FURTHER OBSERVATIONS
ON THE
LIGATURE OF ARTERIES.

By BENJAMIN TRAVERS, Esq. F.R.S.

SURGEON TO ST. THOMAS'S HOSPITAL,

AND

THE LONDON INFIRMARY FOR DISEASES OF THE EYE,

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IN a paper which I had two years ago the honour of reading to the Society, I suggested the temporary application of the ligature as a simplification of the practice employed by surgeons for obliterating the larger arteries.

If the arrestation of the column of blood for a time sufficient to admit of its becoming a solid, constituted the security to be relied upon, or if as formerly supposed, the effect of the ligature were confined to the simple coaptation of the sides of the vessel for a time sufficient to induce their adhesion, the propriety of interfering with it might be questionable. But the facts being established beyond controversy that the round ligature divides the inner tunics, and that the wound

so produced is healed by a process of adhesive inflammation, it seemed probable that the serviceable operation of the ligature was limited to a period far short of that, in which its liberation from the vessel by an ulcerative process could be accomplished.

It is now well known, that the result of tying an artery, and removing the ligature instantly, is a wound or fissure of the middle and internal coats, which is soon occupied by lymph, and gradually obliterated by cicatrization, the vessel remaining pervious. But if three or four ligatures are applied contiguous to each other, forming as many distinct fissures, the lymph is effused in such abundance as to project into the cylinder, and obstruct the passage of the blood. It has been once or twice observed after the application of a single ligature, that the consequent deposition of lymph was more abundant, and projected in the form of a band from the fissure into the area of the tube ; and a single ligature applied for one, two, or three hours, has in some instances presented similar evidence of an increased inflammatory action.

In one experiment in which the ligature had been removed *two* hours after its application, I found the vessel blocked up with lymph mingled with coagula of blood, at the end of fifteen hours.

In a second, after the removal of the ligature

in *one* hour, the same result was obtained upon examination at twenty hours.

In a third experiment, the ligature having been applied for *one* hour, I found the fissure complete but without any appearance of a healing process at the end of thirty hours.

In a fourth, the vessel which had been tied for *one* hour, was pervious to the blood, which escaped freely on wounding it, after the lapse of sixty-five hours.

It appears therefore that much uncertainty prevails concerning the effect of the ligature applied for a minute or an hour: that the mere infliction of the wound is not commonly followed by an inflammation more than sufficient to heal itself, nor does the addition of pressure for an hour or two commonly increase its activity in a marked degree. The exceptions therefore which have occurred must be referred to the difference of organic sensibility, or of temperament and vital power in different animals.

The obstruction of an artery may, I believe, be regarded as an invariable consequence of the application of a ligature for six hours, in the species of animals which were the subjects of these experiments. It is an indispensable condition however, that the mode of applying the ligature be such as to insure the division of the inner tunics, a condition

which it will be more difficult to prevent than to execute, if the ligature be of a proper form. If one end of a ligature of Dutch twine be doubled, so as to form a noose under the single knot, it keeps its seat in the fissure which is formed for its reception with perfect security. This is the description of ligature which I have employed in the experiments about to be related. It is represented in *Plate V. Fig. 1.* By cutting the ends of unequal length they are easily discriminated; and by drawing the noose end, the ligature comes away with the greatest facility, and without any disturbance of the parts. It requires no additional security from what is called the surgeon's knot, or from a double knot; and they are objectionable because less easily removed.

In some former experiments on this subject several circumstances occurred, which impressed my mind with the necessity and importance of further inquiry. I was not informed with certainty if in the vessel, in which lymph was copiously deposited, and no coagulum of blood was present, the circulation was actually arrested. In a case in which the ligature had been removed at six hours, and from the presence of a cylindrical coagulum of blood it was evident that the obstruction was complete, I was unable to say whether the circulation had been arrested by lymph effused prior to the removal of the ligature; or whether it had been restored and only gradually

obstructed by lymph effused subsequently to the removal of the ligature. The probability that the impetus of the circulation, once re-established, would interrupt the adhesive process in the early stage, and prevent or remove the deposition of lymph, seemed to favour the former opinion; while on the other hand, the time allowed for the residence of the ligature appeared insufficient for the actual obstruction of the vessel. The state of the pulse beyond the ligature, which might be naturally expected to throw some light upon this question, afforded none, for it continued in the carotid artery even during the application of the ligature, and was more or less, as a branch or branches, proceeding from the artery above the ligature, were nearer or more distant; although a slight remora, as well as a diminution of fulness in the stroke, was always perceptible by laying a finger on either side of the ligature, so as to compare the pulse above with that below it. For these reasons I determined, in prosecuting these experiments, to place a second ligature upon the vessel an inch further from the heart, in order to arrest the re-fluent blood, and after freely wounding the vessel with a lancet in the interspace, to remove the first or noose ligature.

To ascertain the earliest period at which the ligature might be removed, and the artery wounded without hæmorrhage, was the object of the following experiments.

EXPERIMENT I.

A single noose ligature was made upon the carotid of a horse. At the end of six hours I placed another ligature upon the vessel, an inch or somewhat more above the former. I then half divided the vessel in the interspace, and drew off the noose ligature without the slightest disturbance of the parts. The blood instantly jetted out in a full stream. The first jet was serous, so as scarcely to stain my linen which was besprinkled with it.

Examination. The internal tunic was completely divided, and the fissure partially filled up by soft lymph, which projected a little into the vessel. The deposition had slightly thickened the coats of the artery at this part.

EXPERIMENT II.

The ligature was removed at nine hours. The hæmorrhage was instantaneous and apparently uninterrupted.

Examination. The fissure was filled by lymph, projecting equally in the form of a narrow layer between its edges. *Plate V. Fig. 2.*

EXPERIMENT III.

Ligature removed at twelve hours. No blood issued. In a quarter of an hour afterwards the

animal was knocked down, and the parts removed.

Examination. Complete obstruction of the tube. A strong circular cord of lymph filling the fissure of the inner coat, supported by a conical coagulum of blood above and below it, the former half an inch, the latter an inch long. Considerable effusion of lymph between the internal and middle coats, to the extent of the coagulum, by which the tunics were much thickened, and the cylinder contracted. *Plate V. Fig. 3.*

EXPERIMENT IV.

Ligature removed at 20 hours. No blood escaped, and the obstruction appeared complete. The animal was knocked down ten minutes after the removal of the ligature. The blow was misplaced, and he fell, after much staggering, with great force on the wounded side. The concussion was instantly followed by a copious hæmorrhage from the wound.

Examination. The fissure of the ligature occupied by lymph, which had evidently coalesced from the opposite sides of the vessel and obstructed it, formed a septum which was imperfect, as if ruptured. A string of coagulated blood three inches long was connected with the lymph inferiorly. Above, a broader clot, half an inch long,

extended from the lymph into the wound, and must therefore have been recent. The tube was thickened in its walls by effusion between its coats, and thus narrowed in the vicinity of the ligature.

Plate V. Fig. 4.

EXPERIMENT V.

Ligature removed at twenty-four hours. No escape of blood upon its removal. The animal walked about the yard; and in ten minutes was polled, but was only stunned by the blow. After falling he struggled and threw his head violently from side to side, when the blood rushed out impetuously as before from the half divided vessel.

Examination. The lymph in the fissure presents an appearance very similar to that of the preceding experiment, viz. a ruptured septum. No coagulum of blood was found, except a short and recent one, extending from the breach of the septum into the wound, as in the former experiment, and shewing the obstruction which the lymph had opposed to its passage.

EXPERIMENT VI.

I took the precaution of suffering the animal to survive the operation of removing the ligature and wounding the vessel, for six hours. This was done at sixteen hours. No hæmorrhage en-

sued. The animal was killed in twenty-two hours.

Examination. The vessel was obstructed by a complete membranous septum of lymph, some particles of coagula lay beneath the septum, and adhered to it, but no cylindrical coagulum of blood had formed.

EXPERIMENT VII.

From the last result, I thought it possible that the ligature applied for six hours, might cause the obstruction of the vessel in twelve.

The ligature was drawn off in six hours, and six hours after the artery was divided. The blood flowed freely, but in an evidently diminished column, and with abridged ~~saltus~~.

Examination. The lymph was deposited in a mass occupying two thirds of the area of the vessel. It was however insufficient to obstruct the passage of the blood.

EXPERIMENT VIII.

I wished to know if the obstruction would be equally complete in the truncated artery, in the same space of time as was allowed in Exp. 3.

A ligature was placed on the carotid of a horse;

and while the vessel was held between the fingers of an assistant, one inch below the ligature, the artery was divided and the noose ligature applied to the inferior extremity. In twelve hours the ligature was withdrawn. No bleeding ensued, and at thirty hours the animal was killed.

Examination. The fissure was filled by lymph undistinguishably blended with a clot of blood, projecting one fourth of an inch above it, and reaching downward to the aorta. A considerable branch was occupied by the coagulum; but it did not stop at it, as usual. *Plate V. Fig. 5.*

From these experiments the following conclusions may be drawn.

1st. No material obstruction is opposed to the passage of the blood upon removing the ligature at a period of six or even of nine hours from its application, and consequently its ultimate obstruction under these circumstances must be referable to the gradual completion of the adhesive process.

2dly. The residence of the ligature for a period of six hours affords direct evidence of an inflammatory action in the deposition of lymph between the divided tunics; which deposition is more abundant at nine hours, and sufficient for the obstruction of the vessel in twelve; pre-

senting the form of an interstitial cord between the lips of the fissure, and continuous with it, a membranous septum extending across the vessel*:

3dly. The septum of lymph is formed prior to the coagulum of blood, and in all cases of ordinary circulation is, of itself, adequate to the prevention of hæmorrhage; but under a sudden extraordinary impulse of circulation, or a violent concussion *ab externo*, is liable to be ruptured and give passage to the blood. If however an interval of six hours be suffered to elapse after the removal of the ligature, the same violence is not followed by hæmorrhage, although no coagulum of blood be formed.

4thly. The cylindrical coagulum of blood supporting the septum of lymph is an additional preventive to hæmorrhage under extraordinary impulses. It may be formed at twelve, or may not be formed at twenty-four hours; the nearest collateral branch being equally distant and the obstruction equally complete in both cases.

5thly. A period of twelve hours is sufficient for the obstruction of the vessel by lymph, so as to admit of the removal of the ligature, and the

* This septum is concealed by the cylindrical coagula of blood which adhere to it intimately.

wound or division of the artery without danger of hæmorrhage.

6thly. The addition of the pressure of the ligature to the wound which it inflicts, accelerates the adhesive process; thus within a certain limit, the earlier the removal of the ligature, the more remote is the period of obstruction. If applied for six hours, it is unsafe to open the artery in less than twenty-four hours; if for twelve hours, the artery may be opened immediately.

7thly. The ligature applied for twelve hours upon the truncated artery, is equally safe as upon that which is continuous.

8thly. The coagulum of blood is larger and more extensive in the truncated than in the continuous artery, and is not bounded by collateral vessels, but extends into them; probably owing to the feebler propagation of the heart's impulse along the divided and retracted vessel, and the consequently greater quiescence of the fluid blood.

The experiments next to be related, give the operation of the compressor, and were undertaken with a view to determine its merit as a surgical instrument, comparatively with the ligature. Professor Assalini of Milan, who lately

visited this country, entertains a preference for the practice of compression in the operation for aneurism. He had employed it with success in three cases of popliteal aneurism*.

Dr. Crampton, Surgeon-General of Ireland, and Mr. Dease of Dublin, have likewise used compression for a limited period with success, in two recent cases of popliteal aneurism, of which I do not wish to anticipate the details.

These circumstances I mention, as they give additional interest to the investigation.

EXPERIMENT IX.

The compressor of Assalini was applied to the carotid of a horse, and slackened at the end of sixteen hours, when a free hæmorrhage ensued from a wound with a lancet half an inch beyond the compressed part.

Examination. There was no breach of the inner coat, but a deep indentation of the walls of the vessel was observed where the compressor had been applied, upon which was a very thin pellicle of lymph, and a slender clot of blood was contained

* See the Appendix to Mr. Hodgson's valuable "Treatise on the Diseases of Arteries and Veins," for an account of the instrument and the operations of Professor Assalini.

in the portion of the vessel inferior to that which had been compressed.

EXPERIMENT X.

The compressor was applied for thirty hours. The indentation was conspicuous; but as it was evident that no obstruction had taken place, I did not open the vessel before death.

Examination. The indentation had the appearance of a discontinuity of the inner coat, of the breadth of the compressor, but no læsion was discernible. A slight blush of inflammation appeared about the indented part.

Plate VI. Fig. 1. very exactly represents the preparation.

EXPERIMENT XI.

The compressor was applied for twenty-five hours. In this experiment Professor Assalini accompanied me. The animal was suffered to live a hundred and twenty hours.

Examination. A mass of lymph mixed with much blood exactly occupied the compressed part of the cylinder, and adhered firmly to the internal tunic. The external coat of the vessel was sloughy and ragged where the compressor had been applied. *Plate VI. Fig. 2.*

EXPERIMENT XII.

The compressor was applied for twelve hours, and the animal suffered to live ninety-eight. Owing to the vicinity of an anastomosing branch, the pulse above the compressor was comparatively strong during the experiment.

Examination. The artery was traversed by a septiform layer, and filled by a soft bed of lymph mixed with blood, and adhering closely to its sides, of the extent of the indentation. The cylindrical clot of blood was an inch long, but had not adhered to the lymph, and was lying loose at some distance below it, when the vessel was opened. *Plate VI. Fig. 3.*

EXPERIMENT XIII.

The following were parallel experiments.

The compressor was applied to the carotid of a horse for six hours, and the animal permitted to live for seventy hours. On its removal the part of the vessel to which it had been applied resumed its cylindrical form, but felt rigid, and as if contracted to half its former bulk. At the end of seventy hours the vessel was freely wounded with a lancet, as before described, and the hæmorrhage was profuse.

Examination. The cellular substance was loaded with blood. The artery was less contracted at the compressed than at the wounded part. A thin spiral coagulum of blood, an inch long, adhered at its basis to the sides of the compressed part, having its apex turned towards the heart. It was sufficient to shew that some impediment to the passage of blood had existed. Contiguous to this was a narrow and recent clot of blood extending to the wound made by the lancet, which was in the form of a crescent; and by its contraction gave a bulged or pouch-like appearance to this part of the artery. *Plate VI. Fig. 4.*

EXPERIMENT XIV.

At the same time, and in circumstances as nearly similar as possible, a ligature was applied to the carotid of a horse for six hours, and the animal permitted to live seventy hours. The part retained the form which the ligature had given it, that is, it was strictured at the division of the internal tunics. At the end of seventy hours the artery was wounded as in the former experiment; no hæmorrhage ensued.

Examination. A strong round cord or band of lymph filled the fissure of the artery; the inferior coagulum of blood of the full size of the vessel extended to the subclavian artery, and the upper, likewise of the size of the vessel, was one inch long.

The lancet wound was near the extremity of this coagulum. *Plate VI. Fig. 5.*

EXPERIMENT XV.

I wished to know the effect of leaving the compressor upon the vessel, and the time in which it was liberated by ulceration.

The compressor was screwed home upon the carotid of a dog, and left upon the vessel. In the night between the fourth and fifth days it fell off. The slough was not retained between the teeth of the instrument. On the tenth day the animal continued well, and the wound was healed in a fortnight.

Examination. The artery was completely obliterated where the compressor had been applied. The extremities were solid and conical, being filled with lymph which exhibited abundant vascularity after a fine injection.

These experiments admit of the following inferences.

1. The compressor, like the ligature, effects the obliteration of an artery by exciting inflammation upon its internal tunic.

2. The operation of the compressor differs from

that of the ligature in not producing a læsion of the inner coats, and therefore exciting inflammation upon a continuous surface.

3. The operation of the compressor is slower than that of the ligature. The former applied for thirty hours, leaves an inflammatory blush or a pellicle of lymph upon the inner coat, while the latter applied for only twelve hours, is found to have obstructed the vessel by lymph : again, the former applied for six hours has produced no apparent sign of the adhesive process, when examined at the end of seventy hours ; whereas the latter applied for the same time, and examined after the same interval, is found to have effected the complete obstruction of the artery.

4. The effusion of lymph after the application of the compressor, where the obstruction of the artery has been accomplished, is, *en masse*, to the extent of the part compressed, which is marked by a deep indentation of the walls of the vessel to which the lymph firmly adheres. The mass is of least firmness in the centre, where it is mixed with the red particles of the blood.

5. The application of the compressor for a period of twenty-five hours is followed by a sloughy state of the external coat of the vessel.

6. The compressor left upon the artery is libe-

rated by ulceration in about four days; the adjoining portions of the vessel, being previously secured by the adhesive process, present solid conical extremities. The effacement of the compressed portion of artery is complete; and the appearances correspond precisely with those produced by the application of two ligatures, distant half an inch, more or less, upon a portion of artery denuded of its sheath, in which the interval sloughs and disappears*. I may observe, that where the vessel is left undetached from its sheath in the interval of the ligatures, the tube remains, and although shrunk, continues to be nourished.

7. The organization by blood-vessels, of the lymph obstructing the tube, is distinctly visible in a fortnight after the application of the ligature or compressor.

It appears then that the operation of the compressor and ligature, applied each for one minute, is that of simple pressure opposed to simple wound. If they are applied for a longer time, it is simple pressure opposed to wound and pressure com-

* In a recent case of iliac aneurism, for which the external iliac artery was tied by my colleague Mr. Henry Cline, with perfect success, the single ligature, which came away on the 17th day, brought with it a slough of a cylindrical portion of the artery, about a quarter of an inch long, the ligature encircling it in the middle.

bined. It is undeniable from these experiments that the latter is a more powerful instrument for effecting the object in view ; and this result of the combination is equally conformable to reason and to experience.

The following observations, which these and similar experiments have afforded me the opportunity of making, are rather general than referrible to individual examples.

The union of the sides of a vessel is never immediate or by direct contact, but by the medium of lymph effused. The ultimate operation is the removal of this lymph and the gradual conversion of the vessel into a cord, by a process of absorption.

After the employment of either the ligature or compressor for a time only sufficient to ensure the adhesive process, the separation of the vessel by ulceration does not ensue.

The conical form of the extremities of a vessel which has been severed by ulceration is the effect of the cicatrising process, and is not observed where that has not taken place. In the vessel divided by ulceration, and simply plugged by a coagulum of blood, there is no contraction of the mouth of the artery, consequently it is the result

of the adhesive process, and not of the muscular action of the vessel, which takes place upon a direct division.

Where the cylindrical coagulum of blood is formed, it adheres at its basis to the lymph sealing the vessel, and generally for a small space to the sides of the vessel. It is therefore encrusted or coated with lymph : this lymph, is, I suspect, separated mechanically from the red particles which are accumulated in the interior of the clot, as in a basin, and should not be considered as the product of inflammation. The more the uniting band of lymph, or *couvercle*, as it has been called, is distinct from and independent of the coagulum of blood, or *bouchon*, the more certainly is the vessel obstructed by the adhesive process.

The effect of the ligature is more satisfactory than that of the compressor in this respect. The former presents a more considerable effusion of pure lymph in the form of a distinct membranous septum. The latter exhibits a mass of lymph and blood mixed together, as if the last had been entangled in its passage. The septum is produced from the cleft or fissure formed in the coats of the vessel, and the more abundant supply of pure lymph is derived from the cut surface ; the obstruction is, however, in all cases formed chiefly by lymph, for the circulation will be continued by

the side of a mass of lymph not filling the cylinder, or through a central opening in a septum of lymph.

Where the ulcerative process is to be gone through, the compressor and ligature do not differ in their operation. The principal difference is at the commencement of the operation. Thus the ligature having already divided the inner tunics by its application, the process of adhesion commences at a much earlier period. In the remainder of its operation it has to do with the outer coat exclusively. The fissure looks like a provision for the independent carrying on of the adhesive or defending process. The compressor on the other hand, encircling the entire tunics, and not directly affecting their integrity, consequently ulcerates them progressively, and as the adhesive process begins later, its safety must depend upon the ulceration of the entire cylinder being later accomplished.

The time at which the clot of blood is formed seems to depend on circumstances not very easy to be ascertained. After obstruction for a period of forty-eight hours, I have invariably found it, unless a branch was contiguous to the obstructed part, which however does not always prevent, though it retards its formation. Where the compressor had been applied for thirty hours, there was no appearance of it. It is not always limited by the opening of the nearest branch, and fre-

quently does not extend so far. A slender string or filament of cruor, the incipient coagulum, is generally found where obstruction has taken place; and some small coagula of blood are often mixed with the lymph by which the vessel is obstructed.

The earliest period at which I have seen it formed is one of twelve hours. (Experiment 3.) In experiments 4, 5, and 6, although the animals lived 20, 22, and 24 hours,—the obstruction was equally complete, and the branches were equally distant,—no coagulum had formed. In Experiments 11, 12, 14, and 15, in which the obstruction was complete, and the animals were suffered to live for seventy hours and upwards, the coagulum was present. Its importance is strikingly manifested by a comparison of the results of Experiment 3, with Experiments 4 and 5. Had the clots been fully formed in the latter instances, I feel assured that the hæmorrhage which took place in the last struggles would not have occurred. Why the coagulum was not formed, when the life of the animal was extended to six or eight hours longer than in the first-mentioned experiment, I am at a loss to explain. I have already offered a conjecture concerning the unusual size and extent of the coagulum formed in thirty hours in Experiment 7. The validity of the lymph-plug in the absence of a coagulum under ordinary circumstances is inferrible from Experiments 4, 5, and 6,

and that the effusion of lymph is always prior to the coagulation of blood in the vessel, is sufficiently demonstrated*.

It has been supposed that the vicinity of a branch to the ligature of an artery, as it interfered with

* Mr. Hunter supposes that a disposition to coagulate is given to the blood by the inflamed state of the vessels: and thus he accounts for the coagulum of blood in the artery of a mortified limb. Dr. Thomson refers this phenomenon to the closure by adhesion of the mouths of branches issuing from the trunk, and the stoppage thus put to circulation. I have, however, seen the coagulum occupying the branches as well as the trunk, and presenting a mould of the ramifications. Petit, O'Halloran, and others, noticed the extension of the coagulum into the living portion of the artery, an observation now familiar to most surgeons. Dr. Thomson has observed that in many instances this coagulum was absent where no hæmorrhage had taken place; the extremities of the vessels were closed by the adhesive inflammation which had occurred prior to the separation of the living and dead parts. In other cases the extremities of the arteries of stumps were found open, from which no bleeding had occurred during the spontaneous separation of the limb; and hence Dr. Thomson is of opinion that the coagulation of the blood in the arteries takes place less frequently in mortification than has been supposed. My opportunities of examining the vessels of stumps have disposed me to the general belief that the blood coagulates in the vessels after mortification, but they have not been sufficiently numerous to enable me to say more on the subject. I have attributed the circumstance not to any change in the circulating blood, but to the arrestation of motion in the dead artery in which the coagulation begins, and having once begun, of course extends through the living vessel, which is a *cul de sac*, up to the next large branch or bifurcation, as in tied arteries. The coagulum however is not so compact and firm as after a ligature, but contains a larger proportion of red particles to the lymph.

the coagulation of the blood, rendered the vessel insecure; and I have often heard of a bleeding from the femoral artery where the ligature had been placed below the origin of the profunda. I examined a preparation some time ago, in which a ligature had been placed upon the external iliac between the epigastric and circumflex-iliac arteries, and having been in contact with the former at the angle which it makes at its origin from the iliac, ulceration had taken place, and the bleeding had proved fatal. There was no coagulum formed in the iliac trunk, though the operation had been performed several days before, the circulation through the epigastric having continued. But the lymph-plug at the seat of the ligature on the iliac artery was complete, and the blood had not escaped from it, but had made its way through the ulcerated orifice in the epigastric*.

* I examined the stump of a man whose leg I had amputated above the knee ten days before: the femoral artery was tied with a silk ligature, the ends of which had been cut, agreeably to the suggestion of my friend Mr. Lawrence, close to the knot. The mouth of the vessel was contracted and occupied by a lymph plug, firmly adhering at its circumference. A considerable branch opened at a quarter of an inch or less above the ligature, and no coagulum of blood had formed. The ulceration of the vessel by the ligature was considerably advanced, but the latter was not loose enough to come away with a prudent exertion of force. The portion of the vessel which had been strangulated by the ligature was a slough. The living extremity of the vessel was well defended by the adhesive inflammation which had thickened and rendered compact the surrounding cellular substance, although the face of the stump was in a state of profuse
and

The fluidity of the blood does not therefore in any degree prevent the adhesive process, as is shewn also in the indirect obstruction effected by the ligature applied for six hours, or the compressor for twelve. But if accidentally violence is done to a stump, if the adhesive process is languid, or if the sealed extremity of the vessel is included in a slough, the coagulum of the blood may avail to prevent hæmorrhage until the granulating process is re-established upon the surface*.

and unhealthy suppuration, and pus was abundantly secreted in the cellular interstices of the muscles of the thigh and beneath the integument.

* A man whose leg was amputated in St. Thomas's Hospital, had a profuse hæmorrhage after the separation of the ligature, and after repeated bleedings and ineffectual attempts to suppress them, the artery was exposed by a lateral incision, for a space of two inches above the face of the stump, and ascertained to be thickened by an inflammation of its coats. The actual cautery was applied to it, at the highest, which appeared to be the soundest part, since it was evident the ligature would have little if any chance of effecting its purpose upon so diseased a vessel. Upon the casting off of the eschar, which filled the wound, it was found that granulations had covered the vessel, and a very inconsiderable bleeding followed, which ceased upon the application of linen rags kept constantly moist with cold water. In this and similar cases, which are not uncommon, the process of arresting hæmorrhage is reversed. The slough however produced answers the purpose of the ligature as a present stay to the blood, as it cannot separate until the cellular substance has shot up in granulations over the mouth of the vessel, and has either dislodged it, or set it free. A coagulum of blood may in the interval have taken place within the vessel, and afford additional security, although the internal plug of lymph, which is the sign of a healthy adhesive action, is altogether deficient, from the

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In contemplating the removal of the ligature at a given time, it becomes essential to ascertain if this can be done with equal security when a branch is contiguous as when at a distance. With this view I made the following experiments.

EXPERIMENT XVI.

The carotid of a horse was tied by a noose ligature immediately above a considerable branch going to the top of the trachea and larynx. It was drawn off, and the vessel divided in sixteen hours, when no blood escaped. In twenty-four hours the animal was killed.

Examination. The obstruction was of lymph, some particles of coagulum adhering to it inferiorly. No cylindrical coagulum had formed.

EXPERIMENT XVII.

The femoral artery of a dog was tied below the profunda; the ligature removed, and the artery divided at forty hours; no bleeding ensued. The wound healed speedily. The animal was killed at the end of a month.

incapacity of a diseased artery for that action. Sponge tents and compresses confined upon bleeding vessels which cannot be conveniently secured by the ligature, act in the same way as eschars in suppressing hæmorrhage, and are liberated by a similar process. But where the vessel is healthy, it is closed by the adhesive process upon its interior surface, as well as covered by granulation.

Examination. The artery was obliterated in the interval of the ligatures. The lymph filling the cone-like terminations of the vessel, was shewn to be beautifully vascular by injection.

EXPERIMENT XVIII.

A noose ligature was applied at the same time to the carotid, and femoral artery immediately below the profunda, of a strong healthy dog. In thirty hours the second ligature was applied to each artery, and the carotid first divided between the two, no hæmorrhage ensued. The femoral artery was then divided, but while undergoing this operation the animal struggled violently, and the blood flowed copiously from the carotid, although without saltus. The bleeding ceased in about two minutes, and the animal threw himself upon the ground, when I supposed him exhausted by the loss of blood. Not the slightest hæmorrhage took place from the femoral artery, nor did it recur from the carotid: on the following day the animal ate and drank as heartily as if in perfect health, and has since continued well.

EXPERIMENT XIX.

A ligature was applied at the same time to the femoral artery below the profunda, and to the carotid artery of a large male cat; the ligatures were allowed to remain: both the wounds healed in a fortnight, when the obliteration was found to be equally complete.

From these experiments and those before related, I conclude :

1. That after the proper application of the ligature, the adhesive process is established in equal time in an arterial trunk, whether its branches are contiguous or remote, and of course independently of the fluidity of the blood.

2. That the obstruction of a vessel by lymph is a sufficient safeguard from hæmorrhage in ordinary circumstances, and the absence or slow formation of a clot appears to be referrible to some other cause besides the proximity of a branch.

I shall trouble the Society with only one or two concluding observations.

A ligature is of no farther use when the recent obstruction is complete, for the process of ulceration is so far advanced at seventy hours, as frequently to admit of the drawing away of the ligature with a very slight exertion of force, and it can surely yield no security where this has begun. The ulceration does not proceed with equal rapidity, because the pressure which occasions it is relieved, and the ligature is retained by a portion only of the external tunic of the vessel. It is a mistake therefore to suppose, that a ligature, because it remains fifteen or twenty days upon a vessel, is any barrier to the blood contained in it; and it is scarcely necessary to observe that the hæmorrhage which

follows the forcible removal of a permanent ligature depends upon the rupture, not upon the absence, of the adhesion.

The organization of the lymph is subsequent to the commencement of the ulcerative or separating process, and probably in some instances to the completion of it. The vascularity of the lymph is made apparent by injection at the end of a fortnight, but is much more abundant in a month. Doubtless, however, its organization commences much earlier than it becomes visible. A layer of lymph of two lines in breadth, effused after the excision of a portion of conjunctiva, upon the sclerotic coat of the eye, does not exhibit vascularity for several days.

The ligature, if removed at all, should be removed in the interval which, it is plain from these experiments, takes place between the obstructing and separating processes. If it is attempted later, it is of less, if of any, advantage, as the ulceration has already commenced, which in the other case is prevented from taking place.

I have before stated the advantages which result from the removal of the ligature; they are too obvious to require being enforced. I have now endeavoured to shew the limit of its effective operation, beyond which if retained, it affords none but a fallacious security, and is the sole cause of an

ulcerative process, always tedious and not always free from danger.

The practical application of the facts and deductions contained in this and my former Essay, (Med. Chir. Trans. Vol. IV.) will probably be the subject of a future communication to the Society. It is however, in my judgment, a subject too important to be lightly disposed of; and it carries with it, in reference to surgical practice, a responsibility too serious to justify a rude and hurried trial of its merits. On these accounts I refrain from forcing the public opinion, by stating the immatured experience, in support or in opposition to the practice, which has hitherto obtained. Mr. Wilmot of Jervis Street Hospital, Dublin, to whom I beg to offer my thanks for his obliging permission to relate an interesting case of brachial aneurism, will, I hope, concur with me in thinking these reasons for its postponement satisfactory.

For the present therefore I content myself with submitting these observations to the profession, which, whether they do, or do not lead to any practical improvement, assist in elucidating a subject of admitted importance, and sufficiently explain the motive with which I entered upon the inquiry.

— “*Neque enim fingendum, aut excogitandum, sed inveniendum quid Natura faciat aut ferat.*”

Fig. 1.

Fig. 2.

Fig. 5.

Fig. 3.

Fig. 4.

Fig. 1.

Fig. 2.

Fig. 5.

Fig. 3.

Fig. 4.