practice yet prove, it is equally so in arteries of the first magnitude.

3. That torsion may be "free" or "limited:" the *free* method being applicable to vessels of moderate size, and even to the largest of the extremities; *limited* torsion being more adapted for the large and loosely connected vessels.

4. That in *torsion* as in the *ligature* the permanent hæmostatic processes are alike due to the sealing of the divided inner and middle tunics; but that in the *ligature* there is only an irregular division of these tunics, whilst in *torsion* there is a complete division, separation, retraction, and valvular incurvation.

5. That in *torsion* the *twisted cellular* coat forms, with the retracted and incurved middle coat, the direct mechanical obstacle to the flow of arterial blood, in the same way as the *compressed cellular* coat does in the *ligature*; but that in *torsion* the *twisted cellular* coat and incurved middle coat become subsequently a permanent means of occluding the end of the artery; whilst the *ligature* of necessity becomes subsequently a source of irritation, and too often a means of undoing what has been done by nature's own hæmostatic processes.

6. That in *torsion* the twist in the cellular coat of an artery; the division and subsequent retraction, incurvation, and adhesion of the middle coat; and the coagulation of the blood in the vessel down to the first branch, are the three points upon which its temporary as well as permanent safety depends; whilst the permanent safety of *acupressure* rests only upon the last point alone, and its temporary effects upon the pressure produced by the needle.

7. That there is every reason to believe that when torsion has been successful on its first application, the fear of subsequent hæmorrhage is altogether groundless; for there is nothing, as there is in the ligature, to interfere with the physiological processes set up by nature to occlude the divided vessel; and, unlike acupressure, the temporary obstacle to the flow of blood becomes a permanent one.

8. That upon physiological grounds torsion has decided advantages over the ligature and the acupressure needle; and that if subsequent experience confirms what has been hitherto observed in the experiments on animals and the application of the practice in the human subject, we shall have gained a point of no mean importance and simplified surgery in no slight degree.

Conclusion.

I have thus, as tersely as I could, brought forward all the facts of which I am cognisant bearing upon torsion as a hæmostatic agent, and some of the arguments by which it may be commended to your consideration. I trust I have adduced sufficient to prove it to be well worthy of extended trial.

That it is a reliable practice in many cases when efficiently performed can hardly be disputed; in how many, can only be proved by the ultimate test of all knowledge—experience. It is not a crude idea based upon a theory spun out of a fertile imagination; for it had its origin in observation of nature's own processes; it is based on the well-recognised physiological principles of natural hæmostatics; and it is artificial only so far as the surgeon's art is employed in rendering these processes most available.

Nearly forty years have now passed since its distinguished originator brought it before the notice of our foreign brethren; but I trust before another decade has passed it will have been tested to the full, and that when weighed in the balance of experience it will not be found wanting, for I entertain a high opinion of its capabilities, and believe that in the future it is destined to be a handmaid to the surgeon of no secondary importance.

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DESCRIPTION OF PLATE VIII.

Fig. 1.—Brachial artery from a case of amputation, in which hæmorrhage was arrested by torsion (see pages 207–9). Mode of preparation—artery slit by scissors up to dot; then hardened in spirit, and a longitudinal section made with a sharp knife. Drawn to natural size.

- A. Tunica adventitia; at A' twisting.
- B. Tunica media and tunica interna, without visible line of distinction.
- B'. The same, at point of torsion, ruptured and retracted towards the cardiac end of the artery, at B'' towards distal end, but not so perfectly incurved.
- C. Clot. C' between tunica media and adventitia at point of torsion. C'' in part of artery beyond point of torsion.
- D. Small artery coming off above dot.
- * * * The arrow shows the direction of the blood current.

Fig. 2.—Carotid artery of a dog, showing the effects of torsion (magnified one third). Experiment No. 4. (See pages 210–11.)

- A. Brachio-cephalic artery, dividing into subclavian and carotid.
- B. Part of artery distal to the cut.
- * * * The arrows show the direction of the normal flow of blood.
- d, d. Middle and internal coats; at d' d' very little incurvation; at d'' much thicker than elsewhere by contraction.
- e, e. External coat; at e' twisted.
- f, f. Clot, here and there decolorized.
- g. Ampulla.
- h, h. Portions of artery seized with forceps, much shrunken.

Fig. 3.—Effects of torsion on the living carotid artery of a horse. Experiment No. 7. (See pages 212–13.) Mode of preparation—hardened in spirit and a longitudinal section then cut. Drawn to natural size.

- A. Portion of artery on the cardiac side of the cut.
- B. Distal portion.
- C, c. Corresponding ends of the artery where it was cut and twisted.
- * * * The arrows represent the normal direction of the current of blood before the artery was touched.
- d, d. Middle and internal coats turned in so as to meet at d', with a kind of knob-head at d'', the same merely overlapping each other.
- e, e. Internal coat; at e' separated from the middle by a small quantity of decolorized clot; at e'' e'' points of twisting.
- g, g. Portions of artery seized by the forceps: these show no appearance of sloughing, but rather of atrophy.
- h, h. Clot, in spots decolorized; from h' h' a piece which had contracted no adhesion to the arterial walls, but which fell out in making the section.
- x. Pouch-like swelling containing decolorized clot, and elastic lamellæ from middle coat of artery (?).

DESCRIPTION OF PLATES IX AND X.

PLATE IX.

Illustrating Experiment No. 8 on the horse. Taken from Mr. Towne's model.

*** The arrow indicates the course of the blood. (See pages 213-14.)

Fig. 1.—Carotid artery of a horse to which torsion had been applied.

- A. The external coat which had been twisted.
- B. The retracted and adherent middle coat.
- C. Clot in the meshes of the split middle coat.
- D. Large branch which was open.

Fig. 2.—Carotid artery of a horse to which a ligature had been applied.

- A. Ligature which had nearly ulcerated through the vessel.
- B. Divided and adherent middle and inner tunics.
- C. Clot in the free extremity of the artery which has contracted upon it.

PLATE X.

Figs. 1, 2, 3.—Arteries laid open to show the valvular incurvation and splitting of their middle and inner coats the result of torsion (see page 215).

- A. Twisted external coat.
- B. Valvular incurvation of middle and inner coats.
- C. Splitting of middle coat.