The attitude of the early surgeons to vertebral artery injury could be summed up in the words of Sanson, who, in 1836 wrote: "The vertebral artery cannot be ligated, on account of its great depth, nor compressed, because of the osseous canal which protects it; it can still less be cauterised. The wounds of this vessel are beyond the resources of art."

The first comprehensive report of vertebral artery trauma was published by Matas in 1893. He collected 42 cases from the literature reporting an 80% mortality rate. He credited Maisonneuve and Fravot with the first successful ligation of the vertebral artery. They wrote: "It was suspected that the haemorrhage came from the vertebralis. In the presence of so grave a contingency, for the relief of which the surgical records suggested no remedy, we hesitated, and for a moment felt uncertain as to the proper plan of action. But the life of the patient was involved and we had to stop the haemorrhage at all hazards." This they did, successfully ligating the inferior thyroid artery and the vertebral artery as it entered the canal of the 6th cervical vertebra.

The anatomy and relationships of the vertebral arteries are unique. With the exception of the first part, from its origin to the foramen transversarium of the sixth cervical vertebra, the remainder of its course is relatively inaccessible to direct surgical exposure. The second part is enclosed in the osseous tunnel of the upper six cervical vertebrae, lying immediately anterior to the anterior primary rami of cervical nerves C2–6, and surrounded by a thin-walled plexus of veins. The propensity for penetrating injury to result in an arteriovenous fistula in this portion of the vertebral artery relates to the negative pressure in the vertebral venous plexus and the surrounding osteofascial tunnel which serves to contain haemorrhage and prevent effective external compression. The third portion of the artery curves backward deep in the suboccipital triangle, related to the anterior primary ramus of C1 and the lateral portion of the atlas before piercing the dura and arachnoid to form the fourth part which then unites with the opposite vertebral artery, forming the basilar artery at the lower border of the pons.

While direct surgical approaches to parts 2 and 3 of the vertebral artery have been described, these are generally unfamiliar even to vascular surgeons with considerable trauma experience, and are thus often poorly managed resulting in unnecessary morbidity and mortality.

Vertebral artery injury, due predominantly to penetrating trauma and less commonly blunt injury, has an incidence which is difficult to establish precisely. Asensio et al., in a review of 26 series and 4193 patients with arterial injuries, reported a 1% incidence of vertebral artery trauma, accounting for 9.5% of all cervical arterial injuries. Meier et al. reported that vertebral artery injuries accounted for 19.4% of cervical vascular injuries seen over a 3 year period, during which time routine four-vessel angiography was performed in all patients with severe neck trauma. This compared with an incidence of 3% over the preceding 16 years in the same unit when routine angiography was not performed.

The presence of a vertebral artery injury is frequently missed clinically, particularly when applying a policy of selective neck exploration for penetrating trauma and when routine angiography is not performed. This may account for the well recognised observation that arteriovenous fistulae and false aneurysms may present months or even years after the initial injury. Reid et al. reported that 74% of vertebral...
injuries presented with a penetrating neck wound and/or a stable haematoma and no other clinical findings.\textsuperscript{5}

Patients presenting with neurological deficits invariably have direct spinal cord or nerve root damage rather than ischaemic injury due to vertebral artery occlusion. The risk of ligating or embolising the vertebral artery in the presence of a normal contralateral vessel is small. However, injury to, or occlusion of the fourth part may result in cerebellar infarction.

Two main clinical scenarios present themselves. In the first the patient's presentation is such that angiography cannot be contemplated, due either to uncontrollable bleeding, rapidly expanding haematoma, airway compromise, high-velocity missile injury or "sucking" wound and immediate exploration is mandatory. If an injury to the first part of the vertebral artery is found, this should simply be ligated. However, if the injury is to the second or third part of the vertebral artery, we believe that control should first be attempted by means of packing with haemostatic sponge, bone wax or muscle. Once haemostasis is achieved by this means, the patient should proceed directly to angiography which should ideally be digital subtraction angiography and may be followed by selective catheterisation and angiographic embolisation if appropriate. It is our view that this is a safer and more expedient approach for the average surgeon unfamiliar with the approaches to parts 2 and 3.

In the second scenario, a patient with a penetrating cervical injury presents in a stable condition without indications for immediate exploration. If a vascular injury is clinically suspected in the presence of penetrating wounds of zones 1 or 3 the patient should proceed to immediate angiography. If this reveals a vertebral artery injury, it is our practice to attempt immediate angiographic embolisation. If this fails, we proceed to surgical exploration. The role of angiography in zone 2 injuries with suspected vascular trauma is more controversial with some groups proposing surgical exploration directly. The role of Duplex Doppler remains to be defined but may be valuable for evaluating both carotid and vertebral artery occlusions, false aneurysms or arteriovenous fistulae.

Controversy still exists with regard to selective or mandatory exploration of these penetrating neck injuries. Most centres with a heavy trauma load practise selective exploration, and there appears to be little, if any, difference in mortality or morbidity with this approach. In terms of cost-containment, a selective policy involving routine and extensive investigation such as endoscopy, contrast studies, Duplex Doppler and angiography may be more expensive, but this remains to be established.

The management of vertebral artery injury has been revolutionised by the advances in endovascular surgery since Binkley and Wylie described embolisation of an arteriovenous fistula through a surgical approach to the vertebral artery,\textsuperscript{6} and Debrun \textit{et al.} described fistula occlusion with preservation of the parent artery by means of detachable balloons.\textsuperscript{7}

Prior to these advances, surgery of the traumatised vertebral artery carried considerable risk and a high mortality, particularly in acute injury where a mortality rate of 50% was reported by Fogelman and Stewart in 1956.\textsuperscript{8} More recently Hatzitheofilou \textit{et al.} reported a 20% mortality in 20 patients surgically treated as emergencies for massive bleeding or damaged or compromised airways.\textsuperscript{9}

The advantages of endovascular radiological techniques include high success rate, avoidance of general anaesthesia (thereby allowing continuous neurologic monitoring during trial occlusion), a less invasive, possibly quicker procedure and often preservation of the parent vessel. Quicker recovery and potential cost savings are added benefits. These techniques also allow the assessment of the opposite vertebral artery, its communication with the basilar artery, evaluation of flow in the posterior communicating artery and other possible feeders to the fistula. If the contralateral vertebral artery is hypoplastic (in 15% of normal patients) or occluded, an attempt should be made to preserve the parent vessel by using a detachable balloon.

An arteriovenous fistula is ideally treated by detachable balloon embolisation. Selective catheterisation of the opposite vertebral to determine the presence of retrograde flow down the injured vessel is important. If a false aneurysm or dissection is demonstrated, coils or balloons should be placed both proximal and distal to the pathology. "Cross-over" techniques may be needed initially, or where a recurrence occurs due to retrograde flow from the contralateral vertebral artery. Some controversy surrounds the management of the vertebral artery found to be occluded. Should it be "made safe" with a coil? Reid \textit{et al.} explored all vertebral injuries and reported that the angiographic finding of occlusion was correct in only 7/17 patients and that an artery appearing occluded might have free communication with a false aneurysm.\textsuperscript{5} However, whether selective catheterisation and digital subtraction angiography were used, was not detailed. We have not experienced problems in patients demonstrated to have occluded vertebral arteries angiographically and have not embolised the occluded artery.
Accurate morbidity and mortality rates for these radiological interventions are difficult to obtain because of the small numbers of patients in published series. Morbidities in expert centres range from under 5% (1/21)\textsuperscript{10} down to 0% (0/18)\textsuperscript{11} with no reported mortality. Potential complications include ischaemic events due to vessel occlusion or thromboembolism secondary to catheter manipulation, further damage to the blood vessels, loss of coils or balloons into the venous circulation (usually in situations of very high flow) and cerebral oedema following obliteration of longstanding fistulae with resultant overperfusion of the cerebral circulation (normal perfusion-pressure breakthrough).

As a method of non-invasive occlusion of a false aneurysm of the 3rd part of the vertebral artery, Feinberg has recently described Duplex Doppler-directed manual compression with resultant occlusion.\textsuperscript{12} The use of this specific method might well have been unique, but successful occlusion of an aneurysm of the vertebral artery by compression was described by Weir in 1884, following manual compression by relays of interns and medical students for 7 h.

Current local and international practice favour initial radiologic embolisation for vertebral artery injuries, especially in parts 2 and 3. The introduction of covered stents, and the further development of balloons, microcatheters, coils and guided compression will, in our opinion, further optimise this form of treatment both in acute trauma and in late-presenting arteriovenous fistula and false aneurysms. As surgical approaches to parts 2 and 3 are difficult and foreign territory to the average surgeon, they are not routinely practised but may be required in exceptional cases. Successful management of vertebral artery injury with minimal mortality and morbidity may be expected by applying these guidelines.

References


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