VERTEBRAL ARTERY INJURY DURING ANTERIOR DECOMPRESSION OF THE CERVICAL SPINE

A RETROSPECTIVE REVIEW OF TEN PATIENTS

MICHAEL D. SMITH, SANFORD E. EMERY, ALBERT DUDLEY, KENNETH J. MURRAY, MARVIN LEVENTHAL

From Minnesota Spine Center, Minneapolis, USA

Ten patients who suffered iatrogenic injury to a vertebral artery during anterior cervical decompression were reviewed to assess the mechanisms of injury, their operative management, and the subsequent outcome. All had been undergoing a partial vertebral body resection for spondylitic radiculopathy or myelopathy (4), tumour (2), ossification of the posterior longitudinal ligament (1), nonunion of a fracture (2), or osteomyelitis (1). The use of an air drill had been responsible for most injuries. The final control of haemorrhage had been by tamponade (3), direct exposure and electrocoagulation (1), transosseous suture (2), open suture (1), or open placement of a haemostatic clip (3).

Five patients had postoperative neurological deficits, but most of them resolved. We found direct arterial exposure and control to be safe, quick and reliable. Careful use of the air drill, particularly in pathologically weakened bone, as in infection or tumour, is essential. Arterial injury is best avoided by a thorough knowledge of the anatomical relationships of the artery, the spinal canal, and the vertebral body.

J Bone Joint Surg [Br] 1993; 75-B:410–5.
Received 18 June 1992; Accepted 30 July 1992

M. D. Smith, MD
Minnesota Spine Centre, 606 24th Avenue South, Suite 602, Minneapolis, Minnesota 55454, USA.

S. E. Emery, MD
Department of Orthopaedics, Case Western Reserve University, 1074 Abington Road, Cleveland, Ohio 44106, USA.

A. Dudley, MD
Four East Madison Orthopaedic Surgery, 3091 Greenspring Avenue, Baltimore, Maryland 21211, USA.

K. J. Murray, MD, PhD
Neurosurgical Oncology, Greater Baltimore Medical Centre, Baltimore, Maryland 21204, USA.

M. Leventhal, MD
Department of Orthopaedics, University of Tennessee and Campbell Clinic, 869 Madison Avenue, Memphis, Tennessee 38103, USA.

Correspondence should be sent to Dr M. D. Smith.

0301-620X/93/3522 $2.00

The anterior approach for decompression of the cervical spinal cord and nerve roots is widely used for spondylitic, neoplastic, infective, or post-traumatic problems. The potential complications reported include vocal cord paralysis, dysphagia, injury to the carotid artery, Horner's syndrome, oesophageal perforation, and respiratory obstruction due to acute retropharyngeal oedema or haematoma (Smith and Robinson 1958; Whitecloud 1978, 1989; Graham 1989; Emery, Smith and Bohlman 1991).

Despite these theoretical complications, anterior procedures have been successful and are popular. The approach allows for anterior discectomy and thorough nerve root or spinal canal decompression without exposure of the dura or manipulation of the spinal cord or nerve roots. It results in little epidural fibrosis. Direct relief of anterior compression is assured, and arthrodesis is easy. The use of a transverse incision gives a cosmetic and often imperceptible scar, and most of the complications of the anterior approach do not detract from the excellent long-term clinical results (Williams, Allen and Harkess 1968; White et al 1973; Bohlman 1977; Gore and Sepic 1984; McAfee et al 1987).

In contrast to this, laceration of the vertebral artery during an anterior decompression is a very serious complication. Such injuries have received little attention in the literature, probably because they are infrequent.

Vertebral artery laceration is particularly grave because of the difficulty of controlling haemorrhage, and the uncertain neurological consequences. There are good accounts of the surgical exposure of the artery and of the control of bleeding due to penetrating neck injuries, but little has been published to guide the spinal surgeon in the avoidance or intraoperative management of such an injury. Spinal surgeons who perform anterior cervical decompressions should be prepared to manage an inadvertent laceration of the vertebral artery.

We have reviewed ten patients from a variety of sources who had an iatrogenic injury of the vertebral artery. We aimed to determine the best means of controlling haemorrhage, to discover the mechanism and risk factors, and to develop anatomical and surgical guidelines for the avoidance of such injuries.

Table I. Details of ten patients with iatrogenic injury to a vertebral artery

Case	Age (yr)	Follow-up (mth)	Diagnosis	Procedure	Side		Cause
					Approach	Arterial injury	
1	10	43	Aneurysmal bone cyst with myelopathy C5, C6	Corpectomy C5, C6	Right	Right	Instrumentation
2	68	24	Spondylitic myelopathy	Corpectomy C3, C4, C5	Left	Right	Coarse air drill
3	52	18	Old nonunion of a dens fracture Spondylosis with myelopathy	Corpectomy C2	Right	Left	Coarse air drill
4	38	2	Osteomyelitis and epidural abscess with myelopathy	Corpectomy C6, C7	Right	Right	Instrumentation
5	52	34	Spondylitic radiculopathy C6	Discectomy C5–6	Right	Left	Instrumentation
6	55	12	OPLL* with cervical myelopathy	Corpectomy C4, C5, C6	Right	Left	Coarse air drill
7	86	67	Spondylitic myelopathy	Corpectomy C5, C6	Right	Right	Coarse drill
8	75	2	Metastatic cancer C3	Corpectomy C3	Right	Right	Cavitron
9	67	31	Pseudarthrosis C6–7	Hemicorpectomy C6, C7	Right	Right	Diamond burr
10	43	12	Pseudarthrosis C5–6	Hemicorpectomy C5, C6	Right	Right	Coarse burr

Case	Level of injury	Management	Estimated blood loss (ml)	Neurological complications
1	Mid third	Avitene, gelatin sponge tamponade	2300	None
2	Mid third	Direct electrocoagulation	400	None
3	Lower third	Direct electrocoagulation, proximal and distal vascular clips	2000	Cerebellar infarction with cranial nerve palsies
4	Lower third	Avitene, gelatin sponge tamponade	4500	None
5	Upper third	Direct exposure by separate incision, proximal and distal vascular clips	1700	Transient dysphagia and dysarthria. Persistent posterior circulation insufficiency. Vocal cord paralysis resolved at 6 months
6	Mid third	Direct exposure, proximal and distal vascular clips	2300	Severe quadraparesis with prominent hemiplegia. Marked cerebellar signs
7	Mid third	Transosseous ligation	500	C5 root damage with mild deltoid paralysis
8	Mid third	Transosseous ligation, electrocoagulation	1000	None
9	Disc space	Exposure by vertebrectomy, ligation	1000	C5 root damage with deltoid and biceps weakness which resolved
10	Disc space	Gelatin sponge tamponade	300	None

Case	Non-neurological complications	Postoperative angiogram	Comments
1	None	Artery patent, no pseudoaneurysm	No pain or functional limitations
2	None	No	No pain, Nurick II myelopathy, chronic renal disease with dialysis
3	Upper airway obstruction. Emergency tracheostomy. Posterior fusion C1 to C5 one week later	Collateral flow present, posterior fossa intact	No pain or functional limitations, minor swallowing difficulty
4	Immediate postoperative angiography and embolisation	Posterior fossa intact	Drug abuser, left hospital against advice, lost to follow-up
5	None	Posterior fossa intact	Overhead activities increase vertigo
6	OPLL* dural absence, CSF fistula. Reoperation for dural patch and graft reinsertion	No	Persistent mild central cord syndrome, no pain, able to meet needs of daily living
7	None	No	No pain, deltoid weakness
8	None	No	Death at 2 months: disseminated cancer
9	None	No	Death due to unrelated causes at 33 months
10	None	No	No pain or functional limitations

* ossification of the posterior longitudinal ligament

PATIENTS AND METHODS

We made a retrospective review of medical records at the authors' four medical centres, all being referral centres for complex and tertiary spinal care, and identified ten patients who had had vertebral artery laceration during an anterior operation on the lower part of the cervical spine (C2 to C7). We excluded patients with congenital vascular malformations, post-traumatic arterial injuries or aneurysmal vascular lesions. Table I shows the details of the ten patients. There were nine surgeons involved (three neurosurgeons, six orthopaedic surgeons). Four of the authors had personal experience of one case each; the fifth of two cases. Thus, six of the patients were under the direct care of one of the authors; the other four were managed by four other associates who did not wish to be involved with this paper.

All the operations had been performed using a similar technique with anterolateral exposure, medial to the common carotid neurovascular sheath and lateral to the trachea and oesophagus. The side of the approach, nine right and one left, was based on the preference of the surgeon. During the study period from January 1986 to May 1990, about 1195 anterior cervical spine operations had been performed by the five authors, but we were unable to determine the other four surgeons' case loads. The approximate incidence in the authors' cases was 0.5%.

The first author (MDS) studied in detail the medical records and the operative notes with all pertinent radiographs for risk factors, intraoperative errors, and neurological sequelae. Follow-up reports were obtained at the various centres, usually by the responsible operating surgeon, and included a physical examination and radiographs.

RESULTS

Follow-up averaged 24 months, with two patients having less than one year. One intravenous-drug abuser (case 4) left hospital against medical advice at two months and never returned for removal of halo fixation, and one patient (case 8) died after two months from disseminated metastases. Neither of these had paralysis or any other apparent complication. The other eight patients were followed for at least one year, and none needed further operations for the cervical spine disorder that prompted the index operation. None had late worsening of any neurological complications at the time of discharge, and all with iatrogenic neurological injuries have shown at least some recovery.

Findings. In all cases, the operating surgeon had been unaware of the close proximity of his dissection to the vertebral artery: the first indication of trouble was unexpected and profuse bleeding. Tamponade with gelatin sponges, bone wax, and fibrillated collagen (Avitene; Medchem Products, Woburn, Mass) usually provided prompt temporary control, but in case 6, severe hypovolaemia led to cardiac arrest before temporary control of the haemorrhage allowed adequate restoration of blood volume.

Methods of definitive control varied. In cases 1 and 4, the packing material had been gently removed after an extended waiting period. In these two patients the bleeding had ceased, but blood loss had been considerable (2300 ml and 4500 ml) and the operations were prolonged (7 hours and 8 hours). In case 10 tamponade had been followed by immediate bone-graft placement, and this controlled the bleeding.

In another seven patients, either bleeding had recurred despite tamponade or there had been concern about possible severe postoperative haemorrhage, and direct methods of arterial control had been undertaken, by suture ligation in cases 7, 8 and 9, by metallic clips in cases 3, 5 and 6 and by exposure and electrocoagulation in case 2. In cases 7 and 8 the sutures had been passed blindly through bone using a stout curved needle above and below the area of the arterial injury; these sutures probably caused the spinal nerve root injuries diagnosed later. A separate longitudinal left-sided incision had been necessary in case 5 to provide adequate exposure.

There were no cases of recurrent bleeding or clinically detectable pseudoaneurysm. Four patients had had postoperative angiography, but only one of them (case 4) had been treated by tamponade alone. Because of the possibility of postoperative haemorrhage, this patient had undergone an uncomplicated prophylactic arterial embolisation soon after the operation.

Five patients had postoperative neurological problems, four as a direct complication of the arterial injury. Case 3 suffered a Wallenberg's syndrome (lower cranial nerve and bulbar dysfunction with cerebellar findings: Schellhas et al 1980). An MRI scan showed a large cerebellar infarction (Fig. 1), but the patient's speech, gait and swallowing have improved over the 18-month follow-up. One patient (case 5) had persistent ataxia and vertigo with positional changes of the head, which were thought to be due to impaired posterior circulation; resolution has been slow and incomplete. Cases 7 and 9 had root injuries due to blind suture placement, and had rapid and nearly complete recovery.

The fifth patient, case 6, had a severe quadraparesis, which is still dense but recovering slowly one year later. This patient had ossification of the posterior longitudinal ligament and a grade 4 myelopathy (Nurick 1972). She had absence of the dura and a postoperative cerebrospinal fluid fistula. These other problems could have caused her postoperative quadraparesis.

DISCUSSION

Before this study, we would not have anticipated that 1/200 patients would have arterial lacerations. Most of these occurred during vertebrectomy for spinal cord

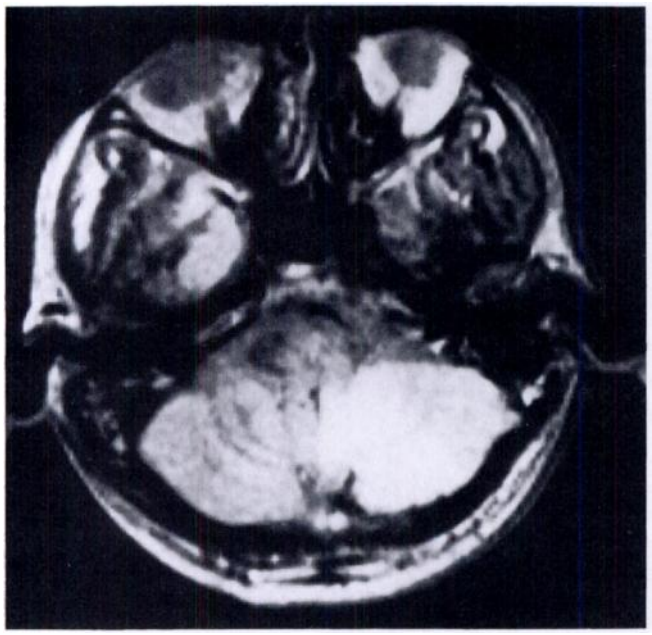

Fig. 1

Case 3. A 52-year-old man with an old upper cervical spine fracture and progressive myelopathy. During decompression of the lateral aspect of the spinal canal with a motorised burr, the left vertebral artery was lacerated. A haemorrhagic cerebellar infarction resulted. Axial MRI of the skull shows an ischaemic area in the distribution of the posterior inferior cerebellar artery.

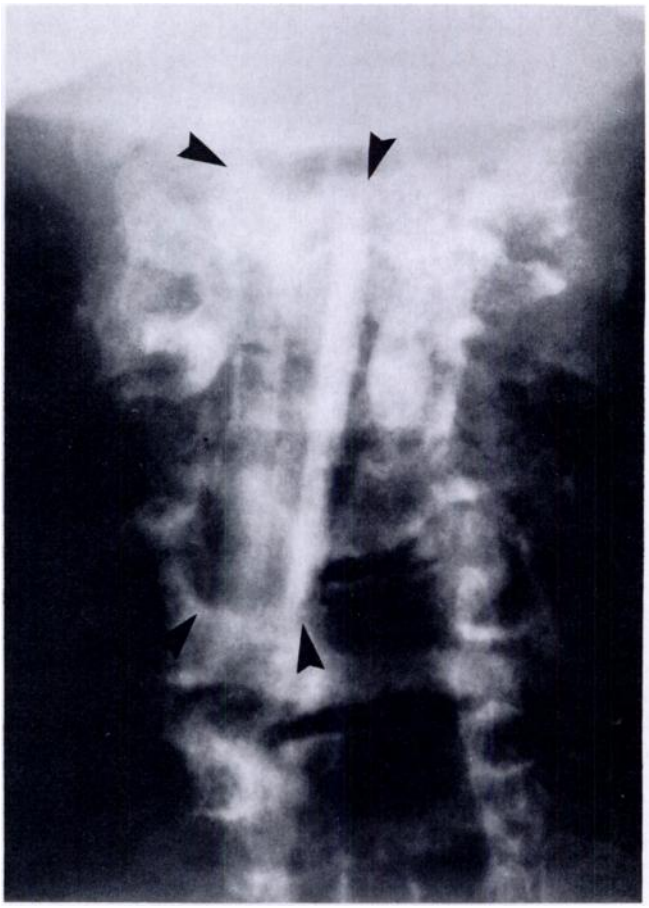

Fig. 2

Case 2. Anteroposterior radiograph of the cervical spine of a patient who sustained a right-sided vertebral artery injury. It is apparent that the surgeon lost his midline orientation. The corpectomy defect is eccentric as shown by the lateral placement of the fibular strut graft.

decompression – a more complex procedure than a simple anterior discectomy. Vertebrectomy usually requires the extensive use of motorised burrs in tight confines, and three common reasons for the lacerations became apparent: the motorised dissection was off midline; the width of the bone and disc removal was excessive; or the bone of the lateral part of the spinal canal was pathologically softened from infection or tumour.

Anatomy. The vertebral artery originates from the subclavian or innominate artery and enters the foramen transversarium of the sixth cervical vertebra. Before this, it is anterior to the transverse process of C7, but usually lateral to the surgical dissection. The artery passes through a series of transverse foramina until it reaches the base of the axis. At this level it curves posteriorly to enter the foramen transversarium in the posterolateral part of the ring of the atlas and perforates the posterior atlantoaxial membrane to pass through the foramen magnum. It then joins the opposite vertebral artery to form the basilar artery, which supplies most of the brainstem and cerebellum. The artery is most vulnerable anterior to C7, laterally at C3 to C7, and posteriorly at C1 and C2.

Operative technique. With the anatomy in mind, the removal of bone and disc material must be performed in the midline and not be excessively wide. To deviate from the midline or to remove bone wider than is necessary risks a laceration, particularly if there is ectasia of the vertebral artery (Fig. 2). The location of the insertions of longus colli may help to maintain orientation. Subperiosteal dissection of their medial borders is performed until the anterior surface of the vertebral body begins to curve posteriorly. The width between the two dissected flaps usually represents the appropriate width of the corpectomy defect needed for spinal canal decompression (Fig. 3). The bone and disc material is then removed in a straight anteroposterior direction. The posterior vertebral cortex, any osteophytes, and the disc material are also removed using a diamond burr, fine curettes, and micro-Kerrison punches as needed. The decompression can then be extended laterally to the uncovertebral joints, as needed, using small diamond burrs or Kerrison punches. The vertebral artery should be above this dissection (Raynor 1983).

We verified the safety of this technique of dissection by studying 25 preoperative, myelographically enhanced, axial CT scans of patients who were about to undergo anterior decompression and fusion. We measured the distances from the floor of the spinal canal to the artery, from the anticipated lateral wall of the decompression to the artery, and the necessary width of decompression through the middle portion of the vertebral bodies at C4, C5 and C6 (Fig. 3). The average width of the spinal cord

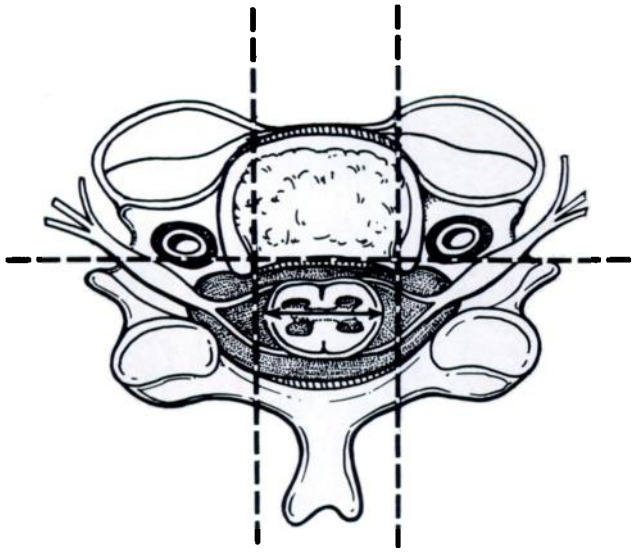

Fig. 3

Diagram of the landmarks used to measure the width of the corpectomy needed for adequate spinal canal decompression. The vertical lines are based on the medial borders of the longus colli muscles. The horizontal line is at the most anterior aspect of the dissection on the floor of the canal showing the lateral position of the arterial foramina.

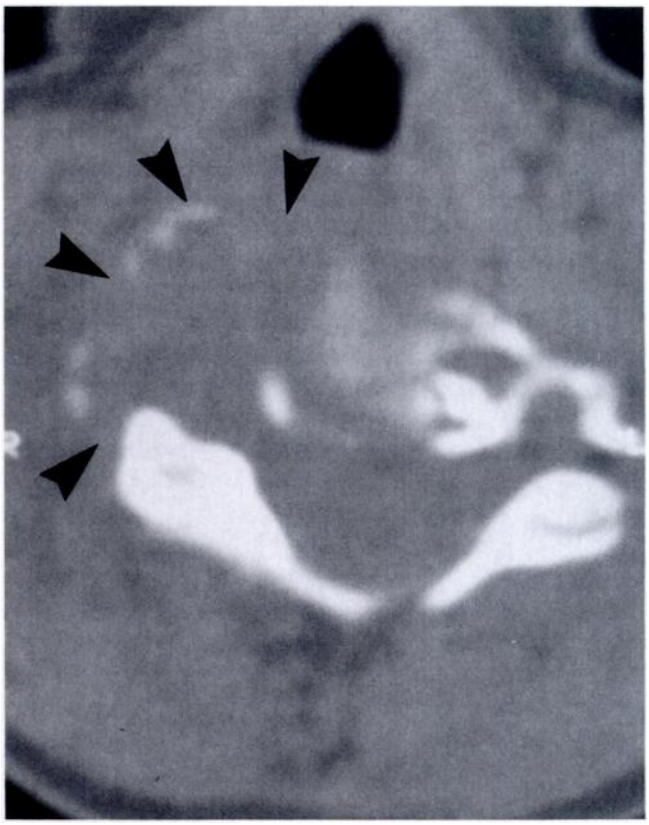

Fig. 4

Axial preoperative CT scan. An aneurysmal bone cyst extends laterally around the foramen transversarium. An angiogram after the operation revealed that the artery was tortuous and displaced anteriorly.

at these levels was 13.7, 13.8 and 13.3 mm respectively. The average lateral dissection of the longus colli insertion needed to provide a lateral guide for an adequate decompression of the central canal was less than 3 mm at all levels, thus leaving at least 5 mm of bone between the artery and the motorised burr. This shows that a central corpectomy can be performed using the anatomical landmarks that we have described, with a 5 mm margin of safety. A small diamond burr, with continuous saline irrigation, can then be safely used to perform a generous decompression of the lateral recesses of the canal with very small risk of entering the arterial foramina.

Preoperatively, the surgeon should note the position of the vertebral arteries on the CT or MRI scans to determine if the arteries are ectatic or are involved in the tumour or infection (Lindsey, Piepmeier and Burkus 1985; Bohlman et al 1986; Born et al 1988: Fig. 4). Preoperative angiography should be considered; if the artery is displaced, tortuous, or dilated, additional prophylactic measures may be needed before decompression, such as its exposure for the proximal and distal placement of encircling vascular loops or sutures. These precautions would have been valuable in cases 1, 4 and 9 (Fig. 4).

In the presence of vigorous bleeding the unplanned exposure of the vertebral artery presents a serious and difficult problem. Our best results were with direct exposure of the artery; blind placement of sutures was effective, but caused nerve root palsies. The use of an inflatable balloon catheter to provide temporary external compression of the vessel within the foramen transversarium is possible when severe haemorrhage interferes with the orderly exposure of the artery (Hatzitheofilou et al 1988). When the arterial injury is on the same side as the original approach, exposure may be facilitated by further lateral dissection of the longus colli and longus capitus beyond the transverse process to expose the foramen transversarium. In these circumstances partial or complete transection of the sternocleidomastoid may allow the surgeon easier retraction laterally of the other muscles; the carotid sheath could also be mobilised and retracted medially or laterally as necessary (Riley 1989). Partial removal of the longus colli muscle and the anterior rim of the foramen transversarium with rongeurs will also allow wider exposure (Verbiest 1969). If the sternocleidomastoid muscle has been divided, it should be re-approximated at the time of wound closure, and the cosmetic results should be acceptable (Southwick and Robinson 1957). If the injury is on the contralateral side and adequate visualisation is not obtained through the initial incision, the operating surgeon could either extend the present incision beyond the midline and expose the artery beyond the contralateral sternocleidomastoid (as described above) or make a separate incision.

Some other published work supports the idea that one vertebral artery can be ligated without serious

consequences (McCormick 1983; Perry 1989), but three of our seven ligated patients had neurological deficits related to the posterior circulation. This rate is greater than that reported by Golueke et al (1987) (six of 23) or Hatzitheofilou et al (1988) (four of 20). These authors were reporting the results of traumatic lacerations in younger patients who were more likely to be able to tolerate unilateral ligation. An additional factor is arterial dominance. In patients with arterial asymmetry, the left-sided artery is usually the larger and provides the greater part of the blood supply to the hindbrain. Ligation or prolonged occlusion by retraction of a left vertebral artery in patients with this vascular pattern increases the likelihood of cerebellar or brainstem infarction (Bohlman and Eismont 1981; Berguer 1985; Bohlman et al 1986).

We would prefer repair rather than ligation of the artery (Perry 1989; De Los Reyes et al 1990), and De Los Reyes et al (1990) describe a patient with a congenital absence of the left vertebral artery who required bypass vein grafting after an iatrogenic right vertebral laceration. This was not possible in any of our patients. An anterior exposure does not allow for direct repair of a laceration of the posterior or posteromedial arterial wall.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

REFERENCES

Berguer R. Distal vertebral artery bypass: technique, the "occipital connection" and potential uses. *J Vascular Surgery* 1985; 2:621-6.

Bohlman HH. Cervical spondylosis with moderate to severe myelopathy. *Spine* 1977; 2:151-62.

Bohlman HH, Eismont FJ. Surgical techniques of anterior decompression and fusion for spinal cord injuries. *Clin Orthop* 1981; 154: 57-67.

Bohlman HH, Sachs BL, Carter J, Riley L, Robinson RA. Primary neoplasms of the cervical spine: diagnosis and treatment of twenty-three patients. *J Bone Joint Surg [Am]* 1986; 68-A:483-94.

Born CT, Petrik M, Freed M, Delong WG. Cerebrovascular accident complicating Klippel-Feil syndrome: a case report. *J Bone Joint Surg [Am]* 1988; 70-A:1412-5.

De Los Reyes RA, Moser FG, Sachs DP, Boehm FH. Direct repair of an extra cranial vertebral artery pseudoaneurysm: case report and review of the literature. *Neurosurgery* 1990; 26:528-33.

Emery SE, Smith MD, Bohlman HH. Upper airway obstruction after multi-level cervical corpectomy for myelopathy. *J Bone Joint Surg [Am]* 1991; 73-A:544-51.

Golueke P, Sclafani S, Phillips T, et al. Vertebral artery injury: diagnosis and management. *J Trauma* 1987; 27:856-65.

Gore DR, Sepic SB. Anterior cervical fusion for degenerated or protruded discs: a review of one hundred forty-six patients. *Spine* 1984; 9:667-71.

Graham JJ. Complications of cervical spine injury. In: *The cervical spine.* Second ed. Philadelphia, etc: J. B. Lippincott, 1989:831-7.

Hatzitheofilou C, Demetriades D, Melissas J, Stewart M, Franklin J. Surgical approaches to vertebral artery injuries. *Br J Surg* 1988; 75:234-7.

Lindsey RW, Piepmeier J, Burkus JK. Tortuosity of the vertebral artery: an adventitious finding after cervical trauma. *J Bone Joint Surg [Am]* 1985; 67-A:806-8.

McAfee PC, Bohlman HH, Riley LH Jr, et al. The anterior retropharyngeal approach to the upper part of the cervical spine. *J Bone Joint Surg [Am]* 1987; 69-A:1371-83.

McCormick WF. Trauma. In: Rosenberg RN, ed. *The clinical neurosciences.* New York, etc: Churchill Livingstone, 1983:III: 241-4.

Nurick S. The natural history and results of surgical treatment of the spinal cord disorder associated with cervical spondylosis. *Brain* 1972; 95:101-8.

Perry MO. Injuries of the brachiocephalic vessels. In: Rutherford RB, ed. *Vascular surgery.* Vol. 2. Third ed. Philadelphia, etc: W. B. Saunders, 1989:604-12.

Raynor RB. Anterior or posterior approach to the cervical spine: an anatomical and radiographic evaluation and comparison. *Neurosurgery* 1983; 12:7-13.

Riley LH Jr. Anterior approaches to the lower cervical spine. In: *The cervical spine.* Second ed. Philadelphia, etc: J. B. Lippincott, 1989:792-5.

Schellhas KP, Latchaw RE, Wendling LR, Gold LHA. Vertebrobasilar injuries following cervical manipulation. *JAMA* 1980; 244: 1450-3.

Smith GW, Robinson RA. The treatment of certain cervical spine disorders by the anterior removal of the intervertebral disc and interbody fusion. *J Bone Joint Surg [Am]* 1958; 40-A:607-24.

Southwick WO, Robinson RA. Surgical approaches to the vertebral bodies in the cervical and lumbar regions. *J Bone Joint Surg [Am]* 1957; 39-A:631-43.

Verbiest H. Anterolateral operations for fractures and dislocations in the middle and lower parts of the cervical spine: report of a series of forty-seven cases. *J Bone Joint Surg [Am]* 1969; 51-A:1489-530.

White AA, Southwick WO, Deponte RJ, Gainor JW, Hardy R. Relief of pain by anterior cervical-spine fusion for spondylosis: a report of sixty-five patients. *J Bone Joint Surg [Am]* 1973; 55-A:525-34.

Whitecloud TS. *Complications of anterior cervical fusion.* St Louis: American Academy of Orthopaedic Surgeons: instructional course lectures, 1978:223-7.

Whitecloud TS III. Management of radiculopathy and myelopathy by the anterior approach. In: *The cervical spine.* Second ed. Philadelphia, etc: J. B. Lippincott, 1989:644-58.

Williams JL, Allen MB Jr, Harkess JW. Late results of cervical discectomy and interbody fusion: some factors influencing the results. *J Bone Joint Surg [Am]* 1968; 50-A:277-86.