OBSERVATIONS
UPON THE
LIGATURE OF ARTERIES,
AND THE
CAUSES OF SECONDARY HEMORRHAGE;
WITH A
SUGGESTION OF A NEW METHOD OF EMPLOYING THE
LIGATURE IN CASES OF ANEURISM.

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THE adhesive inflammation is the primary resource of nature under local injury. It is employed in doing the repairs of the fabric which the other modes of inflammatory action secretly undermine or openly destroy. Suppuration and ulceration are invariably actions of destruction, when uncontrolled by the process of adhesion. This fact is strikingly exemplified in abscesses of the viscera which open externally, and in sloughs of the

intestine *per anum*, as I had lately occasion to shew in detail*. The single tube of the intestine after division or loss of substance is united, and forms a perfect tube again; that of the artery is obliterated: for the faculty of adhesive inflammation, upon which both phænomena depend, resides in the opposite surfaces of these canals, and coagulable lymph, which coats over the tied bowel, seals up the tied artery.

Before this adhesive inflammation was understood, surgeons attributed its proper results to other causes. The obliteration of an artery included in a ligature was supposed to be caused by the coagulation of the blood in the vessel: and as the existence of a coagulum of blood depended upon the exclusion of a portion of it from the circulation, if the ligature was placed in the vicinity of a large branch, the coagulum was not formed, and hemorrhage was inevitable. This was the doctrine recently taught in our schools, and illustrated by preparations; which however illustrate other points that might more accurately explain them.

The permanent obliteration of an artery can only be effected by an inflammatory adhesion of its internal surfaces. The adhesive inflammation of the

* See "An Inquiry into the Process of Nature in repairing Injuries of the Intestines, illustrating the treatment of penetrating wounds and strangulated Hernia." London, 1812.

internal or cuticular coat of arteries is sometimes but rarely spontaneous ; it is excitable in this as in other parts by pressure and by wound.

1. I have seen the aorta just below its curvature, and in another subject a little above its bifurcation, partially filled by pure lymph, without any aneurismal tendency.

2. The obliteration of an artery by pressure is a more frequent occurrence, as in the natural cures of aneurism and in those effected by art. I have a preparation shewing the total obliteration of the right subclavian artery by an aneurism of the arch of the aorta. Mr. Blount informs me that he lately saw an aneurism of the thigh, under the care of Mons. Dubois in Paris, cured by steady pressure upon the vessel continued for twenty-four hours. It is not to my purpose to quote or relate cases, because these facts are familiar.

3. It was discovered by the celebrated Desault, that a round ligature drawn tight upon an artery made a clean cut of its internal coat, and the experiments of Jones, devised and executed with equal felicity, have established that the obliteration of an artery tied with a round ligature, is only the cicatrization of this cut. To ascertain with precision the effects of ligatures of various sizes, both flat and round, I have repeatedly examined the appearances left upon the cuticular coat of the

artery after applying them, and the following is a report of such experiments upon the carotid, iliac, and femoral arteries of the human subject.

		No distinct impression, but a general longitudinal puckering or 'froncement,' as the French term it, of the internal coat, especially opposite the knot.
<i>Broad Tape</i>	-	}
<i>Narrower Do. Do.</i>	-	
<i>Narrow Tape</i>	-	The same, with partial laceration.
<i>Narrower Do. Do.</i>	- -	{
<i>Flat Bobbin</i>	-	The same.
<i>Large Round Do.</i>	- -	Cuts cleaner.
<i>Twist</i>	- - - -	{
<i>Twine</i>	- - - -	
<i>A round ligature including a sheath of linen upon the artery</i>	- - - - -	{
<i>Do. including a cylinder of quill, wood, or other firm substance</i>	- - - - -	{

From these observations it appears that the flat ligature, as it is diminished in breadth, and admits of being more strictly applied, *i. e.* as it approaches to the form and size of the round ligature, imitates its operation, but fails to produce a simple incised wound, which every body knows is the wound best disposed to unite by adhesion. The inclusion of substances soft or hard in the round ligature does not materially alter its effect.

It being established that the internal coat of an

artery is prone to take on the adhesive inflammation, and that it is only by virtue of this inflammation that the vessel can be permanently obliterated, it is not a question of difficult solution, whether the mere apposition of sound surfaces, the apposition of bruised and lacerated surfaces, or the apposition of fresh-cut surfaces is the condition most favourable to union. What is the result of our familiar observation in practice, of the comparative efficacy of pressure, of bruising and tearing, and of cutting, to excite adhesive inflammation? The obliteration of a hernial sac under the pressure of a truss, of an artery overlaid by a heavy tumour, and in general the cementing of entire surfaces is a chronic process. Contused and lacerated wounds oftener suppurate or even slough, than kindly take on the adhesive inflammation. Surgeons anxious to procure a rapid union of parts, incise them for that purpose, as in the hare-lip. The severe operation for hydrocele by incision rarely fails of its object.

It is curious to observe the revolution which has taken place within a few years in this branch of surgical practice, since experimental inquiry has furnished the true explanation of the principle upon which the ligature acts.

Mr. Hunter and the surgeons who after him practised the operation for the popliteal aneurism, were in the habit of applying the ligature with

force only sufficient to bring the sides of the vessel in contact; and some included an extraneous body, as a piece of cork or wood, or a roll of linen, to prevent the lesion of the artery in the act of tightening the ligature. The fear of cutting the coats of the vessel was uppermost in the minds of all, and next to this, the fear of quickening the process of ulceration, and the casting off of the ligature. Scarpa, Richerand, and the other eminent surgeons of the continent are still fettered by these fears. But we see that they are groundless; that, on the contrary, the security and effect of the ligature are ensured by its cutting the middle and internal coats, which it does without danger to the outer, however applied; and that retarding the process of ulceration when the ligature has done its duty, is not only useless but mischievous, as it increases the danger of secondary hemorrhage.

Jones, whose scientific and comprehensive view of this important branch of surgery *, must excite universal regret for his loss and respect for his memory, ascertained, that the effusion of lymph from the wound inflicted by the ligature was sufficient, even if the ligature were removed upon the instant, to obstruct the artery. By including a loose thread along with the artery in the ligature, he

* See "A Treatise on the process employed by Nature in suppressing the hemorrhage from divided and punctured Arteries, and on the use of the ligature, with observations on secondary hemorrhage." London, 1802.

readily withdrew the latter after the infliction of the wound. In one instance he succeeded with a single ligature, and in several instances with two, three, or four, made at a small distance apart. The lymph effused was in proportion to the extent of the section, or if this was incomplete, the union was equally so. He was led to conclude that the complete circular section of the internal coat was indispensable to union, and the success which attended his experiments led him to conjecture, that in some surgical cases removing the ligature as soon as it was made would be an efficient operation. This suggestion, the value of which he left to be determined by future experimenters *, was caught at with eagerness by his readers, and by many considered to be the essence of his publication. It required little sagacity to discover the advantages which would result to practice, if it could be shewn that the effect of the ligature which heretofore required fifteen or twenty days, could be attained with equal certainty in little more than as many seconds. But just as was this calculation in theory, it was not yet realized in practice, and the fact was chiefly valuable as it afforded conclusive evidence of the principle which he had

* " I leave the fact (viz. the complete obstruction of an artery consequent upon the momentary application of a ligature) for those who have opportunities of applying it in practice, when all the circumstances which determine its success or failure shall have been fully ascertained by further experiments on brutes." Jones on Hemorrhage, p. 136.

established, viz. that the obliteration of an artery was effected by the adhesive inflammation. For if the disposition of the cuticular coat to effuse lymph was such, that in some cases the mere wound, setting aside apposition of its edges, the condition commonly necessary to union, was sufficient to produce it, *a fortiori* the wound of which the sides were kept in contact would in all cases unite and by the same medium. But the result of these experiments neither warranted the conclusion that the complete incision of the internal coat was necessary to union, nor that union was a necessary consequence of such an incision. The history of the broad tape or ribband ligature proves that contact without wound will sometimes produce adhesion, and the frequent repetition of Jones's experiment has proved, that wound without contact will often fail to produce it. Among others Mr. Dalrymple, surgeon, of Norwich, has decided the latter point by many trials. He informs me, that he "has repeated the second experiment of Dr. Jones's third chapter, of which the results are represented in his eleventh plate, not fewer than seven times on the horse, and three times on the sheep; and that in every instance he has failed to obtain his results. Not only has no coagulum been formed; but even where the subject of the experiment has been suffered to live until the thirteenth, fifteenth, or eighteenth day after the operation, the canal of the artery has not been found obliterated. In

every instance, indeed, its calibre has been contracted ; still however it has remained pervious in a degree and capable of transmitting a lessened column of blood." The results of these experiments collectively, lead Mr. Dalrymple to the conclusion "that the internal and middle coats of an artery may be divided, the external tunic remaining uninjured, without being followed by the formation of a coagulum, or the obliteration of its canal." I am a good deal surprised at this notable difference in the results obtained by two experimenters of so much accuracy and discernment. To the presence or absence of the coagulum of blood no primary importance attaches, as it is a consequence only of the obliteration of the canal, and of that not always. The contraction of the vessel, contraction being invariably the concomitant of cicatrization, must always be the consequence of a wound of its coats ; and the stated difference of result between the case in which the ligature is taken off the vessel and that in which it remains upon it, I should explain thus : in the former, union takes place between the edges of the severed coat side by side (contraction,) while in the latter it takes place between the opposite sides (obliteration).

The original experiment of Jones, in whatever light we view it, is of unquestionable importance, and deserves to be highly appreciated. While its occasional failure demonstrates that the apposition

of the cut surfaces is essential to the certain obliteration of the vessel, its occasional success establishes that, *cæteris paribus*, it cannot with this precaution fail of its intention. And although uncertainty of result may preclude its application to practical surgery, I should little question its efficacy as a remedy for the aneurism, whether it simply diminished or totally arrested the column of blood, since the only theory of cure in this disease, obvious to my mind, is the diminution of the blood's impulse in the diseased and resistless artery. And here I cannot help observing of what vast importance it is to the progress of science, to register facts of which the use is at present imperceptible or at most indistinct, as beacons for future travellers on the same road. If we reflect how many discoveries have been the creatures of accident, and how few have been led up to and perfected by one and the same mind, it will not appear unfair to conclude that some may have been obscured and others lost, from a too light estimation, or a wilful disregard of these indirect aids and clues to knowledge.

From what has been said of the experiment of Jones, it will be understood that it is evidence over and above what was required, to prove that the wound of an artery is united by the same process as a wound of the skin, but that like this the wounded surfaces require to be supported in contact.

II. It would be well if a surgeon, before tying up the main artery of a limb, were to turn in his mind the series of changes of which this operation is the commencement, the nature and relation of these changes to each other, and the degree in which they may be influenced by the form of the ligature and the mode of applying it.

First, the internal coat is to be excited to an inflammation sufficient for the *vasa vasorum*, as they are called, to pour out lymph, by which the part of the artery adjoining the ligature becomes thickened, and being contracted in the form of a cone, is united at its apex. Within twenty-four hours this process should be considerably advanced, for at this early period begins the ulceration of the exterior tunic in consequence of the pressure of the ligature. The time required for its liberation varies according to the perfect or imperfect application of the ligature. In the arteries of the dog, which are much smaller than the human, ulceration is generally completed in six days. I pass over the clot of blood, because its presence is accidental, though not always unimportant: the gradual obliteration of the old and the enlargement of the new channels of circulation, because these are indirect consequences of the obstruction which do not affect the security of the ligature; but there are direct changes to take place external to the artery. The capillaries of the wounded cellular membrane must assume the healing or adhesive action, and

exude their lymph over and around the artery and into the cells of the membrane surrounding it, so that the ends of the vessel may be covered by lymph and the wound be in part filled by it in six hours. Soon this lymph becomes organized, having a red and granulated appearance; it goes on increasing in thickness until it completely envelopes the vessel, and becomes so firmly compacted therewith as to make its extremities indistinguishable *. After all this, after the severed vessel is thus carefully protected and fortified by a solid bed of lymph, and the wound is on the point of healing, a passage for the ligature is to be ulcerated through the lymph, and if unluckily the wound has closed over the ligature, an abscess must be formed to discharge it †. This is an outline of the changes which are required to ensue, and in the failure of one or other of them, the loss of a link in the chain, we may discover a cause of secondary hemorrhage.

First, the inflammation of the cuticular coat of the artery may be deficient, or not a pure adhesive inflammation, and no healthy lymph be effused. This may arise from the debility of a constitution worn out by disease, from a morbid change in the texture of the vessel, as a deposition of earthy matter in its coats, or a pre-existing erythematous state of the internal tunic; or it may be owing to

* See Fig. 4. Plate 7.

† See Mr. Hunter's first case in the "Transactions of a Society for the improvement of Medical and Chirurgical Knowledge."

the use of a ligature which simply approximates the sides of the vessel, or of one which fritters the cuticular coat to rags instead of simply dividing it. Unhappily neither of these causes will bar the ulcerative inflammation ; they will rather predispose to it, and to such a condition of it as will not be bounded by the ligature *. But should the ulcerative absorption be completed at any point of the cylinder, and no union have taken place, the only security against secondary hemorrhage will be derived from the casual existence and extent of the internal clot of blood.

Secondly, the adhesive action within the vessel may have been healthy and the union of its sides completed at a sufficiently early period, but the muscular parts in the vicinity of the artery having been extensively and rudely torn asunder by the operator's fingers in searching for it, a large portion of it denuded of its sheath in placing the ligature upon it, and perhaps all this violence committed upon a half hectic subject, sinuses are formed upward and downward in the course of the artery †. Here the ulcerative action is undefined by the adhesive. The matter lodges about the artery and dissects the muscles far beyond the limits of the wound, and there is much reason to fear that the

* Mr. Home's case of Mr. Marshal, *ibid.* vol. II.

† Mr. Hunter's 2d case. Mr. Birch's and Mr. Cline's cases, *ibid.* vol. I.

ulcerative absorption by which the ligature is discharged, instead of being confined to the circle of the ligature, will extend upon the parietes, partially as they are defended by coagulable lymph, and destroy this lymph, together with the newly cicatrized extremities. In this way secondary hemorrhage is produced in stumps that ulcerate deeply after amputation, and in abscesses in the vicinity of large arteries. I must remind the reader that the spontaneous steps of nature, in the suppression of hemorrhage from wounded arteries, differ only in the outset from those which follow the employment of the ligature. The blood extravasated into the sheath of the wounded vessel does the office of the ligature; *i. e.* it forms the temporary barrier until the coagulable lymph is effused under the adhesive inflammation which constitutes the permanent one. This analogy premised, I shall here relate a remarkable case of a wounded femoral artery, to shew how the lymph which seals the vessel being destroyed by ulceration in common with other parts, this admirable resource of Nature is cut off.

CASE.

Ann Mould was brought into Guy's Hospital on the 2d of December, 1811, intoxicated. She had been run over by a coach. The wheel had passed over the lower and back part of both her thighs.

A small deep wound was found in the ham, from which there was a free hemorrhage, to appearance venous. The wound was dilated but no bleeding vessel discovered; it was dressed and a gentle pressure applied. From the swollen state of the limb it was thought right to keep up evaporation from the surface. It was evident for some days after the accident that an internal hemorrhage was going on, and the blood extravasating between the flexor muscles on the thigh. The integuments of the whole limb became distended and the wound turned sloughy. Fomentations and poultices were applied; an ichorous and bloody matter issued from the wound, and the swelling of the limb was somewhat diminished. On the 14th of December the wound had assumed a much healthier appearance, and things seemed fair for recovery.

On the 17th at ten o'clock at night, Mr. La Serre was called to his patient on account of so profuse a bleeding from the femoral artery, that he found her dying upon his arrival at her bedside.

Dissection. A large ulcerated cavity containing blood and pus was found between the muscles which form the hamstrings. The femoral artery had been completely divided, its extremities retracted and thrown out of their relative situation. It was plain that the artery had been severed, for the mouth of the inferior portion was conical and sealed by lymph. The other end of the vessel terminated

abruptly in the abscess, a very small crust of blood lying within it. The ulceration was extending in this direction, having destroyed the sheath, dislodged the external clot, and opened the cicatrized extremity of the artery.

From this the fatal hemorrhage issued. Fig. 1. 2. of plate 6, accurately exhibit the contrasted state of the arterial mouths in the preparation.

The internal and external depositions of lymph are induced by the same inflammation, and take place at one and the same time, and both concur essentially to the security of the vessel; when therefore the external deposition is destroyed by a supervening ulceration, the security is diminished in the proportion of its importance. Mr. Abernethy mentions a case wherein ulceration extended to the iliac artery from an adjoining lymphatic gland, by which a great hemorrhage was caused while the ligature below remained firm*.

There is yet another and a prolific source of secondary hemorrhage, even where the ligature has done its duty; I mean the direct sloughing or gangrenous inflammation of the arterial extremity. This happens in aneurisms and amputations upon persons of irritable habits; in casualties which deeply shock the nervous system; and occurs most

* Surg. & Phys. Essays, Part III. p. 167.

especially in the wards of crowded hospitals, where gangrene has become contagious.

EXPERIMENT.

Two ligatures were applied on the femoral artery of an ass at the distance of one quarter of an inch, and were immediately cut away. On the following day the thigh was tumid and hot, and the wound soon ulcerated extensively, yielding a copious and offensive sanies. This condition of the parts increased until the fourteenth day, when the animal was killed. It appeared on dissection that the ulceration had extended farther internally than externally, having spread among the muscles and under the skin for many inches above and below the original wound. A clot one inch and a quarter in length was found within the artery, the effect of the obstruction which had been established by the adhesive inflammation. The portion of artery which had been included between the ligatures and the lymph contained in it, and surrounding it, were actually in a sloughing state. Beyond this part the upper and lower portions of artery, which were of a deep red colour, adhered to the clot sufficiently to prevent hemorrhage.

This case shews the destruction of the external bed of lymph, and the precarious security maintained against secondary hemorrhage where the sloughing inflammation has taken place. It might excite surprise that an operation so favourable to the healing of the wound should prove so severe in its effects; but these are to be ascribed to the standing posture of the animal, which, as it is unfavourable to the return of the blood, and requires a constant muscular exertion, carries the inflammation beyond its due bounds, and hurries the adhesive into the ulcerative action, as would most certainly be the case in the human subject under the same circumstances. For this reason the carotid of animals is to be preferred to the brachial or femoral arteries as the subject of experiment.

CASE.

In the year 1804, an athletic man enjoying vigorous health suffered amputation at the thigh at St. Thomas's Hospital, immediately after a compound fracture and laceration of the leg. The arteries were suffered to bleed freely before they were secured*. The stump early put on a very unfavourable appearance, and at the second dressing was in a sloughing condition. For the first five

* See Mr. Hunter's excellent remarks on bloodletting after severe wounds and amputations. On the Blood, &c. p. 564.

days the man had been kept low ; after the fifth he had a pint of porter daily. On the ninth day he became delirious, at first through the night only, but after the eleventh the delirium was constant. At this time there was general disturbance of the nervous system with watching, and he muttered and picked the bed-clothes. His pulse, though full, was intermitting. On the tenth he began to take wine and bark freely in addition to his porter. On the twelfth day he lay muttering with his eyes close, and pressed the lids together so closely as to resist every attempt that was made to open them. He was perpetually waving his hand above the bed-clothes. His pulse was 120, full and regular. He retained the power of swallowing, but passed his evacuations unconscious of them. He died at the end of the thirteenth day.

Dissection. The stump was excavated by sloughing, and an inch of bone was bare, but in many places the slough had separated, and granulations and good pus appeared. The ligature on the femoral artery was so nearly detached that it came away on removing the dressings. There was found on inspecting the artery, a clot of blood which reached to the first collateral branch, and was one inch and a half long. This coagulum did not quite fill the canal of the vessel, nor did it in the least adhere to its internal coat. The lower was smaller than the upper part of the coagulum, for there the artery was not contracted. The truncated extre-

mity of the vessel was open, ragged and sloughy. There was a very little coagulated lymph round the external coat at its extremity, but none within it. The internal coat was of a uniform vivid red colour, and this extended even above the bifurcation of the aorta and some way down the iliac artery of the opposite side. The viscera were all perfect and healthy. See fig. 3. plate 6.

This case exemplifies an accidental advantage to be derived from the internal coagulum of blood. Hemorrhage was prevented only by its extent. The conical shape of the clot and the sloughs lying about the extremity of the vessel, evince that it had been contracted, and had undergone the adhesive process. Had the collateral branch opened at the distance of three or four lines from the extremity of the artery, the clot, which would have been accurately of the same extent, must have been carried away by the torrent of the circulating blood, when from the death of the lymph it became the only remaining stay to hemorrhage.

EXPERIMENT.

The left femoral artery of a large Newfoundland dog was tied with a single ligature. A portion of the sheath and the anterior crural nerve were included in the ligature. Next day the animal was

very lame in his left leg, and his toes doubled under him as he walked. There was no sensible change in the temperature of the limb. On the fifth day a hemorrhage took place from the wound. On the sixth day the dog was ill and refused to eat. On the seventh he was found dead from a return of hemorrhage during the night.

Dissection. A very extensive sloughing of the cellular membrane around the wound had taken place. The artery itself had sloughed at the part where the ligature was applied, and its divided portions had retracted. Each end of the vessel was dead to some distance above and below the slough. See fig. 4. plate 6.

In this experiment an additional cause to the strained position of the limb probably operated to produce the mischief. This was the inclusion of the nerve in the ligature. See the report of a similar experiment by Pouteau*, followed also by fatal hemorrhage.

It would be superfluous to expatiate upon the obvious and important practical lessons which these experiments convey; first, the perfectly relaxed and easy position of the limb after the operation, from inattention to which Petit lost a patient by

* *Melanges de Chirurgie*, p. 302.

secondary hemorrhage* ; and secondly, the application of the ligature to the artery exclusively.

The last narrative calls to my mind the case of a female upon whom Mr. Abernethy performed the operation for a popliteal aneurism. Pain and sickness were experienced after the operation, fever and restlessness came on, and a fatal hemorrhage happened on the third day. Dissection shewed that the whole surface of the wound was in a sloughy and putrid state. The internal coat of the artery was highly inflamed and its orifice pulpy and sloughy†.

Secondary hemorrhage sometimes results from the laceration of the young and tender cicatrix, when the ligature is violently plucked away. Of this I could recite an instance, but it is not to be classed among the natural causes.

The causes which I have enumerated are threefold.

1. Failure of the adhesive inflammation.
2. Diffused and extending ulceration.
3. Sloughing or gangrenous inflammation.

* Mem. de l' Acad. Roy. des Sciences. An. 1732.

† Surg. Obs. on Aneurism, p. 229.

These may be severally induced by many other circumstances than those which I have mentioned. Each admits of being aggravated if it is not occasioned by unskilful operations and ill adapted ligatures.

III. The desiderata in the operation for aneurism, as it is at present performed, are to excite with certainty and rapidity the adhesive union of the sides of the artery; to limit the ulcerative process as much, and to complete it as early as possible.

I have already pointed out the difference in the action of ligatures to accomplish the purpose of their application.

In this country the broad ligature is exploded from reputable surgery*; the ligature in use is round, whether larger or smaller, and two are generally applied at an interval sufficient to admit of the division of the included portion of artery, after

* The surgeons of the Continent are greatly behind-hand on this subject, notwithstanding the indefatigable labours of Professor Scarpa. They clearly do not understand the train of actions set up by the ligature. It is astonishing that so intelligent a person as Scarpa should still practise the sheathing of the artery with linen. He cannot surely know that it is unnecessary to the security of the external coat, and that in twelve hours the vessel would be as well sheathed with lymph which this wadding intercepts, and through which it must work its way by ulceration.

which the extremities retract to a considerable distance within the sheath. When the ligature is applied with but moderate tightness, from fear of injuring the arterial coats, it is liable to be thrown off the divided vessel, an event of which I was once a witness. On this account it was proposed to pass a stitch through the artery to retain it, which if the ligature were lax would not prevent hemorrhage, and was an useless precaution if drawn tight, because in this case it indents the external coat in a groove where it divides the muscular and internal, and thus obtains a firm seat. But I can see no advantage resulting from the division of the artery, and although the practice was introduced upon authority to which I pay the highest respect, the benefit has been rather supposed than proved. If it carries with it no advantage, it is not free from objection. The ligatures must be applied at a greater distance apart than would be necessary if the vessel were left continuous, and the retraction which ensues upon division renders the cavity of the wound larger and the effusion of lymph of necessity greater than it would otherwise be, for this always extends beyond the extremities of the divided vessel*. Even though the external wound is of the full extent required for the convenient application of the ligatures, they will be carried to a distance under the muscles and integuments, and the suppuration which they excite will

* See fig. 4. plate 7.

be more profuse and more confined, a circumstance of which I have before shewn the evil consequences. If on the other hand two ligatures are applied, and the included portion of artery left to fade, or only one ligature is used, a practice much to be preferred, the extremities, being previously fixed by adhesion to the sheath, will retract very inconsiderably, if at all. I was led to this observation by comparing the appearances of parts in which these different methods of operating had been practised. I tied one carotid of a dog according to the present mode of operating, and the other with a single ligature, and found a remarkable difference in the extent of surface of the wound, the distance of the arterial extremities, and the quantity of lymph shed over and around them.

In addition then to the greater simplicity of the operation; the limitation of the bed of the wound, and the casting off of the ligatures at the point of their original application opposite to it, are advantages obtained by the non-division of the vessel. These circumstances are important, as they limit the suppurative and ulcerative processes to a smaller compass, and quicken the separation of the ligature. To some this last might appear an objection, as it was formerly urged against the tight ligature, under the idea that the adhesion might not be previously established. But experiment proves that a due relation is preserved between the leading and

the subsequent stages of inflammation ; the actions are not single and independent, but form a train and go on in harmony with each other, so that the quickness of the ulcerative is only a consequence of a proportionate celerity of the adhesive action. In this respect the actions of inflammation ensuing upon injury are not strictly morbid, for they bear a stronger affinity to the phænomena of health than of disease, and thus we talk of healthy inflammation and healthy pus. A perfect union by the first intention is the best security against slow or spreading ulceration ; and the means above explained, by which we secure a perfect union, tend in the greatest degree to make ulceration quick and definite. Formerly lax ligatures were used to retard ulceration, so that by the same means by which ulceration was rendered slow, adhesion was rendered imperfect.

I have been led to these observations, in considering the present method of operating. But it appears to me that the residence of the ligature on the artery stamps an imperfection on the operation for the aneurism, which the facts ascertained by experiment plainly indicate to be remediable. Such is the rapidity of the union by adhesive inflammation, that lymph is in a state favourable for organization in less than six hours in a wound, the sides of which are preserved in contact. And long previous to the appearance of that coagulable lymph which is the medium for the inosculation of ves-

sels, a glutinous exudation from the cut surfaces fastens them together. In my experiments on the intestines of dogs I had many proofs of this, and the same thing has been observed in wounds of other parts. But would the pared edges of a hare lip unite by adhesion, favourably as they are disposed to union when brought in contact, if they were allowed to remain asunder? Certainly not. It occurred to me therefore, that if a round ligature were applied and suffered to remain upon the vessel for a few hours, it would have fulfilled the intention of its application, and by its removal at this period the dangers and inconveniences attending its stay would be obviated. Suppuration, which chiefly results from the irritation of the extraneous body, was never observed in less than twenty-four hours, and very seldom so soon; and although the ulcerative absorption, which sets the ligature free, commences at the period of suppuration, it is never finished in less than eight, seldom in less than fifteen, and often not in twenty days. Now if the opposite lips of the wound in the artery were kept in contact for a time sufficient to ensure their adhesion, suppuration and ulceration of the external coat of the artery would probably never ensue; the artery would be obliterated without losing continuity, and the wound would heal like a simple wound, by the first intention. This reasoning seemed to me plausible enough to justify an experiment or two; I made them, and the following is the report.

EXPERIMENT I.

The right carotid of an ass was exposed by dissection. A piece of coloured twine was laid parallel with the artery and included with it in a round ligature drawn into a single knot. The integuments were then stitched together by an interrupted suture, and at the end of six hours the circular ligature was drawn away by the slip of twine. The animal lost very little blood, although from the depth of the vessel and the condition of the beast it was not completely exposed and secured without a considerable separation of parts. The diary of his life for a fortnight succeeding the operation presents nothing worthy of note. The natural functions went on as before, the wound discharging pus freely. I should observe that the peculiar texture of the integument of these animals causes every wound extending beneath it to suppurate.

In the act of manducation on the day fortnight of the operation, a stream of arterial blood jetted from the wound. I was present and allowed it to continue; it did so for ten minutes or thereabouts, when the animal fainted; it stopped, and did not afterwards recur*. In two days after he seemed to have recovered the loss of blood, and to be as well

* This blood must have issued from a branch opened by ulceration in the cavity of the wound.

as before. The wound was healing. The ass was now killed, and the appearance of the artery upon examination is represented faithfully in fig. 3. plate 7.

EXPERIMENT II.

The carotid of a blood horse was tied, a slip of twine being included in that which formed the ligature as in the preceding experiment. The wound was brought together by a single suture, and the ligature withdrawn by means of the slip in *two* hours. The operation was done at six o'clock p.m. and the animal knocked down fifteen hours after, viz. at nine o'clock of the following morning. The appearances upon the examination of the artery are represented in fig. 1. plate 7.

EXPERIMENT III.

The left carotid of the ass which was the subject of the first experiment, was treated in the same manner as the right had been, except that the ligature was withdrawn at the expiration of *one* hour. Next day the animal was killed, having survived the first operation seventeen days, the second

twenty hours. The appearances of the left carotid are preserved in fig. 2. plate 7.

That the coaptation of the wounded surfaces of the cuticular coat of an artery, if preserved for a short period after the infliction of the wound, renders its obliteration certain, is a fair inference from these experiments. A more extended scale of inquiry, however, is required to establish the uniformity of their results. They afforded evidence that the circulation was arrested, by the absence of the pulse in the artery continuing after the removal of the ligature; and the vessel was therefore concluded to be as impervious as if the ligature had remained upon it. But upon this event I think it would be impossible to calculate with confidence, unless the ligature were suffered to remain upon the vessel for a time sufficient to insure the organised adhesion of its sides. In Jones's experiments, the return of the circulation was invariably ascertained after the removal of the ligature; and he seems to have regarded this as a proof that the subsequent obliteration of the canal was effected by a process independent of the coagulation of the blood. But in all these and similar experiments, the blood, as blood, has no concern in the obliteration of the vessel; the conical coagulum of blood is not formed in the first stage of the obstruction; its formation is gradual, and appears to require a change in the properties

of the vessel consequent upon the abolition of its function. And although the presence of the conical clot satisfactorily demonstrates the obstruction of the canal, it is sometimes very inconsiderable, and at other times deficient, where the obstruction is complete. It is a mistake therefore to regard the coagulum of blood among the immediate effects of the ligature; it is an incidental consequence only of the permanent obstruction which it has been supposed to constitute; without which it never could be formed, nor, if formed, ever be competent to the purpose of permanently obstructing the canal of an artery.

In the materials of this paper I have derived assistance from my friend and colleague Dr. Farre. It would be injustice to myself, as well as to him, to conceal an obligation, which I feel it creditable to owe, and grateful to acknowledge.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Drawn by H. Thomson & Engraved by J. Stewart