

ON THE VASCULAR LESIONS PRODUCED BY GUNSHOT INJURIES AND THEIR RESULTS.

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THIS communication must be prefaced by the remark that the writer fully appreciates the fact that it deals solely with a certain stage of progress of the lesions described. The circumstances of the present campaign, which necessitate the rapid evacuation of all patients able to bear transference to England, have prevented not only the opportunity for treatment, but also of prolonged observation. None the less, the material dealt with provides many points of interest for consideration; and if its publication had been further delayed, at least another twelve months must have been allowed to elapse before any reliable permanent results were ready for observation and review. Such results, moreover, may well form a part of a more extensive report when the campaign is ended.

The present war has afforded some surprises with regard to gunshot injuries inflicted upon the blood-vessels. Primarily it was expected that the experience gained in the South African and succeeding wars would be merely confirmed; but one of the first observations made was to the effect that *isolated* injuries either to the vessels or the great nerve cords were vastly less frequent than was the case during the period in which the dome or ogival tipped bullets were in use. It became at once apparent that the instability of flight of the sharply pointed bullet, unless the latter strikes the body at an exact right angle to the surface, is opposed to the production of neat and limited perforations such as were common with the better balanced earlier forms, and that the injuries to the blood-vessels as a class are not only more severe in themselves, but also accompanied by more extensive destruction of the surrounding soft tissues.

Later experience of the common use of the high explosive shell, and especially of the various forms of bomb (all of which furnish a large number of small, sharp, ragged fragments), has shown also that these missiles are as frequently the cause of vascular injuries, resulting in one of the various forms of traumatic aneurysm, as rifle bullets, although the wounds are of a somewhat different character. The increased number of wounds caused by missiles of this class has in fact greatly multiplied the number of traumatic aneurysms met with amongst the wounded.

Of some interest, though of less common occurrence, are the vascular injuries produced by the shrapnel ball, since these are practically identical with those caused by the old round ball of 'Brown Bess' (*Fig. 120*). An aneurysm resulting from a bayonet wound has not yet come under my observation.



FIG. 120.—LATERAL WOUND OF THE COMMON CAROTID ARTERY, AND COMPLETE SEVERANCE OF THE INTERNAL JUGULAR VEIN.

The vein is thrombosed, and the opening in the artery partially closed by fibrinous clot. The patient died of secondary hæmorrhage on the twenty-fourth day.

This illustration is inserted for purposes of comparison. The specimen from which it has been drawn came from the Peninsular War, and it is interesting to note that the injury caused by the old round ball differs but little from those produced by the modern rifle bullet. The dilatation of the contused trunk in the neighbourhood of the wound is a rather striking feature. (*Museum Royal Army Medical College, No. 34'2.*)

PART I.

CONTUSIONS OF THE BLOOD-VESSELS.

Before proceeding to the consideration of the actual perforating injuries of the blood-vessels, some attention needs to be bestowed upon the contusions and incomplete lesions of their walls.

Arterial Thrombosis.—The fact that primary arterial hæmorrhage is so frequently and efficiently controlled by the rapid formation of a firm thrombus, is undoubtedly referable to the contused nature of the injury to the vessel wall in gunshot wounds.

Arterial thrombosis is also far from uncommon when the passing missile fails to produce a perforating lesion, merely contusing the vessel or carrying away a part of the external coat. It has been shown experimentally that ruptures of the intima and muscularis may be produced by contusion of the vessel, though the formation of extensive thrombi has not, I believe, been observed under aseptic conditions. During the present campaign, arterial thrombosis from this latter cause has been a fairly common occurrence, as the result both of limited and extensive contusions of the walls of the vessels. The process has been observed in the case of apparently clean, uninfected bullet tracks, and also in extensive septic wounds in the immediate neighbourhood of the vessels (*Fig. 121.*)

FIG. 121.—INJURED POPLITEAL ARTERY AND VEIN, FOLLOWED BY GANGRENE OF THE LEG (*Case 91*).

The vein has suffered complete severance as a result of the passage of the bullet. The ragged, frayed ends of the vein are well shown. The amount of separation of the ends is less than the average distance, a fact readily explained by the firm nature of the connection normal to this particular artery and vein. The lower end of the vein is still occupied by a thrombus.

The artery, which has suffered a severe contusion, presents a fusiform enlargement occupied by a thrombus opposite the gap between the ends of the severed vein. Both above and below the thrombosed spot the calibre of the vessel is notably diminished, a condition usually seen when the normal arterial circulation is arrested either by a thrombus or a large wound involving the lumen. (Under the care of CAPT. W. G. MUMFORD, No. 13 General Hospital, Boulogne.)



In certain positions, and in the case of wounds which heal with no clinical evidence of infection, it is often extremely difficult or actually impossible to determine whether the lesion consists in mere contusion or complete solution of continuity of the vessel. This is notably the case in tracks traversing the root of the neck. With these injuries, complete disappearance of the pulses at the wrist, not infrequently associated with a brachial monoplegia of a more

or less complete degree, is not at all uncommon. When, under these circumstances, no systolic bruit is present at the supposed site of injury, and no aneurysmal swelling develops at a later date, we are absolutely unable to decide whether we have a case of contusion, or one of complete division of the artery to deal with. On the one hand we are aware that a contusion may account for the symptoms, on the other that a complete division of the vessels may be accompanied by identical signs. (See *Case 104*, operated upon by Colonel Gordon Watson.)

Thrombosis in connection with incomplete lesions of the vessel wall may be limited in extent—either not completely obstructing the flow of blood, or only doing so temporarily—or it may be very extensive. The latter condition is met with mainly, if not solely, in connection with extensive septic wounds, and has long been familiar to the military surgeon (*vide* a specimen of femoral thrombosis sent home by Mr. Guthrie from the Crimean War, preserved in the museum of the R.A.M. College). These thrombi may extend over some inches of the artery, and may occasion primary gangrene of the limb ;

may be followed by the occurrence of secondary hæmorrhage ; or may afford an origin for emboli, which, becoming arrested in the peripheral circulation, may lead to gangrene or nutritional disturbance at a later date. In the last particular the limited thrombi are of the greatest interest.

It is not easy to decide how often incomplete lesions of the walls of the arteries eventually lead to the develop-

FIG. 122.—CONTUSION OF THE BRACHIAL ARTERY, WITH INCOMPLETE LACERATION OF THE WALLS OF THE VESSEL (*Case 94*).

The adventitia is ruptured, the muscularis almost intact, and the intima broken. Over the damaged portion of the intima a local lateral thrombus has developed. The importance of this specimen, taken in connection with the cases of probable contusion of the carotid arteries followed by cerebral embolism, is obvious. a. External aspect. b. Internal aspect. (Under the care of LIEUT. LLEWELLYN, No. 25, General Hospital, Camiers.)

ment of secondary aneurysm ; but in the light of their obvious importance as a source of secondary hæmorrhages, it appears highly probable that the origin of some aneurysms detected at a comparatively late date may be attributed rightly to such primary injuries. Moreover, actual dilatation of large arteries has been observed to occur as an early result of an incomplete lesion.

Secondary hæmorrhage from vessels the seat of incomplete lesions is most commonly met with in the case of arteries exposed in septic wounds, and may occur comparatively early as a result of disintegration of the infected thrombi. It is even more likely to occur than when complete severance of the vessel has been effected, since in the latter event the ends of the vessel have retracted, and the thrombus, as more deeply situated, stands a better chance of escaping infection.

Primary gangrene, especially in the lower extremity, is not uncommon. This might be expected, because the obstruction to the lumen of the vessel is often much more extensive, and hence more liable to involve the origin of important collateral branches, than is the case when the vessel is completely severed.

Thrombosis as a consequence of contusion is more commonly seen in the veins than in the arteries, and in connection with a much slighter degree of damage to the walls of the vessels. I have seen it on several occasions when ligaturing an artery which had suffered a lateral wound. The latter observation is important in its bearing on the question of the danger of simultaneous occlusion of both main artery and vein resulting in gangrene of the limb. I am more and more disinclined to believe that the co-existing localized thrombosis of the vein in any way endangers the vitality of the limb should the artery need to be tied. In fact, from a considerable amount of experience, I am not sure that the balance of the normal circulation is not afterwards better maintained. At the same time, I must allow that a local thrombosis at the point of injury sometimes favours the development of an extensive peripheral thrombosis, for I have seen it on more than one occasion, yet not giving rise to gangrene.

Arterial Embolism.—The most interesting and often the most serious sequence of arterial thrombosis is the detachment of emboli from lateral thrombi of insufficient size to occlude the vessel, or from those which only temporarily occlude the vessel. This accident must, I think, be considered entirely apart from the cases in which the detachment of the embolus is a direct consequence of septic infection and disintegration of the thrombus. It is a question of considerable importance, because it has been stated that the process does not take place in the absence of infection.

The evidence that I have to offer of the occurrence of such embolisms depends mainly on clinical observation; unfortunately one of the patients in whom it was observed died in the hospitals abroad, and in him no autopsy was made.

Fig. 122, however, affords absolute proof of the occurrence of lateral thrombosis as a result of a non-perforating lesion of an artery.

The specimen was obtained by Lieut. T. L. Llewellyn under the following circumstances. A man giving instruction at a bombing school was wounded by the premature explosion of the bomb. A fragment of the bomb-casing entered on the inner aspect of the arm, and lodged beneath the skin of the outer side, the track of the missile crossing the course of the brachial artery one inch below the insertion of the deltoid. The fragment of shell was removed at the casualty clearing station and the patient was sent down to the base.

On admission, it was noted that the radial artery at the wrist was barely pulsating. As an injury to the brachial artery was suspected, the vessel was exposed and found to have been contused by the missile. The bruised spot felt hard, and appeared to be occupied by clot, but pulsation was present in the vessel both above and below the obstruction. Ligatures were placed above and below the injured portion, which was excised. The distal tied end pulsated visibly. The patient made an uninterrupted recovery, pulsation in the radial artery at the wrist being strong a week later.

The occurrence of arterial embolism as a sequence of contusion is best illustrated by the relation of some cases in which it was observed.

Case 87.—(Under the care of **LIEUT.-COL. GORDON HOLMES.**)

A man was admitted four days after the reception of a small slit-like wound situated at the anterior border of the left sternomastoid, one inch below the angle of the mandible. The man had lain two days in the trenches after receiving the wound, and when removed he was unconscious and hemiplegic. When examined at the base, a small circular induration was present over the upper part of the left carotid artery, but pulsation in the vessel above that spot and in the left temporal artery was not reduced in strength or volume, and no bruit was present at the site of the lesion. The heart sounds were normal.

The patient remained in the hospital for fourteen days, during which time he improved somewhat; there was little change in the hemiplegia, but speech was regained although reading was difficult; the capability of writing returned, and the mental condition steadily brightened. He was transferred to England in this condition.

Case 86.—(Under the care of **CAPT. WOLFENDEN.**)

A man was wounded by a bullet which entered the anterior border of the right sternomastoid muscle an inch above the sternum. The bullet was retained over the spines of the 6th and 7th dorsal vertebræ. There was complete paralysis of both lower extremities, and incontinence of urine and fæces. Besides the spinal lesion, complete loss of power was present in the left upper extremity, and the man was dull and stupid. Pulsation in the right carotid artery was normal, no bruit was present, and no abnormal sounds could be detected on auscultation of the cardiac area.

No improvement occurred, and the man was transferred to England.

In connection with the above two cases of embolism following contusion of the artery, it may be convenient to insert the following ones, illustrating the occurrence of similar phenomena where the vessel, although wounded, still remained patent, and capable of carrying on the circulation satisfactorily prior to the detachment of an embolus.

In the section dealing with carotid aneurysms, an example of an embolus becoming detached from the sac during the process of cure will also be found (*Case 2*).

Case 16.—(Under the care of **LIEUT.-COL. BUTLER.**)

A man was wounded by a bullet which entered in the left posterior triangle and emerged near the angle of the left scapula. He remained in the trenches three days after reception of the injury. A large hæmothorax was present on the patient's admission, and an arterial bruit was audible over the left subclavian artery. A left brachial monoplegia was present. Two days later the left hand was noted to be cold and blue, and no pulsation could be felt in the vessels below the bifurcation of the brachial. The hand became gangrenous, and was amputated a week later. The hæmothorax suppurated and was drained; but the man did well, and no sign of any aneurysm developed locally.

Case 12.—(Under the care of **MAJOR DAVIES-COLLEY.**)

A man with a small, slit-like wound at the anterior margin of the left sternomastoid, at the level of the angle of the mandible, was admitted without any previous history, but completely aphasic. There was no further paralysis, but the left palpebral fissure was small, and the right pupil was larger than the left. An arterio-venous aneurysm with a double murmur and thrill was present, pulsation being palpable both from without and on palpating the tonsil. No improvement occurred, and the man was apparently unable to comprehend remarks addressed to him. He was transferred to England at the end of fourteen days.

Cases of embolism in connection with the disintegration of septic thrombi are included in the tables at the end of the paper.

NATURE OF THE WOUNDS OF THE VESSELS.

Regarding the anatomical characters of the wounds produced by the rifle bullet, there is little to be added to what is already known. The wound itself is of a contused nature, the margins being tattered and irregular in the recent state, later becoming rounded and smooth during the process of repair or the formation of an aneurysm. The characters are sufficiently illustrated in the figures and accompanying legends.

The introduction of the unstable pointed bullet has, however, considerably varied the proportional occurrence of the different forms of wound. Complete severance of continuity, or wounds involving the greater part of the circumference of the vessel, have become more frequent, while perforations involving both sides of the lumen of the vessel have become rare. A difference in this respect between arteries and veins has been conspicuous amongst the cases which have come under my own observation, as transfixion of the vein has been met with several times in association with a lateral wound of the artery (see *Figs. 126 and 130*). I have only seen three cases of perforation of an artery—the popliteal in one instance (see *Fig. 140*), the femoral in the adductor canal in a second, and the brachial in a third. The femoral perforation was ragged, and apparently larger in diameter than the base of the bullet which produced it; when exposed from Hunter's canal, the clot which occupied the popliteal space could be squeezed across the vessel through the two perforations by pressure upon the surface of the limb.

Wounds produced by fragments of shells or bombs differ somewhat in character, more nearly resembling the incised variety, sometimes being little more than minute punctures (see *Figs. 123 and 124*).

A word may be added as to the anatomical characters of the wounds of the veins. The liability to perforation has already been referred to. When completely divided, the appearance of having been torn through is very marked, the margins are often much frayed (see *Fig. 121*), and the tendency to retraction is strong. The common result is the formation of an occluding local thrombus, naturally more constant in the central end of the divided vessel. I have frequently seen free hæmorrhage from the distal end, when the central is completely closed. The occurrence of thrombosis is obviously of great moment in regard to the conditions favouring or otherwise the formation of an aneurysm of the arterial or arterio-venous variety respectively.

If sufficient time has elapsed to allow of repair, the mouth of the completely divided vein may, under certain anatomical conditions, be spread out as a trumpet-shaped opening in the aneurysmal sac. In one instance where the junction of the subclavian and first part of the axillary vein (*Case 21*) had been divided, the two ends, which opened into an aneurysmal sac, were separated by a distance of two and a half inches, while the upper opening, which had acquired connections to the clavicle and first rib, was of sufficient calibre to allow the introduction of the tip of the index finger. Needless to say, very free hæmorrhage occurred when the sac was laid open, and was with great difficulty controlled. The experience is one to be especially kept in mind if an aneurysm in this region requires to be dealt with. *Fig. 127* shows well the different characters of arterial and venous wounds, that in the more resistant

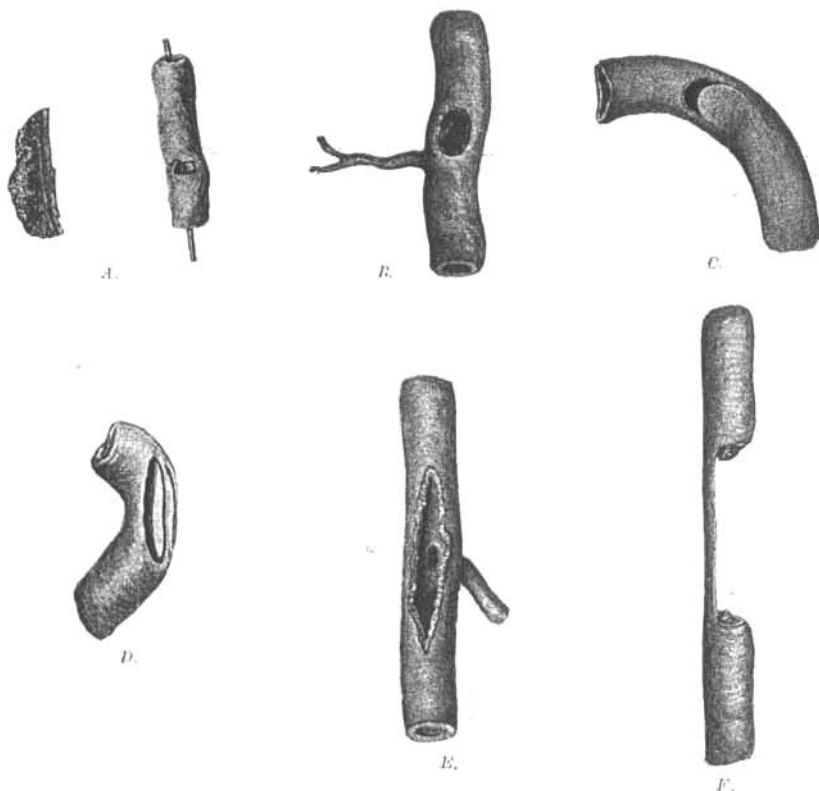


FIG. 123.—TYPES OF ARTERIAL WOUNDS.

A. Small portion of the femoral artery (*Case 51*) removed at the time that the aneurysm was extirpated and the vessel ligatured, with the piece of shell which produced the injury. The regular outline and smooth margins of such an incised wound at the end of ten days is well shown. A typical soft musical bruit was present before the operation. (Under the care of CAPT. WOLFENDEN, No. 11 General Hospital, Boulogne.)

B. Oval wound of superficial femoral artery (*Case 39*). The wound is in immediate proximity to a lateral branch fixing the artery. Shell injury. (Under the care of CAPT. STANLEY RAW.)

C. Diagrammatic representation of a flap-like wound of subclavian artery (*Case 18*). Large mass of primary clot; no aneurysmal sac formed; secondary cellulitis of neck; secondary hæmorrhage. Shell injury. (Under the care of LIEUT.-COL. GORDON WATSON.)

D. Oval wound of superficial femoral artery (*Case 40*). The thin strip of arterial wall between the main opening and the lateral slit shows this to have been actually a perforation. Secondary hæmorrhage appears to have taken place through the lateral slit. The specimen has become bent during the process of preparation. Bullet injury. (Under the care of LIEUT.-COL. GORDON WATSON.)

E. Unusually long lateral wound of axillary artery. Note the branch arising immediately opposite the centre of the wound. (Under the care of LIEUT.-COL. ELLERY.)

F. Diagrammatic representation of a three-fifths division of the femoral artery. This form is frequent, and amounts practically to a complete division of the vessel. It is, however, a more serious injury, since the remaining bond of union prevents free retraction and contraction of the ends, and hence spontaneous thrombosis and closure of the vessel is less likely to take place. Bullet injury.

It will be noted that all these vessels were exposed from three to ten days after the infliction of the wound, hence the margins of all are more even and rounded than in the recent stage of the injuries. No typical example of double perforation is included, because no opportunity has occurred for the removal of such a wound.

and brittle arterial wall being a simple transverse cleft, while the opening in the vein caused by contact of the same bullet is irregular in outline and roughly stellate in character, with small flaps.

EFFECTS OF GUNSHOT WOUNDS OF THE BLOOD-VESSELS.

Primary Hæmorrhage.—Little needs to be said on this subject: recent experience appears to fully confirm the ancient opinion that spontaneous cessation of bleeding is a common result in all except the largest vessels of the trunk. In type bullet wounds the almost invariable history given by the wounded men is one of a primary spurt of blood, often abundant, but readily controlled by local pressure and the application of a dressing. It is not a common event in the case of small wounds of the soft parts for recurrent hæmorrhage to take place when the dressings are renewed. In large, open wounds, vessels of the calibre of the brachial or femoral arteries are frequently met with completely divided, but occluded by a firm efficient thrombus, and the latter is usually not displaced by the manipulation necessary for the cleansing of the wound. In such cases the calibre of the vessel is commonly greatly reduced, and this reduction in size becomes a permanent change.

It must not be assumed that the above remarks concerning the common spontaneous cessation of primary hæmorrhage from arterial wounds is intended in any way to minimize the importance of what does occur. The loss of blood which accompanies the receipt of the injury is often very considerable; and although it may not immediately endanger the patient's life seriously, or call for surgical intervention to prevent its recurrence, yet the resulting anæmia is often persistent for some time, and may heavily handicap the patient's chances should a secondary operation become necessary. It has, indeed, much surprised me to see patients die a few hours after an operation in which, although a considerable amount of blood has been lost during the procedure, yet the patient has left the table in sufficiently good condition for no great anxiety to have been felt regarding his ultimate recovery. I believe this to be a definite sequence of the primary loss of blood, and it is a moment to be fully considered should the question of the performance of any operation likely to entail loss of blood arise.

Again, the absence from this series of aneurysms of the great vessels of the trunk, sufficiently emphasizes the fatal nature of wounds of the larger arteries.

Secondary Hæmorrhage, apart from that occurring in connection with arterial hæmatomata, is so large a subject as to be outside the scope of this paper; in addition, the most serious and common secondary hæmorrhages occur from the smaller vessels, are dependent solely on the presence of sepsis, and hence cannot be regarded as due to the special form of wound. Some remarks on secondary hæmorrhage in special cases are made in the sections on the treatment of wounds of individual arteries.

ARTERIAL HÆMATOMA AND FALSE ANEURYSM.

Apart from external hæmorrhage, the most common sequence of a gunshot wound of a large vessel is the development of an arterial hæmatoma, usually a large pulsating collection of blood lying at first in the tissues, its

line of extension being dependent on the anatomical arrangement of the part concerned. The most characteristic are those which develop in connection with comparatively superficial vessels such as the common femoral or the third part of the subclavian. In these the hæmatoma is commonly accompanied by widespread ecchymosis of the overlying integument. When the deeper vessels are wounded ecchymosis is rare, the soft fluctuating local swelling is replaced by a tense general swelling of the limb, and no definite limitation of the extent of the cavity can be determined.

The first secondary change consists in coagulation of the effused blood at the circumferential part of the cavity, which process tends to check primarily any further extension of the extravasation. As the process of coagulation

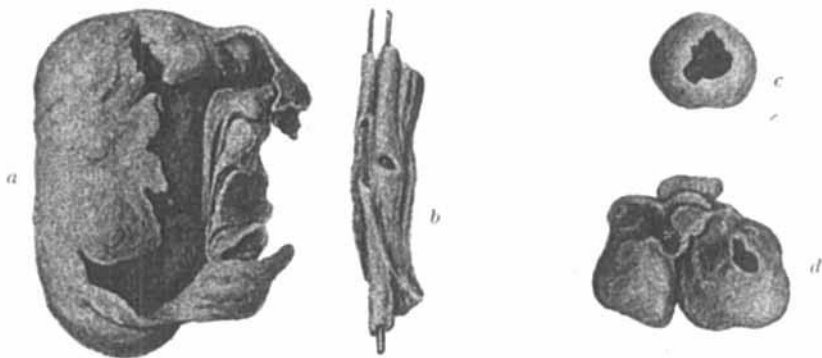


FIG. 124.—THREE SMALL FALSE ANEURYSMAL SACS DEVELOPED IN CONNECTION WITH WOUNDS OF THE POSTERIOR TIBIAL ARTERY.

The largest and most irregular (a) has beside it the artery (b) showing a small lateral wound and one of the venæ comites also wounded. The patient from whom it was removed had a compound fracture of the leg, the wound accompanying which was badly infected. Pulsation and a purely arterial bruit were not noted until the tenth day. On the fifteenth day secondary hæmorrhage occurred, and the limb was amputated (*Case 83*). (Under the care of LIEUT.-COL. BUTLER, No. 13 Stationary Hospital.)

The smallest sac (c) is fairly symmetrically globular; the hole by which the wound in the artery communicated with it is well shown, also the tenuous nature of its margins. A magnified section of the wall of this sac is seen in *Fig. 125* (*Case 84*). (Under the care of CAPT. CLEMENT SMITH, No. 13 General Hospital, Boulogne.)

The third sac (d) resembles the two others in character; the small hole communicating with the lumen of the artery is seen. The whole structure is somewhat tripartite in outline, but the two secondary masses contain only a small cavity, and consist mainly of solid clot. (Under the care of CAPT. W. G. MUMFORD, No. 13 General Hospital, Boulogne.)

proceeds, shrinkage of the resulting clot takes place, with the result of producing a definitely localized, pulsating swelling which may project boldly from the surface of the part of the body affected. The extent to which coagulation may proceed varies; in a minor proportion of the cases the central portion of the effusion remains fluid in direct continuity with the contents of the wounded artery, and the condition of arterial hæmatoma persists for some time. This class of case is that most liable to suffer from the effects of infection of the surrounding tissues, which may result in secondary extension, or external secondary hæmorrhage. It is most frequently met with in situations such as Scarpa's triangle, in which the blood effusion is afforded but slight support by the surrounding structures.

In other instances, particularly in the case of vessels well supported by the surrounding structures, the entire effusion may become metamorphosed into a firm clot, and the primary systolic bruit produced by the wound in the artery may disappear completely. If a primary bruit disappears, we may assume a limited lateral wound of the artery to be present. The further progress of such cases varies; the large hard clot is a primary cause of danger, since it tends to exert very firm pressure on the collateral vessels, and hence gangrene of the peripheral part of the limb is apt to occur, especially if the femoral or the popliteal artery has been wounded.

A more common result is the secondary development of a false aneurysmal cavity. The impact of the blood-stream opposite the defect in the arterial wall tends to hollow out a rounded space in the recently coagulated blood, or to regularize any residual space remaining in the clot. The resulting cavity acquires a boundary formed by the deposition of well-marked layers of laminated clot, resembling that met with in typical spontaneous aneurysms. The sacs when small and recent are readily separable from the surrounding mass of conglomerate primary clot. The wall of the sac is thickest at the point most distal from the arterial wound, becoming gradually thinner as it approaches the opening in the artery, to the edges of which it is united by a comparatively tenuous layer. When laid open, the smooth, shining, inner surface of the sac suggests the presence of an endothelial lining, even at an early stage of development. When this stage has been reached the designation of

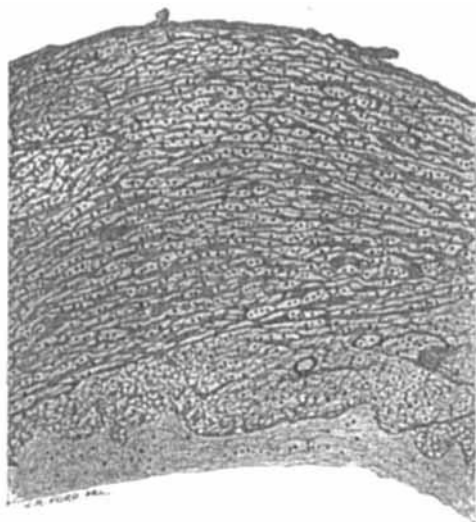


FIG. 125.—A SECTION OF THE WALL OF THE SMALL ANEURYSMAL SAC SHOWN IN *Fig. 124, c*. MAGNIFIED TO DEMONSTRATE ITS STRUCTURE (§ objective).

The wall is formed by interlaced concentric laminae of fibrin and, within the meshes of the network, blood-corpuscles. No fibrous tissue has yet been developed.

arterial hæmatoma ceases to be applicable, and the term false aneurysm is preferable, since the old irregular blood cavity is gone and is replaced by a distinctly new formation. In *Fig. 124, c* and *d* show examples of two such sacs developed in connection with the posterior tibial artery; both were wiped out of the deep layers of the calf through incisions made to evacuate large masses of clot with which their connection had been severed.

In the case of larger vessels, when hæmorrhage necessitates an early operation similar cavities are found in the clot and in connection with the open wound in the artery; but they may be still incomplete, the laminated clot and smooth surface being more dome-shaped, and hardly extending to the actual lips of the arterial wound.

I believe this process occurs whenever a false aneurysmal sac is really

developed, since such cavities, whenever they have existed for a short period, are roughly or symmetrically spherical in form, while the original space occupied by the arterial hæmatoma is usually extremely irregular. The subclavian aneurysm depicted in *Fig. 132* is a good example, the original collection of blood having occupied the whole posterior triangle of the neck. Again, when the femoral artery is wounded by a bullet traversing Hunter's canal, the original blood effusion travels into the posterior compartment of the thigh through the opening in the adductor muscles. Yet the cavity of a traumatic aneurysm developed in this position is in my experience almost invariably a rounded sac limited to the anterior aspect of the adductor muscles, and not an hour-glass sac extending from the front to the back of the limb. The great mass of primary blood-clot is in fact quite independent of the eventual aneurysm.

In some instances the original large common space occupied by the hæmatoma becomes loculated, and the circumferential part may become cut off. This was the case in the subclavian aneurysm depicted in *Fig. 132*, p. 386. The fluid contained in the superficial loculus in the posterior triangle had already become decolorized at the time of operation, and was quite independent of the deeper aneurysmal cavity beneath the remains of the scalenus anticus. In this case the loculus was a development of much importance, since the thinning of its walls, with the consequent apparent increase in size in the swelling to which pulsation continued to be communicated, was regarded as indicating the necessity for operation.

Behaviour of Surrounding Tissues.—It must not be assumed that the processes of diminution of size and solidification of the walls of the aneurysmal sac depend solely on the absorption and contraction of the primary clot, the hollowing out of the interior, and the deposition of fibrinous laminæ capable of later development into fibrous tissue. Nor do these things alone ensure the limitation and final solidity of the aneurysm. A not less important part is played by the surrounding tissues, which appear to react in a remarkable manner to the stimulus afforded by the presence of the blood-clot in their midst. The connective tissue of the vascular cleft, the intermuscular spaces, and the muscles themselves, become infiltrated with serum and an abundance of leucocytes destined to take part in the subsequent absorption of the clot.

A considerable part of the mass of the tumour in the early stages consists of this surrounding infiltration, and the gradual disappearance of the latter and of the œdema accounts for much of the diminution of the apparent size of the tumour. It is this induration which affords support to the original blood-clot and tends to prevent further extension of the aneurysm.

The presence of this change in the tissues is also an important element in the surgical treatment of the aneurysm. Even the process of exposure and delimitation of the sac is rendered more difficult by the swollen, indurated condition of the connective tissue, and the separation and displacement of muscles is interfered with by the firm adhesion between them and their sheath. Still more difficult in the earlier stages is the freeing of the blood-vessels themselves, since they are embedded in a mass of tissue like firm bacon, from which they can only be cleared by the use of the knife. It is this infiltration which renders operations for the suture of the vessels so difficult and

unsatisfactory, because it interferes not only with the insertion of sutures, which readily cut out, but also renders it a troublesome task to free the vessels sufficiently to approximate the ends without tension if any loss of substance has occurred.

Before passing on to a consideration of the signs and symptoms of traumatic aneurysm, the question of tardy development should receive some notice. It is a striking fact that the existence of an aneurysm is in so many cases not noted until days, weeks, or even months after the reception of the original injury. No doubt in many cases this is due to the small size of the sac, and to imperfect observation in consequence of the haste with which many patients with small wounds are necessarily evacuated. Giving due weight to this explanation, it is an undoubted fact that the development is sometimes a late one, and mention of the significance of incomplete lesions of the vessels in this relation has already been made. Another explanation of the tardy development of the aneurysm, however, is undoubtedly to be found in the secondary giving way of an originally perforating lesion in which the process of spontaneous healing commences and eventually fails. The most striking instances are afforded by the cases in which the original hæmatoma has been evacuated without the discovery of any bleeding point, and the wound has been allowed to heal. In connection with arteries, even of the magnitude of the external iliac, which were actually exposed during the process of clearing out the hæmatoma, a secondary aneurysm has been seen to develop several days later while the patient has remained under observation. A more common occurrence is the complete extinction of any local pulsation by pressure exerted on the main vessel owing to the rapid transformation of the effused blood into a firm coagulûm. This pressure may suffice to prevent any passage of blood through the arterial wound, and thus lead to the extinction of the bruit, and may also obstruct the circulation to an extent involving loss of vitality of the limb (see *Fig. 126, Case 75*). Yet no signs of an aneurysm will be present, although such may readily appear at a later date when the absorption of the original blood-clot has allowed of sufficient dilatation of the lumen of the vessel for the restoration of the circulation.

Signs and Symptoms.—The obvious local signs of an arterial hæmatoma or a false aneurysm need no further description; but a few additional remarks may be devoted to two points—the characteristic arterial bruit, and the effect on the general circulation. The presence of this bruit indicates an incomplete solution of continuity, that is to say a lateral wound in the wall of the artery; it is in fact a sign of a wounded artery rather than of an aneurysm. It may be added that absence of a peripheral pulse is a less reliable sign of a complete solution of continuity, because this absence may result from external pressure upon the main vessel.

The systolic murmurs vary greatly in intensity, depth of tone, and musical character. As a rule, during the first few days they tend to be shrill and loud, and are audible along a considerable length of the vessel on the peripheral side of the wound. It is not common for the bruit to be conducted for any material distance centrally, and frequently it is scarcely audible a couple of inches above the situation of the wound. The character of the bruit obviously depends on the size and shape of the opening in the vessel and the

degree of irregularity of its margins. As the process of rounding off the ragged margins of the arterial wound progresses—a species of incomplete repair—the murmur tends to become softer and deeper in tone. The effect of diminution in size and increased regularity of surface of the blood cavity may also be a factor in the production of this change of character. It may be remarked that at the same period the heart's action is commencing to recover somewhat from the disturbance caused by the wound of the vessel and the resulting interference with the distal circulation, hence the pulse is less rapid and forcible. In the early period the heart in the great majority of cases is dilated, the apex-beat lying in the nipple line or outside it, and the cardiac action is tumultuous. A rise of the pulse-rate to from 90 to 120 is almost the rule, and the rapidity may persist for some weeks, especially if a septic wound is existent together with the aneurysm. As already mentioned, complete coagulation of the effused blood of the hæmatoma may cause a temporary or permanent cessation of the murmur; in the latter case it may be assumed that a chance of closure of the arterial wound exists. In cases where hard clot forms early, the consequent pressure on the arterial wound may not only prevent the further escape of blood, but also the production of a bruit. In these a murmur may develop later; hence the importance of repeated examinations.

The importance of auscultation as a means of determining the existence of a patent opening in the wall of an artery cannot be too strongly urged, since it is the only method of forming a certain diagnosis in some cases, for instance in a swollen thigh or calf in which no pulsation is detectable. I do not believe that the fact that external pressure on the vessel may give rise to a less definite murmur in any way invalidates this statement, for the bruit produced by pressure is rare, and far less loud and definite in character.

Progress and Complications.—It may be broadly stated that the typical course of an arterial hæmatoma is one leading to contraction and localization, a definite false aneurysm being the commonest final result. In the most fortunate cases the aneurysm itself may consolidate spontaneously, and a cure by natural processes occurs. Among the large arteries, this termination is most commonly met with in the lower few inches of the common femoral or in the upper third of the popliteal artery.

Certain complications, however, occur with some degree of frequency. The most common of these are symptoms dependent on the pressure of the effused blood and clot on neighbouring structures, the development of peripheral gangrene, the occurrence of secondary hæmorrhage, the detachment of emboli from the thrombus, and very rarely the sequence of inflammation from secondary infection. I propose to deal with these complications *seriatim*; but before proceeding to their consideration it should be pointed out that they occur for the most part during the stage to which the term arterial hæmatoma is strictly appropriate; that is to say, prior to the definite formation of the smooth secondary rounded sac which has been already described. When this sac has once become complete and of moderate thickness, the condition is far better described by the term false or traumatic aneurysm, and the development of a definite fibrous-tissue wall may be confidently expected. In this stage complications are not to be greatly feared—apart from the obvious

fact that the wall may be of insufficient strength to withstand the force of the circulation when active movements are resumed, and the aneurysm may consequently enlarge. For this reason it appears to be both proper and convenient to employ the terms exactly, and in relation to the stage of development which the condition has reached.

Pressure Symptoms.—The most common pressure symptom is naturally peripheral œdema, sometimes increased in consequence of concurrent injury to the vein. Occasionally, thrombosis of the deep veins may give rise to a tense persistent swelling of the limb, but this is not common, and in most instances depends on infection travelling from the wound. Pain from pressure on neighbouring nerves is not an uncommon symptom, but it is rarely persistent, and diminishes *pari passu* with the localization and contraction of the hæmatoma or aneurysm. It must be borne in mind also that the pain may depend on concurrent injury to a peripheral nerve.

The most serious effect of pressure is that dependent on obstruction of the blood-stream in the collateral branches of the artery, since this may lead to peripheral gangrene of the limb, not an uncommon occurrence in the lower extremity. This complication is more fully dealt with in the sections dealing with special vessels.

Secondary hæmorrhage may occur at two periods, either in the first few days, or after the lapse of a week or ten days. The earlier variety is the less important. It frequently consists in little more than leakage from a small wound during the early progress of contraction of the cavity: a small quantity of blood, really of the original effusion, may escape, soil the dressing for two or three days, and then entirely cease. It is important to appreciate that such leakages are no indication for operative measures, and that they are not to be regarded in the same light as small repeated hæmorrhages from a septic wound.

The later form of secondary hæmorrhage is vastly more dangerous. It may show itself in two forms, either a rapid extension of the swelling in the limb, or as external hæmorrhage. It is rare for this form of hæmorrhage to depend on septic infection of the aneurysm itself; it rather appears to depend on a defective process of localization which allows some part of the limiting boundary of clot to give way, often as a result of infection of the surrounding tissues, or as a result of a rise in the general blood-pressure accompanying increased activity, and perhaps from free movement of the limb on the part of the patient.

In some cases it appears to have resulted from the giving way of the actual line of union of small aneurysmal sacs such as are depicted in *Fig. 124* from the original arterial wound, the margins of which have become thinned, smooth, and rounded in the process of repair. It may be repeated that the margins of the sac joining the circumference of the wound of the artery are the most tenuous part of the sac, while the dome opposite the opening, which bears the full force of the blood-stream, is the thickest. Again, in the process of cicatrization of a wound of the intestine, we know that the early connecting layer of lymph is strongest at the end of the third day, and that during the next four or five days, while the process of organization of the lymph into connective tissue is taking place, the union is perceptibly

weaker and less able to bear strain. A similar weakening of the line of union between the margins of the sac and the arterial opening may be safely assumed to take place while the same process of conversion of lymph into connective tissue is progressing, and the ease with which sacs can be swept off the vessel confirms this assumption. This is the dangerous period, which should be remembered as an indication for complete rest to the limb, the more so as it is obvious that the artery, even in its more fixed condition from surrounding infiltration of the vascular cleft, is yet a more freely movable structure than the sac when active muscular contractions occur.

While it has been stated above that infection of the boundary of blood-clot is infrequent, yet it must be borne in mind that the track of the missile may none the less be infected and remain unrepaired, thus not only weakening the support afforded to the clot by the surrounding tissues at a local spot, but also furnishing a ready path for the escape of the blood. As has been mentioned elsewhere, even an extensive cellulitis involving the whole limb only attacks the actual wall of the aneurysmal sac at a late date.

Late secondary hæmorrhages are extremely dangerous to the vitality of the limb, whether they take the form of extensions from the blood cavity, or of external bleeding, and may also cause grave risk to the patient's life.

The question of arterial thrombosis and *embolism* has been already dealt with under the heading of arterial contusion, and will be again referred to in the special sections.

Secondary Inflammation.—The rarity with which secondary inflammation occurs in traumatic aneurysm, affords one of the most striking proofs of the enormous capability of the blood, even when extravasated, to withstand and overcome bacterial infection. Among the whole series of cases dealt with in this communication, only two instances of death resulting from acute infection of the blood-clot were met with. In these cases the infection was anaerobic in nature. In one case blood-clot rapidly broke down into a brown fluid offering a strong resemblance to fæces, and the patient died from a sudden profuse secondary hæmorrhage (see *Case 6* amongst the series of carotid aneurysms). It occasionally happens that a false aneurysm already localized becomes hot and reddened over the surface, and this must be regarded as an indication for active surgical treatment. In the only case operated upon for this reason, the aneurysmal sac itself afforded no signs of inflammatory change, and the operation wound healed by primary union (*Case 51*).

On the other hand, many cases came under observation, especially in the thigh, where widespread infection of the surrounding tissue had led to extensive suppuration, requiring free incisions for its relief, in which an existing large aneurysmal sac remained unaffected. In one instance anaerobic infection led to destruction of practically the whole of the musculature of the thigh, and yet an extensive aneurysmal sac failed to give way. It is clear that a strong distinction must be drawn between infection of the aneurysm itself and infection of the surrounding tissues.

The risks of infection are greatest during the arterial hæmatoma stage, when the collection of blood is large and the bounding layer of clot thin. Under these conditions the effusion of blood may increase in amount, or secondary hæmorrhage may occur. Either of these accidents may necessitate

an immediate ligature of the artery, and the cases are of a very unsatisfactory nature, since they are not infrequently followed by further secondary hæmorrhage, not from the point of ligature upon the main trunk, but from wounded collateral branches exposed in the septic original wound cavity which failed to bleed at the time of the operation.

ARTERIO-VENOUS ANEURYSM.

Arterio-venous aneurysms, although perhaps the most characteristic of all the after-results of gunshot wounds, are far less common than purely arterial aneurysms, and are as a rule a later development. In the latter respect they exhibit a sharp contrast with the allied condition of aneurysmal varix, the development of which commonly follows directly on the reception of the wound in the vessels.

Reasons have already been given for regarding the sac of a false arterial aneurysm as a secondary development from the stage of simple arterial hæmatoma, and there is evidence which suggests that the sac of an arterio-venous aneurysm is in the great majority of cases a virtually arterial sac developed in a similar manner. This evidence rests partly on direct observation of the condition of the wounds in the vessels at a certain stage, and partly on the mode of development of the physical signs.

First with regard to the nature of the wounds of the vessels. Any of the forms may be followed by the formation of an arterio-venous aneurysm.

1. If the lesion consists in a pure perforation of both artery and vein (a comparatively rare condition with the pointed German bullet), the aneurysmal sac will commonly be situated either on the distal side of the artery; or between the two vessels; or occasionally a sac may develop from either perforation in the artery; the wound in the vein away from the artery has usually cicatrized. The actual size of the aneurysmal swelling is increased by the dilatation of the lumen of the vein.

2. If the lesion consists in complete division of both artery and vein, a common cavity with which the four open vessels communicate may result. Under such circumstances the aneurysm is liable to retain for some time the characters of an arterial hæmatoma, it tends to extend rapidly, and gangrene of the limb or secondary hæmorrhage is not uncommon. Such cases are not numerous, and generally demand early surgical treatment, either on account of rapid extension, or the occurrence of one of the complications indicated. It is an interesting fact that under these conditions the peripheral circulation may sometimes be maintained by blood passing through the cavity intervening between the ends of the injured vessels.

3. In the great majority of cases the wound in the artery is lateral in character, associated either with a lateral wound, a double perforation, or complete division of the vein. Examples of this form of injury are seen in *Figs. 126, 127, pp. 370, 373.*

4. The sac may sometimes depend mainly on the venous injury, the vein being widely opened or completely divided, while only a small opening persists in the artery. In such cases the wall of the sac is thin and ill developed.

The case illustrated by *Fig. 126* is a good example of delay in the formation of an arterio-venous aneurysm. The conditions for its development are present and favourable, but sufficient time had not elapsed for the process to be completed, or even actually commenced. The blood in the primary hæmatoma, as is often the case, had coagulated into a large firm clot in which no cavity existed. The clot exercised pressure, not only on the main trunk, but also on the collateral branches of the wounded vessel, and gangrene of the leg resulted, necessitating an amputation.

A second cause for delay in the development of arterio-venous aneurysms is found in a temporary closure of the openings or opening in the vein by a thrombus. Such occluding thrombi are naturally far more common in veins than in arteries, by reason of the lesser force of the venous circulation. It may happen that the opening into the vein is occluded by a foreign body; thus, in one instance operation on an apparently pure arterial injury disclosed a wounded artery, with the piece of shrapnel case which had caused it filling and controlling the contiguous opening in the vein.

FIG. 126.—WOUNDED POPLITEAL ARTERY AND VEIN, FOLLOWED BY GANGRENE OF THE LEG (*Case 75*).

The wound in the artery involves nearly half its calibre and gapes widely, resembling a hole in a flute; the margins of the opening are comparatively smooth. The limb was amputated on the fifth day.

A characteristic traversing perforation of the vein is shown, the shape of the openings being irregularly circular, and less symmetrical than similar wounds produced in the artery.

The extravasated blood from these wounds had clotted firmly *en masse*; no murmur was audible in the swelling formed by the clot. Gangrene of the leg and foot was definite on the fourth day. (Under the care of CAPT. WEST, I.M.S., Meerut Stationary Hospital, Boulogne.)

The clinical evidence in support of the comparatively late development of arterio-venous sacs is equally strong. The first indication of the possible formation of an aneurysm is the presence of the characteristic systolic arterial bruit, a sign which can be detected prior to the appearance of either swelling or pulsation. In many cases the systolic bruit may become softer as the margins of the opening in the arterial wall become smoother in the process of repair, and then is replaced by the characteristic double murmur of the arterio-venous communication, and a bubbling thrill becomes palpable. This sequence of events may occupy a few days, or sometimes as much as a couple of weeks. I have observed it on many occasions.

Signs of Arterio-venous Aneurysm.—These are sufficiently familiar; but observation of a large number of cases has revealed some points of interest with regard to the characters of the murmurs which accompany the condition. The fact that the systolic element of the bruit may be audible first has already been dwelt upon. It remains to say that the characters of this may vary



considerably : it may be soft and musical, or harsh in sound. Sometimes it acquires a 'slamming' character, simulating in an exaggerated degree the so-called 'pistol shot' murmur heard in valvular disease over the aortic orifice of the heart. Such murmurs are associated with a highly excitable state of the general circulation and cardiac dilatation, conditions which in some degree accompany every traumatic aneurysm in its earlier stages. The increased rapidity of the pulse tends to settle down, but does not always subside at once even when the wound in the vessels has been dealt with by operation. It is much exaggerated in cases in which a septic wound complicates the aneurysm itself. The loud systolic murmur is conducted widely, usually peripherally, and to a much less extent centrally ; but in exceptional cases it may be transmitted centrally, even from the thigh to the heart's apex. This latter phenomenon is always of a temporary nature, lasting not more than three or four days. The diastolic roar is conducted in either direction, but as might be expected, more freely in a central direction in the vein. It is always loudly audible in the opposite side of the neck in cervical aneurysms, and when the aneurysm is at the root of the neck, may be audible over the whole cardiac area, quite separately from the normal valvular sounds of the heart itself.

In some instances the murmur may be conducted by the whole mass of the tissues of the limb, and be audible wherever the stethoscope is placed upon the surface. In these, the sound may be heard even when the ear is in neither direct nor indirect contact with the limb. These phenomena are more common in the lower limb, and in the early or arterial hæmatoma stage when a large collection of effused blood is present.

As a rule, the murmur is only conducted along the actual line of the peripheral vessels ; and the presence of the bruit either at the wrist or the ankle is a valuable indication of the persistence of a column of blood in the vessels when the amount is of insufficient volume and force to be palpable as a pulse.

The height of pitch of the murmur is a valuable guide to the exact site of the arterio-venous communication. It is highest and loudest immediately over this spot, the tones gradually softening and deepening in either the upward or downward direction as the stethoscope is moved along the lengthening column of blood in the course of the vessels.

Bubbling Thrill.—What has been said as to the development of the murmur holds equally good for that of the thrill. It is not detectable in the earlier stages, as is the case with the aneurysmal varices, and it tends to become stronger during the first days. Thus, while one day it may be scarcely palpable, and of the slight 'faradic current' type, over a popliteal aneurysm where pulsation in the tibial vessels is absent at the ankle ; on the following day, with the reappearance of the pulse, the thrill may be comparatively strong. The thrill is not a valuable localizing sign, and is in no way comparable to the pitch of the murmur as indicating the actual point of communication of the artery and vein.

Obvious signs of obstruction to the peripheral venous circulation are rarely present in the early stages of an arterio-venous aneurysm, except in the form of general swelling of the limb. Extensive thrombosis is occasionally met with, but usually in connection with a septic wound.

The process of gradual contraction and consolidation of the sac differs little from that already described in the case of pure arterial traumatic aneurysm; but the progress to spontaneous consolidation and cure observed in the latter is rarely or never seen in the arterio-venous variety. The resumption of active life on the part of the patient is therefore liable to be followed by increase in the size of the aneurysm, and the development of pressure symptoms or those of venous obstruction. Such secondary effects are much more marked in the lower extremity than in the upper.

ANEURYSMAL VARIX.

The establishment of a direct lateral anastomosis between a contiguous artery and vein is the most remarkable result of gunshot injuries to the vessels. The occurrence is in great part dependent on the anatomical arrangement of the two vessels, viz., contiguity and parallelism of course, and the most typical examples are seen when the missile passes between the artery and vein, causing a lateral wound in both. *Fig. 127* depicts an aneurysmal varix of this class; it will be seen that a transverse slit wound has been caused in the artery, and a roughly stellate one in the less brittle vein. Examination of the carotid sheath and vascular cleft showed that absolutely no bleeding had taken place into the tissues, and that direct primary adhesion between the margins of the wounds of the two vessels had resulted. No better anastomosis could have been established by the most skilful surgical operation. A similar observation was made in a case of femoral varix included in Surgeon-General Stevenson's Report on the surgical cases noted in the South African War. The frequency with which such primary adhesion without the occurrence of hæmorrhage takes place is further supported by the number of cases reported in which surgeons have failed to discover the actual point of communication between the two vessels, even when exposed by an open incision. I have myself suffered the same experience in a case of femoral varix, reported below. The direct nature of the adhesion between the vessels sufficiently explains the fact that the signs of an aneurysmal varix are developed immediately after the reception of the injury in the great majority of instances. The only secondary change which develops under these circumstances is a dilatation of the lumen of the vein, with thickening of its wall. The dilatation may be sufficient to create suspicion as to the presence of an aneurysmal sac, the more so as the arterial pulsation is communicated to the enlarged vein. Aneurysmal varices may perhaps sometimes follow wounds in which such accurate primary adaptation of the two vessels is impossible; in such instances the development of thrill and murmur may be a later event. Under these circumstances one can only suppose either that the union and cicatrization has been effected under a mass of blood-clot, such as has been described as present at a certain stage in the development of the traumatic aneurysms, but in which no secondary cavity has been formed; or that a temporary venous thrombosis occurred. A case of injury to the innominate vessels, in which a thrill and double murmur developed at a late period, is quoted on p. 376. Here no evidence of an aneurysmal sac could be detected, but as the lesion was within the chest, one cannot be certain on this point (*Case 1*).

An extended experience of cases of aneurysmal varix has led one to doubt, however, whether this condition often develops except in instances in which the vessels are wounded by a missile which passes between the artery and the vein implicated, or in the rare instance of a perforation of both vessels from side to side, in which the two outer openings cicatrize while those in the contiguous side of the vessels adhere. As to the occurrence of the latter process, I have no experience; but if a pure aneurysmal varix is eventually

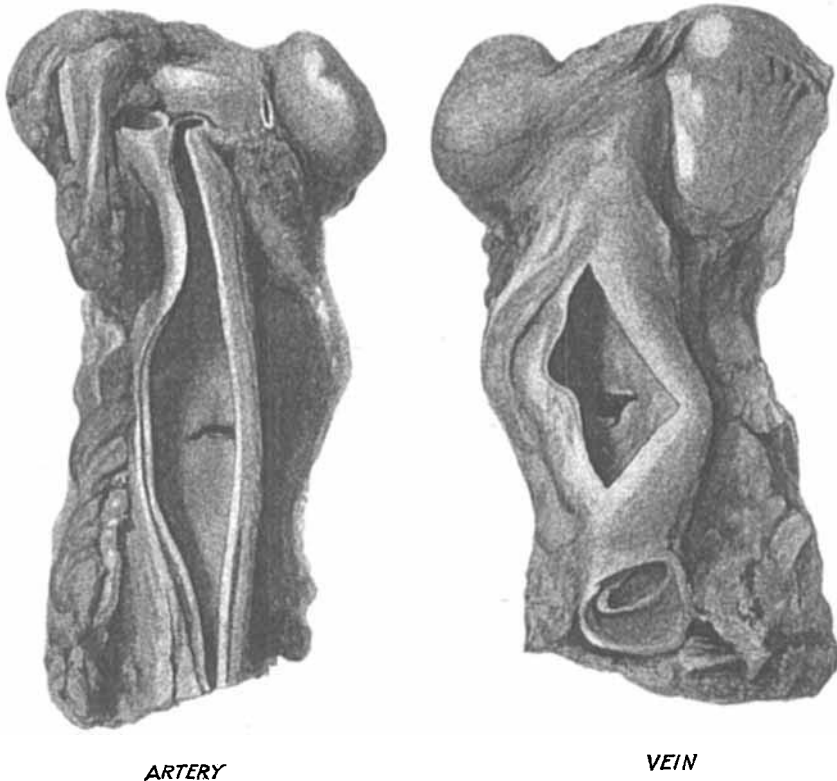


FIG. 127.—ANEURYSMAL VARIX OF THE LEFT COMMON CAROTID ARTERY AND INTERNAL JUGULAR VEIN (*Case 4.*)

A simple transverse lateral slit is seen from the interior of the artery, and a roughly stellate opening from the interior of the vein. No blood had been extravasated into the vascular cleft, and adhesion between the two vessels was immediate and complete.

The typical signs of a carotid aneurysmal varix were present. The patient died on the seventh day from concurrent injuries to the head. (Under the care of MAJOR PARSONS, No. 11 General Hospital, Boulogne.)

developed, I am inclined to think it usually follows the spontaneous consolidation of a false aneurysmal sac on the free side of the artery.

A case such as that depicted in *Fig. 130*, p. 381, offers a considerable field for speculation; here no aneurysmal sac had developed at the end of the eighth day, neither was there any collection of blood in connection with the wounds in the vessels except that enclosed in the sheath of the left vagus. The track leading from the arterial wound into the larynx had remained

narrow—so narrow, in fact, that it was only discovered by a very careful search when the specimen was dissected. It seems possible that a permanent indirect aneurysmal varix might have been developed here; or an arterio-venous aneurysm, the sac of which occupied the distended sheath of the vagus, might have formed between the vessels; or again, a sac might have developed between the wound of the artery and the larynx.

The presence of an aneurysmal varix may be accompanied by no further physical signs than the double murmur and bubbling thrill. What has been said regarding these signs under the description of arterio-venous aneurysm applies equally well to aneurysmal varix. Besides these phenomena, some swelling usually exists due to dilatation of the vein in the vicinity of the communication. When this dilatation is considerable, communicated pulsation from the artery may raise the question of the existence of an aneurysmal sac. The dilatation of the vein may persist in the rare cases in which the arterio-venous aperture closes spontaneously (Sir W. Osler, *Lancet*, 1913, vol. ii, p. 1248).

In the early stages some general swelling of the limb may be met with, due to the disturbance of the normal venous circulation. In the upper extremity this swelling is often quite temporary, but in the lower limb it may be more or less persistent, and at a later date the superficial veins may develop varicosities. A sense of weight in the limb, or more rarely actual pain, may call for operation; but the condition is rarely sufficiently serious to make such a procedure necessary.

GENERAL TREATMENT OF VASCULAR LESIONS.

I do not propose to treat this question at any length, first of all because the cases on which this paper is founded have been observed during a very short part of their course, and even in the instances in which early operative interference has been necessary, I am unaware as to the final influence exerted by the operations on the general nutrition of the parts supplied by the peripheral circulation. The bald facts observed as to the frequency of gross secondary lesions, such as gangrene or secondary hæmorrhage, are recorded in the special sections.

Again, with regard to the primary treatment of wounds of the large arteries I can say little, except that the immediate ligation of large trunks has not been a very successful measure, and that where a proximal ligature at the seat of election has been employed, I have seen several cases arrive at the general hospitals with incipient or definite gangrene, even in the case of the upper extremity. It is clear that immediate ligation of the large trunks under the conditions of military surgery is often followed by a want of compensation on the part of the collateral circulation, and beyond this, that the prospects of success are jeopardized by the circumstance that such operations need to be performed at a moment when the patient is suffering from a general loss of blood. This is especially notable in the case of ligation of the common carotid artery, which is followed by cerebral softening to a degree quite unapproached by what is familiar after operations for the cure of aneurysms of lengthy duration. In one case in which the common

carotid needed to be ligatured on the third day as a result of the relief of pressure on the wounded spot consequent on the removal of a piece of shrapnel case from the neck, the patient died within forty-eight hours, and the softening extended to the basal ganglia on the opposite side of the brain (Lieut.-Col. Cameron).

As to the treatment of secondary hæmorrhage, there is nothing special to be recorded.

The primary treatment of an arterial hæmatoma should be rest and an expectant attitude. Ligature of the artery at an early date is objectionable if it can be avoided; not only has the collateral circulation not acquired sufficient compensatory enlargement, but the conditions for the proper fulfilment of this process may be seriously interfered with, either by pressure from the blood-clot around the wound in the vessel, or, still more seriously, by concurrent wounds, or laceration from tearing, of some of the collateral branches themselves. As a result of these conditions, under the best of circumstances the general nutrition of the limbs suffers permanent injury, and actual gangrene is not infrequently the result. Beyond this, if wounded collaterals lie in the wall of the cavity of the hæmatoma, they may not bleed at the time of ligature of the main trunk, and hence are a not infrequent source of secondary hæmorrhage. I have seen the latter result on several occasions, where the ligature of the artery has been necessitated either by rapid extension of the hæmatoma, hæmorrhage, or a septic condition of the accompanying wound of the soft parts. An arterial hæmatoma should only be interfered with under one of the latter conditions, either of which may render a prompt operation unavoidable.

The large majority of the hæmatomata eventually become false aneurysms. For this condition, also, an expectant attitude is the best for some weeks; if during this time steady decrease in size and increase in the firmness and solidity take place, a much longer period should be allowed to elapse, in the hope that spontaneous consolidation of the sac, with persistence of the lumen of the artery, will supervene. Such an occurrence is not very rare, and the result is far superior to any obtainable by ligature or excision, and probably in no way inferior to that to be attained by successful suture of the opening in the arterial wall. Again, the later the date (within reason) at which the operation is undertaken, the better are the prospects of finding the vessel sufficiently free in the vascular cleft to allow a fair trial of the operation of suture. In certain positions a proximal ligature at the seat of election suffices to cure a false aneurysm, but the method is uncertain, and should not be adopted in any situation where the sac and the opening in the vessel can be dealt with locally.

There is no material difference in the early treatment of arterio-venous aneurysm; it needs only to be borne in mind that spontaneous cure is not likely to occur, and that proximal ligature of the artery, especially in the lower limb, is to be avoided, as gangrene of the limb was a common result of this treatment during the South African campaign. A local operation, with ligature of both vessels above and below the communication, or some form of suture, is the proper treatment for the condition. *B* and *E*, Fig. 123, p. 360, show well the danger of limiting the operation to double ligature of

the artery alone. The branch arising in immediate proximity to the wound in the artery would certainly, if not ligatured, have ensured the persistence of at any rate the signs of an aneurysmal varix.

Aneurysmal varices never need early treatment, and it is rare that an operation is required at a later date. The communication may close spontaneously, even after a long interval. Operation is needed most often in the lower limb, and should be of the same character as that recommended for arterio-venous aneurysms.

I much regret not being able to give any information regarding the treatment of gunshot wounds of the arteries by direct suture. In the cases I have myself seen, the nature of the defect in the arterial wall, the condition of the surrounding tissues, or the fact that the septic condition of the primary track afforded small hopes of performing an aseptic operation, militated against the choice of the method. In two cases which I saw some weeks after the operation, no peripheral pulse was present, suggesting that local thrombosis had vitiated the objects aimed at. An examination of the published results attained during the Balkan War also appeared to me inconclusive. Prof. Bier, at Brussels, in 1915, designated suture 'the operation of the future;' but no details of his cases have come to hand, and he admitted that thrombosis had occurred in a certain proportion. He also says that a circular suture is often needed, which observation is no doubt true. It would also be interesting to know whether the positions of flexion necessary to allow union of the line of suture in the absence of tension, have not resulted in furnishing the additional difficulty of straightening out a contracted limb.

PART II.

INJURIES TO THE VESSELS OF SPECIAL REGIONS.

Before proceeding to a consideration of certain points peculiar to injuries of the vessels of different regions of the body, it may be well to emphasize the fact that the material on which this paper is based has been gleaned from observations made in the general hospitals only. It seems necessary to repeat this statement, lest any attempt should be made to found statistical conclusions on the numbers to be obtained from the tables at the end of the paper. These tables leave out all reference to the nature or results of any treatment of arterial wounds that may have been carried out as a matter of urgency at the field ambulances or casualty clearing stations; hence they only deal with cases during a certain limited period of their course, and that one in which the immediate dangers of the injuries have been already surmounted. Again, with regard to the nature and distribution of the injuries, it will be at once evident that those included furnish an incomplete record only, and that complete divisions of the smaller vessels, although common, are unrepresented.

Innominate Vessels.—The only case is one of aneurysmal varix.

Case 1.—A man was admitted with a small slit entry wound situated over the left sternoclavicular joint. The missile was retained and its position was never discovered. The patient was suffering from an extensive right hæmothorax and was very ill. During the next ten days he improved, and meanwhile the whole chest was examined almost daily, and was also aspirated.

On the eleventh day a double machinery murmur was heard for the first time by Capt. T. R. Elliott, under whose observation the man had been since his admission. The systolic element was of the 'slamming' or 'pistol-shot' character, the roar was conducted loudly to both sides of the neck and to the base of the heart. A bubbling thrill was palpable in the line of the right axillary vein. A week later there was little change, except that the thrill was now felt only in the line of the jugular vein in the neck, and that the murmur was louder and more definitely localized over the line of the innominate vessels. No local dullness was to be detected beneath the first piece of the sternum or in the upper right intercostal spaces. The patient was shortly afterwards transferred to England.

There are only two comments to make on this case. With regard to the doubt as to the localization of the arterio-venous communication aroused by the fact that the bubbling thrill was first palpable over the right axillary vessels, I think I may have been deceived as to the actual localization, the more so that the permanent thrill in the jugular took up the direct line of the innominate vessels, and it is possible that what was first felt was innominate and not axillary.

The other point is the late advent of the signs of arterio-venous communication, a phenomenon suggestive rather of an aneurysm than a varix. As to this feature, I think the case should be considered in connection with the left subclavian injury (*Case 16*, p. 358) and the right subclavian aneurysm (*Case 17*, p. 385), in both of which a hæmothorax co-existed and was discovered many days prior to the signs of aneurysm. As in those instances, it appears probable that the blood from the wounded vessels trickled steadily into the pleural cavity, and no opportunity existed for the formation of local clot or the development of a local aneurysmal sac. Only when the pleura was distended, so that resistance to the further entry of blood was developed, did the local changes necessary for the completion of the conditions antecedent to the formation of an aneurysm or varix become established.

This is the only innominate varix I have met with during the thirteen months I have been on the look-out. The single instance I observed in South Africa eventually underwent spontaneous closure five years later.*

Carotid Vessels.—This series consists of fourteen cases, including one of the internal and two of the external carotid artery. Eight were of the right, and six of the left, vessels. Six of the injuries to the common carotid were to the upper third of the vessel, three to the middle part, and one to the lower third. In two cases the bullet took a vertical course from the head to the root of the neck: in one of these the centre of the vessel appeared to be the part wounded, in the other the injury was really to the thyroid vessels. Ten of the injuries were caused by bullets, and five by shell fragments: two of the bullets and four of the shell fragments were retained. Two cases were instances of contusion causing thrombosis and cerebral embolism. As a result of the wounds, false arterial aneurysms followed in two cases, arterio-venous aneurysms in three, and the clinical evidence was in favour of aneurysmal varices in seven. The great preponderance of the latter condition is a striking feature; though if the opinion expressed in the general section as to its causation is correct, no doubt the carotid vessels are so arranged with

* *Surgical Experiences in South Africa, 1899-1900*, 2nd edition, p. 140.

regard to the internal jugular veins as to allow the passage of the missile between the two vessels to be easy.

Five deaths occurred in the series, three from secondary hæmorrhage, one from acute infection of the clot, and one from cerebral embolism following on contusion of the artery.

Only two cases were operated upon, both by simple ligature of the common carotid for arterial aneurysms. One operation was for an aneurysm of the internal carotid, and was completely successful, the other was followed by hemiplegia due to a cerebral embolus.



FIG. 128.—A DISSECTION OF THE NECK, SHOWING THE APERTURE OF EXIT OF A BULLET TRACK CROSSING THE COURSE OF THE RIGHT CAROTID ARTERY AND INTERNAL JUGULAR VEIN, AND ESTABLISHING A COMMUNICATION BETWEEN THEM.

A glass rod projects from the track, and the blood-clot seen in the opening is in direct continuity with the wound in the vein. The arterial wound has not been exposed.

The wound underwent anaerobic infection, and the patient died from secondary hæmorrhage, associated with left hemiplegia, on the sixth day (*Case 6*). (Under the care of LIEUT.-COL. BUTLER, No. 13 Stationary Hospital, Boulogne.)

Little requires to be specially mentioned with regard to the signs and symptoms in these cases: all were typical, but it is worth recording that only one of the ten patients in whom arterio-venous communications existed complained of hearing the buzzing of the murmur, and in this man the trouble only persisted for a few days. The pulse-rate was augmented, but in most of the cases only from 80 to 100, once to 120. It is noteworthy that in the two cases of contusion followed by cerebral embolism the pulse-rate was 120

and 140 respectively; in the latter, death was imminent when the patient was seen.

Complications.—These were of much greater interest, and deserve a short recital of the cases in which they occurred.

1. INFECTION OF THE PRIMARY BLOOD EFFUSION.

Case 6.—(Under the care of LIEUT.-COL. BUTLER.)

The patient was wounded two days prior to admission; there was no information as to the occurrence of primary hæmorrhage, but the patient was ill and very anæmic. Temperature 101°; pulse 104.



FIG. 129.—A MESIAL SECTION OF THE SAME NECK.

A glass rod in the retropharyngeal space indicates the central portion of the track of the bullet. The retropharyngeal space itself is highly distended by gas emanating from the action of anaerobic bacilli, but no pus was present in the space. The condition illustrates well the fact that the extension of the gas precedes that of actual invasion of the tissues by the anaerobes, and renders the latter process more easy and rapid. (Under the care of LIEUT.-COL. BUTLER, No. 13 Stationary Hospital, Boulogne.)

A circular wound two and a half inches in diameter existed at the posterior border of the sternomastoid, two inches above the clavicular origin of the muscle. A small entrance wound at the back of the neck was closed. From the wound a dark brown discharge with a strong fæcal odour was escaping; the nurse indeed said that 'fæces' were coming out of the neck. *B. aerogenes capsulatus* was cultivated from the fluid.

Four days after the reception of the wound a sudden severe secondary hæmorrhage took place. This was arrested by plugging the wound with gauze soaked in

adrenalin. On removal of the plug the next day, some pulsation was noticed, and auscultation revealed the presence of an arterio-venous double bruit. Shortly afterwards the patient became hemiplegic, and he died on the sixth day.

The right side of the neck is shown in *Fig. 128*. The opening, still occupied by blood-clot, is exposed, and leads down to an opening in the internal jugular vein; the wound in the artery was not exposed. No laminated cavity had been formed; hence the condition was still that of an arterial hæmatoma, in which the rare accident of acute infection had occurred. The hemiplegia was no doubt embolic in origin, but unfortunately no examination of the brain was made.

Fig. 129 is of much interest as illustrating the size which collections of gas may reach in suitable situations in *B. aerogenes capsulatus* infections. The large space behind the pharynx and œsophagus contained gas only.

The case illustrates also the two further complications about to be considered.

2. SECONDARY HÆMORRHAGE.

Case 8.—(Under the charge of CAPT. OLIVER.)

A man was admitted three days after the reception of a transverse bullet-wound of the neck. The aperture of entry half an inch below the upper margin of the left ala of the thyroid cartilage, and the aperture of exit at the margin of the right trapezius muscle, two and a half inches above the clavicle, were both minimal in size, and closed.

The skin of the left side of the neck was of an orange tint from fading ecchymosis, and there was some general swelling of the neck, but no localized tumour or expansile pulsation. The man was breathing quietly, but the voice was hoarse and low, the latter fact being ascribed to recurrent laryngeal paralysis. The pulse was 120, of fair strength, and regular. On auscultation a loud double arterio-venous murmur was heard, most marked at the posterior border of the left sternomastoid muscle, in which position a bubbling thrill was also palpable and strong.

The man showed little distress, and for the next four days lay quietly in bed, the swelling of the neck steadily decreasing. He took his food easily, the breathing was practically normal, and no suspicion arose that the vascular injury was not settling down as is usually the case.

At 8 p.m. on the tenth day after the injury, without any warning, about half a pint of bright blood was coughed up. I saw him at 9 p.m. when, except that he was rather excited, he seemed little changed. In view of the amount of blood coughed up, it appeared advisable to ligature the root of the carotid artery, or possibly deal directly with the wound in the vessels.

Open ether narcosis was chosen and the man was anaesthetized, nothing special being noted in the breathing except that the inspirations were shallow and the patient went slowly under the influence of the anaesthetic. As the first incision was made the man ceased to breathe, and since there was evidently mechanical respiratory obstruction, I opened the trachea. Much fluid blood and clot escaped, but no relief was afforded, and the man died.

At the autopsy, the trachea and all the bronchial tubes were found full of blood and clot, there was massive collapse of the lower lobe of the right lung, and localized patches of collapse in both right and left lungs. An enlarged thymus was present, and some post-operative ecchymosis of the mediastinal tissues. Beyond the presence of some enlarged mesenteric glands no further visceral disease was discovered.

The condition of the vessels is shown in *Fig. 130*. A double perforation of the vein and a lateral wound of the carotid were present, while the two vessels were separated by the left vagus nerve. The latter had been perforated, and beyond the blood which had collected within the confines of its

sheath, no hæmorrhage of any moment had taken place into the vascular cleft. It is difficult to say whether the later condition in this instance would have been an arterio-venous aneurysm, the sac of which was in part formed by the sheath of the vagus; but up to the time of death it can only be regarded as an early indirect aneurysmal varix. The quiet manner in which sufficient hæmorrhage occurred to flood the lungs and drown the patient is very remarkable, since the man was under constant opportunities of being seen by the nurses, as well as by his neighbouring fellow-patients, in a large, well-lighted ward, and it is clear that the process produced neither discomfort nor distress. I believe this is to be explained by the anæsthetic condition of the larynx, which was pierced through the area of distribution of both superior laryngeal nerves. The recurrent laryngeal paralysis was probably due to the direct injury to the left vagus, and not merely to concussion of the larynx.

The secondary hæmorrhage was of the class which may occur when the process of formation of a false aneurysm in connection with a wound in an artery is either retarded or absent. There is no evidence that infection of the wound was in any way to blame; it is probable that the healing of the track leading from the larynx to the artery was retarded by the normal movements of respiration and deglutition, while the wound in the artery itself received support neither from coagulated blood nor from the reactionary infiltration of the tissues which usually reinforces the pressure exercised by the clot. It should be noted also that this patient had a pulse of about 120, which may also have had an influence on the occurrence of the bleeding.

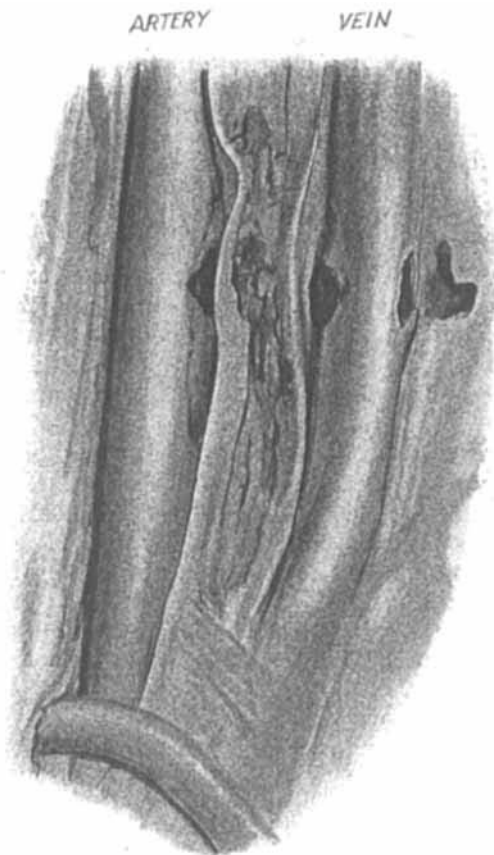


FIG. 130.—WOUNDS OF THE LEFT COMMON CAROTID ARTERY AND INTERNAL JUGULAR VEIN (Case 8, p. 380). (Twice the natural size.)

A traversing perforation of the vein is seen, with fairly symmetrical openings, and a lateral transverse wound of the artery. Between the vessels the left vagus is shown, greatly enlarged by the extravasation of blood into its sheath.

The signs were those of a typical carotid aneurysmal varix; no symptoms attributable to the vagal injury were noted beyond hoarseness of voice from abductor paralysis. The patient died from secondary hæmorrhage. (Under the charge of CAPT. OLIVER, No. 13 General Hospital, Boulogne.)

Case 14.—(Under the care of CAPT. MUMFORD.)

A man was admitted two days after receiving a bullet wound. The bullet struck the tip of the nose, passed through the upper lip, wounded the tongue, and then entering the sinus pyriformis, travelled vertically down the neck. Its final resting place was never localized.

There was considerable swelling of the right side of the neck, and some ecchymosis, but no evidence of the existence of an injury to the carotid vessels.

On the third day after admission two severe attacks of dyspnœa and some hæmoptysis occurred. In the second of these the man died.

At the autopsy, the trachea, bronchi, and lungs were swamped with blood, and there was septic pneumonic consolidation of both bases. Extravasated blood was present in the neck and in the anterior and middle mediastina. A large amount of blood had also trickled down the gullet, and the stomach was loaded with clot. No injury to the main carotid trunks had occurred, but the thyroid gland was much lacerated, and its capsule bounded a large hæmatoma.

In this instance again, the uneventful development of the hæmorrhage was very striking. Until the first attack of dyspnœa the man appeared to be progressing well, and the moderate hæmoptysis excited little suspicion. There is no doubt that commencing infection influenced the occurrence of the secondary bleeding, and was perhaps mainly responsible for it.

The gradual unnoticed filling up of the lungs and stomach by blood welling up from the wound in the fossa pyriformis, I believe again to be explained by the presence of anæsthesia in the area of distribution of the superior laryngeal nerve consequent on the wound of the pyriform fossa and larynx.

3. EMBOLISM.—The occurrence of arterial embolism in contusions of the carotid arteries, in connection with an arterio-venous aneurysm, has already been referred to under the heading of contusions of the vessels; it may be worth while to complete this subject by quoting briefly a case in which the same accident followed ligature of the carotid for a false arterial aneurysm.

Case 2.—(Under the charge of CAPT. FITZMAURICE KELLY.)

A man was admitted on the fourth day after receiving a wound at the level of the upper margin of the right ala of the thyroid cartilage. The missile was retained. The blood spurted 'as from a tap' at first, and the patient fainted, but a pad was applied and hæmorrhage ceased permanently.

On admission, a pulsating tumour two and a half by three inches was present at about the level of the top of the thyroid cartilage; there was a little general œdema of the side of the neck, and ecchymosis along the line of the vascular cleft, extending down over the front of the first piece of the sternum. A loud simple systolic bruit was audible on auscultation. The patient improved when kept at rest, the pulse averaging 88, and the œdema of the neck decreased.

On the ninth day, some evidence of extension along the line of the vascular cleft suggested the wisdom of ligaturing the artery, and this was done by Captain Kelly. The ligature was placed below the omohyoid, and pulsation in the aneurysm ceased. The patient progressed well for four days, the aneurysm solidified, and feeble pulsation could be detected in the distal portion of the carotid.

On the fifth day after the operation, the patient, who had been bright and well all the afternoon, suddenly became drowsy and hemiplegic. On the twentieth day he was transferred to England, in fair bodily and mental condition, but still completely hemiplegic.

Prognosis and Treatment.—The series affords little opportunity for remarks, but some points may be considered.

First, as to primary ligature of the wound in the artery, it might be argued that the occurrence of secondary hæmorrhage in two out of fourteen

cases indicated the danger of expectant treatment. I would only point out that the primary infection in *Case 6* would probably have rendered the proceeding nugatory, and that in *Case 8* a primary operation might have proved a procedure of much risk and difficulty. Further, primary ligature for gunshot wounds has acquired a very unenviable character, from the frequency with which it has been followed by cerebral softening and death



FIG. 131.—ARTERIO-VEINUS ANEURYSM OF THE EXTERNAL CAROTID ARTERY.
The small aperture of entry is seen anteriorly (*Case 10*). (Under the care of MAJOR SHEA,
Rawul Pindi Hospital, Wimeroux.)

of the patient. I only happen to have seen one case of this character, where the removal of a fragment of shell relieved a wound in the carotid from pressure, and the hæmorrhage demanded an immediate ligature. The patient died forty-eight hours later, and at the autopsy the cerebral softening involved not only the corresponding cerebral hemisphere, but also the basal ganglia of the opposite side.

Practical experience has shown that the danger of cerebral anæmia and softening is very greatly lessened if time has been allowed for the patient to recover from the primary general anæmia, and for the collateral vessels to become enlarged.

Of the cases related in an earlier paper on this subject,* no untoward accident followed the only three cases treated by primary proximal ligature, and in two arterio-venous aneurysms the anastomotic communication which again became evident a short time after the operation closed spontaneously during the course of the succeeding twelve months. One of the two latter patients is now on active service in France. I am not prepared to suggest that it may not be better in suitable cases to ligate the vessels above and below the aneurysm; in fact, in the case just related (*Case 2*) the adoption of this course would have probably prevented a very serious complication, that of cerebral embolism. Still, I think the more extensive operations must be used with judgement, since they are obviously much more risky procedures if a large sac is present. As to the ideal operation of suture of the wound in the vessel, I have no experience.

Aneurysmal varices should in my opinion be left alone, unless they are causing obvious trouble.

Subclavian Vessels.—The series contains seven cases of injury to the subclavian vessels, four caused by bullets, three by shell fragments. Five were of the right artery, two of the left. One involved the vessel in the first part of its course, two in the second part, and four in the third.

One of the cases was a simple division of the artery, in which spontaneous cessation of the hæmorrhage took place. In one, a large hæmothorax took the place of an ordinary arterial hæmatoma. Of the remaining five cases, in three an arterial hæmatoma and resulting false aneurysm developed, and in two an arterio-venous aneurysm.

The complications consisted of a concurrent hæmothorax in two cases, a concurrent injury to the brachial plexus in two, a brachial embolism in one, and secondary hæmorrhage and death in one. One other death followed upon an operation, from hæmorrhage.

Case 16, in which a brachial embolism occurred, has been already related in the section relating to arterial embolism in general, but a remark may be added as to the presence of the hæmothorax in this patient. It is reasonable to assume that the hæmothorax took the place of the ordinary hæmatoma usually situated amongst the tissues. In a similar instance I observed in South Africa the termination was still less happy, since the man died from secondary hæmorrhage some days after an incision.† In the case under comment the man escaped this accident, in spite of the fact that the hæmothorax suppurated and required to be drained. The wound in the artery presumably healed spontaneously.

Case 18.—(Under the care of **LIEUT.-COL. GORDON WATSON.**)

This case is worthy of comment in that it is an instance of a large wound of the second part of the artery in which the extravasated blood clotted completely without the formation either of a pulsating tumour or the development of a bruit

* *Surgical Experiences in South Africa, 1899-1900, 2nd Ed.*

† *Ibid.* p. 128.

to arouse suspicion. The fragment of shell entered and became embedded in the posterior triangle. Some free hæmorrhage which accompanied the removal of the fragment was checked by plugging the wound. An extensive cellulitis requiring incisions followed this procedure, but the patient was progressing well until the tenth day; on this day, as on the twelfth and fourteenth, secondary hæmorrhage followed the removal of the dressings, the blood coming out with 'a swish.' On the fifteenth day an attempt was made to deal directly with the wounded point, but when the wound was opened up the bleeding was so sharp, and the infiltrated tissues so difficult to deal with, that the operation had to be abandoned and the wound again plugged. The man died the same evening.

At the autopsy, pus was found both in the anterior and posterior mediastina, whence indeed it had flowed freely during the last short operation. A flap-like wound involving two-fifths of the circumference of the artery on the mesial side of the origin of the superior intercostal artery was found (see Fig. 123, C), and also the two firmly-healed ends of the completely severed subclavian vein.

The case is instructive as illustrating the fact that concurrent wounds of the artery and vein are by no means always followed by the development of an arterio-venous aneurysm, especially when the vein has been completely divided. The flap-like character of the arterial wound was perhaps such as to allow the vessel to have healed without the eventual development of an aneurysm at all.

To Lieut-Col. Gordon Watson I am also indebted for permission to quote the following case of complete division of the third part of the artery.

Case 104.—The patient was admitted with a brachial monoplegia and absent radial pulse. At an operation done for the repair of the divided cords of the brachial plexus, it was discovered that complete severance of the artery had been effected by the bullet, and followed by no serious hæmorrhage, either external or into the tissues. The mesial end of the vessel had retracted beneath the anterior scalene muscle, the distal end was seen curled up at the lower end of the operation wound.

In connection with these three cases, a fourth (*Case 17*), under the care of Lieut-Col. Butler, in which a right hæmothorax, preceded by hæmoptysis, followed on a bullet wound of the right posterior triangle, is worthy of mention. The interest lies in the fact that no aneurysm was discovered until three weeks after the patient's admission to the base hospital, although the condition of the patient's chest required a daily examination, and the course of the bullet, entering at the outer part of the sternomastoid and emerging at the superior angle of the scapula, had suggested an injury to the great vessels. When detected, it consisted of a small, hard, rounded swelling one and a half inches in diameter. The pulsation was scarcely expansile in character and not strong, but a very loud systolic murmur of the 'pistol-shot' type, conducted both upwards to the neck and downwards into the arm, was audible on auscultation. The radial pulse was good, perhaps a little weaker than the left. The patient was transferred to England, and the aneurysm was of the type in which spontaneous consolidation is possible. Its late appearance may have been due to the fact that the conditions favouring the early development of a sac—viz., the support of the surrounding tissues and the influence of the boundary formed by them in producing an early coagulation of the effused blood—were absent; while in their place the right pleura formed a potential space into which the fluid blood trickled by a slow stream through a narrow track.

Case 15.—(Under the charge of DR. RONALD GRAY.)

This was of great interest from several points of view. A man was admitted three days after being wounded by a bullet which entered about the apex of the right posterior triangle and emerged at the back of the shoulder above the posterior margin of the scapula. The entry wound was minimal in size. There was a complete brachial monoplegia. A large, soft, pulsating swelling extended upwards to the level of the top of the thyroid cartilage, raised the sternomastoid slightly,

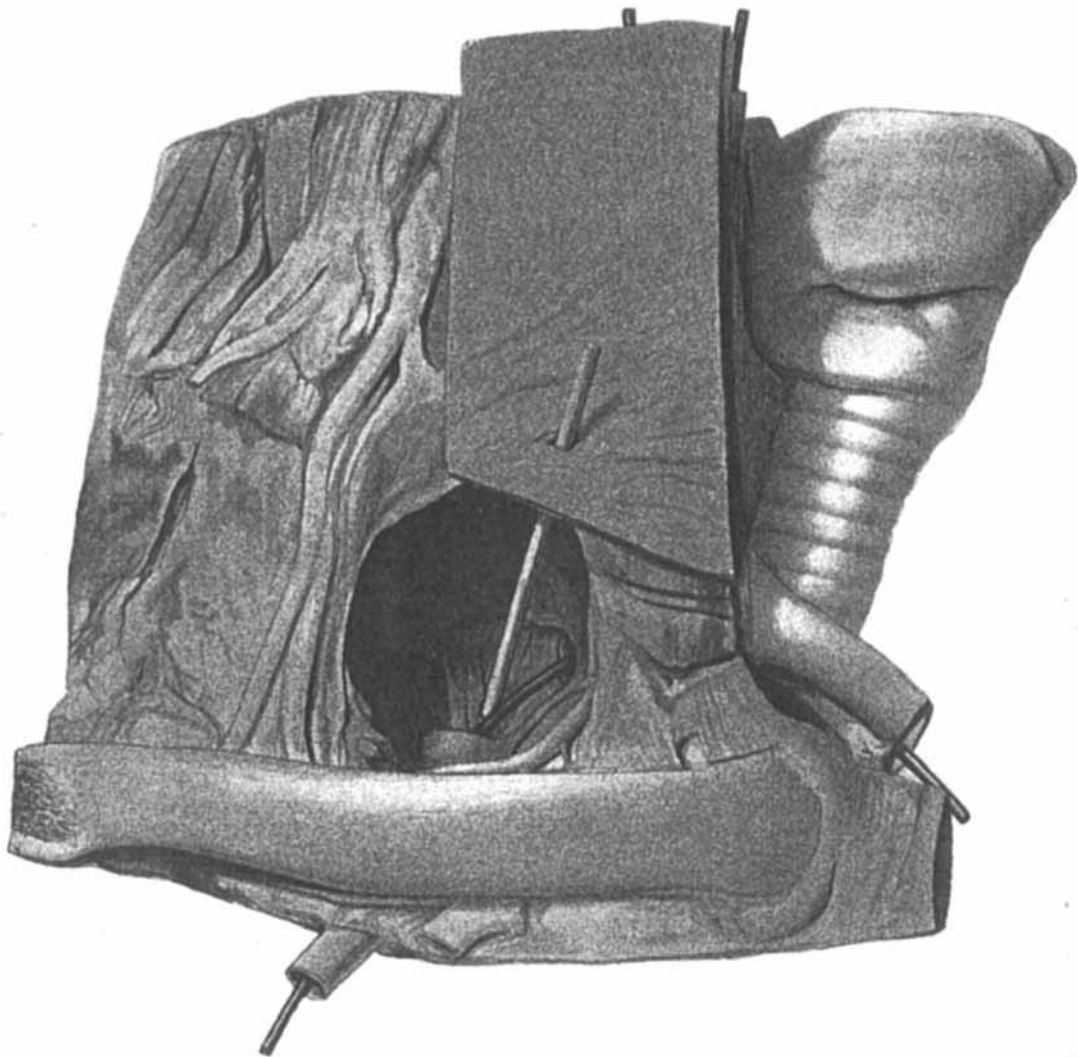


FIG. 132.—ARTERIAL ANEURYSM DEVELOPED IN CONNECTION WITH A COMPLETE DIVISION OF THE SECOND PORTION OF THE RIGHT SUBCLAVIAN ARTERY.

The distal end of the vessel is shown by the dark glass rod. The white rod passes through the original aperture of entrance of the bullet, and indicates its course. The anterior scalene muscle was destroyed in half its width by the bullet. The incision in the sternal portion of the sternomastoid muscle was made for the purpose of applying an arterial clamp to the innominate artery during the progress of the operation on the aneurysm (*Case 15*). (Under the care of DR. RONALD GRAY, No. 7 Stationary Hospital, Boulogne.)

but did not extend beneath the trapezius. The radial pulse was absent. A simple systolic bruit was audible throughout the swelling, but was not widely conducted. The man was very pale and anæmic.

During the next fourteen days complete rest was maintained, and the swelling became much more localized; but on the thirteenth day it was noted to be much softer and apparently increasing. For the latter reasons I decided to operate. As a precaution, the innominate artery was first exposed by an incision along the anterior border of the sternomastoid, and a clamp was placed upon it. An incision was now carried from the lower end of the first one, along the clavicle, and a triangular flap raised outwards. The swelling was then exposed and opened. A cavity containing a greenish fluid, bounded by decolorized lymph, was found completely shut off from the deeper swelling by the deep layers of the cervical fascia. The aneurysm was then opened, a procedure which was followed by an alarming rush of blood, controlled only by pressure downwards and inwards

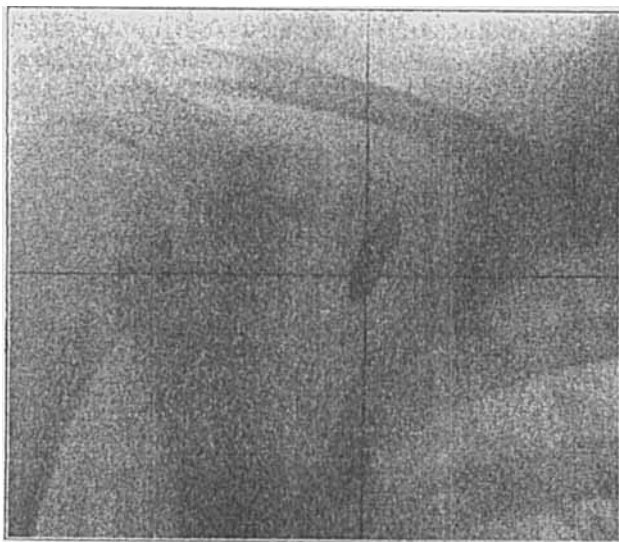


FIG. 133.—SKIAGRAM SHOWING SIZE, SHAPE, AND POSITION OF A FRAGMENT OF SHELL WHICH WOUNDED THE SECOND PART OF THE RIGHT SUBCLAVIAN ARTERY, GIVING RISE TO AN ARTERIO-VEINOUS ANEURYSM.

The resemblance in shape of the fragment to a deformed bullet is of interest (*Case 19*). (Under the care of CAPT. GREAVES, No. 26 General Hospital, Etaples.)

towards the transverse processes of the cervical vertebræ. After some trouble the bleeding, which came from the central end of a complete division of the artery in its second portion, was stopped, and it was thought wiser to tie the first portion of the subclavian trunk when the clamp was removed from the innominate. No trace of the subclavian vein was seen. The patient was much blanched from loss of blood at the end of the operation, and three hours later he died, in spite of a saline infusion.

Fig. 132 shows the condition found at the operation. One point, the destruction of half the width of the anterior scalene muscle, the phrenic nerve lying intact on the fascia at the very edge of the remaining part, is instructive, since had the muscle been divided—as was at one moment contemplated during the difficulties of the operation—the nerve could not have escaped. The

hæmorrhage came from the return flow in the branches of the first and second parts of the artery.

Special points of interest are, firstly, that the space occupied by the original hæmatoma had become loculated and the loculi shut off, while a typical false aneurysm had developed after the manner described in *Part I* of this paper; secondly, that although both the vein and artery had suffered division, a simple arterial aneurysm only developed. I believe this latter to be a far from uncommon result when the vein is completely severed, retraction, thrombosis, and spontaneous closure taking place, while the arterial wound may remain patent. Another example is seen in *Case 18*, already related.

The remaining two cases in the series were both of the arterio-venous variety; both were caused by fragments of shells, and in both, arterio-venous aneurysms resulted, doubtless from partial lesions of the vessels. In neither did any inflammatory change in the clot give rise to anxiety, although the fragments of shell were of some size and were retained; a skiagram showing these in one case is seen in *Fig. 133*. In one, pain and swelling in the upper part of the forearm suggested a small embolism, but no untoward effect followed.

Treatment.—The recital of these cases renders any further remarks on treatment superfluous. The two cases operated upon illustrate well the hazardous nature of the procedure, and the lesson that they are not to be interfered with unless obvious indications exist. In any case, a period of prolonged rest is likely to make an operation easier and safer, and early interference is to be deprecated. Professor Bier, at the meeting of Military Surgeons in Brussels, in 1915, gave an account of a hundred operations for traumatic aneurysms, with eight deaths: it is noteworthy that four of the eight resulted from operations at the root of the neck.

Axillary Vessels.—Fourteen cases of injury to the axillary vessels are included; twelve of these were occasioned by bullets, two by fragments of shells. In two instances there is a record of free primary hæmorrhage, in one of moderate hæmorrhage, and in the remaining eleven it was not severe enough to be recorded.

In five cases it was not possible to determine the actual nature of the lesion, since the only definite sign consisted in absence of the pulse at the wrist, which sign persisted during the whole time the patients were under observation. It is noteworthy that in all five of these cases there was more or less complete paralysis of the upper extremity from concurrent nerve injury.

Five of the lesions were of the right vessels, seven of the left, and in two no record has been kept. In nine cases aneurysms developed, one of the first part, three of the second, and five of the third part of the artery. Five were pure arterial aneurysms, three arterio-venous aneurysms, and one an aneurysmal varix.

The most important and common complication was injury to the brachial nerves; of the whole number of fourteen cases a more or less complete brachial monoplegia was present in nine. It is obvious that the concurrent arterial injury renders the prognosis of the nerve injury very unfavourable, while on the other hand the existence of the primary nerve lesion seriously prejudices

the result to be obtained by surgical treatment of the artery. In this situation, if an operation by suture is practicable, it is specially worthy of consideration.

The other common complication is the co-existence of a hæmothorax; this was present in five out of the fourteen cases, and in view of the fact that the great majority of injuries to the axillary vessels are caused by missiles crossing their course, the proportion seems a moderate one (35·7 per cent).

Case 29, under the care of Capt. Wolfenden, offers some special interest from the point of view of the possibility of the spontaneous cure of a wounded axillary artery, since the swelling, and also a definite arterial bruit after being audible for some four weeks, disappeared completely. As the cessation of the bruit was accompanied by disappearance of the brachial pulse, the occurrence can scarcely be regarded as a satisfactory prognostic sign in a patient the subject of a concurrent brachial monoplegia.

In five of the cases some form of operation was attempted, resulting in the local cure of the aneurysm in four, and death from hæmorrhage in one. A few further remarks may be made on this short series.

In *Case 28*, under the care of Capt. Wolfenden, an early operation was performed on the ground of free primary hæmorrhage followed by a rapidly increasing hæmatoma. A proximal ligature was placed on the third part of the subclavian artery at the field ambulance two hours after the reception of the wound. The operation efficiently controlled the primary hæmorrhage, and prevented the subsequent development of an aneurysm; but the vitality of the limb was seriously endangered, for when the patient arrived at the general hospital, the hand was cold and blue, the forearm swollen and dusky in colour, and the arm was swollen. Common sensation was also absent below the elbow. The limb improved later, but the free part of the thumb, the whole of the little finger, and the tips of the remaining three, became completely gangrenous.

The third part of the subclavian was tied in two other instances, once (*Case 22*) as a preliminary to laying open the sac, and once (*Case 24*) as a curative measure for a false aneurysm of the third portion. In neither instance could the operation be regarded as entirely satisfactory, since in the first, in spite of the precaution, hæmorrhage from the distal end of the wounded vessel was alarmingly free, and the small incision made into the sac had to be rapidly enlarged to obtain control of the bleeding; and in the second a fluid collection of blood persisted for some weeks after the operation, devoid of pulsation, but leaving the limb very stiff and wasted after its absorption.

In the other two cases a local operation was performed; the first, on a false arterial aneurysm, by Capt. Fitzmaurice Kelly, was a success (*Case 25*, and *Fig. 184*); in the second, on an arterio-venous aneurysm, a fatal result followed. The latter operation, performed by myself (*Case 21*), was undertaken on the ground of increase in size of the swelling and thinning of its walls. This case has already been referred to on p. 359. The hæmorrhage was almost entirely venous, and the difficulty in controlling it is there explained. In spite of its amount, the patient left the operating table in fair condition, although very pale. As in the case of subclavian aneurysm (*Case 15*), death occurred from simple anæmia some six hours later. It is worth noting that



FIG. 134.—ARTERIAL ANEURYSM OF THE SECOND PORTION OF THE LEFT AXILLARY ARTERY (*Case 25, p. 389*).

The aperture of entry of the bullet is seen in the outer part of the deltoid region, small and typical. The bullet itself was retained under the small prominences, due to the presence of subjacent blood-clot, seen over the sternum; note also the ecchymosis in this region. The anterior wall of the axilla projects as a large dome-like cavity. The wrist-drop, due to injury to the musculospiral nerve, is well shown. (Under the care of CAPT. FITZMAURICE KELLY, No. 13 General Hospital, Boulogne.)

throughout the early stage of the operation an attempt was made to control the hæmorrhage by digital compression of the third portion of the subclavian artery, a measure which later events showed to have increased the difficulties in which I found myself. I should perhaps again emphasize what has already been said as to the risks attendant on the treatment of aneurysms at the root of the neck or close below the clavicle, and add that, in spite of the experience of this case, I believe a strictly local operation is the right procedure; and when it is considered safer to secure open control of the third part of the subclavian artery, this should be maintained by an arterial clamp, or a temporary ligature.

Brachial Vessels.—This series contains only eleven cases, a very small number considering the frequency with which these vessels are wounded. The small number included in my record depends on the fact that such injuries are very easily treated, that the vessel is often ligatured primarily, and that in consequence of their minor importance, cases come comparatively rarely under the observation of the consulting surgeon. On the other hand, the series includes a surprising number of bad results, especially in the occurrence of gangrene, a complication hardly to be expected in dealing with wounds of these vessels.

Of four cases of simple ligature complicated by fractures of the humerus, gangrene occurred in three. In one of these, probably a tourniquet left in position for sixteen hours was to blame, and very severe primary hæmorrhage in another. In a fifth case the wound in the vessel apparently healed without any complication, in a similar manner to those of the axillary artery mentioned above.

In five cases an arterial false aneurysm developed, all of which were treated by direct ligature; in one gangrene followed. One aneurysmal varix is included, but no arterio-venous aneurysm. In one instance (*Case 34*) of wound of both artery and vein, the opening in the latter was closed by a fragment of shell which projected into the cavity of the vessel. The tendency of the completely divided brachial artery to thrombose and heal spontaneously is well known.

Radial and Ulnar Vessels.—One arterio-venous aneurysm of the ulnar, one of the radial, and one arterial false aneurysm, complete the whole series,



FIG. 135.—SKIAGRAM SHOWING FRAGMENT OF SHELL ON CHEST WALL, AND SMALLER FRAGMENTS IN ENTRY END OF WOUND TRACK, WHICH GAVE RISE TO THE DEVELOPMENT OF AN ANEURYSMAL VARIX IN THE THIRD PART OF THE RIGHT AXILLARY ARTERY. (*Case 26.*) (Under the care of CAPT. GREAVES, No. 26 General Hospital, Etaples.)

obviously enormously out of proportion to the number of vessels which must have been wounded. None the less, traumatic aneurysms of these vessels are rare, doubtless on account of their small size, and the frequency with which they suffer complete division.

Femoral Vessels.—The number of injuries and aneurysms included amounts to nearly half the whole series, a proportion corresponding with the length and size of the vessels. Of the thirty-six aneurysms, fifteen were of the common femoral, seven of the superficial femoral in the middle part of its course, and nine were situated in the lower third of the artery. The frequent occurrence of wounds of the vessel in Scarpa's triangle is no doubt due to its exposed position, while the fixation of the artery in the lower third renders escape of the vessel almost impossible if a bullet crosses its course. In the middle third the main trunk is comparatively movable, and is only in special danger at the points from which lateral branches are given off. The mobility of the femoral artery in the greater part of its course exerts a considerable influence on the exact character of the wounds; thus we find amongst twenty-three cases operated upon in which direct observation was possible, that in seventeen the wound was lateral, in one the lateral wound involved more than two-thirds of the calibre, and hence was comparable to a complete division, in four the vessels were completely severed, and in only one instance was the artery perforated. The perforation occurred in the most fixed portion of the vessel at the extreme limit of Hunter's canal (the adductor canal).

Of the twenty-six cases in which the nature of the missile was certain, in nineteen the wounds were produced by bullets, in five by fragments of shell, and in two by shrapnel balls.

In the whole series of thirty-six cases, primary hæmorrhage is noted to have been free in nine, while secondary hæmorrhage occurred in six instances. Gangrene of the limb was met with seven times.

Arterial hæmatomata or false aneurysms developed in twenty-three cases, arterio-venous aneurysms in six, and aneurysmal varices in five.

Femoral aneurysms exhibit in a marked degree the tendency to localization common to all traumatic aneurysms; but, on the other hand, the anatomical construction of the limb, and especially the width and length of the vascular cleft, favour the development of very extensive primary extravasations of blood. In Scarpa's triangle such extravasations are very superficial, they are usually attended by extensive ecchymoses, and from the want of support by the surrounding structures they tend to be large and soft, and to coagulate later than is the case elsewhere in the limb. Hence, if they are co-existent with a septic wound, especially a large 'explosive' exit in the buttock, the danger of secondary hæmorrhage is greater than it is in extravasations at a lower level. Over such superficial hæmatomata the nature of the wound of entrance is often very characteristic. As the effused blood contracts and undergoes absorption, the small closed wound with its circumferential area of thickening tends to project from the surface as a small papule with a depressed centre. Such a wound is shown in *Fig. 186, Case 55*, where the appearance has been very admirably depicted by the artist, Mr. Maxwell. A similar prominence of the wound may be met with in other parts of the body, but is more common in this region than elsewhere. In the lower part

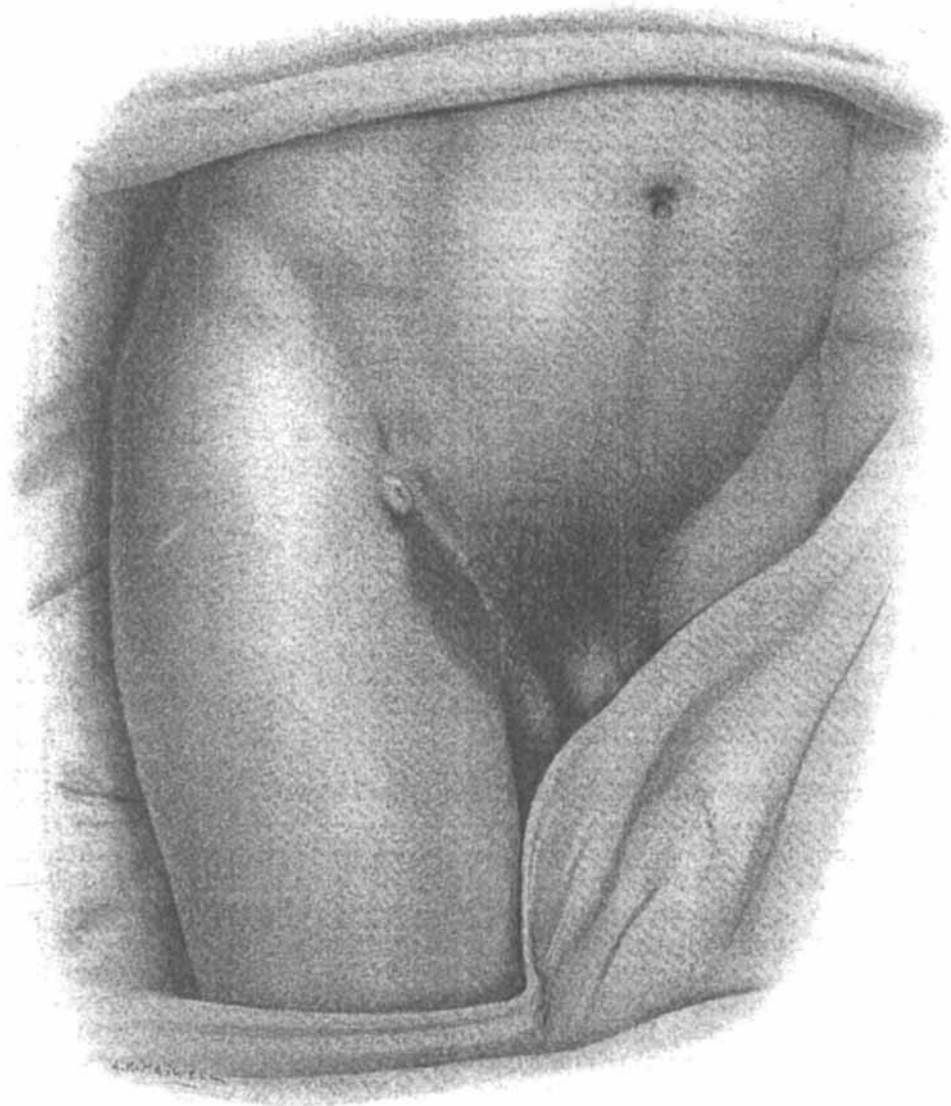


FIG. 136.—ORIFICE OF ENTRY OF A BULLET WHICH CAUSED A COMMON FEMORAL ARTERIO-VEIN ANEURYSM. (*Case 55*).

The minimal size of the aneurysm can be appreciated by regarding the outline of the groin. The cutaneous ecchymosis over the adductor region still persists, while the papular form of the orifice of entry, with its central depression, so characteristic of such wounds during the process of absorption and contraction of the underlying blood-clot, is well shown. (Under the care of CAPT. MARTIN, No. 7 Stationary Hospital, Boulogne.)

of the course of the artery, the blood effusion gives rise to a tense fusiform enlargement of the whole limb; the blood not only collects in the line of the vascular cleft, but when the wound extends from front to back of the limb, the primary effusion passes through the opening in the adductor muscles, and may collect in very large quantity in the posterior compartment of the thigh; or when the vessel is wounded in the adductor canal the effusion continues into the popliteal space. The fact that these extensions commonly take no part in the persisting false aneurysm has already been sufficiently dwelt upon in *Part I* of this article. The extension in three cases of wound of the profunda is worth noting as being identical. In each the vessel was wounded near its origin, and in two cases completely severed. The blood effusion in all extended upwards into Scarpa's triangle, and did not pass below the middle of the thigh; hence a wound of the common femoral was diagnosed. A similar course was taken by an effusion from the internal circumflex artery.

Gangrene was met with in five cases (13·8 per cent), in all of which operations were performed; twice it had commenced before the artery was ligatured, once the patient was suffering from the condition known as 'trench foot' in both extremities, once it followed upon two severe secondary hæmorrhages in a patient dying from septicæmia, and once it only involved the toes. In one case only it followed the operation of ligature, on the sixth day. In all five instances the patients were the subjects of severe wound infection.

Secondary hæmorrhage was four times an indication for operation, and it followed operations on three occasions, in each leading to a fatal issue.

Operations, consisting without exception of ligature of the artery above and below the wound, were performed in twenty-five of the cases included. The common femoral was the seat of ligature in five (two deaths), the superficial femoral in seventeen (three deaths), the profunda in two (one death), and the internal circumflex in one. There were, therefore, six deaths, a mortality of 24 per cent. In no instance did secondary hæmorrhage occur from the point of ligature of the trunk.

Sixteen of the operations were performed for the treatment of arterial hæmatomata or false aneurysms. The indications for operation were in eight cases infection of the accompanying wounds of the soft parts; in one, extension of the hæmatoma; in two, secondary hæmorrhage; and in two, impending gangrene. The remaining four were operated upon as suitable cases for ligature. Three of the sixteen died, in each instance as a result of secondary hæmorrhage from small branches in the depth of a septic wound of the thigh. In all but one of the cases the lesion of the artery consisted in a lateral wound; in several the vein was thrombosed as a result of contusion.

In one case of solid arterial hæmatoma due to complete severance of the vessels, not included in the above numbers, gangrene of the foot and leg was pronounced on the fourth day, and amputation was performed.

In only six of the thirty-six cases did arterio-venous aneurysms develop; two of these were of the common femoral, and neither patient was in a condition suitable for operation when he left the country; four were in connection with the middle part of the superficial femoral vessels. No special point needs to be emphasized regarding patients transferred without being subjected to opera-

tion. Of the three operated upon, one had already developed a serious infection of an explosive exit wound in the buttock, and the foot and lower third of the leg were gangrenous. It appeared preferable under these conditions to deal directly with the wounded artery, rather than to perform a high amputation which would still have a septic wound-track at its base. The operation was performed on the fourth day after the reception of the wound, and two days later the patient died of toxic infection dependent on an acute gaseous cellulitis of the buttock in connection with the original bullet track.

The second case was of interest mainly from the fact that the vein had suffered complete division, and the central end was thrombosed. The arterio-venous communication was between a small lateral wound of the artery and the open end of the distal portion of the vein. The indication for the operation was impending gangrene of the foot, and the operation was so

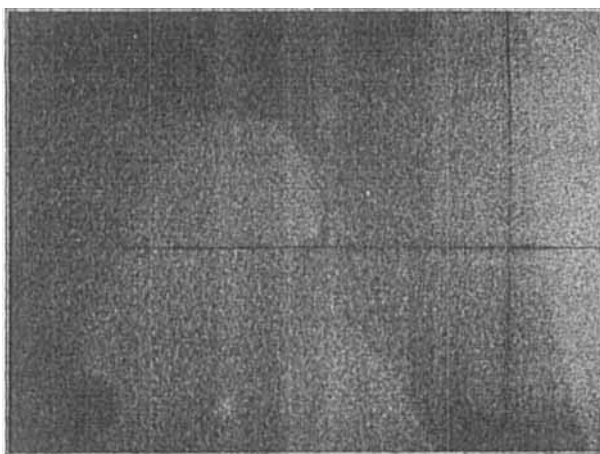


FIG. 137.—SKIAGRAM SHOWING A RETAINED SHRAPNEL BALL IN THE ADDUCTOR REGION OF THE LEFT THIGH WHICH HAD WOUNDED THE VESSELS AND GIVEN RISE TO A COMMON FEMORAL ARTERIO-VEINOS ANEURYSM. (Case 67.) (Under the care of CAPT. GREAVES, No. 26 General Hospital, Etaples.)

far successful as to limit the eventual gangrene to the sole. Mr. Lawford Knaggs wrote me some months later that the foot was still in jeopardy. It should be added that a condition of slight 'trench foot' was existent in the sounder limb.

The third case formed an excellent example of the difficulties attendant on some injuries to the femoral vessels in the middle part of the thigh. Ligation of the main trunk had but little influence on the hæmorrhage, which continued from many points after the vessel had been occluded. It became necessary to leave a number of forcipressure forceps in the wound, and to plug it, to prevent a hopeless degree of anæmia. The patient did well, and the aneurysm was cured.

The five cases of aneurysmal varix offer little scope for comment, since the signs were typical, and no unpleasant symptoms accompanied the

condition. Two were operated upon, the development in one being accompanied by a moderately severe anaerobic infection necessitating primary incisions. The operation on the vessels was done on the seventy-third day, a small lateral opening in the artery and a greatly dilated vein being dealt with. A second large vein, probably a dilated great anastomotic branch, lay side by side with the femoral vein at the site of the communication at the lower end of Hunter's canal.

The second case (*Case 64*) was operated upon on the sixteenth day, and is worth brief recital as illustrating a not uncommon difficulty in dealing with this condition. The position of the wounds, and the loudness and high pitch of the murmur, apparently indicated the level of the communication to be about the centre of Hunter's canal. The vessels were freely exposed, but no dilatation nor any 'shivering' of the vein was discovered. The thrill could be controlled by a clamp at the upper limit of the wound; but in spite of a somewhat free separation of the vessels, I failed to locate the point of communication. The wound was therefore closed, and the patient sent home. During the succeeding five months this patient was in various hospitals in England, and then returned to his depot at Winchester for light duty. He was thence transferred to the Royal Hampshire County Hospital, suffering with pain and swelling of the limb. Mr. Godwin, under whose care he came, has kindly furnished the following note of the operation he performed. The account is of special interest, as the vessels were repaired successfully by suture, and also because the difficulty experienced at the primary operation is shown to have depended merely on a faulty localization of the point of injury.

On admission, the right leg was slightly swollen and œdematous. On palpation a very distinct thrill was discernible over the whole of the inner side of the thigh and popliteal region, and a very loud, harsh, roaring bruit was heard all over the femoral and popliteal vessels. The patient was kept at rest for two weeks, and as there was no improvement it was decided to operate.

Operation.—An elongated internal incision was made in the line of the adductor magnus tendon, giving enough room to allow of control of the femoral and popliteal arteries. On exposing the vessels, it was found that the communication between the artery and vein was just below the opening in the adductor magnus tendon.

The vessels were carefully dissected out. The vein was somewhat dilated, and there was quite a small sac between the artery and vein.

Crile's clamps were applied to the vessels and to a branch of the artery, which was taken to be the internal articular branch, coming off just opposite the hole in the artery. The sac was dissected off. The hole in the vein was found to be larger than that in the artery. After cutting away about half an inch of the vein, an end-to-end anastomosis was done with fine silk sutures under sterilized paraffin and saline without any undue tension on the vessel. It was not possible to do an end-to-end anastomosis of the artery, so the edges in the hole of the vessel were refreshed, and the artery was closed laterally with fine silk sutures, and a graft from the internal saphenous vein was sewn over the sutured vessel, with the suture line on the opposite side. On removing the clamps the circulation was perfect, and there was no hæmorrhage from the stitched vessels. The wound was closed, and the limb was put on a back splint slightly flexed. Healing by primary union occurred, and the stitches were removed on the tenth day. The operation lasted two hours.

After-treatment.—Gentle massage and movements. There was never any swelling or œdema of the leg after the operation, and when seen five months later, the circulation was normal and the patient doing light duty.

Two of the three cases of injury to the profunda are worthy of quotation for several reasons, such as the size attained by the hæmatoma, the uncertainty of the diagnosis, the difficulty experienced in controlling the hæmorrhage at the time of operation, and the fact that both operations were followed by a fatal result.

Case 69.—(Under the care of CAPT. OLIVER.)

A man was admitted with a shell wound of the thigh, one and a quarter by one inch in size, three inches below the mid point of Poupart's ligament, and apparently superficial in nature. The wound was fairly clean on admission, there was some swelling of the thigh, no pulsation, and the tibial pulses were normal.

Two days later there was a marked increase in anæmia, associated with great increase in the size of the thigh, and the development of pulsation and a systolic bruit. The swelling extended from the level of the anterior superior spine to the middle of the thigh. A temporary elastic ligature was applied to the common femoral artery, the swelling was incised, and two pints of clot were evacuated. A lateral wound was discovered on the outer side of the origin of the deep femoral artery; a ligature was applied below this, and the common femoral artery definitely closed also. After four days' satisfactory progress, gangrene of the toes set in, and a few days later the man succumbed to a general toxæmia.

Case 71.—(Under the care of CAPT. MAX PAGE.)

A man was admitted with two wounds, one penetrating the right chest, the second traversing the buttocks and wounding the rectum. A large hæmatoma was present in Scarpa's triangle. During the following week the temperature rose (reaching 103°), with occasional rigors, and the hæmatoma showed signs of breaking down.

Under spinal anæsthesia the suppurating hæmatoma was incised; it extended deeply through the obturator foramen, and the common femoral vessels were felt pulsating in its anterior wall. On the same night a severe secondary hæmorrhage took place; this was controlled by placing a ligature on the common femoral artery, but the patient died a few hours later.

A subsequent examination of the limb showed the deep femoral artery to have been completely severed at its origin from the common femoral. It had no doubt been thrombosed, but the clot had given way as a result of secondary infection.

Case 72.—(Under the care of CAPT. OLIVER.)

In this case the internal circumflex branch only was wounded. A large hæmatoma was found as in the previous case, unaccompanied by the presence of either pulsation or bruit. The posterior tibial pulse was ablated, and the whole thigh was white and tense. Softened clot commenced to escape from the wound of entry, and on the eleventh day the opening in the front of the thigh was enlarged, a great quantity of clot evacuated, and an opening discovered in the internal circumflex artery close to its origin. The man made an uninterrupted recovery.

General Consideration of the Treatment of Femoral Aneurysm.—The indications for active treatment in the early stages have been already set forth in the foregoing pages; they consist in (1) Spreading infection of the surrounding tissues; (2) Extension of the blood effusion, or external secondary hæmorrhage; (3) Threatening gangrene of the limb; and (4) The rare event of acute infection of the hæmatoma itself.

Under other circumstances, rest to the limb and an expectant attitude should be maintained for a fortnight or three weeks, and this course is not to be deviated from on account of a local septic state of the wound in the soft parts; for while the clot bounding the hæmatoma rarely gives way, the wound

made for the operation on the artery cannot be kept free from infection. Unfortunately I am not in a position to be able to quote numbers as to the frequency with which gangrene follows a primary ligature of the vessel; but I know it to be common, and have been told of several instances. Beyond this, few successful cases of primary ligature of the femoral vessels reach the general hospitals.

Certain conditions special to operations in the thigh may be shortly considered.

1. Condition of the tibial pulses as an indication for operation. The presence of the tibial pulses at the ankle, regarded as an indication of the persistence of a column of blood circulating in the main vessel, must always be of importance; but in the early stages it is no evidence of an enlarged collateral circulation, for when existent it is promptly extinguished by ligature of the femoral trunk, and only in two instances did it reappear during the average period of fourteen days during which the patients remained under observation. On the other hand, the disappearance of an existing tibial pulse while the patient is under observation is a serious sign of increasing vascular obstruction, especially if this be contemporaneous with the cessation of the arterial murmur and with hardening of the aneurysmal swelling. Under these circumstances an operation is imperative, and may save the vitality of the limb, stave off impending gangrene, or even cause a recession in the line of advance in an already gangrenous limb.

2. What influence does simultaneous ligature of the vein exert on the after-history of these operations? I believe that it is of no immediate detriment; I have myself ligatured both vessels on two occasions for arterial aneurysms, and have seen it done three times. Beyond this, it is a necessary procedure in cases of arterio-venous aneurysm if ligature and excision be the operation chosen, and it has not proved dangerous. Further, in many cases of arterial wound, the bullet has contused the neighbouring vein and caused thrombosis, and here again no immediate ill effect appears to be seen in the results of arterial ligature. As to the permanent effect on the general nutrition of the limb, it is too early to speak.

3. What is the effect of arterial ligature on threatening or early gangrene? It has not proved of such marked benefit as might be inferred from the reports of isolated cases. It is most satisfactory in those cases where the pressure of large blood effusions or of hard, clotted extravasations on the collateral circulation can be relieved. It may be added that in a few cases in which the operation has been done in the absence of large extravasations, it certainly has not acted hurtfully.

4. Two practical points are worth reiterating:—

i. These operations are without doubt most safely performed with the aid of an *Esmarch's tourniquet*. If the application of this be impracticable, a temporary ligature of the common femoral or external iliac artery is advisable, or they should be exposed, and the lumen occluded by the application of an arterial clamp. When the blood effusion extends freely beneath Poupart's ligament, and an incision for the external iliac is dangerous, the abdominal aorta should be controlled by a drainage tube tourniquet tied round the waist. For this last resource I am indebted to Capt. Wolfenden,

who so controlled the aorta during a ligature of the common femoral which he helped me to perform.

The precaution of employing a tourniquet is not advised merely for the control of bleeding from the main vessel, which can usually be readily maintained by digital pressure. The main trouble in stopping the hæmorrhage lies rather in the difficulty of securing the wounded branches in the large cavity in the thigh, this difficulty being most marked when the branches of the profunda are those concerned.

ii. In dealing with large hæmatomata in the middle part of the thigh, it is well to remember that the mobile vessels have travelled in the direction of least resistance, i.e., away from the femur, and that they will probably be found in the inner wall of the cavity, and not upon its floor.

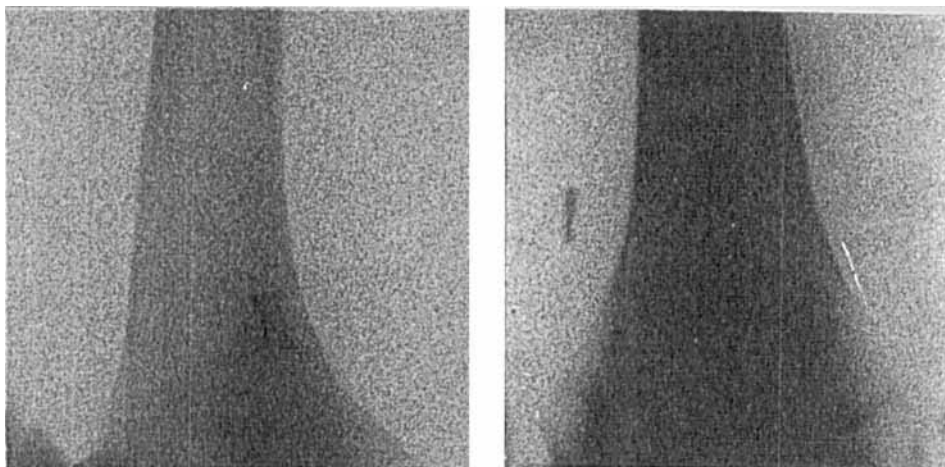
As far as the experience gained by observation of cases recently operated upon goes, ligature of the common femoral artery appears to seriously compromise the subsequent general nutrition of the limb, apart from the risks of actual gangrene. This vessel is one for wounds of which suture should, if possible, be attempted, so as to maintain the viability of the trunk. In order to attain this desirable object, cases should be allowed a considerable time to finally settle down. Under existing conditions almost any aneurysm which arrives in England is at once treated by ligature, even when the surgeon in France has considered that the chances of spontaneous cure were fair. This is obviously a class of case that suffers materially from passing from the hands of one surgeon to another, when each new medical attendant is fully acquainted neither with the stage of the condition at a prior date, nor with the opinion held by the surgeon previously in charge of the patient.

Popliteal Vessels.—The series of injuries involving the popliteal artery and vein is small. It is also the most unsatisfactory with regard to immediate results or the effect of operative treatment, that is dealt with in this communication. It is not possible to determine with certainty whether the series is in any way representative of this class of injury as a whole, since it is clear that many patients suffering with small type bullet wounds traversing the popliteal space are not infrequently regarded as trivial cases and promptly transferred home without exhaustive examination. This source of fallacy is not however confined to wounds in this area, and reasons exist for regarding injuries to the popliteal space as especially dangerous to the vitality of the limb. Such are: (1) The depth of the popliteal space, and the resistant character of its walls; (2) The constriction exercised on the main trunks by the fibrous and bony structures bounding their points of entry and exit into and from the space; (3) The fixation and relative incapacity for rapid dilatation of the collateral branches which arise from them; and (4) The fact that patients with wounds in this area are apt to maintain the knee in a position of flexion, in which the circulation through the main trunks is more seriously interfered with than in most other situations. Be this as it may, the fact remains that of sixteen injuries to the popliteal vessels here included, the limb had to be amputated in eight, and this in spite of the fact that the wounds of the soft parts were in no case serious.

In only eight of the cases were aneurysms developed, six arterial and two arterio-venous. The remaining eight patients were dealt with during the

wounded artery stage. In eight cases the wounds were caused by bullets, in four by shell fragments, and in four the nature of the projectile is not known.

The nature of the wound in the artery was lateral in seven, a complete severance in four, a perforation in one, and unknown in three. In one case the lesion consisted in perforation of the vein and thrombosis of the artery (see *Fig. 121*, p. 355). In two instances a lateral wound of the artery was accompanied by complete division of the vein, and in two by venous thrombosis. These details show the injuries to have been generally of a severe class. In four cases a hæmarthrosis of the knee was present, and five were complicated by the co-existence of fractures.



FIGS. 138, 139.—SKIAGRAMS SHOWING THE POSITION, SHAPE, AND SIZE OF A FRAGMENT OF SHELL WHICH HAD WOUNDED THE POPLITEAL ARTERY AND GIVEN RISE TO THE FORMATION OF AN ARTERIAL ANEURYSM (*Case 78*). (Under the care of CAPT. GREAVES, No. 26 General Hospital, Etaples.)

The complication which eventually demanded amputation in nine of the sixteen cases was gangrene; in eight of these the gangrene was primary, in one only did it follow ligation of the artery. The artery was ligated in seven cases in the hope of arresting or causing recession of impending gangrene; this procedure failed in all but three cases. In one impending gangrene was averted, in a second it was limited to the tip of the great toe, and in a third to the anterior half of the foot; there is little doubt that in all three the procedure was successful. In the other four a secondary amputation was necessary.

The literature of the Manchurian war, especially the writings of Zoege von Manteuffel, aroused great hopes of successfully treating early or impending gangrene arising from injury to the popliteal vessels by prompt ligation. It was suggested that in this position, especially, the relief of pressure by blood-clot on the collaterals would greatly improve the peripheral circulation. This

small series of operations is therefore disappointing; but it must be added that in none of the cases dealt with did much pressure by clot exist, in the majority there was none, and in the only case in which it was a prominent element an amputation was unavoidable by reason of the stage the gangrene had already reached.

Only four of the whole series escaped gangrene, two treated expectantly—one arterial, one arterio-venous—and two treated by ligature. In the first of



FIG. 140.—SKIAGRAM SHOWING THE BONES OF THE THIGH AND LEG OPPOSITE THE POPLITEAL SPACE (*Case 108*).

An impacted bullet is seen lying transversely in the popliteal space, the point of which, after traversing the popliteal vein, lodged in the popliteal artery without penetrating the anterior wall. Removal of the bullet some days after its entrance was followed by free hæmorrhage, necessitating ligature of both vessels. (Under the care of MAJOR STONEY ARCHER, No. 5 General Hospital, Angers.)

the two latter, gangrene was impending, while the second was the simple perforation illustrated in *Fig. 140*.

Secondary hæmorrhage was met with once only, and was followed by gangrene demanding amputation of the leg.

With regard to the question of the danger of simultaneous ligature of the artery and vein, it may be added that this was done in one of the successful cases. In two others the vein was completely severed and the proximal end thrombosed, and in two the intact vein was thrombosed. The case of arterial

contusion and thrombosis accompanying the divided vein has been already referred to (p. 355).

Posterior Tibial Vessels.—Injuries to the vessels in the calf, and also of the anterior tibial artery, have been very common, and a certain number of aneurysms have been met with. As a rule the results have either been of small importance, or the aneurysms have been promptly dealt with, hence my attention has been drawn to very few of the cases by the officers in charge.

Only three cases appear in the general table; and these do so, because from them were derived the three small arterial sacs which have served so useful a purpose in the description of the development of false aneurysms. (See *Fig. 124.*)

TABLE OF ARTERIAL OR ARTERIO-VEINUS

NO.	UNDER CARE OF	BULLET OR SHELL	NATURE OF WOUND. PRIMARY HÆMORRHAGE	POSITION IN COURSE OF ARTERY	ARTERIAL OR ARTERIO-VEINUS ANEURYSM, OR ANEURYSMAL VARIX	SECONDARY HÆMORRHAGE: DATE
INNOMINATE.						
1	Major Steel	No information	Small slit entry over left sternoclavicular articulation. No history of pain. Hæmorrhage	—	? Varix	None
CAROTID.						
2	Capt. Kelly	Bullet	Type. Profuse primary hæmorrhage	Upper third right common carotid	Arterial	None
3	Lt.-Col. Watson	Bullet	Type. No history of primary hæmorrhage	Right common carotid	Aneurysmal varix	None
4	Major Parsons	Bullet	Type. No history of primary hæmorrhage	Left common, middle third	Varix	None
5	Major Shea	Bullet	Type. No history of primary hæmorrhage	About centre of left common carotid	Varix	None
6	Lt.-Col. Butler	Shell	No history of primary hæmorrhage	Right common carotid	Arterio-venous aneurysm	Fourth day
7	Dr. Ronald Gray	Bullet	Slit in posterior triangle, margin of trapezius. Considerable primary hæmorrhage	Right common carotid	Arterio-venous aneurysm	None
8	Capt. Oliver	Bullet	Type. No history of primary hæmorrhage	Right common carotid	Varix	Tenth day : $\frac{1}{2}$ pint

I must not close this paper without expressing my warmest appreciation of the kindness of the many medical officers under whose charge the whole series of cases were observed by me, and who took every opportunity of aiding me in the investigation of the patients. To them I owe much, and I take this occasion of offering my sincere thanks. I am also much indebted to my friend and A.D.C., Lieut. L. W. Shelley, for his constant help in the recording and arrangement of the cases.

Lastly, I am further much indebted to Mr. Beadles for his beautiful dissections, and to Messrs. Maxwell and Sewell who have drawn the illustrations.

ANEURYSMS AND ANEURYSMAL VARICES.

GANGRENE	TREATMENT	RESULT	NOTES. COMPLICATIONS
—	Complete rest	Transferred	No murmur noticed before eleventh day. Chest examined by competent observer. Right radial pulse weak
See notes	Common carotid tied below omohyoid eleventh day	Transferred	Cerebral embolism. Hemiplegia fifteenth day. Slight improvement of paralytic symptoms when transferred to England. See text, p. 382
--	Complete rest	Transferred	Slight thrill right side. Definite soft double murmur. No pulsating tumour
—	Complete rest	Died	Death due to concurrent injury to head. See text, p. 372, and illustration, <i>Fig.</i> 127
—	Complete rest	Transferred	Typical double murmur and thrill. Noise of murmur bothered him at first, not noticed at end of ten days
See notes	—	Died	Death sudden. Hemiplegia. Large retropharyngeal and retro-oesophageal space due to gaseous cellulitis. See text, p. 379
—	Complete rest	Transferred	Bullet retained beneath skin above centre of left clavicle. Much ecchymosis of left shoulder. Circumflex nerve affected slightly. Voice hoarse at first, now normal. Murmur conveyed to heart. Tumour of considerable size
—	Complete rest	Died	Laryngeal paralysis. P.M.—Lungs full of blood. See text, p. 380

[Continued on next page]

TABLE OF ARTERIAL OR ARTERIO-VEINUS

No.	UNDER CARE OF	BULLET OR SHELL	NATURE OF WOUND. PRIMARY HÆMORRHAGE	POSITION IN COURSE OF ARTERY	ARTERIAL OR ARTERIO-VEINUS ANEURYSM, OR ANEURYSMAL VARIX	SECONDARY HÆMORRHAGE: DATE
CAROTID—continued.						
9	Lt.-Col. Butler	Shell	Type. No history of primary hæmorrhage	Left common carotid upper third	Varix	None
10	Major Shea	Shell	Slit level of top of thyroid cartilage. Free primary hæmorrhage	Right external carotid	Varix	None
11	Capt. Clementi Smith	Shell	Small slit. Shrapnel retained. Profuse primary hæmorrhage	Left external carotid	Varix	None
12	Major Davies-Colley	? Shell	Small incised, ant. margin of left sternomastoid at level of angle of jaw. No history of primary hæm.	Upper third left common carotid	Arterio-venous aneurysm	None
13	Capt. Max Page	? Bullet	Type. No history of primary hæmorrhage	Right internal carotid	Arterial	None

THYROID VESSELS.

14	Capt. Mumford	Bullet	Wound of tip of nose and upper lip. Bullet not localized. No history of primary hæmorrhage	Thyroid vessels	Arterial	Third day
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SUBCLAVIAN.

15	Dr. Ronald Gray	Bullet	Type. Severe primary hæmorrhage.	Second portion right	Arterial	None
16	Lt.-Col. Butler	Bullet	Type. No history of primary hæmorrhage	First part left	Arterial	None
17	Lt.-Col. Butler	Bullet	Type. No history of primary hæmorrhage	Third part right	Arterial	None
18	Lt.-Col. Gordon Watson	Shell	Middle of posterior triangle. No history of primary hæmorrhage	Second part left	Arterial	Free, twelfth and fourteenth days
19	Capt. Greaves	Hand Grenade	Ragged wound 1½ in. long above clavicle over anterior border of sternomastoid. No history of primary hæmorrhage	Second part right	Arterio-venous aneurysm	None
20	Capt. Greaves	Shell	Right side middle of anterior border of trapezius. No history of primary hæmorrhage.	Third part right	Arterio-venous aneurysm	None

ANEURYSMS AND ANEURYSMAL VARICES—*continued.*

GANGRENE	TREATMENT	RESULT	NOTES. COMPLICATIONS
—	Complete rest	Transferred	Loud deep double murmur below wound. Two days later systolic elements of a loud, 'slamming' character, conducted to left subclavian artery
—	Complete rest	Transferred	Double murmur, systolic element traceable to heart (<i>Fig. 131, p. 383</i>)
—	Complete rest	Transferred	Typical double murmur. Systolic element most marked over wound, roar below. First cervical transverse process chipped
See notes	Complete rest	Transferred	Complete aphasia. Pupils, R < L. Left palpebral fissure small. No difference in sweating. Embolism (cerebral). See text, p. 358
—	Common carotid tied about fifth day	Cured	Had tense swelling of soft palate and right side of pharynx, which gradually disappeared after ligature of common carotid. No cerebral symptoms. Right facial weakness (? peripheral). See text, p. 378
None	Complete rest	Died	On third day two severe attacks of dyspnoea, in second of which man died. Much fullness of right side of neck. No wound of great vessels, but left half of thyroid ploughed up, and large blood cavity See text, p. 382
None	Ligature second part fourteenth day	Died	See text, p. 386
Moist, from fingers to middle of hand	Amputation at middle of forearm	Transferred	Arterial bruit. No aneurysm detected. Large hæmothorax, which suppurred. Embolism of brachial artery. See text, p. 358
None	Complete rest	Transferred	Right hæmothorax. See text, p. 385
None	Division of sternomastoid, exposing junction of subclavian and internal jugular vein. Sac opened by removal of plugs. Re-plugged. Free hæmorrhage	Died	P.M.—Pus in posterior mediastinum. All tissues stiff and infiltrated, even in anterior mediastinum. See text, p. 385
None	Complete rest	Transferred	Typical murmur, conveyed to both sides of neck, audible over whole præcordium. Large swelling. Weakness of upper extremity
None	Complete rest	Transferred	Had pain in forearm and local swelling; ? embolism

[Continued on next page]

TABLE OF ARTERIAL OR ARTERIO-VEINUS

No.	UNDER CARE OF	BULLET OR SHELL	NATURE OF WOUND. PRIMARY HÆMORRHAGE	POSITION IN COURSE OF ARTERY	ARTERIAL OR ARTERIO-VEINUS ANEURYSM, OR ANEURYSMAL VARIX	SECONDARY HÆMORRHAGE DATE
AXILLARY.						
21	Capt. Bradford	Bullet	Moderately severe primary hæmorrhage	First part left	Arterio-venous aneurysm	Secondary extension
22	Lt.-Col. Butler	Bullet	Entry wound slit midway between middle of clavicle and ant. axillary fold. Exit wound circular over fifth dorsal spine. No history of primary hæm.	Second part left	Arterial	Secondary extension
23	Major Sinclair	Bullet	Type entry and exit. No primary hæmorrhage	Third part left	Arterio-venous aneurysm	None
24	Capt. Martin	Bullet	Type entry and exit. Large primary hæmorrhage	Third part left	Arterial	None
25	Capt. Kelly	Bullet	Entry wound 4-in. below spine of scapula. Bullet retained over sternum. No history of prim. hæm.	Second part left	Arterial	None
26	Capt. Greaves	Shell	Entry wound slightly excavated. Circular. Considerable primary hæmorrhage	Third part right	Varix	None
27	Capt. Burrows	Shell	Large gaping wound left scapular region. No history of primary hæmorrhage	Second part	Arterio-venous aneurysm	None
28	Capt. Woffenden	Bullet	Primary hæmorrhage in free gushes. Hematoma in axilla and on chest wall	Third part left	Arterial	None
29	Capt. Wolfenden	Bullet	Entry slit above centre of right clavicle. Exit vertical border right scapula. No primary hæmorrhage	Third part right	Arterial	None
BRACHIAL.						
30	Capt. Rahili	Shell	Wound from posterior triangle to axilla. Free primary hæmorrhage	Upper third left	Arterial	None
31	Lt.-Col. Butler	Shell	No history of primary hæmorrhage	Lower third left	Arterial	Secondary hæmorrhage
32	Dr. Graham Jones	Bullet	Explosive wound of forearm. No history of primary hæmorrhage	Lower third right	Arterial	None

ANEURYSMS AND ANEURYSMAL VARICES—continued.

GANGRENE	TREATMENT	RESULT	NOTES. COMPLICATIONS
None	Operation twenty-fourth day. Division of pectorals. Severe hæmorrhage. Ligation of artery and vein.	Died	See text, p. 389
None	Third part of subclavian tied, then axillary in third part, on seventeenth day	Cured	Free hæmorrhage after tying subclavian (third part) until third part of axillary tied. Suppuration occurred in axilla, which cleared up under treatment. No radial pulse returned
None	Complete rest	Transferred	Seventh day murmur became louder and higher pitched. Hæmothorax. Brachial monoplegia
None	Complete rest	Transferred	Hæmothorax. Operation, third part of subclavian tied in England. After operation fluid blood in sac persisted for some weeks
None	Operation twenty-fifth day. Sac opened and artery ligatured above and below opening	Transferred	Brachial monoplegia. See text, p. 389, and illustration, Fig. 134, p. 390
None	Complete rest	Transferred	Œdema of upper limb probably due to tourniquet. Ulnar anæsthesia
None	Complete rest	Transferred	Murmur and swelling gradually diminished
Little finger and free part of thumb and last joints of remaining fingers	Primary proximal ligature two hours after wound	Transferred	Brachial monoplegia. See text, p. 389
None	Complete rest	Transferred	Brachial monoplegia and hæmothorax. Systolic bruit disappeared, also swelling (? spontaneous cure)
None	Double ligature	Cured	Aneurysm size of tangerine orange. Median nerve appeared uninjured at operation, although loss of function existed
Gangrene of hand	Ligature of brachial	Cured	Amputation mid-forearm
None	Double ligature of brachial	Cured	Two-thirds division of artery, with retraction of open ends three-quarters of an inch

[Continued on next page]

TABLE OF ARTERIAL OR ARTERIO-VEINUS

NO.	UNDER CARE OF	BULLET OR SHELL	NATURE OF WOUND. PRIMARY HÆMORRHAGE	POSITION IN COURSE OF ARTERY	ARTERIAL OR ARTERIO-VEINUS ANEURYSM, OR ANEURYSMAL VARIX	SECONDARY HÆMORRHAGE: DATE
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BRACHIAL—continued.

33	Lt.-Col. Gordon Watson	Bullet	Wound of thumb. Bullet passed up forearm to above elbow. Considerable primary hæmorrhage	Lower third left	Arterial	None
34	Capt. Martin	Shell	No history of primary hæmorrhage	Middle third right	Arterial	None
35	—	Bullet	Type wounds. No history of primary hæmorrhage	Right	Varix	None

ULNAR.

36	Lt.-Col. Gordon Watson	Shell	Entry wound small, perforating upper third close to inner border of ulna. Exit wound large, ragged, 1 in. long, middle and lower third flexor surface of forearm ulnar side. No history of primary hæmorrhage	Left	Arterio-venous aneurysm	Twice. First on eleventh day, second on twelfth day
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RADIAL.

37	Capt. Rankin	Shell	Dorsum of hand	Right	Arterio-venous aneurysm	—
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FEMORAL.

38	Major Littler Jones	Bullet	Type wounds. No history of primary hæmorrhage	Lower third rt. superficial fem.	Arterial	None
39	Capt. Stanley Raw	Shell	Small entry wound inner side of thigh. No history of primary hæmorrhage	Middle third rt. superficial fem.	Arterial	None
40	Lt.-Col. Gordon Watson	Bullet	Type wounds. No history of primary hæmorrhage	Middle third rt. superficial fem.	Arterial	Sec. hæm. tenth day
41	Major Littler Jones	Bullet	Type wound. Large primary hæmorrhage	Lower third superficial fem.	Arterial	None
42	Lt.-Col. Butler	No information	No primary hæmorrhage	Superficial fem. lower third left	Arterial	None
43	Capt. Max Page	Bullet	Type entry and exit. No primary hæmorrhage	Superficial fem. lower third right	Arterial	None
44	Capt. Burn	No information	Small slit in groin. No history of primary hæmorrhage	Common fem. left	Arterial	None
45	Capt. Max Page	Bullet	Type entry and exit. Free primary hæmorrhage	Common fem. left	Arterial	None
46	Lieut. Anderson	No information	No history of primary hæmorrhage. Entry wound over Hunter's canal	Middle third superficial fem.	Arterial	Sec. hæmorrhage ninth, twelfth, and thirteenth days

ANEURYSMS AND ANEURYSMAL VARICES—continued.

GANGRENE	TREATMENT	RESULT	NOTES. COMPLICATIONS
None	Double ligature	Cured	Wound of artery, three-quarters of an inch long, one inch above bifurcation
None	Ligature	Cured	Complete perforation of artery and perforation of vein. Shell fragment still lodged in vein. Only systolic bruit. Fair radial pulse returned fourth day
None	Complete rest	Transferred	Thrill and double murmur. Radial pulse smaller than left. Some dilatation of veins of forearm
None	Portion of artery excised with venæ comites	Cured	Small sac found in connection with artery, communication between the inner vena comes and artery
—	Double ligature and excision	Cured	
None	Double ligature of artery	Cured	Small lateral wound of artery excised, three inches of vein thrombosed. Bullet struck femur and carried small fragments of bone into track
None	Double ligature of artery	Cured	Indication for operation, cellulitis of thigh. Lateral wound of vessel. See <i>Fig. 123 B</i>
None	Double ligature artery tenth day. Piece of vessel excised	Cured	Indication for operation, secondary hæmorrhage. Lateral wound of vessel. See <i>Fig. 123 D</i>
None	Double ligature of artery <i>in situ</i>	Cured	Complete division of vessel, 'smashed up'
None	Double ligature of artery	Cured	Gaseous cellulitis of leg
None	Double ligature	Cured	Perforation of artery. Vein thrombosed
Gangrene of foot and lower third of leg	Artery and vein ligatured	Cured	Sent home with localized gangrene of foot. 'Slamming' systolic murmur
None	Artery ligatured twenty-seventh day	Cured	Much wasting of limb subsequent to operation. Otherwise did well
None	Double ligature tenth day	Died	Lateral wound of artery. Indication for operation, cellulitis of thigh and secondary hæmorrhage. Branches ligatured on thirteenth day

[Continued on next page]

TABLE OF ARTERIAL OR ARTERIO-VEINOUS

NO.	UNDER CARE OF	BULLET OR SHELL	NATURE OF WOUND. PRIMARY HÆMORRHAGE	POSITION IN COURSE OF ARTERY	ARTERIAL OR ARTERIO-VEINOUS ANEURYSM, OR ANEURYSMAL VARIX	SECONDARY HÆMORRHAGE DATE
FEMORAL—continued.						
47	Lt.-Col. Butler	Bullet	Type entry. No exit. No history of primary hæmorrhage	Common fem.	Arterial	None
48	Capt. Wolfenden	Bullet	Type entry. Explosive exit in left buttock. No history of primary hæmorrhage	Common fem. left	Arterial	Secondary hæmorrhage fourth and fifth days.
49	Capt. Rahili	Shell	Very free primary hæmorrhage. Entry and exit large	Middle third rt. superficial fem.	Arterial	None
50	Capt. Wolfenden	No information	Entry outer margin anterior surface of thigh. Large exit in adductor region	Superficial fem. middle third left	Arterial	Secondary hæmorrhage
51	Capt. Wolfenden	Shell	Entry wound only, under surface of thigh. No history of primary hæmorrhage	Superficial fem. junction of lwr. and middle third left	Arterial	None
52	Capt. Wolfenden	Bullet	No history of primary hæmorrhage	Superficial fem. middle third left	Arterial	None
53	—	Bullet	Type entry and exit	Common fem. right	Arterial	None
54	—	Bullet	No history of primary hæmorrhage	Common fem. right	Arterial	None
55	Capt. Martin	Bullet	Type entry and exit wounds. No history of primary hæmorrhage	Common fem. right	Arterial	None
56	Major Hull	No information	Wound lower end of Hunter's canal. No history of primary hæmorrhage	Superficial fem. middle third	Arterial	None
57	Major Maynard Heath	Bullet	Type entry and exit	Superficial fem. middle third	Arterio-venous aneurysm.	—
58	Lt.-Col. Gordon Watson	Bullet	Type entry wound. Bullet retained right side of scrotum. Much primary swelling of scrotum and effusion in left iliac fossa, and œdema of limb	Left common femoral	Arterio-venous aneurysm	None
59	Capt. Max Page	Bullet	No great primary hæmorrhage	Left superficial fem. middle third	Arterio-venous aneurysm	None
60	Capt. Max Page	Bullet	Type entry. Exit explosive	Left superficial fem. middle third	Arterio-venous aneurysm	None

ANEURYSMS AND ANEURYSMAL VARICES—*continued.*

GANGRENE	TREATMENT	RESULT	NOTES. COMPLICATIONS
None	Artery ligatured fourth day	Cured	Indication for operation, gaseous cellulitis of thigh. Large pulsating swelling extending up to Poupart's ligament
Threatening before death after hæm. fourth day	Artery ligatured fourth day	Died	Hæmatoma extended widely into iliac fossa. Indication for operation, suppuration in thigh. Secondary hæmorrhage from collateral branches. Lateral wound of artery
None	Artery and vein ligatured twenty-second day	Cured	Wound of artery involving three-fifths of lumen. Indication for operation, secondary extension
None	Operation third day. Artery ligatured, portion excised	Cured	Indication for operation, widespread cellulitis of thigh. Lateral wound of artery
None	Double ligature. Operation tenth day	Cured	Indication for operation, surface redness. See p. 368 <i>Fig. 123 A</i>
None	Double ligature. Operation twentieth day	Cured	Fractured femur Lateral wound of vessel at origin of profunda. Surrounding tissues acutely inflamed
None	Complete rest	Transferred	Systolic bruit, rather high pitched, conducted mainly downwards
None	Complete rest	Transferred	Fractured upper end of femur. No bruit present
None	Complete rest	Transferred	Very small aneurysm. See <i>Fig. 136, p. 393</i>
Gangrene to middle of leg	Amputation	Transferred	Large swelling due to coagulum, and much ecchymosis
None	Tumour laid open fourteenth day. Artery tied. Free hæmorrhage from branches controlled by pressure forceps	Cured	Seven days after operation forceps came away and wound healed
None	Complete rest	Transferred	Double murmur, systolic element of 'sledge-hammer' type audible at cardiac apex. Thrill and bullet palpable in scrotum. Extreme anæmia
Patch of gangrene on sole of foot	Double ligature of artery. Distal ligature of vein	Cured	Small lateral wound of artery. Complete division of vein. Indication for operation, gangrene of foot. See text, p. 395
Gangrene of foot and lower third of leg	Common superficial and deep femoral ligatured fourth day	Died	Patient died from gaseous cellulitis of buttock, second day. Indication for operation, gangrene of foot. Large tumour. Fractured neck of femur

[Continued on next page]

TABLE OF ARTERIAL OR ARTERIO-VEINUS

NO.	UNDER CARE OF	BULLET OR SHELL	NATURE OF WOUND. PRIMARY HÆMORRHAGE	POSITION IN COURSE OF ARTERY	ARTERIAL OR ARTERIO-VEINUS ANEURYSM, OR ANEURYSMAL VARIX	SECONDARY HÆMORRHAGE. DATE
FEMORAL—continued.						
61	Lieut. Colquhoun	Bullet	Type entry. Exit explosive. Severe primary hæmorrhage	Left superficial femoral	Arterial	None
62	Capt. Wolfenden	Bullet	Type entry. Retained. No history of primary hæmorrhage	Left superficial fem. middle third	Arterio-venous aneurysm	None
63	Major Gillies	Bullet	Type wounds. Fairly severe primary hæmorrhage	Right common femoral	Arterio-venous aneurysm	None
64	Capt. Wolfenden	Bullet	Oblique wound just extending to line of femoral vessels. No history of primary hæmorrhage	Rt. superficial fem. lower third	Varix	None
65	Capt. Clementi Smith	No information	Wound oblique; track crossing lower quarter Hunter's canal. No history of prim. hæmorrhage	Left superficial fem. lower third	Varix	None
66	Capt. Kelly	No information	Small slit $1\frac{1}{2}$ inches below Poupart's ligament. Severe primary hæmorrhage	Left common femoral	Varix	None
67	Capt. Greaves	Shrapnel ball	Wound of entry small. Retained. A good deal of primary hæmorrhage	Left common femoral	Varix	None
68	Major Gillies	Bullet	Type entry and exit. A good deal of primary hæmorrhage	Left common femoral	Varix	None
69	Capt. Oliver	Shell	Wound $1\frac{1}{2}$ by 1 in., apparently superficial	Left profunda femoris	Arterial	None
70	Capt. Max Page	No information	Slit wound above inner third Poupart. No history of primary hæmor.	Left profunda femoris	Arterial	Secondary hæmorrhag
71	Capt. Max Page	No information	Wound traversing buttocks and rectum. No history of primary hæm.	Left profunda femoris	Arterial	Secondary hæmorrhag
72	Capt. Oliver	No information	Wound over origin of profunda, about $1\frac{1}{2}$ -in. circle. Clot protruding. No history of primary hæmorrhage	Internal circumflex branch of profunda	Arterial	None
POPLITEAL.						
73	Capt. Martin	Shell	Free primary hæmorrhage	Left	Arterial	None
74	Capt. West	Bullet	Small entry and exit. No history of primary hæmorrhage	Left	Arterial	None

ANEURYSMS AND ANEURYSMAL VARICES—continued.

GANGRENE	TREATMENT	RESULT	NOTES. COMPLICATIONS
None	Artery ligatured	Cured	Fracture of femur, two inches destroyed
None	Complete rest	Transferred	Systolic element of the murmur heard at cardiac apex
None	Complete rest	Transferred	Murmur audible over every part of limb. No thrill
None	Hunter's canal opened. Communication not found	Transferred	Explored artery not ligatured. See text, p. 396
None	Operation. One inch of vessels excised seventy- third day,	Cured	Gaseous cellulitis of thigh on admission
None	Complete rest	Transferred	Typical varix. No symptoms
None	Complete rest	Transferred	General thrombosis of limb with much fever. General condition good when patient went home—thrill more localized, murmur quieter
None	Complete rest	Transferred	Machinery murmur conducted upwards and along whole of leg, not heard in heart
Gangrene of toes	Common femoral ligatured	Died	Septicæmia. See text, p. 397
Gangrene of foot	External iliac ligatured on fifteenth day, and common femoral on sixteenth day	Died	Suppuration and incipient gangrene at time of opera- tion. Recurrent secondary hæmorrhage and gangrene causes of death
None	Common femoral tied	Died	Artery completely divided at point of origin. Large hæmatoma in Scarpa's triangle. See text, p. 397
None	Hæmatoma laid open and interior circumflex artery ligatured	Cured	See text, p. 397
Threatened	Artery and vein tied 24 hours after wound for threatening gangrene	Cured	Operation at clearing station. At base patient was found to have hæmarthrosis, and bullet in knee-joint. Leg in good condition six days later
Gangrene of whole foot. Sec. throm- bosis of leg	Double ligature of artery	Cured	Lateral wound inner side of artery. Azygos articular arising opposite wound. Vein severed. Fracture of femur. Hæmarthrosis. Gangrene arrested.

(Continued on next page)

TABLE OF ARTERIAL OR ARTERIO-VENOUS

No.	UNDER CARE OF	BULLET OR SHELL	NATURE OF WOUND. PRIMARY HÆMORRHAGE	POSITION IN COURSE OF ARTERY	ARTERIAL OR ARTERIO- VENOUS ANEURYSM, OR ANEURYSMAL VARIX	SECONDARY HÆMORRHAGE : DATE
POPLITEAL — <i>continued.</i>						
75	Capt. West	Bullet	Type wound. No history of primary hæmorrhage	Right	Arterial	None
76	—	Shell	Lacerated wound of popliteal space left side. No history of primary hæmorrhage	Left	Arterial	None
77	Capt. Rankin	Bullet	Entry wound inner and upper part of popliteal space. No primary hæmorrhage	Left	Arterio-venous	None
78	Capt. Greaves	Shell	Entry wound upper part of popliteal space inner side. No history of primary hæmorrhage	Right, upper third	Arterial	None
79	Col. Scott	No information	Not much primary hæmorrhage	Left	Arterial	None
80	Capt. Oliver	Bullet	Type wound	—	Arterial	None
81	Major Littler Jones	Bullet	Type wounds. No primary hæmorrhage	Right	Arterio-venous	None
82	Col. Elder	Bullet	Entry, type. Bullet retained. No primary hæmorrhage	Left	Arterial	None
TIBIAL.						
83	Lt.-Col. Butler	Shell	Wound size of shilling 3 in. above interior malleolus, communicating with fracture. No history of primary hæmorrhage	Left posterior tibial lower third	Arterial	Severe about fifteenth day
84	Capt. Clementi Smith	Bullet	Type entry and exit. No history of primary hæmorrhage	Left posterior tibial	Arterial	Slight first three days.
85	Capt. Kelly	Bullet	Large explosive exit in calf	Right anterior tibial	Arterial	None

ANEURYSMS AND ANEURYSMAL VARICES—*continued.*

GANGRENE	TREATMENT	RESULT	NOTES. COMPLICATIONS
Gangrene of foot	Leg amputated	Recovered	Three-fifths lateral wound of artery, pure perforation of vein. No aneurysm had formed, but there was a large mass of hard coagulum, especially prominent on inner aspect of thigh. See <i>Fig. 126</i>
Gangrene of foot and leg to four inches below knee	Leg amputated	Recovered	Large sac with blood-clot. Vein severed. Artery nicked
None	Complete rest	Transferred	Double murmur, systolic element 'pistol-shot' in character and conducted centrally only, just above pulsating area. Six days later conduction upwards more extensive but not 'pistol-shot' in character. Other leg had been amputated
None	Complete rest	Transferred	Murmur gradually became of lower pitch and softer. Looked like possible spontaneous cure. Artery ligatured the day after patient arrived at hospital in England. See <i>Figs. 138, 139</i>
Impending gangrene on fourth day	Artery ligated by internal incision. Amputation later lower third thigh on 17th day, for gangrene of leg	Recovered	Indication for operation, impending gangrene
Early gangrene at end of two days	Amputation of leg	Recovered	
Early gangrene on tenth day	Artery and vein tied	Cured	Indication for operation, gangrene, which was arrested, only small patch on heel and end of great toe persisting. Effusion into knee-joint. Double murmur, systolic element conducted in both directions
None	Popliteal ligatured on 12th day	Cured	Marked cedema of leg after operation, suggesting thrombosis. Foot-drop, and loss of sensation which was returning
None	Leg amputated	Recovered	See <i>Fig. 124, a and b</i>
None	Wounds enlarged and clot cleared out. Small aneurysmal sac came away.	Cured	After operation hæmorrhage controlled by packing See <i>Fig. 124, c</i>
None	Double ligature of artery	Cured	Left leg amputated

INJURIES TO VESSELS WITHOUT

NO.	UNDER CARE OF	BULLET OR SHELL	NATURE OF WOUND. PRIMARY HÆMORRHAGE	POSITION IN COURSE OF ARTERY	ARTERY AND VEIN OR ARTERY ONLY	SECOND. HÆMORRHAGE. PRESENCE OR ABSENCE OF HÆMATOMA
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THROMBOSIS AND SUBSEQUENT EMBOLISM.

86	Capt. Wolfenden	Bullet	Wound of neck. Retained over spine of sixth and seventh dorsal vertebræ. No history of primary hæmorrhage	Lower third right carotid	Contusion of artery	No second. hæmorrhage. No hæmatoma
87	Lt.-Col. Gordon Holmes	Bullet	Small, slight, near anterior border of sternomastoid, 1 in. below angle of jaw. No history of primary hæmorrhage	Left carotid	Contusion of artery	No second. hæm. Small circular area of induration over artery. No definite hæmatoma
88	Lt.-Col. Cameron	No information	Large wound inner side of thigh. Femoral vessels felt at bottom of wound. Very septic. No history of primary hæmorrhage	Superficial femoral	Contusion of artery	Secondary hæmorrhage eighth day. No hæmatoma
89	Capt. Bradford	? Bullet	Exit and entry, type. No past history of primary hæmorrhage	Right carotid	Contusion or complete division	No second. hæmorrhage. No hæmatoma

THROMBOSIS.

90	Capt. Wolfenden	No information	No history of primary hæmorrhage	Left femoral	Artery thrombosed	No second. hæmorrhage
91	Capt. Mumford	Bullet	Entry small, clean, 2 in. above patella, middle of thigh. Exit ragged, dirty, just below flexure of hamstrings. No history of primary hæmorrhage	Left popliteal	Wound of vein only. Arterial thrombosis	No second. hæmorrhage. No hæmatoma
92	---	No information	Wound of thigh	Femoral	Artery injured and thrombosed	No second. hæmorrhage. No hæmatoma
93	Lieut. Harmens	No information	Wound of thigh. Large septic. Artery exposed. No history of primary hæmorrhage	Femoral	Artery thrombosed	No second. hæmorrhage. No hæmatoma
94	Lieut. Llewellyn	Bomb fragment	Entry, incised, inner side of right arm. Exit, incised, outer side of arm 1 inch below insertion of deltoid. No history of primary hæmorrhage	Brachial	Artery thrombosed, lateral thrombus	No secondary hæmorrhage

THE FORMATION OF ANEURYSM.

DISTAL PULSE	GANGRENE	LIGATURE OF VESSEL. AMPUTATION	RESULT	NOTES. COMPLICATIONS
Normal	—	None	Transferred	Left brachial monoplegia. Paraplegia. See text, p. 358
? Left temporal pulse stronger	—	—	Transferred	Mental condition very dull, improved later. Slight hemiplegia. Pupils equal. Speech not bad, difficulty in reading. Could not write at first. See text, p. 358
No distal pulse	Gangrene chiefly of dorsum of foot, reaching to junct. middle and lower third of leg	Femoral ligatured in wound	Died	Embolism of popliteal artery
No temporal or carotid pulsation	—	—	Died	Patient unable to speak, conscious. Sweating more left side of face than right. Pupils, right larger than left, both react. Died. No P.M.
No distal pulse	No gangrene	Double ligature	Cured	—
No anterior or posterior tibial pulse	Lower leg and foot blue, cold, and insensitive	Amputation	Recovered	Suppurating knee-joint. See Fig. 121, and text, p. 355
No record	None	Expectant	Transferred	Leg kept in good condition. Had pulmonary embolism
No distal pulse	Gangrene of foot and leg almost to knee	Leg amputated. No ligature necessary for femoral artery	Recovered	—
Radial pulse barely perceptible	None	Vessel ligatured above and below, bruised portion excised	Cured	See Fig. 122, p. 356, and text, p. 357

NO.	UNDER CARE OF	BULLET OR SHELL	NATURE OF WOUND. PRIMARY HÆMORRHAGE	POSITION IN COURSE OF ARTERY	ARTERY AND VEIN OR ARTERY ONLY	SECOND. HÆMORRHAGE. PRESENCE OR ABSENCE OF HÆMATOMA
95	—	Shell	Wound of popliteal space	Popliteal	Artery and vein	No second. hæmorrhage. No hæmatoma
96	Major Hull	Bullet	Transverse wound of ham. Primary hæmorrhage	Left popliteal	Artery completely divided. Vein thrombosed	No second. hæmorrhage. No hæmatoma
97	Capt. Mumford	Bullet	Entry above patella, left side. Exit, flexure of ham. No history of primary hæmorrhage	Left popliteal	Artery divided at the junction of upper and middle thirds. Vein unhurt	No second. hæmorrhage. No hæmatoma
98	Capt. Oliver	Bullet	Type entry and exit. No history of primary hæmorrhage	Left axillary	Artery completely divided? or contused	No second. hæmorrhage. Probable hæmatoma.
99	Lt.-Col. Gordon Holmes	Bullet	Entry anterior axillary fold, exit posterior axillary fold. No history of primary hæmorrhage	Axillary	Artery completely divided? or contused	No second. hæmorrhage. No hæmatoma
100	Capt. Kelly	Bullet	Entry one inch below and two-thirds inch inside coracoid process. Exit post. axillary fold. Severe primary hæmorrhage	Axillary	Artery completely divided? or contused	No second. hæmorrhage. No hæmatoma
101	Lt.-Col. Moore	Bullet	Wound track crossing junction of second and third parts axillary artery. No history of primary hæmor.	Axillary junction of second and third part	Artery completely divided? or contused	No second. hæmorrhage. No hæmatoma
102	Capt. West	Bullet	Entry just below right coracoid process. Exit outer margin of erector spinæ	Axillary	Artery completely divided? or contused	No second. hæmorrhage. No hæmatoma
103	Lt.-Col. Gordon Watson	Bullet	Bullet retained supraclavicular fossa. No history of primary hæmorrhage	Brachial	Artery completely divided	No second. hæmorrhage
104	Lt.-Col. Gordon-Watson	Bullet	No primary hæmorrhage	Third part subclavian right	Artery completely divided	No second. hæmorrhage. No hæmatoma
105	Col. Cameron	No information	Wound of popliteal space. No history of primary hæmorrhage	Popliteal artery	Complete division	Secondary hæmorrhage eighth day
106	Major Sinclair	Rifle Grenade	Entry just to outer side of anterior axillary fold. Exit half way down axillary border of scapula	Right brachial	Complete division? or contusion	No second. hæmorrhage. No hæmatoma
107	Capt. Oliver	Time fuse	Entry just above centre of outer aspect of arm, 2 in. by 1 in. Retained. No history of primary hæmor.	Right brachial	Large tear in wall of brachial artery	No second. hæmorrhage. No hæmatoma

WOUNDS OF ARTERIES.

DISTAL PULSE	GANGRENE	LIGATURE OF VESSEL. AMPUTATION	RESULT	NOTES. COMPLICATIONS
None	Gangrene of leg	Amputation	Recovered	—
No anterior or posterior tibial pulse	Impending gangrene of foot and leg	Both ends of artery ligatrd. for impending gangrene. Second amputation twelfth day	Recovered	Ends of artery one inch apart. Clot in proximal end. Vein unwounded but thrombosed
No pulsation in tibial arteries	Gangrene of foot and leg	Both ends of artery lig. Amp. fifteenth day	Recovered	Bad attack of septic bronchopneumonia
No brachial or radial pulse	No gangrene	—	Transferred	Monoplegia all muscles, some sensation in radial and circumflex areas. No murmur
No radial, brachial, or axillary pulse	No gangrene	—	Transferred	Brachial monoplegia
No pulsation in radial or brachial	No gangrene	—	Transferred	Brachial monoplegia. Hæmothorax
No radial pulse	No gangrene	—	Transferred	Brachial monoplegia. Hæmothorax. No murmur. No pulsation below site of wound
No radial or brachial pulse	No gangrene	—	Transferred	Palsy of branches of posterior cord. No murmur
No radial pulse	All digits dry gangrene to metacarpophal. joint	Brachial artery ligatured	Transferred	Musculospiral injured by fracture of humerus. Piece of bone in sheath of nerve
Radial pulse absent	No gangrene		Recovered	Spontaneous cessation of hæmorrhage. Division of middle and posterior cords of brachial plexus. See text, p. 385
No record	Gangrene of foot and leg to middle third	Thigh amputated	Recovered	Amputation for secondary hæmorrhage and gangrene which was secondary to hæmorrhage
Radial pulse minimal	No gangrene	—	Transferred	Complete loss of power in arm, and lowered sensation. Two ribs fractured. No murmur
No radial pulse before or after operation	No gangrene	Proximal ligature	Cured	Missile removed. Large tear in wall of brachial artery

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NO.	UNDER CARE OF	BULLET OR SHELL	NATURE OF WOUND. PRIMARY HÆMORRHAGE	POSITION IN COURSE OF ARTERY	VASCULAR LESION	SECONDARY HÆMORRHAGE: DATE
POPLITEAL ARTERY AND VEIN.						
108	Major Stoney Archer	Bullet	No history of primary hæmorrhage. Bullet palpable in popliteal space	Popliteal	Puncture of artery, transfixion of vein	Free hæm. on removal of bullet
FEMORAL VEIN.						
109	Capt. Oliver	Shrapnel ball	Ball retained left buttock. Free primary hæmorrhage	Vein in Hunter's canal	Yenous injury	Sec. hæm. controlled by finger
PRIMARY LIGATURE (BRACHIAL).						
110	Capt. Clutterbuck	No information	Free primary hæmorrhage. Puttee tourniquet for 16 hours	Left brachial	—	None
111	—	No information	Severe primary hæmorrhage	Brachial	—	Sec. hæm. after four pints saline in axilla

VASCULAR LESIONS.

GANGRENE	TREATMENT	RESULT	NOTES. COMPLICATIONS
None	Vessels ligatured	Cured	See Fig. 140
None	Femoral vein tied at top of Hunter's canal, with second ligature above	Cured	Discharged with normal limb
Gangrene of finger tips. Terminal phalanx mummified	Artery tied at casualty clearing station. Amputation of arm for prolonged sepsis	Recovered	—
Gangrene of forearm and hand	Vessel tied in wound. Amputation later	Recovered	—