Color-coded Duplex sonography of vertebral arteries

11 cases of blunt cervical spine injury

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In 11 patients with locked cervical spine facets after blunt injury, the patency of the vertebral arteries was evaluated by color-coded Duplex sonography (CCDS) up to 11 years after the accident. In 7 patients the dislocations had been reduced, 2 had been treated conservatively, and 9 had been fused.

In 9 patients (3 of them with persistent locking) the mean systolic peak flow velocity was 55 cm/sec and the vessel diameter was 0.35 cm. Only 2 patients had an abnormal CCDS. In 1 with persistent locking the ipsilateral vertebral artery was occluded, and in the other flow signals were abnormal and the vessel diameter was smaller than on the contralateral side. The high coincidence of vertebral artery occlusions and locked dislocations, as well as fracture dislocations reported by others, was not confirmed in our series.

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The amazingly high rate of vertebral artery occlusions in cervical spine dislocations reported by Louw et al. (1990) prompted us to conduct a follow-up study of our own patient material. Instead of an invasive method we used color-coded Duplex sonography (CCDS; Kuhn et al. 1991, Stevens 1991).

Patients and methods

Of a series of 20 patients with locked cervical spine facets who underwent treatment during the past 11 years, those without permanent neurological disabilities caused by spinal or brain injuries were recalled for vascular evaluation. 11 patients showed up for reexamination (Table 1). The interval between the injury and the follow-up study was 1–11 years. 8 of our patients were men and 3 were women. Their mean age at the time of the injury had been 26 (12–49) years. 10 patients presented with a unilateral locked-facet syndrome, while 1 patient had a locked facet on the right side and a perching facet on the left. On lateral views the vertebral bodies were displaced anteriorly by 7 (4–18) mm. Levels affected were C2/3 in 1 patient, C4/5 in 4 patients, C5/6 in 1 and C6/7 in 5 patients. 4 patients had sustained additional fractures of the spinous process or the vertebral arch at the level of the facet dislocation; in 2 patients small fragments were seen at the anterior superior edge of the next lower vertebra; another 2 showed fractures of the next lower vertebral body without dislocation of the fragments; 3 patients did not present with any additional bone lesions. All patients, except for 1, underwent computerized tomography.

Injuries were caused by sports activities (3 patients) or motor vehicle accidents (7 patients). 1 patient was hurt by a train.

Only 3 patients had not sustained any neural injuries. 1 patient had no more than a radicular lesion. Spinal cord injuries were diagnosed in 6 patients. Of these, 2 presented with upper paraparesis and 1 with quadriparesis. 2 patients had severe brain injuries from direct skull trauma; 1 of these probably had not sustained any spinal or radicular injuries.

In 2 patients the dislocation was not reduced, and treatment was conservative. 2 patients were stabilized without prior reduction, in 7 patients stabilization was preceded by reduction. Surgical procedures included anterior interbody fusion with bone grafts and plates in 4 patients, posterior fusion with grafting and wire fixation in 1 patient, temporary wire fixation in another patient and combinations of anterior interbody fusion with plates and posterior fusion with wires and hooks in 3 patients. 1 patient had undergone vertebral angiography 3 years before our study.

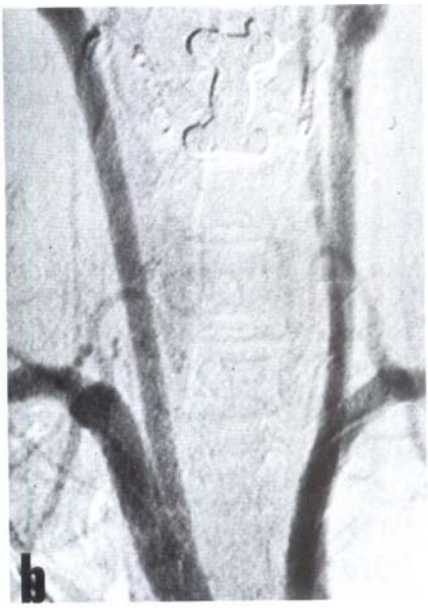
CCDS was done 4 (1–12) years following the accident. A fully integrated system (2D-CCDS, pulsed and

Table 1. Observatons in 11 patients with locked cervical spine facets

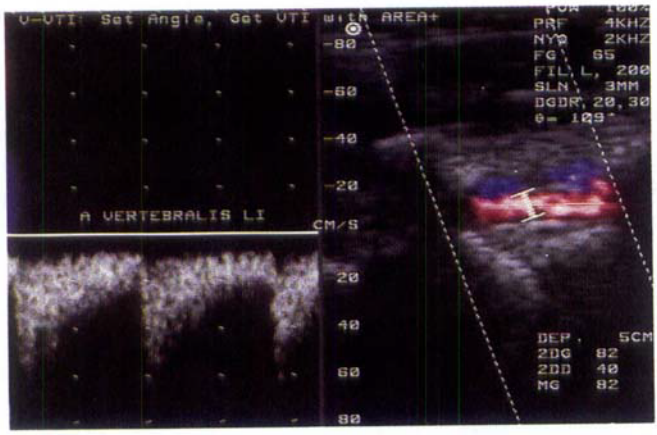
A	B	C	D	E		F	G		H	Problems	Comments
1	6/7	+/+	–/–	40	40	R	3	3	80 bil	neck config.	identical flow prox. and dist. to C6/7
2	6/7	+/+	+/+	40	40	L	4	4	100 bil		
3	6/6	+/+	+/+	40	40	R	3	3	100 bil	neck config.	
4	4/5	–/–	–/+	0	50	R	0	3	130 bil		see case report
5	6/7	+/+	–/–	60	60	R	3	4	75 bil	poorly eval. at C6/7	identical flow prox. and dist. to C6/7
6	5/6	+/+	+/+	50	50	R	4	4	100 bil		
7	4/5	+/+	–/–	78	78	R	4	4	80 bil	no definition at C4/5	identical flow prox. and dist. to C4/5
8	2/3	+/+	+/+	70	100	L	3 at C2/3	4	170 r 90 l		see case report
9	4/5	+/+	+/+	60	60	L	4	4	80 bil		
10	4/5	+/+	+/+	60	60	L	4	3	90 bil		
11	6/7	+/+	+/+	70	70	Bil	3	2	85 bil	metal echo	evaluable despite metal artifac

A Patient
B Cervical level
C Definition of vertebral artery origin: R/L.
D Definition of vertebral artery course: R/L.
E Peak flow system vertebral artery (cm/sec): R, L
F Side locked. Reduction was performed in all patients except 3–6
G Vascular diameter (mm): R, L
H Peak flow system comm. carotid

Occlusion of right vertebral artery just distal to its origin.



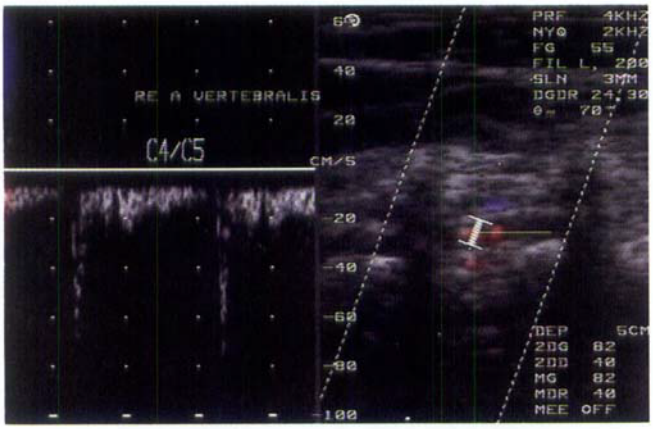
Vasculature as seen on DSA.

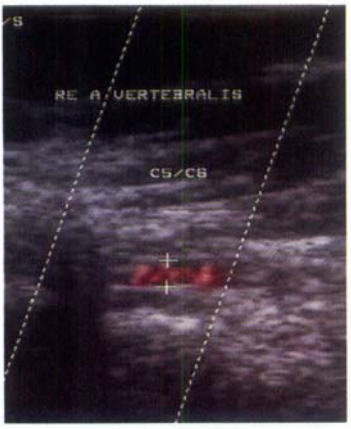


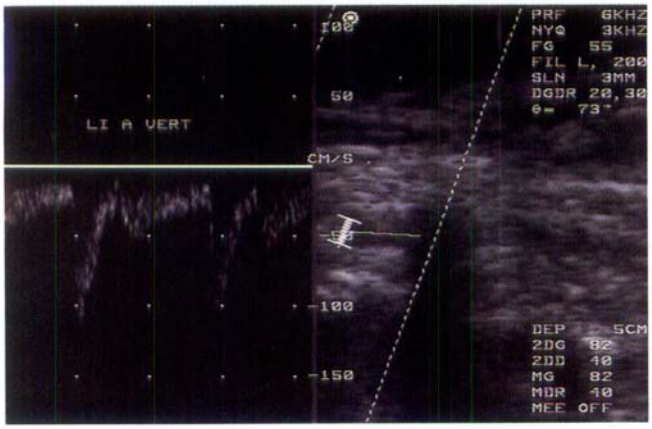
Left vertebral artery, showing flow curve typical of a central vessel .

CW Doppler) with a quantitative analysis function and a linear 5 MHz transducer was used. At their origin and along their course around the atlas the vertebral arteries were also scanned with the CW Doppler technique, and their condition was evaluated from the flow curves (4 MHz pencil probe). Results were documented on video tape and printer. To get a complete set of data on the condition of the large cervical vessels and to rule out pre-existent lesions the carotids were imaged analogously. The patients' head was kept

Case 8.







Right vertebral artery (top) compared to contralateral vessel (bottom), systolic peak clearly narrower; no evidence of postsystolic dip. Faster diastolic flow components less prominent. This tracing is suggestive of a "prestenotic" flow pattern.

Diameter of right vertebral artery (top) 3 mm versus 4 mm in left vertebral artery (bottom).

in a neutral position; if necessary, it was slightly rotated to facilitate vertebral artery imaging. Extreme head positions were avoided. As all the cervical vessels were investigated, the mean examination time was 50 minutes.

Results

In 10 patients the carotids, which were measured first, did not show any morphologic abnormalities of whatever origin; systolic peak flow velocities were identical bilaterally as were the shapes of the flow curves. The entire extracranial segment was visualized. Except in 2 patients (to be discussed later), the mean systolic peak flow velocity in the common carotids was 88 (75–120) cm/sec. The vertebral arteries were imaged from their origin to the level at which they wrap around the atlanto-occipital joint. As they are surrounded by a bone canal along part of their course, this investigation was technically more challenging. In 9 patients the origin proved to be fully evaluable; accident-related or other abnormalities were absent. The following segment was well defined in only 6 patients. In 3, the affected segment was either poorly evaluable or defied evaluation altogether. However, identical flow velocities proximal and distal to it, without any abnormal flow patterns, suggested that the vessels were intact. At the level of the atlanto-occipital joint the underlying anatomy ruled out vertebral artery imaging, but evaluable information was obtained by CW Doppler studies.

In only 2 patients was CCDS hampered by the configuration of the neck so that some technical devices had to be used. In a single patient stabilized with an

anterior plate and a posterior wire loop, echoes were reflected from the metal implants. While these were annoying, they did not reduce the evaluability of the recordings to any major extent.

In 9 patients, 3 of them with persistent locking, flow velocities and vessel diameters were identical bilaterally with means 55 (40–78) cm/sec and 3.5 (2–4) mm. An overview of the data obtained is shown in Table 1. Two patients with vascular pathology will be described at some length in what follows.

Case 4

A woman aged 28 years at the time of the accident was involved in a motor vehicle accident and sustained fractures of the body of C4, the lamina and the spinous process of C5. She was treated in halo traction for 4 weeks, and she was then prescribed a Minerva brace for 6 weeks. At the time of primary treatment, unilateral locking of the right facet at the level of C4/5 went undiagnosed. The resultant instability prompted anterior fusion 3 months after the accident; the facet was irreducible, and fusion was done with the facet locked. The patient complained of radicular symptoms, but signs of vertebro-basilar insufficiency were also present. Nonselective subtraction angiography showed that, extracranially, the right vertebral artery failed to fill. Intracranially, it showed filling from the contralateral side up to the level of a vessel which we interpreted to be the posterior inferior cerebellar artery. The availability of an angiogram enabled us to validate the findings of CCDS done 6 years after the accident; there was full agreement between the 2 techniques. The possibility of recording signals from the accompanying veins made CCDS the more sensitive technique. The signals reflected from the vessel walls proved that the occlusion of the right vertebral artery clearly was of traumatic origin. At the take-off of the vertebral artery a short pulse-synchronous signal was recorded without diastolic flow (stump signal). Like the angiogram, CCDS showed the left vertebral artery to be intact; the flow velocity was 50 cm/sec, the diameter was 3 mm. The angle between the ultrasonic beam and the blood flow direction was usually 45°. A potential causal relationship between the accelerated flow in the common carotid (130 cm/sec) and the unilateral vertebral artery occlusion cannot be established on the basis of the available data and is, at best, speculative.

Case 8

Falling off a jump board, a 12-year-old boy sustained a dislocation with unilateral locking at the level of C2/3 on the left side. Closed reduction was done under general anesthesia on the day of the accident, and the patient was placed in halo traction. As the lesion proved to be unstable radiographically, stabilization was attempted 5 days after the accident. In view of the patient's age, it consisted of posterior wiring with only 1 wire loop. After the wound had healed, a Minerva brace was prescribed for 10 weeks. The further course was uneventful. Radicular symptoms and signs of vertebro-basilar insufficiency were absent. On CCDS done 4 years after the accident, the left vertebral artery was found to be normal, the systolic peak flow velocity was 100 cm/sec and its diameter was 4 mm. The flow curve recorded by pulsed Doppler sonography was also normal. In the right vertebral artery, by contrast, the diameter was reduced to 3 mm and the flow to 70 cm/sec. On the flow curve the postsystolic dip was absent and the faster diastolic flow components were less prominent. The systolic peak was clearly narrower than on the left side. Together with the outcome of CW Doppler sonography, which showed tortuosity or elongation of the vessel at the level of C2/3, the combination of these signs suggests the presence of a prestenotic flow pattern.

The data obtained from the common carotid arteries were of particular interest: systolic peak flow velocities were 170 cm/sec in the right and 90 cm/sec in the left common carotid arteries.

Discussion

Duplex sonography has gained a firm place in the work-up of patients with cardiovascular disease. Color-coded Duplex sonography (CCDS) is a more sophisticated version of the original technique. Both imaging techniques simultaneously record structure and flow signals. On CCDS all flow signals recorded in B-mode are displayed simultaneously in color, irrespective of the quality of the B-scan. The quality of flow can be evaluated from the image itself, from the acoustic signals and by quantitative analysis (laminar versus turbulent flow, flow velocity). The signals reflected are analyzed by their duration, their amplitude, their phase, and their frequency. 2-dimensional gray scale images are derived from the duration and amplitude of the echo signals. The phase shift and the frequency differential between the transmitted and the reflected signals (Doppler frequency) are an indicator of the direction and velocity of flow. Continuous color-coded flow recordings facilitate the detection of abnormal flow patterns.

To the best of our knowledge, CCDS studies of vascular anomalies in the vertebral circulation have not been published to date. In our Case 8, with a dislocation at the level of C2/3, the presence of a congenital

variation of 1 vertebral artery should be considered in the differential diagnosis as a matter of course, even though a traumatic origin appears to be much more likely. The compensatory nature of the accelerated flow velocities in the common carotids recorded in our 2 patients with vascular abnormalities is at best speculative. While we cannot offer any explanations for the right–left differences in flow velocities in Case 8, system-inherent factors and lateral differences in the examination technique can be ruled out. Similarly, contralateral compression of the common carotid artery cannot have been responsible for the increased flow velocity in the left vertebral artery, because it was not done in any case.

Most of the vertebral artery lesions reported in the literature were located in the upper cervical spine, while an involvement of the segments below C2 appears to be the exception rather than the rule. Hyperextension injuries are usually reported to be the principal cause underlying traumatic vertebral artery lesions. In view of the underlying anatomy, this is no doubt true for the upper cervical spine and the V3 vertebral segment. But, like Louw et al. (1990), we feel that in the lower cervical spine distraction–flexion injuries are the main determinants for traumatic lesions of the vertebral arteries in their V1 and V2 segments, although our data do not confirm the high coincidence of vertebral artery occlusions.

Whether the discrepancies between the data of Louw et al. (1990) and ours are attributable to the interval between the accident and the vascular studies is speculative. Their patients underwent angiography immediately after reduction, but the technique of reduction was not specified. Some of their patients may well have presented with transitory occlusions of spastic origin.

Traumatic vertebral artery lesions may well be more common than suggested by the rate at which they are currently diagnosed. Neurologic symptoms which cannot be explained by a concomitant spinal injury or an accident-related major brain injury, but are rather suggestive of vertebro-basilar insufficiency should prompt examination by CCDS.

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