

# ARTERIOVENOUS ANEURYSM OF THE VERTEBRAL VESSELS\*

## REPORT OF TEN CASES

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THE MANY VASCULAR INJURIES resulting from wounds received in the recent war have given rise to an unprecedented number of arteriovenous fistulae and aneurysms. At the Ashford General Hospital approximately 500 operations have been performed for these conditions. Ten of these were arteriovenous fistulae of the vertebral vessels in their cervical or extracranial course. It is the purpose of this communication to report these cases and in so doing to review the anatomy of the vessels, the diagnosis of the lesion, and to suggest operative methods of approach and treatment based on this experience.

Reports of arteriovenous aneurysms of the extracranial portion of the vertebral vessels are rare, and have in most instances been concerned with the recording of an experience in the treatment of one case. However, Matas,<sup>1</sup> in 1893, collected 19 cases from the literature and included one of his own. In addition, Perrig<sup>2</sup> collected 60 instances of vertebral aneurysms, but in some of these the diagnosis was open to question. Recently, Heifetz,<sup>3</sup> in reporting a case of his own, collected the literature on this subject, and from his excellent review it would appear that somewhat less than 100 instances have appeared in literature. Moreover, in these reports the differentiation between arteriovenous fistulae and false arterial aneurysms is not clearly brought out. Undoubtedly this number does not represent the true incidence of the condition, since single cases, particularly if ending fatally, are not so apt to be reported. At any rate, it remains among the rarest of arterial injuries, probably because of the anatomic location of the vessels.

The mortality in previous reports, either as a direct consequence of the lesion or its treatment, appears to be above 50 per cent, far higher than that of aneurysms or arteriovenous fistulae in any other location. Here, again, the anatomic position of the vessels is undoubtedly a contributing factor because of the difficulties attendant upon the operation.

### ANATOMY

The extracranial portion of the vertebral artery lies deep in the neck. For descriptive purposes it is divided into three parts: The *first portion* which runs from its origin in the subclavian artery to the foramen in the

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transverse process of the sixth cervical vertebra; the *second portion* which runs through the foramina in the transverse processes of the upper six cervical vertebrae; and, the *third portion* which consists of that part of the vessel from its exit from the foramen in the atlas until it enters the skull through the foramen magnum (Fig. 1).

It is important to remember that the vertebral artery is the *first branch* given off by the subclavian artery. It springs from the upper posterior

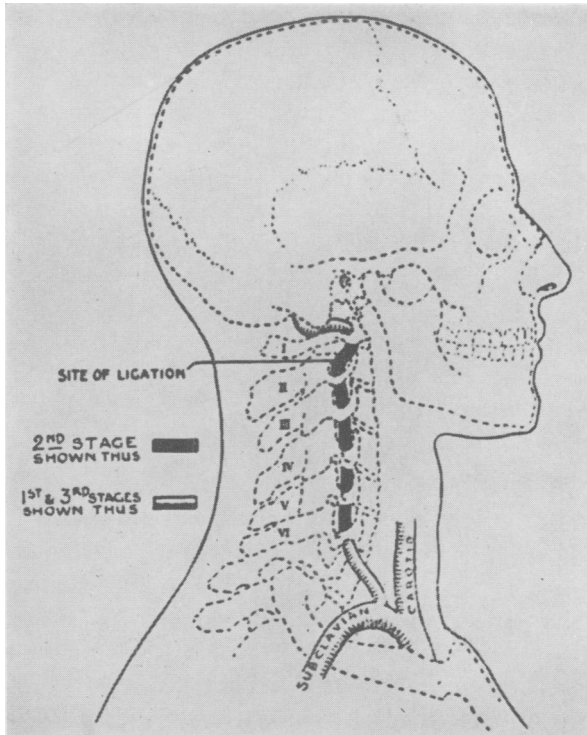


FIG. 1.—Diagrammatic representation of the first, second and third portions of the vertebral artery. The second portion is shown in black. (From Henry).

aspect of the first portion of that vessel just lateral and posterior to the common carotid artery and about .5 cm. from the medial margin of the anterior scalene muscle. This muscle is a guide to the artery. The thyrocervical trunk arises from the upper portion of the subclavian just distal to the vertebral, and because of their close approximation they may be mistaken for each other unless careful dissection is employed.

The *first part* runs upward and backward between the longus colli and anterior scalene muscles. Behind it is the transverse process of the seventh cervical vertebra and the sympathetic chain. In front of it is the vagus nerve, the internal jugular vein, and in front of this vein, the sternomastoid muscle. The upper portion of this part is crossed by the inferior thyroid

artery as it passes medially. The vessel *does not* enter the foramen in the transverse process of the seventh cervical vertebrae, but as previously stated, lies in front of it.

As the *second part* passes upward through the transverse processes of the upper six cervical vertebrae it lies anterior to the cervical nerves and beneath the anterior scalene muscle. In this portion it is surrounded by a venous plexus which terminates below in the vertebral vein. Overlying the vessel and slightly to its medial side is the internal jugular vein and more superficially the sternomastoid muscle. In the upper part of the second portion the spinal accessory nerve is found about two fingerbreadths below the mastoid process. Deep to the sternomastoid muscle the dense prevertebral fascia covers the levator scapulae muscle. This muscle arises from the transverse processes of the upper four cervical vertebrae and, therefore, directly overlies the vertebral vessels in their course through the upper four foramina.

The *third part* begins at the point where the vessel emerges from the foramen of the atlas. It turns backward and lies in a groove on the upper surface of that bone. Here the vessel is covered by the semispinalis capitis in the suboccipital triangle. The guide to the upper portion of the vessel is the transverse process of the atlas which can easily be palpated one fingerbreadth below and one in front of the tip of the mastoid bone. It is more easily identified when the sternomastoid muscle is detached from its origin, as will be discussed below.

#### DIAGNOSIS

Of all the aneurysms and fistulae in the body the diagnosis of those of the vertebral vessels is the most difficult to make. It was made with certainty in only five patients in this series, although it was suspected in others. It is likely to be confused with more common lesions in this region, particularly fistulae between the internal jugular vein and branches of the external carotid artery. It may also be confused with fistulae arising from other branches of the subclavian artery, particularly the inferior thyroid, the transverse scapular and transverse cervical vessels. Since the common carotid lies moderately superficial in the neck where it can be occluded by digital pressure, the bruit of fistulae arising from branches of this vessel are usually obliterated with ease. *If the bruit does not disappear on compression of the common carotid artery the vertebral vessels should be suspected as the site of the lesion.* Since the vertebral vessels lie deep in the neck, obliteration of the bruit is difficult to obtain by pressure.

#### OPERATION

The approach to any portion of the vertebral vessels is a difficult one because of its deep position and because of the vital nature of its surrounding structures. Since the anatomy of the three parts varies greatly, the approach to the vessels in these regions will be considered separately.

In the first portion it can best be reached through an incision parallel

to the fibers of the sternomastoid muscle and directly over the interval between the sternal and clavicular heads of that muscle. After the deep fascia is incised, the two heads of the muscle are separated and retracted (Fig. 2). If necessary to obtain better exposure no harm is done by transversely dividing some of the fibers of this muscle. When the internal jugular vein is

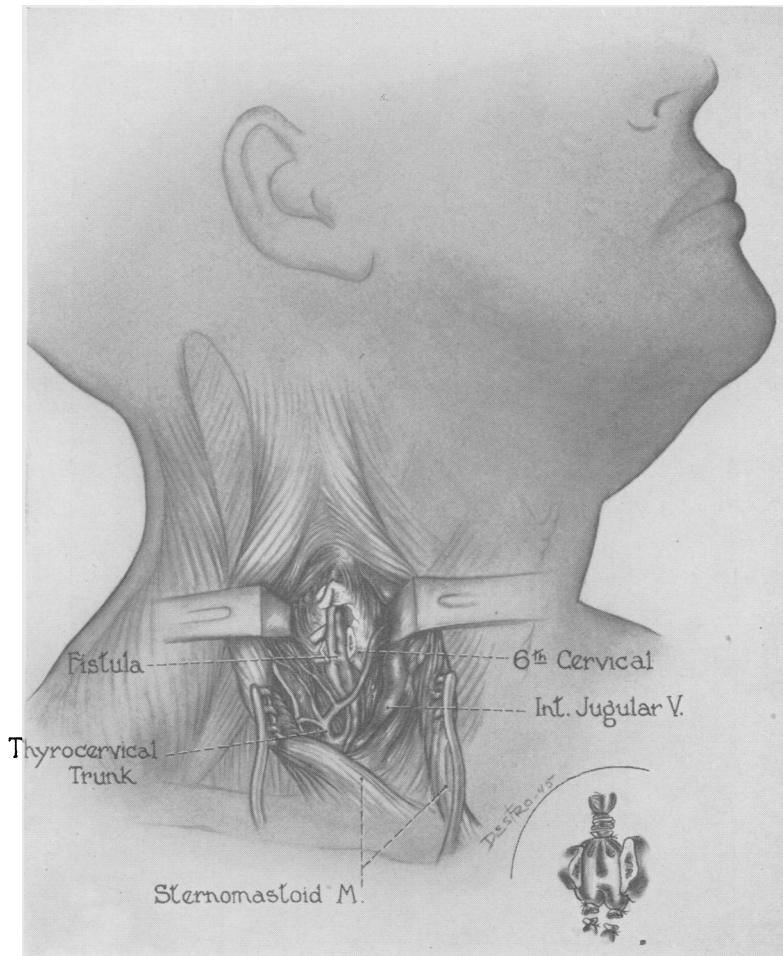


FIG. 2.—The approach to the first portion and the lower part of the second portion of the vertebral vessels.

encountered in the depth of the incision it is retracted medially and the triangular interval between the longus colli and the anterior scalene muscles is developed. The inferior thyroid artery will be found running upward and medially and crossing in front of the vertebral artery in this region, and the two must be carefully isolated. On the left the thoracic duct passes in front of the artery. The vertebral artery arises medial to the inferior thyroid and in this location can be identified by its pulsation. The vertebral

vein lies anterior to the artery. This portion of the vertebral artery should always be identified as a preliminary step in operations on the vessel elsewhere in its course. A ligature passed around the vessel, but not tied, serves as a protection should hemorrhage occur later in the operation. It should be remembered, however, that there is a rich anastomotic blood supply in the vertebral system, and that ligation of the proximal artery will only diminish and not control hemorrhage. Ligation at this point in the operation should

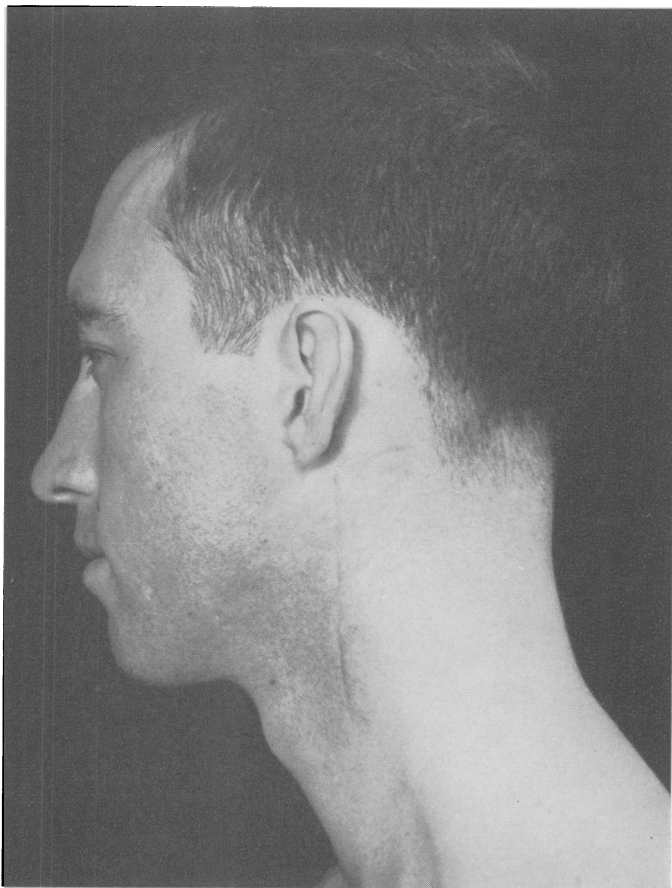


FIG. 3.—The incision for exposure of the third portion of the vertebral vessels.

not be done since it will obliterate the thrill and bruit, thus, making identification of the fistula more difficult.

The second portion of the vessel is reached by an incision along the anterior border of the sternomastoid muscle. When the deep fascia is opened the muscle is retracted laterally and the carotid sheath identified and retracted medially. It is usually necessary to divide the omohyoid muscle as it passes across the carotid sheath. The anterior scalene muscle which arises from the transverse processes of the third, fourth, fifth, and sixth

cervical vertebrae is retracted laterally and, if necessary, may be detached from its origin to fully expose the transverse processes through which the vertebral vessels pass. The interval between the transverse processes is less than a fingerbreadth, and ligation in this region is particularly difficult unless one or more of the transverse processes is removed by rongeur. When this is done a ligature may be passed, preferably on an aneurysm needle, about the vessel or it may be occluded by the use of heavy metal clips.

Exposure of the upper portion of the second part and of the third part of the vertebral vessels is by far the most difficult. Henry<sup>4</sup> has described a

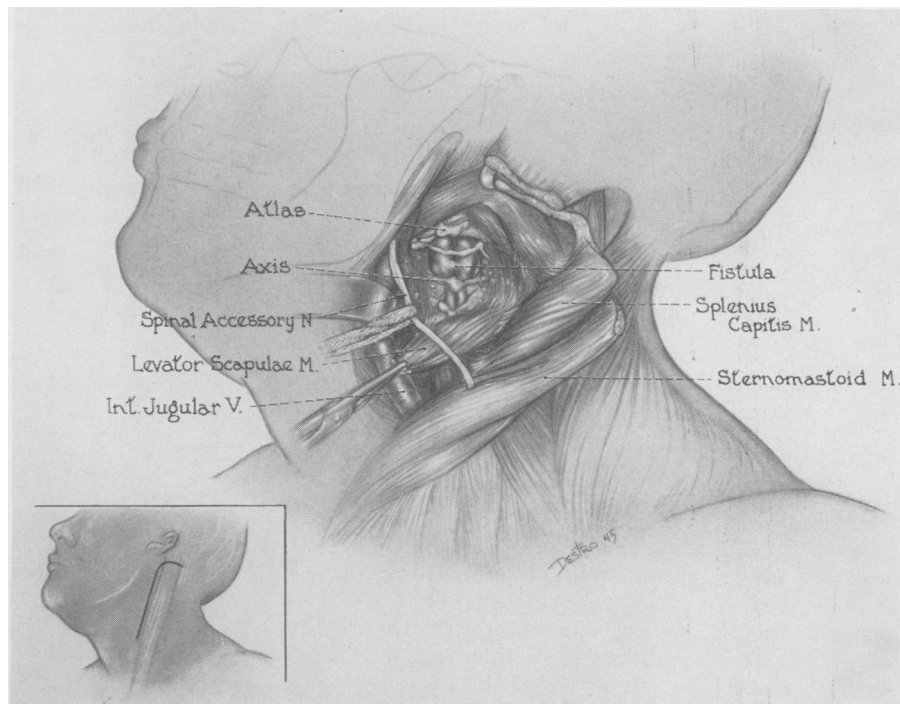


FIG. 4.—The exposure of the upper portion of the vertebral vessels.

method of approach for the purpose of ligating this portion of the vessel which we have successfully employed in four instances (Cases 3, 6, 9 and 10). The patient lies on his back with the neck extended and the chin turned to the side opposite the involved vessels. An incision is made along the anterior border of the sternomastoid muscle from the middle of the neck to the mastoid process (Fig. 3). The deep fascia is opened and the insertion of the sternomastoid is cut away from the bone and the muscle reflected laterally. The spinal accessory nerve is isolated and mobilized as it passes laterally and downward beneath the sternomastoid muscle (Fig. 4). With the reflection of the muscle the tip of the transverse process of the atlas is easily identified. The prevertebral fascia is divided from above downward

and the origin of the levator scapulae muscle is cut away from the atlas and axis and turned downward. Further dissection will expose the vertebral artery and surrounding venous plexus in the interval between the atlas and axis, as well as in its third portion.

The fistula in all the cases of this series was produced by trauma. In nine patients it was due to direct injury of the vessels by a missile, usually a small fragment of high explosive shell. In one instance (Case 6), there was no penetrating wound and the fistula followed severe external trauma caused by a blow from a piece of wood. In none was there a fracture of the transverse process of the vertebra discernible by roentgenogram, but this type of injury should be borne in mind as a possible cause of the condition.

In the ten cases here reported the lesion was located in the first portion of the vessel in one instance, in the second portion in six instances, and in the third portion in three instances. In none was any attempt made to repair the fistula. The position of the vessels as well as their small size will preclude any effort of repair. Its anatomic position prevented actual excision of the fistula except in three instances (Cases 1, 2 and 8), and, therefore, its obliteration was usually accomplished by proximal and distal ligation of the vessels and the placing of mass ligatures. It is to be stressed that complete control of the blood supply is necessary for the prevention of hemorrhage. One should not hesitate to remove the transverse processes of the cervical vertebrae in order to completely expose the lesion and its contributing vessels.

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*CASE 1.—A-V fistula, left vertebral vessels, upper third, due to bullet wound November 10, 1942. Excision of fistula through suboccipital approach, June 15, 1943. Secondary hemorrhage controlled by ligation of the vertebral artery and packing wound. Cured.*

On November 10, 1942, this soldier was struck in the left malar region with a 44-caliber bullet. The missile traversed the face, the lateral aspect of the neck, and became imbedded in the soft tissues of the left occipitomastoid region. There was no extensive external hemorrhage, but the tissues of the left side of the neck swelled considerably. Within a few days he noticed a loud buzzing in his left ear. Upon occasion his pulse rate would become rapid. On December 22, 1942, the bullet was removed, and on February 22, 1943, the left common carotid artery was ligated without change in his symptoms.

On admission to the Ashford General Hospital, two months later, there was a small scar over the left malar region; the wound of entry. There was an operative scar 4 cm. mesial to the tip of the left mastoid. The tissues in this region appeared full in comparison to those on the right. Palpation revealed a deeply situated pulsating mass with a distinct systolic thrill. On auscultation, a continuous bruit accentuated in systole with maximal intensity over the occiput could be heard. This could be obliterated by deep pressure over the sternomastoid muscle. Arterial pulsation was absent over the left common carotid artery, the site of the earlier ligation. It was thought that this was an arteriovenous fistula of the cirroid type, probably involving the occipital artery and vein deep to the muscles and posterior to the mastoid process. The question of involvement of the vertebral artery with accompanying veins in this region was considered.

An excision of these vessels was carried out June 15, 1943. A semicircular incision beginning over the left mastoid muscle was carried upward over the base of the skull to the midline. The deep muscles were cut and retracted caudally. The external carotid artery was ligated; however, this had no effect upon the aneurysm which could be seen and felt at the base of the skull. The aneurysm was excised by ligating and cutting numerous arteries and veins which could be seen to communicate with vessels entering the skull. Considerable bleeding was encountered which was controlled by coagulation and by the use of fine silk ligatures. At the end of the operation the bruit and thrill had disappeared.

Two weeks later, as a result of a friendly wrestling match, the wound was opened and severe secondary hemorrhage occurred. This was controlled by hemostats, which were left in place, and by packing. Following this the vertebral artery was ligated in its first portion, which apparently controlled the bleeding since no further hemorrhage occurred with removal of the clamps and packing five days later. The wound healed uneventfully. There was no return of the bruit and thrill upon discharge three months later and upon review examination three months after discharge.

CASE 2.—*A-V fistula, left vertebral vessels, upper third, due to shell fragment wound September 14, 1943. Ligation of left vertebral artery January 20, 1944, with improvement. Partial excision of fistula February 2, 1944. Complete excision April 20, 1944. Cured.*

On September 14, 1943, this soldier was struck in the left side of the face by a fragment of high explosive shell. The wound of entrance was just anterior to the left ear and there was no wound of exit. He was unconscious for approximately three hours after the injury. There was considerable bleeding from the wound. On regaining consciousness he noticed impairment of hearing on the left with numbness and weakness of the left side of the face. On the following day he developed an occipital headache and diplopia which persisted for nine days. The left side of the face became markedly swollen. On admission to the Ashford General Hospital, four months later, there was a paralysis of the left side of the face, impairment of hearing of the left ear with narrowing of the left external auditory canal and the left ear drum completely replaced by granulation tissue. A continuous bruit and thrill were present over the left side of the face and neck, with maximum intensity in the occipital region. An expansile pulsation was noted in this region. A metallic foreign body was present at the tip of the spinous process of C-1 on the left. A diagnosis of arteriovenous fistula of the vertebral vessels was made.

On January 20, 1944, the external carotid artery and the first portion of the vertebral artery on the left were ligated. There was a definite decrease in the bruit when the vertebral artery was ligated. On February 2, 1944, an attempt was made to excise the arteriovenous fistula. A 10-cm. longitudinal incision was made from the skull downward along the posterior border of the sternomastoid muscle. After opening the deep fascia a large plexus of arteries and veins, in which a thrill could be felt, was disclosed. The veins were dilated and friable, and they, together with a mass of arteries, were individually isolated, ligated, and removed. It was felt that further extension of the aneurysm might be present in the deeper structures, but continuation of the procedure at that time was not justified as it was hoped that a cure had been accomplished from this procedure. Following operation the bruit was markedly diminished but was still audible. On April 13, 1944, the right vertebral artery was ligated. On April 20, 1944, an incision was made through the old scar along the posterior border of the sternomastoid muscle. Deep in the wound a pulsating mass could be felt which was in the vertebral vessels between their exit from the transverse process of the first cervical vertebra and their entrance into the skull through the foramen magnum. This position made the approach extremely difficult since there was no means of isolating the blood vessels. However, the mass was exposed, the vertebral vessels at the base of the skull were clamped, and the fistula was excised. The vessels were ligated with silk



with considerable difficulty and one vessel which split to the foramen magnum was sutured after the hemorrhage was controlled by finger pressure. This was done by passing three silk ligatures under the finger. When the mass was removed no further bruit or thrill was heard or felt. The postoperative course was uneventful. There was no recurrence of the bruit or thrill at the time of discharge two months later.

CASE 3.—*A-V fistula, left vertebral vessels, second portion, due to shell fragment wounds June 28, 1944. Ligation of vertebral artery in the first portion, December 30, 1944, with improvement. Ligation of the vertebral artery between atlas and axis, February 3, 1945, with further improvement. Removal of transverse processes of third and fourth cervical vertebrae and mass ligation of fistula, April 25, 1945. Cured.*

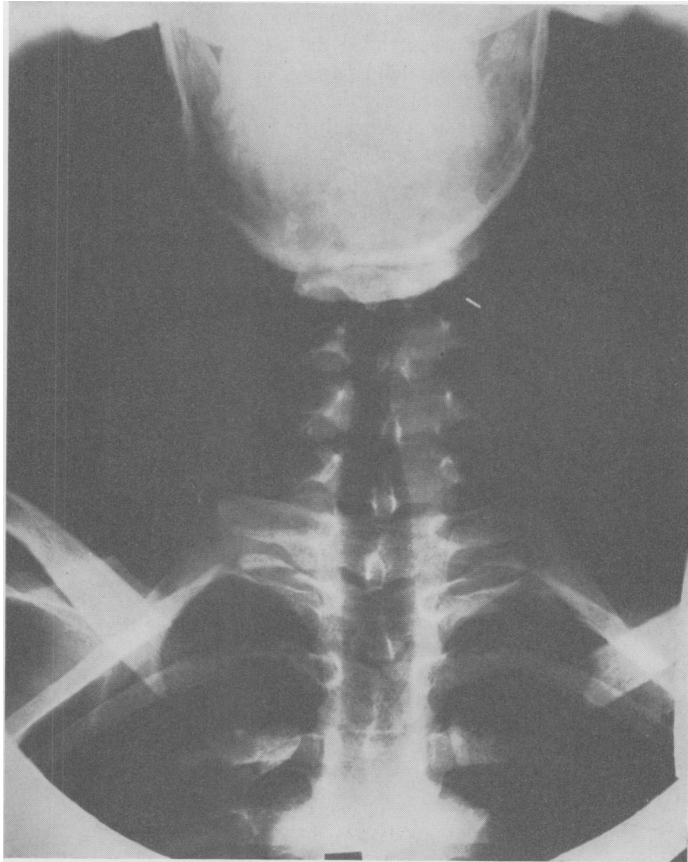


FIG. 5.—Case 3: Silver clip on the upper portion of the vertebral artery.

On June 28, 1944, this soldier was struck in the right arm and neck by multiple fragments of an artillery shell. There was profuse bleeding from all wounds. The neck wound was débrided and healed promptly. Approximately three weeks later he noted a buzzing sensation in the left side of the neck but did not hear any noise. He reported this to his medical officer who made a diagnosis of arteriovenous fistula. On admission to the Ashford General Hospital, five months later, there was a small scar overlying the upper portion of the left sternomastoid muscle about 4 cm. below the angle of the mandible. There was a continuous bruit and thrill heard and felt over this area, which

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were transmitted up the scalp to the parietal region and into the neck to the clavicle. Deep pressure failed to obliterate the bruit and thrill. It was thought that this was an arteriovenous fistula of the second portion of the left vertebral vessels. On December 30, 1944, the first portion of the vertebral artery was ligated and divided. This caused the thrill and bruit to be almost completely obliterated. On February 3, 1945, an incision was made from the level of the thyroid cartilage upward along the anterior border of the sternomastoid muscle to the mastoid process and then turned backward severing the sternomastoid from the skull at its insertion. The muscle was retracted laterally and the third cervical nerve and the spinal accessory nerve were isolated. The levator scapulae muscle was detached from its origin from the atlas, axis, and third and fourth cervical vertebrae. The vertebral vessels were then isolated between the transverse processes of the atlas and axis. The sensory branch of the second cervical nerve overlying the vessels was dissected free and the vertebral artery was divided between ligatures. Several smaller vessels in this region were also ligated. The vein was not ligated. This stopped the thrill but a bruit was still present.

The bruit increased in intensity and, April 25, 1945, the scar on the left side of the neck was excised and the sternomastoid muscle retracted laterally. The transverse processes of the first, second, third, and fourth vertebrae were exposed. The levator scapulae muscle was detached from the transverse process of the atlas and the spinalis group of muscles freed from the transverse processes of the above vertebrae by sharp and blunt dissection. The lateral roofs of the foramina transversarium of the third and fourth cervical vertebrae were removed by rongeur. This exposed the vertebral vessels for a distance of 4 or 5 cm. The fistula was apparently at the level of the inferior border of the canal of the third vertebra. Ligatures were passed about the vessels proximal and distal to the fistula and the vessels ligated. Silver clips were applied above and below the fistula (Fig. 5). This caused the bruit and thrill to completely disappear. There was no recurrence of the bruit or thrill at the time of discharge three months later.

*CASE 4.—A-V fistula, right vertebral vessels, second portion, due to rifle bullet wound September 15, 1944. Removal of transverse process of sixth cervical vertebra. Mass ligation of vertebral vessels, January 16, 1945. Cured.*

On September 15, 1944, this soldier was struck in the right side of his neck by a rifle bullet. The wound of exit was in the anterior aspect of the left infraclavicular region. There was profuse bleeding from the right side of the neck, which was controlled by pressure. On September 17, 1944, the wound of the left shoulder region was débrided and a plaster splint applied because of a fracture of the left clavicle. Several weeks later a pulsating mass in the right side of the neck was discovered. The wound on the right healed without difficulty. On admission to the Ashford General Hospital, five weeks later, there was a healed wound, about 3 cm. in length, on the right side just above the clavicle. There was also a granulating wound in the left infraclavicular region. There was a continuous bruit and thrill in the anterior triangle of the right side of the neck, which was transmitted along the course of the carotid vessels and was audible in the chest. Upon obliteration of the fistula the pulse fell from 84 to 76 and the blood pressure in the right brachial artery rose from 160/90 to 160/110. It was thought that this was an arteriovenous fistula of the right common carotid artery and internal jugular vein. On January 16, 1945, a longitudinal incision was made on the right from the clavicle to the level of the thyroid cartilage. The incision was extended between the two heads of the sternomastoid muscle and the common carotid artery and internal jugular vein were isolated. There was no evidence of a fistula present in this region and as pressure beneath the clavicle caused the bruit and thrill to disappear it was felt that the fistula was at a more proximal point. The lower end of the incision was then extended laterally over the clavicle and the proximal third of this bone resected subperiosteally. Isolation of the common carotid artery to the innominate revealed no evidence of a fistula. It was then discovered that the fistula involved the

vertebral vessels at a point near the bony canal of the sixth cervical vertebra. The carotid artery and internal jugular vein were retracted medially and the vertebral vessels isolated to the point where they passed into the foramen transversarium of the sixth cervical vertebra. Occlusion of the artery at this point caused the thrill to disappear but the bruit was still audible. The lateral roof of the foramen transversarium of the sixth cervical vertebra was removed by rongeur, and occlusion of the vessels just proximal to the fifth cervical vertebra did not cause the thrill to disappear. The artery and vein proximal to the fistula were doubly ligated, transfixed and divided. Ligatures were passed about the vessels distal to the fistula in the space between the

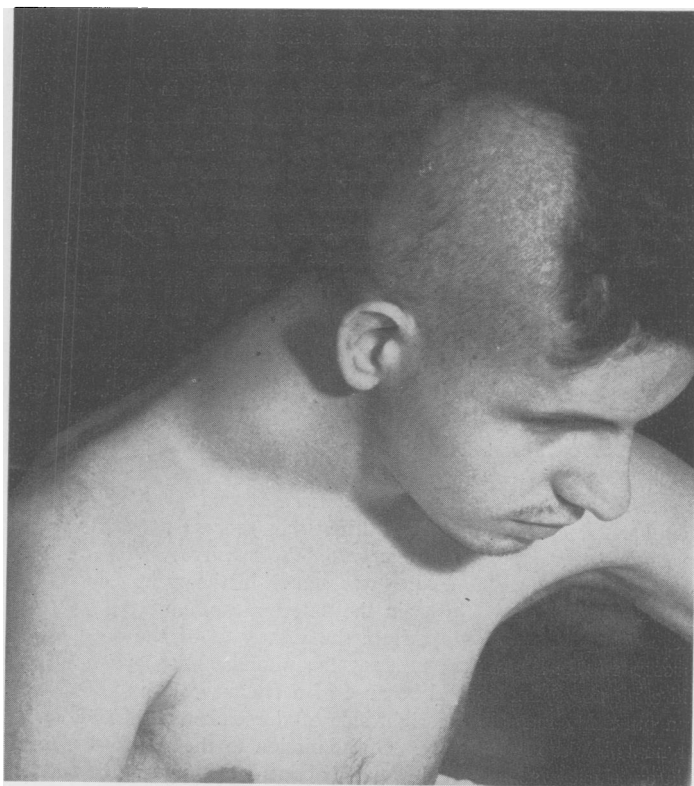


FIG. 6.—Case 5: Swelling of the neck produced by false sac of vertebral arteriovenous aneurysm.

fifth and sixth vertebrae and the vessels doubly ligated. There was moderate hemorrhage from the venous plexus extending into the spinal canal, which was controlled by pressure and muscle packing. The bruit and thrill completely disappeared. The wound healed without difficulty. The bruit and thrill had not recurred at the time of discharge four months later.

*CASE 5.—A-V fistula, with false sac, right vertebral vessels, second portion, due to shell fragment wounds January 14, 1945. Ligation of vertebral artery in first portion, and intrasaccular closure of fistula with sutures and silver clips, March 13, 1945. Cured.*

On January 14, 1945, this soldier was struck in the right shoulder, neck, and the left side of back by multiple fragments of a high explosive shell. There was no loss of consciousness and he was able to walk about after injury. About two weeks later he noted a swelling in the lower posterior aspect of the right side of his neck. Ex-

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amination revealed the presence of a continuous bruit and a pulsating mass in this region. On admission to the Ashford General Hospital two months later there was a fusiform, firm swelling in the posterior aspect of the right side of the neck (Fig. 6). No thrill could be felt in this region, but a continuous bruit was heard along the anterior and posterior borders of the mass. The bruit could not be obliterated by occlusion of the common carotid artery low in the neck. It was thought that this was an arteriovenous fistula, with false sac, possibly involving the transverse cervical or the vertebral vessels.

On March 13, 1945, a preliminary incision was made just above the clavicle and the clavicular portion of the sternomastoid muscle divided. The transverse cervical

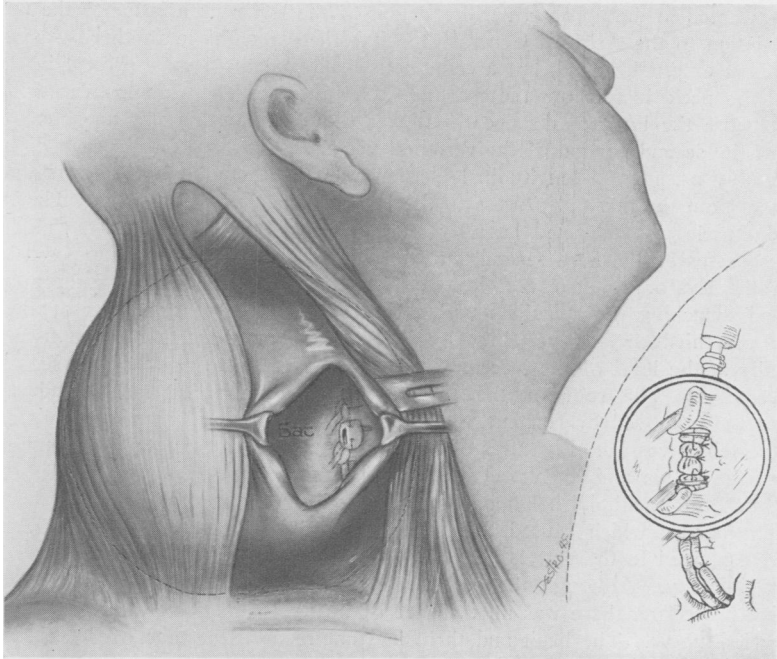


FIG. 7.—Case 5: Exposure of the vertebral vessels by incision through the false sac. Insert shows obliteration of the fistula by clips and mass ligatures.

artery was ligated, which had no effect upon the bruit. The anterior scalene muscle was divided, exposing the subclavian artery. Occlusion of the vertebral artery caused the bruit to disappear. A "bulldog" clamp was applied to the vertebral artery and another clamp applied to the subclavian, hoping that some anastomotic circulation would be retarded. Another incision was then made longitudinally in the posterior triangle of the neck anterior to the trapezius muscle. The spinal accessory nerve was exposed and retracted from the wound. The sac was opened and a large clot, perhaps 500 cc., was evacuated. Two openings into this sac were found to come from the vertebral artery at the interval between the fourth and fifth processes of the cervical vertebrae. Four sutures of silk and three silver clips were placed on the vessel which stopped all the bleeding. The vertebral vein was probably included in these ligatures and clips. The vertebral artery was then ligated but not divided at the point where it was previously dissected near its origin from the subclavian artery. (Fig. 7) The wounds healed without difficulty. There was no recurrence of the bruit at the time of discharge four months later.

CASE 6.—*A-V fistula, left vertebral vessels, second portion, due to injury from falling log February 13, 1945. Removal of transverse process of second cervical vertebra. Multiple ligation of vessels and application of silver clips at point of fistula, May 24, 1945. Cured.*

On February 13, 1945, this soldier was struck on the left side of the face and neck by a falling log. There was no evidence of a penetrating wound. The patient was unconscious for about 30 minutes. There was marked swelling of the left side of the neck for ten days. Severe headaches of the left parietal region were present for two weeks, with stiffness of the neck and tenderness along the cervical vertebrae. Following the injury a roaring sensation developed in the left ear which was accentuated by each heart beat. About a month after injury the presence of a continuous bruit was noted in the upper posterior portion of the left neck inferior to the mastoid. On admission to the Ashford General Hospital, three months later, there was no evidence of an external wound, but a continuous bruit and thrill were present in the left side of the neck just below the mastoid. Occlusion of the common carotid artery did not cause the bruit to disappear. It was thought that this was an arteriovenous fistula of the second portion of the vertebral vessels.

On May 24, 1945, a longitudinal incision was made on the left side of the neck extending from the mastoid process to the level of the thyroid cartilage. The sternomastoid muscle was retracted laterally and the carotid vessels medially. The transverse processes of the first, second, and third cervical vertebrae were exposed by detaching the levator scapulae muscles from the transverse processes of the atlas and axis, and detaching the spinalis muscles from the transverse processes of the first, second, and third cervical vertebrae by sharp and blunt dissection. The fistula was apparently at the level of the inferior border of the vertebral canal of the second cervical vertebra. The roof of the foramen transversarium of the second cervical vertebra was removed by rongeur. This allowed exposure of approximately 2.5 cm. of the vertebral vessels. Ligatures of silk were passed about the vessels proximal and distal to the fistula and the vessels doubly ligated above and below the fistula. This caused the bruit to diminish but not disappear. The collateral vessels were ligated in a similar manner which caused the bruit and thrill to completely disappear. Silver clips were applied to the vessels proximal and distal to the fistula. The wound healed without difficulty. Although the patient developed Horner's syndrome following the operative procedure, there was no evidence of injury to the posterior root of the second cervical nerve. The bruit and thrill had not recurred at time of discharge three months later.

CASE 7.—*A-V fistula, right vertebral vessels, second portion, due to shell fragment wounds February 20, 1945. Quadruple ligation of vessels, July 27, 1945. Cured.*

On February 20, 1945, this soldier received high explosive shell fragment wounds of the right side of the neck, shoulder, arm, and chest wall. The wound of the neck bled profusely and was controlled by a pressure bandage. The right upper extremity was paralyzed at the time of injury but there was returning function at the time of admission to the Ashford General Hospital. The wounds of the neck were not débrided. Within 24 hours after admission to an Evacuation Hospital, the presence of a bruit and thrill were discovered in the right side of the neck. Examination at the time of admission to the Ashford General Hospital, June 11, 1945, revealed a small scar in the right lower neck. A definite thrill was felt and a continuous bruit heard in this region. The bruit was transmitted up the course of the carotid vessels and also along the axillary vessels. The bruit and thrill could not be completely obliterated by pressure. Almost complete obliteration caused the pulse to drop from 92 to 84 and the blood pressure to change from 110/70 to 110/80. There was partial brachial plexus paralysis with atrophy of the right hand and fingers, but function was returning. On July 27, 1945, a curved incision was made along the anterior border of the sternomastoid muscle and then laterally over the proximal half of the clavicle. The

medial half of the clavicle, including its articulation, was excised subperiosteally. The attachment of the sternomastoid muscle to the periosteum of the clavicle was divided. The internal carotid artery and internal jugular vein were identified and isolated. The vertebral artery was isolated and occlusion of this vessel caused the bruit and thrill to disappear. Dissection of the vertebral artery and vein was then carried out up to the point where the vessels entered the sixth cervical vertebra. The vessels in this region were involved in scar tissue and the fistula was found to be present at this point. The proximal artery was ligated and divided. Dissection was continued until the point of entrance into the transverse process was completely isolated. It was then planned to do a mass ligation of the artery and vein at this point. As this procedure was being carried out, the artery was torn at the site of the fistula. Bleeding was controlled by digital pressure and the roof of the foramen transversarium of the sixth cervical vertebra was removed by rongeur. The interspace between the fifth and sixth vertebra was then cleared, permitting visualization of this segment of the vessels. Silk ligatures were passed about the vertebral vessels and the vessels ligated. This completely controlled the bleeding. The proximal vein was then ligated and divided. There were no postoperative complications, and no recurrence of the bruit.

CASE 8.—*A-V fistula, left vertebral vessels, first portion, due to shell fragment wounds February 28, 1945. Excision of fistula with false sac, June 15, 1945. Cured.*

This soldier received mortar shell wounds of both legs, back, and left side of the neck, on February 28, 1945. There was no excessive bleeding. He was unable to talk for four or five days following injury, but his voice gradually returned to normal. During January 1945, two attempts were made to remove foreign bodies from the neck but both attempts were unsuccessful. During an eye examination in June 1945 the presence of a bruit and thrill in the left lower portion of the neck was discovered. On admission to the Ashford General Hospital, June 15, 1945, there was a definite Horner's syndrome on the left and a partial left facial palsy. There were three small scars on the left side of the neck and beneath the superior scar a thrill was palpable. On auscultation a continuous bruit was heard. The bruit and thrill could not be obliterated by pressure occlusion of the common carotid artery. The bruit was transmitted along the course of the left transverse cervical vessels which were thought to be the site of the lesion. On August 2, 1945, a transverse incision was made over the medial half of the left clavicle and the middle third of the clavicle resected subperiosteally. A longitudinal incision was made between the two heads of the sternomastoid muscle with the lower end of the incision forming an inverted "T" with the transverse incision. The two heads of the sternomastoid muscle were separated, the carotid sheath was opened and there was no evidence of the fistula involving the carotid artery and internal jugular vein. The transverse cervical and transverse scapular arteries were isolated as they crossed the anterior scalene muscle and these vessels were traced to their origin from the subclavian as the thyrocervical trunk. The fistula did not involve these vessels. The subclavian artery was isolated medial to the anterior scalene muscle. The vertebral artery was isolated at its origin and occlusion of this vessel caused the bruit and thrill to disappear. During the dissection of the vertebral artery, the vessel was torn at its origin and it was necessary to ligate the subclavian artery proximal and distal to the origin of the vertebral. The vertebral artery and vein were then dissected distally and a false sac, measuring about 2 cm. in diameter, was encountered with the distal portion of the sac lying near the foramen transversarium of the sixth cervical vertebra. The sac was opened during the dissection and hemorrhage controlled by digital pressure until silk ligatures were passed about the distal artery and vein. After ligation of these vessels and ligation of the proximal vein there was no further bleeding. The portion of vessels containing the fistula and the false sac was excised. The thoracic duct was ligated and divided during the dissection. **There were no postoperative complications and no evidence of accumulation of chyle**

in the wound. His convalescence was normal and there was no recurrence of the bruit.

CASE 9.—*A-V fistula, right vertebral vessels, second portion, due to shell fragment wounds, July, 1944. Removal of transverse processes of the second and third cervical vertebrae and mass ligation of fistula, December 8, 1945. Cured.*

This soldier was wounded in July, 1944, by fragments of a high explosive shell. There was a wound below and behind the right mastoid process and a wound on the back of the right hand. He was unconscious for fifteen minutes and bled profusely from the wound in the neck. The wounds were débrided and he was returned to England where the fragment was removed from the right hand. Forty-three days after injury he was returned to combat duty. Four months later he was evacuated because of combat exhaustion. Upon routine physical examination the presence of an aneurysm of the right neck was discovered and he was returned to the United States. On admission to the Ashford General Hospital, November 21, 1945, his only complaint was that of a buzzing sensation in his right ear when lying on that side. Examination on admission showed a healed wound just posterior to the upper third of the right sternomastoid muscle. In this region a thrill was felt and a continuous bruit heard. The bruit was transmitted throughout the neck, upward behind the ear. It was easily obliterated by pressure over the right common carotid artery. Upon obliteration of the fistula the pulse fell from 80 to 72 per minute and the blood pressure rose from 120/68 to 120/80. A diagnosis of arteriovenous fistula of the internal carotid artery and internal jugular vein was made. On December 8, 1945, an incision was made parallel to the anterior border of the right sternomastoid muscle. Since it was thought that the fistula involved the internal carotid artery, the carotid vessels were identified at their bifurcation and ligatures passed about the common, internal, and external carotid arteries. Occlusion of these vessels singly or in combination did not diminish the bruit. Compression at a slightly lower level in the neck obliterated the thrill. Dissection was carried out inferiorly and the vertebral artery was identified. It was found that occlusion of this vessel stopped the bruit and thrill. Ligatures were passed about the vertebral vessels. The incision was then extended upward with detachment of the sternomastoid, longus colli, splenis capitis and levator scapulae muscles from their origins. In this manner the transverse processes of the upper two cervical vertebrae were exposed. The transverse processes of the second cervical vertebra were removed and a ligature was passed about the vertebral vessels at this point. Occlusion of the vessels did not result in cessation of the thrill. The third transverse process was similarly removed with isolation of the vessels at the level of the third cervical vertebra. Compression at this point resulted in cessation of the thrill. The vertebral vessels were then ligated at the site of the second and third transverse processes. A mass ligature was tied in the interval between these sutures with further obliteration of a segment of vessel. Slight bleeding was encountered at this time due to the tearing of small branches of the vertebral artery. A tantalum clip was applied at the site of the fistula to further insure occlusion. The vertebral artery was doubly ligated in its first portion and a tantalum clip was applied at the point at which it entered the sixth vertebra. His recovery was normal. There was no recurrence of the bruit and the condition was considered as cured on discharge two months later.

CASE 10.—*A-V fistula, left vertebral vessels, third portion, due to shell fragment wound, December 18, 1944. Preliminary temporary occlusion of vertebral artery in the first portion, removal of transverse process of the atlas, and mass ligation of the fistula, January 31, 1946. Cured.*

This soldier was wounded in action December 18, 1944, when he was struck in the left side of the neck by a shell fragment. The wound of entrance was just inferior and posterior to the angle of the mandible. There was no wound of exit. There was no excessive bleeding and no loss of consciousness. The wound was

allowed to heal by second intention. There was marked diminution in the hearing of the left ear after the injury, and he was conscious of a continuous buzzing in that ear. He was evacuated to the United States and admitted to the Ashford General Hospital on November 8, 1945. Examination revealed a scar, about 1 cm. in diameter, just inferior and posterior to the angle of the left mandible. There was a small sinus in the region of this scar from which a small amount of serous fluid could be expressed. A continuous thrill was heard over this region, which was transmitted to the base of the neck. The bruit could not be obliterated by occlusion of the common carotid artery or by pressure anywhere in the neck. A diagnosis of vertebral arteriovenous fistula was made. On January 31, 1946, a 6-cm. transverse incision was made above the medial end of the left clavicle. The two heads of the sternomastoid muscle were separated and the vertebral artery, near its origin from the subclavian, was isolated. Occlusion of the artery caused the bruit to be diminished but did not completely obliterate it. This wound was covered, and a 10-cm. longitudinal incision was made along the medial edge of the sternomastoid muscle extending from the level of the thyroid cartilage upward to the mastoid process, and then curved laterally over the mastoid process so that the sternomastoid muscle was detached at its insertion. The spinal accessory nerve was isolated and the sternomastoid muscle reflected outward and downward. The splenius capitis muscle was reflected downward from the transverse process of the atlas which exposed the vertebral vessels between the axis and atlas. Compression of the vessels in this region caused the bruit to be diminished but not completely obliterated. It was then felt that the fistula involved the third portion of the vertebral vessel. The rectus capitis muscle was detached from its origin to the transverse processes of the atlas and axis and reflected downward which exposed approximately 2 cm. of the third portion of the vessels. It was necessary to remove the transverse process of the atlas in order to adequately expose the third portion of the vessels. The vessels were mass ligated distal and proximal to the fistula with two ligatures which were passed about the vessels. This caused the thrill to completely disappear but the bruit was still slightly audible. It was assumed that there were branches between the proximal and distal ligatures. Three other sutures were passed about the vessels between the proximal and distal ligatures which caused the bruit to completely disappear. The vessels were not divided. The divided muscles were approximated with interrupted silk sutures. The postoperative course was uneventful. There was no evidence of recurrence of the bruit or thrill two months after operation.

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DISCUSSION.—DR. RUDOLPH MATAS, New Orleans, La.: Doctors Elkin and Harris have presented a contribution of outstanding merit in the surgical history of the vertebral arteries. Their experience with the arteriovenous aneurysms of these arteries is unequalled in the number of cases reported. Their anatomic studies of the vertebrals from their origin in the subclavians and their long travel to the base of the brain, inside the osseous encasement of the vertebral canal, is in accord with the physiologic importance as feeders of the medulla, and with the need for their protection against injury and accident. It is by a study of these natural defenses, so well-presented by the authors, that the comparative rarity of wounds and aneurysms of