Vertebral artery trauma: transcatheter embolization.

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Vertebral Artery Trauma:
Transcatheter Embolization

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Injuries of the vertebral arteries in four patients were treated by transcatheter embolization. Embolotherapy was performed after incomplete or unsuccessful surgery in three of the patients and as a preventive measure in lieu of surgery in the fourth patient. All procedures were successful and without complications. An injured vertebral artery is usually extremely difficult to approach surgically, but because of extensive collateral blood supply it is usually expendable; therefore, it becomes an inviting target for management by interventional angiographic techniques. Embolotherapy of an injured vertebral artery is easier, faster, and safer than its surgical ligation and, therefore, decidedly superior. With few exceptions, embolotherapy should be considered the preferred method in the management of vertebral artery trauma.

Injuries of the vertebral arteries are relatively uncommon and their operative management usually requires major surgery. The increasing success of interventional angiography in the management of posttraumatic hemorrhage has encouraged its use in vertebral artery trauma as well. The first successful procedures were reported in 1978 [1, 2]; since then only 11 cases of successful embolization or balloon occlusion of injured vertebral arteries have been added to the literature [3–10], two of them by one of us [3, 4]. Embolization of 22 vertebrovertebral arteriovenous fistulas was reported by Riche et al. [11], but the causes of the lesions were not disclosed.

The purpose of this communication is to report four new cases of embolization in the treatment of vertebral artery trauma and to briefly discuss the etiologic, anatomic, clinical, surgical, and angiographic aspects of such injuries, with emphasis on the angiographic diagnosis and the use of interventional angiographic techniques in the management of injured vertebral arteries.

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Materials and Methods

In each case the investigation began with an arch aortogram and continued with bilateral selective vertebral arteriography. The injured vertebral artery was deemed expendable if it did not supply branches to the spinal cord and if both vertebrals merged normally to form the basilar artery. For selective angiography and embolization we used 5-French catheters. These were either preformed H-1 cerebral catheters (Cook Co., Bloomington, IN) or catheters made at table-side by the angiographer from polyethylene tubing (Becton-Dickinson, Inc., Rutherford, NJ).

Embolizations were performed using stainless steel coils with Dacron strands, available in varying sizes from the manufacturer (Cook Co.). The coils were advanced with the help of Teflon-coated, long-tapered guidewires (Cook Co.) and placed in selected locations within the vertebral arteries. The size of the coil was selected according to the diameter of the target artery and the length of the segment to be occluded. When several coils were necessary, different sizes were used and the coils were placed in such a way as to become entangled with one another.

Detachable balloons were not available during the period these patients were treated and,

under the circumstances specific to each patient, would probably not have been used. Their applications are discussed later.

Gelfoam was generally considered unsuitable for use in the vertebral artery. However, it was used once, to embolize a small branch of the thoracoacromial artery (case 4), when it was judged that there was no risk of releasing Gelfoam microemboli into the central nervous system.

Case Reports

Case 1

A 28-year-old man was admitted with a gunshot wound to the neck. Physical examination on admission showed a high cervical, posterior left paraspinal entrance wound and no exit wound; there was no audible bruit over the neck. Neurologic examination was noncontributory. Radiographs of the head and neck showed that the residual wound tract passed near the left C2 transverse process, terminating with the bullet lodged in the anterior wall of the left maxillary antrum.

Angiography revealed minimal spasm of the left internal carotid artery and partial disruption of the wall of the left vertebral artery (Fig. 1A). Because of the risk of delayed rupture and the potential for hemorrhage in an area of very limited surgical accessibility, prophylactic embolization of the injured vertebral artery was contemplated. Since the study showed a normal, wide, right vertebral artery and no communication between the left vertebral artery and the spinal circulation, the left vertebral artery was considered expendable and was occluded by transcatheter placement of a single 5-mm coil at the level of the injury. A postembolization arteriogram confirmed the success of the procedure (Figs. 1B and 1C).

There were no complications, and a follow-up arteriogram on the 11th day after embolization showed persistence of the vertebral occlusion. The patient was subsequently released from the hospital in good condition.

Case 2

A 48-year-old man was shot in the neck and was admitted at a rural hospital with C6 quadriplegia. The residual wound tract was anteroposterior, traversing the midline through the C5 and C6 vertebrae and spinal cord. Endoscopy failed to show evidence of tracheal or esophageal injury. On hospital day 7 the patient suffered cardiorespiratory arrest and was successfully resuscitated. On the 11th day he was transferred to the Veterans Administration Medical Center Hospital in Houston. The exit wound was found to be discharging pus, but there was no evidence of cerebrospinal fluid infection or leak.

On days 13 and 14 the patient bled from the pharynx and right nostril; soon afterward a subcutaneous hematoma appeared in the left supraclavicular region, the exit wound began discharging hemopurulent materials, and the patient became hypotensive. Endoscopy and suction of the oropharynx yielded large quantities of clot. Angiography revealed hemorrhage from a tear in the left vertebral artery (Fig. 2A). Coils were placed through the catheter in the vertebral artery, above and below the tear. A subsequent angiogram (Fig. 2B) confirmed the success of the embolization. There was no further bleeding, but deterioration continued and the patient died of progressive pulmonary insufficiency 19 days after the shooting.

Case 3

A 49-year-old man was admitted with a left thoracocervical gunshot wound and a gunshot wound to the left hand. In the emergency room, a left hemothorax was diagnosed and treated by tube thora-

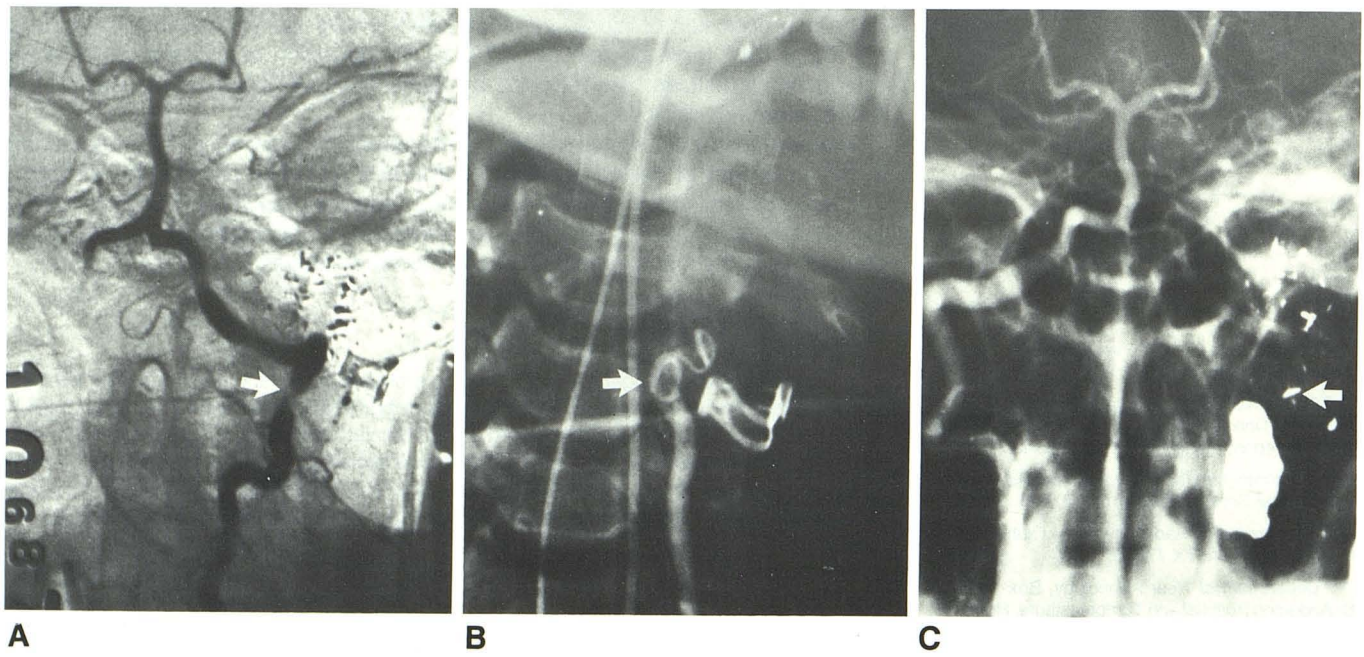

Fig. 1.—Case 1
***A*, Selective left vertebral arteriogram. Partial disruption of arterial wall at C2 level (*arrow*). There was no hemorrhage at the time of study.**
***B*, After embolization with a single 5-mm coil (*arrow*), there is no blood flow in artery.**
***C*, Selective right vertebral angiogram. Retrograde flow in left vertebral artery does not descend to level of injury (*arrow*). Coil is hidden behind deformed bullet.**

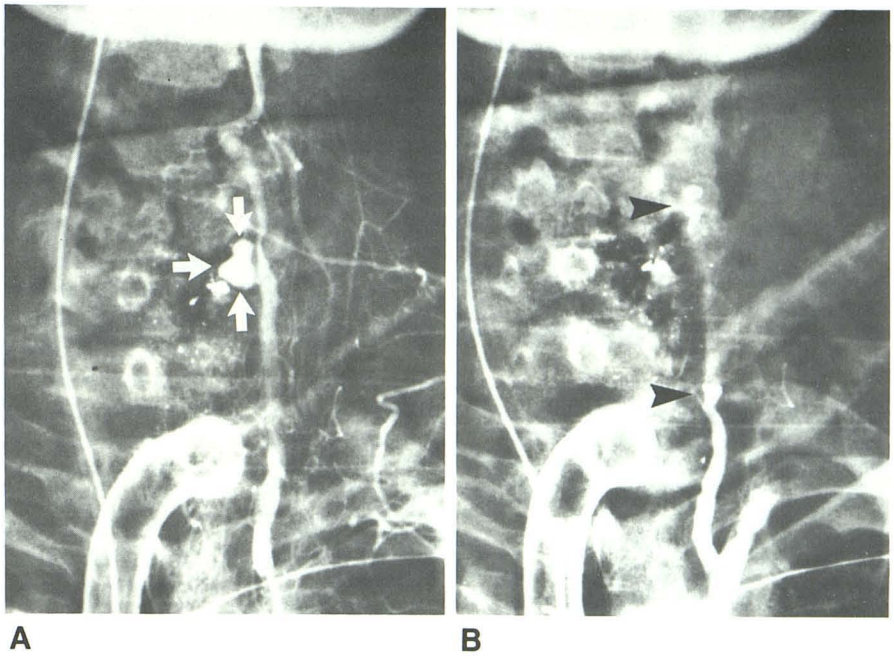

Fig. 2.—Case 2.
***A*, Selective left vertebral arteriogram. Hemorrhage from puncture wound of left vertebral artery (*arrows*).**
***B*, Control study after embolization. Injured segment has been effectively trapped by placement of coils above and below it (*arrowheads*).**

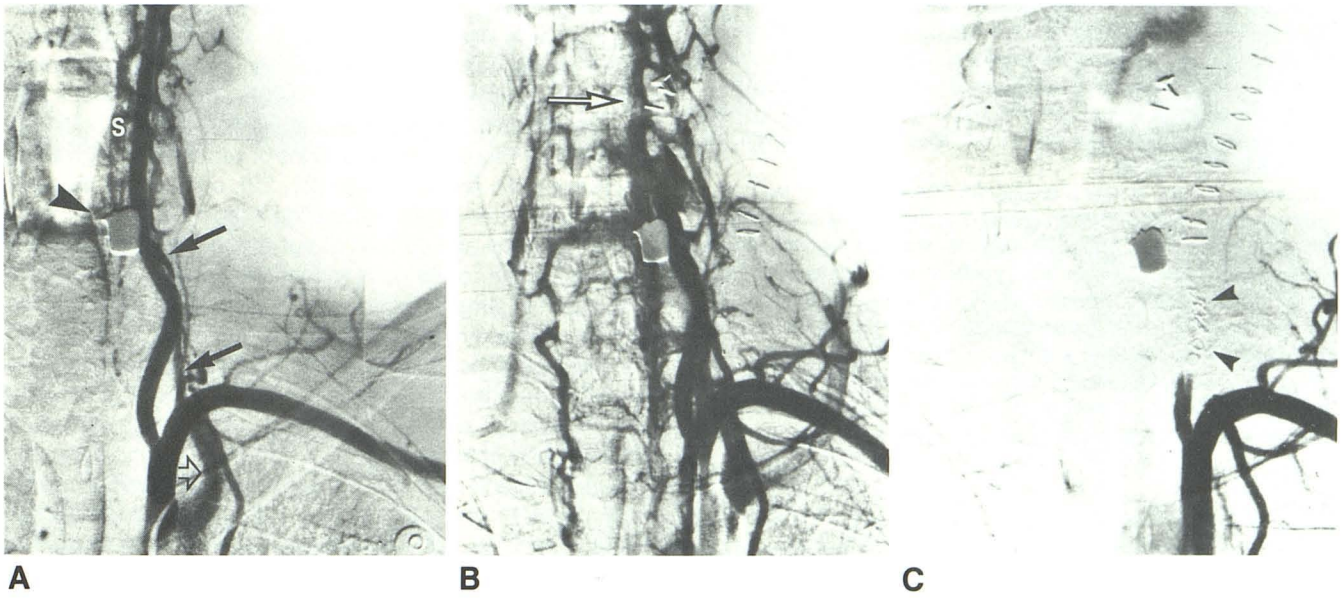

Fig. 3.—Case 3.
***A*, Left subclavian arteriogram. Vertebrovertebral arteriovenous fistula (AVF) is partially hidden by bullet (*arrowhead*), with early appearance of multiple epidural and cervical veins and anterior longitudinal epidural venous sinus (S). Left vertebral vein is initially narrow and in part superposed on artery (*solid arrows*), becoming wider as it enters mediastinum (*open arrow*).**
***B*, Postoperatively, arteriography documents failure of proximal ligation of vertebral artery. The point of distal ligation of the artery is marked by vascular clips (*arrow*). AVF remains open, with brisk shunting.**
***C*, Four coils have been placed in proximal segment of vertebral artery (*arrowheads*), and a control study shows obliteration of AVF.**

costomy. Neurologic examination was within normal limits. Because the residual wound tract traversed the lower cervical spine on the left, angiography was performed. The study demonstrated a vertebrovertebral arteriovenous fistula with brisk shunting into the epidural and cervical venous plexus (Fig. 3A).

The angiographer's proposal to embolize the lesion was declined by the attending surgeon. The left vertebral artery was surgically ligated distal to the arteriovenous fistula, but its proximal segment could not be reached. The operation required removal of much bone to gain access to the artery, and it was made extremely difficult by constant, massive venous bleeding. The patient was in the operating room for almost 9 hr and required 11 units of blood.

From the operating room the patient was returned to the angiography suite, where a postoperative angiogram documented the persistence of the arteriovenous fistula (Fig. 3B). The proximal segment of the vertebral artery was embolized with four coils, obliterating the

fistula (Fig. 3C). The patient recovered uneventfully and was released from the hospital 10 days after surgery.

Case 4

A 31-year-old man was admitted because of progressive left spastic hemiparesis. At age 16 he was shot in the neck and underwent emergency surgery for repair of bullet wounds to the cervical esophagus and trachea. It is unknown whether angiography was performed at any time during that hospitalization. The patient recovered and was released from the hospital, despite a persistent bruit over the left side of the neck, and he appears to have been in good health for 13 years.

Symptoms began to appear 2 years before the current admission, at which time he had hyperreflexia in all four extremities, spastic paresis of both left extremities, and a loud left cervical bruit. Angiography (Fig. 4A) revealed a large arteriovenous fistula connecting the proximal left vertebral artery to the internal vertebral venous plexus, and most probably to the anterior longitudinal sinus. It was decided to trap the fistula by coil embolization at a later date.

Three days after the first angiogram the left vertebral artery was occluded by coils above the arteriovenous fistula (Figs. 4B–4D). At this point the attending surgeon elected to complete the trapping surgically. After proximal ligation of the left vertebral artery, a postoperative angiogram demonstrated additional tributaries to the same or an adjacent fistula from branches of the ascending cervical artery (Fig. 4E). The same tributaries were still functioning 11 days later (Fig. 4F) and were embolized with coils (Fig. 4G). Additional tributaries from the costocervical trunk were embolized by coil, and one from the thoracoacromial artery was embolized with Gelfoam (Fig. 4H). Arteriography then showed that all left subclavian tributaries had been obliterated (Fig. 4I).

However, a right vertebral angiogram revealed that at least one proximal right vertebral branch crossed the midline and connected with the arteriovenous fistula (Fig. 4J). As this last connection was minimal, and given both the risks involved in attempting to work within the now solitary vertebral artery and the possibility that the remnant fistula might thrombose spontaneously [3], it was decided not to pursue this tributary, and the procedure was terminated. The patient recovered uneventfully and was released from the hospital. On follow-up he was noted to be without permanent neurologic sequelae and had no detectable bruit anywhere in the neck.

Discussion

Trauma to the vertebral artery is relatively uncommon. In material published between 1960 and 1975 and collated by Rich and Spencer [12], a vertebral artery was injured in only 12 (0.6%) of 2071 civilian vascular injuries. However, liberal routine use of diagnostic angiography in the past decade has shown that the vertebral arteries are injured more often than was hitherto suspected. In series published after 1975, vertebral artery trauma was found in 2.4–6.1% of all arterial injuries [13, 14] (Ben-Menachem Y, unpublished data) and in 7.1–19.4% of cervicocranial arterial injuries [14–18].

In the majority of cases the trauma is penetrating. Firearms are the most common wounding agents in adults in the United States, followed by stab wounds [13, 15–17]. Violent blunt trauma accounts for a much smaller number of vertebral artery injuries in the adult, but it is by no means rare; of 14 cases on file with one of us (Ben-Menachem Y, unpublished data), four were the result of blunt trauma. In children, blunt trauma appears to be the leading cause of vertebral artery injury [14]. The degree of violence capable of wounding the vertebral artery is not necessarily high, which accounts for the numerous reports of vertebral artery injury secondary to chiropractic manipulation [18, 19].

The anatomic environment of the vertebral arteries affects the potential for wounding of the arteries, as well as the diagnosis and management of vertebral artery trauma. Except for their short, proximal course in the thoracic outlet, the vertebral arteries are surrounded by bone and fascia. The rich network of veins in the immediate vicinity of the vertebral arteries increases the likelihood of formation of an arteriovenous fistula. Because in a fistula the artery bleeds into a vein, the fistula offers a degree of protection to the patient [9, 16], but at the same time interferes with the diagnosis [15]. Also, by "arterializing" all area veins, it makes control of hemorrhage during surgery extremely difficult, as occurred in case 3. If the primary arteriovenous shunt is into the internal vertebral venous plexus, and should diagnosis and treatment of the fistula be delayed, the ensuing venous dilatation may cause spinal cord compression. Such is assumed to have been the mechanism responsible for the symptomatology in case 4.

The peculiar anatomic termination of the two vertebral arteries—fusion into a single midline vessel—and the available collateral network [20] limit the occurrence of damage to the central nervous system to events resulting in involvement of a dominant or solitary vertebral artery, to trauma that produces emboli, or to simultaneous wounding of both vertebrals [19]. Therefore, clinical signs of vertebral artery trauma are nonspecific and unreliable [21, 22], often being those of local injury by the original wounding agent [16].

It is generally agreed that all but the most superficial penetrating injuries to the neck require exploration. This can be in the form of surgical exploration of all injuries or as selective surgical management. In selective management, patients in hemorrhagic shock and/or with neurologic, respiratory, and digestive tract injuries undergo emergency surgical exploration, whereas all others are studied by angiography, contrast swallow, and endoscopy [17]. The debate among surgeons who recommend mandatory surgical exploration of all penetrating neck wounds [21, 23] and those advocating selective management [15, 18, 24] appears to have been settled in favor of the latter, not only because selective management is significantly less expensive [17], but also because of the routine use of angiography in the initial assessment of trauma. In the neck, one of the greatest diagnostic contributions of exploratory angiography has been in improved detection of vertebral artery trauma [9, 13, 16, 17, 24]. Meier et al. [16] reported that routine angiographic assessment of most penetrating neck wounds in their institute has increased the number of diagnosed vertebral artery injuries from 3% of all cervical vascular injuries between 1957 and 1973 to 19.4% for the years 1978–1980.

Opposition to the prevailing opinion in favor of mandatory surgical or angiographic exploration was raised by North et al. [25], who regard angiography as unnecessary when there is no clinical evidence of vascular injury, but recognize that "one cannot be absolutely certain in such instances that a

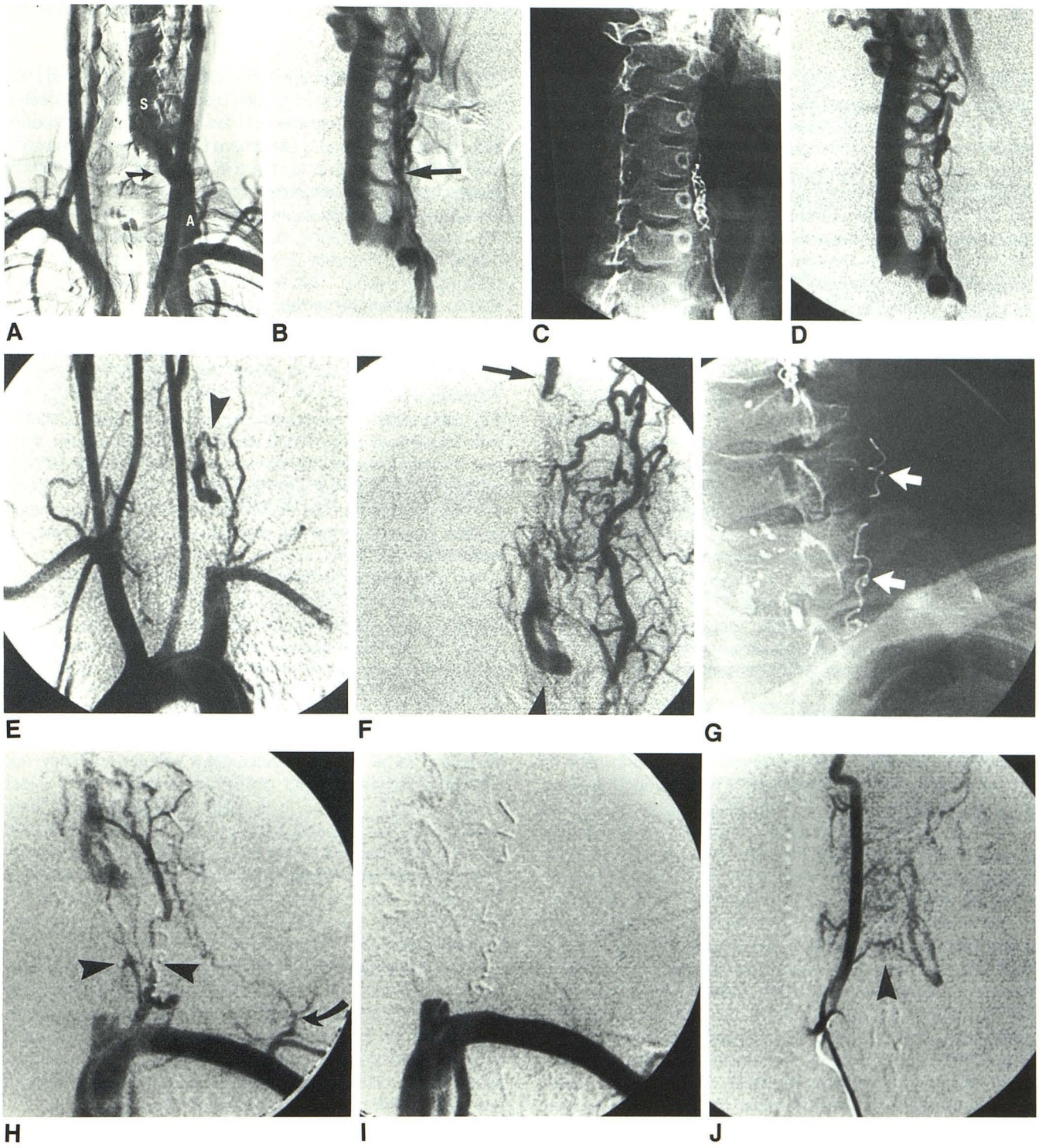

Fig. 4.—Case 4.

A, Aortic arch study 15 years after gunshot wound in the neck. Very wide arteriovenous fistula (AVF) (*arrow*) connects left vertebral artery (A) to anterior longitudinal epidural sinus (S).

B, Preembolization study shows brisk AV shunt, but also directly opacifies vertebral artery distal to AVF (*arrow*). There is widespread cervical venous dilatation.

C, After verifying absence of left vertebral arterial branches to spinal cord, several coils were placed in left vertebral artery above AVF.

D, Control angiogram shows obliteration of artery above AVF. In operating room, vertebral artery was ligated at its origin.

E, Aortic arch study immediately after surgery shows additional tributary to same or adjacent AVF from left ascending cervical artery (*arrowhead*). No further treatment was contemplated for that session.

F, On postoperative day 11, selective ascending cervical angiogram shows that residual AVF failed to thrombose (*arrowhead*) and there is good communication to distal vertebral artery (*arrow*).

G, Artery is occluded by coil (*arrows*).

H, After coil embolization of ascending cervical artery, subclavian study shows that AVF is still supported by branches of costocervical trunk (*arrowheads*) as well as by muscular branch of thoracoacromial artery (*arrow*). These were embolized, respectively, by coil and Gelfoam.

I, Final left subclavian angiogram confirms that all embolizations have been effective.

J, Selective right vertebral arteriogram immediately after completion of embolizations on left. Early appearance of at least one small tributary branch to AVF across midline (*arrowhead*).

dissection or other vascular lesion is not present." In our opinion, one must always be assured of a precise diagnosis of injury or normalcy, and to this end exploratory angiography should be mandatory for all penetrating neck wounds as well as for many injuries from violent blunt trauma, except when patients require emergency surgery. This is especially important with respect to the vertebral artery in view of its anatomic environment and lack of clinical presentation when injured [15, 16, 21, 22]. It is possible that in case 2 angiographic diagnosis and embolization immediately after the shooting might have resulted in a more favorable posttrauma course.

In the majority of cases the injured vertebral artery can be surgically ligated or trapped without fear of brainstem infarction. Repair is contemplated only when the contralateral vertebral artery is either hypoplastic, absent, or terminates in the posterior inferior cerebellar artery [16]. Methods of surgical management of vertebral artery trauma, either by surgery alone [16] or by a combination of surgical ligation and temporary occlusion by Fogarty balloon catheter [26], have been proposed and tried successfully, and complications are rarely reported [22]. However, the anatomic location and the relation of the vertebral arteries to neighboring venous channels pose some serious challenges to the surgeon, not the least of which are the need to cut through bone to approach the artery and the excessive bleeding that usually complicates any operation, even ligation of the artery in the thoracic outlet [9]. The operation in case 3 was described by the surgeon as a "veritable bloodbath."

In surgery for arteriovenous fistula another pitfall is the inability of the surgeon to identify all fistulous communications when more than one fistula exists, as was seen in case 4. Indeed, when a fistula results from a bullet wound, several separate fistulas may exist [9]. One must also expect to find, in addition to the main arterial component of the fistula, several smaller arterial tributaries draining into the same or adjacent venous conduits. This stems from the mechanism of tissue destruction in gunshot wounds [27–29]: the tissue in front of the nose of the moving bullet is accelerated forward at the velocity of the projectile and the tissue alongside it is displaced laterally by pressure waves. Thus is formed a *temporary cavity* that can attain a diameter 30 times the bullet's caliber. Having reached its maximum size, the temporary cavity starts to collapse, then reexpands and contracts several times in diminishing amplitudes. The most serious tissue damage is inflicted as the cavity collapses, simultaneously affecting all blood vessels within its perimeter. The point is well demonstrated in case 4, where, after a combined angiographic-surgical trapping of the vertebral artery, tributaries from four other arteries—including the opposite vertebral artery—were identified.

Another serious objection to surgical intervention arises when the injury to the vertebral artery accompanies an unstable fracture of the cervical spine in a patient who is neurologically intact. This combination of injuries should dissuade one from attempting surgery, or indeed any manipulation of the neck, so as not to risk iatrogenic quadriplegia [3]. Transcatheter embolization is an excellent alternative to surgical management of such patients.

The objectives of therapeutic embolization of any artery are to obviate surgery and to reduce blood loss and its sequelae [3]. Embolization is feasible if (1) the injured artery is expendable, (2) the injury is at a site where surgery could be hazardous or impossible, and (3) there is increased risk of hemorrhage should the artery recanalize [9]. Furthermore, after an artery sustains an injury, bleeding may not be observed at the time of angiography, but may be delayed. If the artery meets criteria 1 and/or 2 above, it can be embolized as a preventive measure. This was the rationale behind the decision to embolize the vertebral artery in case 1.

In vertebral artery embolization the choice of occluding agents is limited to those materials that, once deposited, will remain in place and not fragment. The materials of choice are therefore steel coils [2, 6–10] or detachable balloons [5, 30, 31]. Before the introduction of steel coils we used Gelfoam with excellent results [3, 4]. Gelfoam was also used to occlude one distant accessory tributary artery of the fistula in case 4, without ill effect, after it was deemed safe to do so. However, it is best to avoid the use of Gelfoam near the central nervous system, because of the risk of small-particle detachment and embolization [3, 4, 9].

The choice between coils and detachable balloons is determined by the type of arterial injury and by the angiographer's expertise [32]. Clearly, a detachable balloon is the agent of choice for treatment of an arteriovenous fistula if one wishes to preserve the patency of the artery [5, 30, 31] and should have been the most logical management in case 3. However, once the artery was ligated surgically, the advantage of the balloon over a coil was removed. In case 4 the fistula was much too large to be embolized by balloon, certainly not without a palpable risk of pulmonary embolus from a lost balloon. Also in case 4, it is quite possible that we were dealing with an accessory fistula—the residual lesion that was first seen only after the primary fistula was obliterated—and this lesion was not at all amenable to balloon treatment. In cases 1 and 2, where the vertebral artery had to be sacrificed, coils were the preferred agents, being far less expensive and easier to use than detachable balloons.

When the artery has been completely transected, only proximal embolization is possible [4, 6, 9, 10]. If there is significant retrograde hemorrhage from the distal segment on injection of the contralateral vertebral artery, such bleeding must be controlled surgically. In one case, an arteriovenous fistula of the distal segment closed spontaneously within a few weeks after proximal embolization [3].

If the proximal segment of a transected vertebral artery is too short, too wide, or unsuitable for embolization for other reasons, temporary control of the hemorrhage can be achieved by occlusion with a balloon catheter. The inflated balloon serves to prevent hemorrhage before and during surgery. Moreover, since it is a palpable intraarterial foreign body, it can guide the surgeon to the exact location of the injury. This can be of tremendous help when exploring a massive hematoma [4].

Transcatheter embolization is the treatment of choice for injuries of the vertebral arteries whenever it is technically feasible. The method is simpler, safer, and far more cost-

effective than surgery and, at times, can allow preservation of the patency of the injured artery.

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