Acta orthop. scand. 45, 182–192, 1974

Departments of Neurosurgery and Orthopaedic Surgery, Odense Hospital, Odense, Denmark.

FRACTURE OF THE ODONTOID PROCESS OF THE AXIS

J. HUSBY & K. HARRY SØRENSEN

Accepted 14.viii.73

The diagnosis and treatment of fractures of the odontoid process still pose many problems. The injury is potentially fatal or may entail extremely serious neurological complications, but such complications may be completely avoided by early diagnosis and adequate treatment.

Odontoid fractures make up around 13 per cent of all fractures affecting the cervical spine (Amyes & Anderson 1956) and they are being diagnosed with increasing frequency (Nachemson 1960), mainly because of the increasing traffic intensity (Amyes & Anderson 1956, Schatzker et al. 1971).

The fracture was not recognized primarily in 6 out of Amyes & Anderson's 63 cases, in 4 out of Nachemson's 26 cases, and in 2 out of Schatzker et al.'s 37 cases.

Where treatment is concerned the views are still controversial as to the indication for conservative *versus* operative treatment, and the reported frequency of non-union has varied widely.

MATERIAL AND METHODS

During the 10-year period 1961–1970, 32 patients with fracture of the odontoid process were treated in the Departments of Neurosurgery and Orthopaedic Surgery in Odense. The age distribution and sex ratio are shown in Table 1. Sixty-nine per cent are from the last 4 years. This is due to the increasing traffic intensity, 81 all the women were under 20 or over 60.

In the five two-year periods 0, 6, 4, 13, and 9 patients were treated. Thus, 67 per cent are from the last 4 years. This is due to the increasing traffic intensity, 81 per cent having sustained their fractures in traffic accidents (Table 2), mostly motor car accidents. Only 6 patients sustained the fracture by falling, one at floor level, and 5 from heights varying from less than half a metre to an air crash.

Nineteen patients were unconscious for a short time, but awake at admission, and 4 were unconscious for a long time. Practically all the conscious patients complained of occipital pain and stiffness, but these complaints were of highly

Table 1. Sex and age at time of accident.

Age (years)	Males	Females
4–19	3	4
20–39	10	2
40–59	5	0
60–78	4	4
Total	22	10

Table 2. Cause of accident.

Fracture:	Low	High
Motor car	14	4
Motor cycle	0	2
Moped	1	0
Bicycle	1	1
Run over	3	0
Fall	3	3
	22	10

Table 3. Displacement of the odontoid process as seen on X-ray films.

Displacement	Forward	Backward	Right	Left	Total pts.
2–4 mm	8	1	1	1	12
5–9 mm	7	2	1	–	10
10–25 mm	2	2	–	–	4
Angulation					
3–9°	–	–	4	4	8
10–19°	3	–	–	1	4
20–29°	5	2	–	–	7
30–34°	–	3	–	–	3

varying severity. Two did not consult a doctor until a few days after the accident, and another 2 were given physical therapy for pain in the neck. Three had acute operation under anaesthesia for other injuries without the fracture of the odontoid process being detected. All 3 fractures were displaced and unstable. There were no neurological deficits. In 23 cases the fracture was diagnosed immediately after the accident, but in five patients 4–14 days later and in four 3–7 weeks after the accident. A total of 21 patients (66 per cent) had to be examined by tomography on one of the first days. In 10 cases the first X-ray films were assessed as being normal.

Figure 1. X-ray film of a fracture of the odontoid process of the axis in a 23-year-old man who had run his car into a tree at a speed of 140 km/h, without a safety belt. The odontoid process was displaced 15 mm and tilted 23° forward. No neurological deficit.
A low, unstable odontoid fracture which united after fusion, preceded by cranial traction with the odontoid process displaced 2 mm forward, not tilted.

Radiologically only 4 fractures were non-displaced, whereas in 24 cases there was displacement of the axis and in 18 cases angulation. Out of 17 anteriorly displaced fractures 8 were simultaneously tilted, the tip of the odontoid process pointing forward. Of five cases with posterior displacement 4 were tilted backwards. As is apparent from Table 3, the displacements were by no means slight. In 14 cases there was an axial displacement of the odontoid 10–25 mm in relation to the atlas and head as measured on the X-ray film (but in fact less marked), and in 14 cases there was a 10–34° angulation of the odontoid. Initially the displacement may have been greater, especially in traffic accidents (Figure 1).

Other injuries were demonstrated in more than half the cases. Six had other cervical fractures, several of which were multiple, but all were stable. One developed herniation of the 6th cervical disc, 4 sustained a slight cord injury causing in three very mild persisting neurological deficits. Nine sustained extremity fractures and three chest injuries. Two had fairly mild cerebral contusion, and three had cranial fractures. In ten patients pre-existing degeneration and narrowing of cervical discs were demonstrated.

Treatment

In the matter of treatment we made a distinction between *low* and *high* fractures. The low fractures are generally more stable, having a broad, often irregular fracture surface proceeding down into the body and to the sides at its base. The high fractures are in fact invariably unstable and unite poorly, as the area of the fracture surface is smaller, the fracture being situated in a kind of "neck". The stability was evaluated by traction on the head without anaesthesia under fluoroscopy, using flexion-extension on 7 low and 2 high fractures. The odontoid process was mobile in 2 low and in the 2 high fractures. Under anaesthesia 2 low fractures and a high one were reduced. One high, greatly displaced fracture was reduced without anaesthesia.

Twelve patients were treated by bed rest for about two months, five of them with cranial traction, whereas four were positioned on a double mattress with backward-

Table 4. Treatment.

	Fracture	
	Low	High
(Reduction under anaesthesia)	*(2)*	*(2)*
Collar	8	1
Hanging head (2 months) + collar	4	–
Cranial traction + collar	3	1
Bed rest + collar	3	–
Cranial traction (fracture of femur)	1	–
Fusion + Minerva-jacket	–	7
Fusion + collar	1	1
	20	10

bent head because of anterior displacement. In practically all nine cases the position improved. All patients, except for one child, were treated subsequently with a collar (of leather or plastic) until an average of 6½ (3–11) months after the accident (Table 4).

Nine patients underwent posterior fusion of C 1–C 2, but two of them of C 1–C 3. After the sutures had been removed, a Minerva jacket was worn for 4 months, later for only 3 months. Thereafter, the patients wore a collar until 7 (3–11) months after the accident. Fusion was performed on all patients with high fractures.

Only one patient with a high odontoid fracture was not subjected to operation. This was a 63-year-old woman with rheumatoid arthritis treated with cortisone over a period of 10 years who had been in a motor car collision. Several wounds were sutured under anaesthesia. Thereafter, the odontoid fracture was diagnosed. The odontoid process was dislocated 25 mm backward. In the Department of Neurosurgery it was reduced to a normal position without anaesthesia. The cranial traction slid off because of osteoporosis, so that fusion was abandoned. After bed rest for two months with the head between sand bags, re-dislocation occurred. Now, reduction was impracticable, as the atlantal arch had sunk down behind the body of the axis. Four years later, after the patient had constantly worn a plastic collar, she had no subjective complaints, and mobility was good. There were no neurological deficits.

Technique

Since 1965 we have been using a special operative technique for posterior cervical fusion: The neurosurgeon (J.H.) and orthopaedic surgeon (K.H.S.) operate jointly. The patient is placed in the prone position with cranial traction and face support. The posterior arches of the atlas and axis are exposed by a midline incision, and their cancellous bone is exposed 2½ cm to each side. From the wing of the iliac bone two bone grafts are removed, 25 mm wide and 30–40 mm long (Figure 2), comprising just over half the crest and the external lamina with underlying cancellous bone which is removed in a groove shape just beneath the crest to fit the subsequent site of the atlantal arch. A groove is created in the cancellous bone

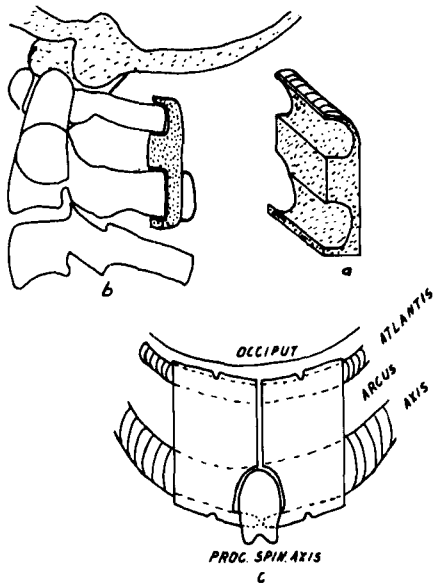

Figure 2. Drawing of the fusion: The graft (a) trimmed into fashion. The graft in situ *viewed from the lateral (b) and posterior (c) aspect.*

rather more inferiorly, at the site of the contact surface of the axial arch. The two grafts are placed, cancellous surface forward, against the two arches, one on the right and one on the left side in such a way that the cristal edge just fits over the upper margin of the atlantal arch and the two grooves fit the two arches. On a level with the base of the spinous process of the axis the medial edges are cut off the grafts, and centrally on the upper and lower edge of the two grafts a small notch is created for a 0.35 mm thick twined steel wire already placed in front of the arches of the atlas and axis, both on the right and on the left side. While tightened with wire tiers, first the right and then the left steel wire is tied separately, so that the grafts are firmly pressed against the arch, and the non-removed cancellous bone projects between the two arches, preventing them from being pressed together and thus preventing angulation at the site of the fracture. Finally, a free end of the steel wire from the right and left knot is tied transversely above and the other two ends below the spinous process of the axis respectively (Figure 3). In our hands, this technique has proved simple and reliable.

RESULTS

Thirty patients attended follow-up 8 years—13 months after the accident. Two had died. One succumbed 8 days after the accident to pulmonary embolism (extremity fracture). Autopsy showed the odontoid process to be firmly wedged into the body. The other patient died

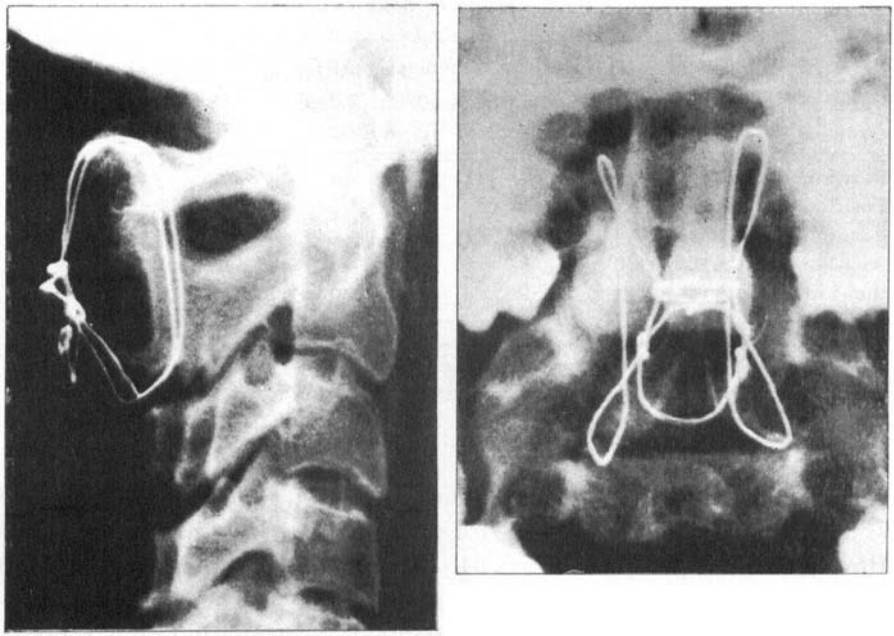

Figure 3. A 17-year-old girl with a fracture of the odontoid process of the axis. X-ray film of fusion viewed from the lateral (a) and anterior (b) aspect. Solid union of the graft 3 years after the operation. Note the steel wire arrangement and the graft which projects between the arches of C 1 and C 2.

two years after the accident, then aged 78, of arteriosclerotic heart disease. He had primarily undergone posterior fusion of a high, unstable odontoid fracture which had apparently united in a normal position eight months later. These two patients had not had any neurological deficits.

Among the remaining 30 followed patients 14 were entirely symptom free. Sixteen had subjective complaints, in most cases mild and not incapacitating. These complaints were pain, fatigue, or restricted mobility. No patient had developed secondary neurological signs. Only one patient was completely disabled, having constant pain and marked, pain-conditioned fixation of the cervical spine. The odontoid process had united with an 8 mm posterior displacement, tilted 34° backward and 8° to the left. There was incongruence and a narrow joint space on the left between the atlas and axis. The patient refused an offer to have fusion performed. The patients had been off work for an average of 7 months after the accident (those who had been treated by fusion for only 6 months).

Table 5. Results as regards union.

Union	Primary position of odontoid process			
	Displaced/angulated		Normal position	
	Conserv.tr.	Fusion	Conserv.tr.	Fusion
Position unchanged	11	1		
Position improved	–	5		
Position deteriorated	1	–		
Position anatomic.correct	5	1	2	1
Non-union	3	1*		
	–	–	–	–
Total 30	19	8	2	1

* os odontoideum

The mobility of the cervical spine for flexion + extension averaged 109° for conservatively and 91° for operatively treated patients. Lateral flexion to the right and left was 64° and 44°, and rotation was 112° and 76° respectively. The minimum distance from the chin to the manubrium sterni was 0–2 cm in 17 patients, 2–5 cm in 10, and 5–8 cm in only 3.

Union was confirmed by tomography in 18 out of the 30 patients. The results as regards union may be seen from Table 5: Out of 19 primarily displaced and conservatively treated fractures 11 had united in an unchanged position, 5 in an anatomical, and one in a negligibly poorer position, whereas 3 had not united. Eight primarily displaced fractures were treated by fusion; all showed solid union. In addition, the odontoid fractures had united in 7 cases (in an improved position in 6). In the last patient treated by fusion an os odontoideum had not united, and indeed this could not be expected. Three primarily non-displaced fractures united in an unchanged position.

Three out of 30 fractures, or 10 per cent, had failed to unite. One of these patients was described above. Another patient, aged 65, treated with a plastic collar for only 3 months, showed non-union with instability 15 months after the accident. Fusion was then carried out, and 6 months later there was solid union of the fusion as well as pseudarthrosis. In the third patient radiography 4½ years after the accident showed that union was not solid, but there was no instability of the odontoid process. The patient was symptom free and working and had in the meantime sustained two severe head injuries, so fusion was not suggested.

DISCUSSION

Thus, our investigation has confirmed that fractures of the odontoid process of the axis occur most often in traffic accidents, most commonly in men, and that the injury is increasing in frequency, as also reported by Amyes & Anderson (1956), Nachemson (1960) and Schatzker et al. (1971).

We have also been able to demonstrate the difficulties in diagnosing the fracture. The explanation is that pain in the neck and fixation are not always sufficiently marked to draw attention to this site, as the patients are often suffering from multiple injuries. Radiographically the fracture is not uncommonly overlooked, partly because other fractures of the skull or cervical spine call attention to themselves and partly because the first films taken in the acute situation may be of a poor quality. For diagnostic purposes it is contra-indicated to take primarily lateral views in forward and backward flexion. According to our experience, tomography should be used to a far greater extent than hitherto. For several years at the Odense Hospital routine films of the cervical spine have been taken, in the acute situation, of all patients even with mild concussion or a suspicion thereof, and thereby several odontoid fractures have been disclosed. The reason why a relatively large number of our fractures were diagnosed at a late stage is that a number of the patients had primarily been treated elsewhere. As early as 1935 Meyerding advocated X-ray examination of the cervical spine in all patients with mild pain at the back of the neck after head injury.

As for treatment widely differing principles have been suggested. Blockey & Purser (1956) advised reduction during cranial traction, maintained for 6 weeks and followed by 6 weeks in a Minerva jacket. Five of their eleven patients exhibited non-union, but the authors did not feel there was an indication for treating it, particularly by fusion, as the non-union was not considered dangerous and as no late complications had occurred. Amyes & Anderson (1956) also advised conservative treatment of all patients according to the same principles, but maintaining immobilization until radiological union, at least for 6 months, using posterior atlanto-axial fusion only if stability was not attained in 9 months. After adequate treatment they had no late complications, but 5 per cent developed non-union owing to inadequate treatment.

Alexander et al. (1958) emphasized that fusion protected against

late complications, but stated that fractures proceeding into the body may unite satisfactorily without operation.

Nachemson (1960) found three months' immobilization to be sufficient, but eight out of his 18 patients had non-union after an average period of 11 years. These patients had less complaints than the others, and treatment by fusion was not felt to be indicated.

Schatzker et al. (1971) also used 4–6 weeks' cranial traction, followed by 6 weeks in a Minerva jacket or a collar, but they found non-union in 14 out of 22 cases, whereas 2 of 15 posterior atlanto-axial fusions by the technique of Gallie (1939) failed to unite, and in 9 cases the odontoid fracture had also not united. After experimental investigations these authors classified the fractures into high and low, according to whether they were estimated to be above or below the accessory ligaments. However, the frequency of non-union proved the same in both groups, but invariably highest in cases of displaced fractures. Thus, the classification into high and low fractures was not used in selecting the therapeutic method. These authors advised fusion in the event of non-union, if the patients are to lead normal lives.

In more recent materials the tendency to operative treatment is on the whole stronger. This must be viewed on the basis of a greater risk of another trauma to pseudarthroses in the great traffic intensity of our times. Thus, Hentzer & Schalimtzek (1971) have reported that the risk of secondary spinal cord injury must be considered to be great in non-union. They reported two patients with non-union who secondarily sustained cord injury, fatal in one case.

Thus, it is difficult to avoid non-union, but the risk involved in it may apparently be obviated by performing fusion, also in cases where the non-union of the odontoid process nevertheless persists. According to our findings, as well as those of others, long-lasting follow-up is needed after conservative as well as operative treatment, and union has to be verified by tomography at least 6 months after the accident, and up to that time a bandage has to be worn. However, during the last 3 months it is usually sufficient to wear Camp's plastic collar.

In our experience the treatment should consist of fusion in all cases of high fracture and, if anatomical reduction and fixation cannot be maintained, also in cases of low, unstable fractures. Posterior atlanto-axial fusion may be performed without increasing the risk, even in elderly persons, and it affords the most favourable results when carried out by a neurosurgeon and an orthopaedic surgeon jointly. It is not necessary to extend the fusion to the occipital bone, blocking movements between the head and the atlas.

SUMMARY

At the Departments of Neurosurgery and Orthopaedic Surgery, Odense Hospital, Denmark, 32 patients were treated for fracture of the odontoid process of the axis during the eight-year period 1963–1970. Sixty-nine per cent were males.

Traffic accidents were responsible in 81 per cent of the cases. In 28 per cent the diagnosis was made 4 days to 7 weeks after the accident. Tomography was often necessary for the diagnosis. Twenty-four fractures were displaced (max. 25 mm), and 24 were angulated (max. 34°). Four patients had slight contusions of the spinal cord.

Twenty-one were treated conservatively, nine by a collar and twelve by bed rest. In nine patients posterior cervical fusion was done by a special technique, followed by a Minerva jacket for 3 months. Most patients were treated subsequently with a collar for up to 6 months after the accident. All high fractures except one were treated by fusion using a special technique.

The 30 surviving patients were re-examined 13 months to 8 years after the accident. Fourteen were symptom free, whereas 15 had slight complaints. One patient was totally incapacitated. None had late neurological deficits.

Twenty-seven fractures had united, 12 in the original position, one in a more displaced position, and nine in a normal anatomical position. Three non-operated cases had failed to unite (10 per cent).

The authors advise routine X-ray examination of the cervical spine in all patients with concussion or admitted because of a suspicion thereof, and tomography if there is a suspicion of odontoid fracture, so that this fracture is not overlooked as often as in the past. Posterior atlanto-axial fusion is advised in all high and certain unstable low fractures. All patients should be immobilized for a minimum of six months, and the union should be verified by tomography.

REFERENCES

Alexander, E., Forsyth, H. F., Davis, C. H. & Nashold, B. S. (1958) Dislocation of the atlas on the axis. *J. Neurosurg.* **15**, 353–371.

Amyes, E. W. & Anderson, F. M. (1956) Fracture of the odontoid process (report of 63 cases). *Arch. Surg.* **72**, 377–393.

Blockey, N. J. & Purser, D. W. (1956) Fractures of the odontoid process of the axis. *J. Bone Jt Surg.* **37**-B, 794–801.

Gallie, W. E. (1939) Fractures and dislocations of the cervical spine. *Amer. J. Surg.* **46**, 495–499.

Hentzer, L. & Schalimtzek, M. (1971) Fractures and subluxations of the atlas and axis. *Acta orthop. scand.* **42**, 251–258.

Meyerding, H. W. (1935) Fracture of odontoid process. *Proc. Staff Meet. Mayo Clin.* **10**, 710.

Nachemson, A. (1960) Fracture of the axis. *Acta orthop. scand.* **29**, 185–217.

Schatzker, J., Rorabeck, C. H. & Waddell, J. P. (1971) Fractures of the dens (odontoid process). *J. Bone Jt Surg.* **53-B**, 292–405.

Correspondence to:

K. Harry Sørensen, M.D.
Department of Orthopaedic Surgery
Odense Hospital
5000 Odense
Denmark