FROM THE SURGICAL AND ORTHOPAEDIC CLINICS,
AKADEMISKA SJUKHUSET, UNIVERSITY OF UPPSALA, SWEDEN.
HEADS: PROFESSORS OLLE HULTÉN AND CARL HIRSCH

FRACTURE OF THE ODONTOID PROCESS OF THE AXIS

A clinical study based on 26 cases

By

ALF NACHEMSON

INTRODUCTION

Although an uncommon lesion, fracture of the odontoid process of the axis is by no means so rare as to constitute a curiosity. It has long been regarded as a serious injury, for the probable reason that many cases with slight symptoms initially failed to be properly diagnosed and went without treatment. Afterwards, even negligible trauma could cause a displacement of the fracture resulting in grave neurologic complications.

A review of the literature discloses that in many instances authors report only a few cases and from this limited experience categorically express widely differing opinions on therapy and healing incidence. The desirability, therefore, of constructing a somewhat more reliable basis for both treatment and has prognosis stimulated the present investigation.

Magnant (1931) and Pool (1951) stated that in the 19th century the mortality rate was believed to be as high as 90 %. Fritsche (1913) reported it as 60 %, Osgood & Lund (1928) found it to be 50 %, whereas during the past decade it has dwindled to 10 % (Amyes & Anderson, 1956; Rogers, 1957).

As to the healing incidence, Schwartz & Wigton (1937) stated that callus formation does not occur anywhere in this region, while Hambly (1944) on the other hand was positive that bony union always results provided the displacement, if any, is slight, and the fracture is immobilized in plaster for three months. Brooks & Birkett (1944) emphasized the odontoid process as a skeletal area where bony healing takes place slowly and where it is not unusual to see healing by fibrous union only.

EARLIER INVESTIGATIONS ON THE OUTCOME OF THE LESION

In a case reported by Elliott & Sachs (1912), death resulted from tetraplegia manifesting itself 32 years after the injury. Autopsy revealed fracture of the odontoid with forwards displacement of the odontoid fragment and atlas. The patient had sustained repeated traumata to the head at intervals of 5–6 years. In each instance, definite evidence of neurologic disorders had been present, but these symptoms had receded.

Baumecker (1935) described a case examined after 4 years, where the patient was in full employment even though the fracture had failed to heal.

Charbonnel & Sicard (1938) reviewed 34 cases of atlanto-axial fractures, the great majority of which were believed to be odontoid fractures. The results had been reported by the attending physicians. Disability had lasted 6 months on an average. In four cases with late displacement operative fusion as recommended by Albee had been performed. The remaining cases had been treated by immobilization in plaster, or by traction, for about 3 months. These authors stated that the results were good in 20 %, acceptable in 50 %, and bad in 30 %, but since they failed to specify criteria for the different groups, these figures are difficult to evaluate.

Amyes & Anderson (1956) reviewed their experiences with a series of 63 cases which, however, were not subjected to a detailed follow-up examination. The total mortality rate was 8 %. They reported only three cases of pseudarthrosis, but it seems reasonable to suspect that this low figure may be influenced by the absence of a follow-up roentgen examination. Two of the five deaths were caused by spinal cord compression. In their material, the incidence of odontoid fractures was 13 % of all cervical fractures. Treatment consisted of traction with Crutchfield tongs and a plaster collar. The patients were kept under observation until the fracture appeared to be healed or had at least become immobilized.

Blockey & Purser (1956) published a follow-up study of 11 cases. They differentiated between fractures in children and in adults; in their opinion fracture of the odontoid is in children, up to the age of 7 years, always an epiphyseal separation. In the two children included in their series, the fracture had healed within 7–13 weeks and a roentgenologic check 3 years later showed the fracture line to be no longer visible. Of the 9 adults, bony healing had occurred in only 5

cases. The four unhealed cases had been kept under observation for 2–4 years and examined by tomography. None of them, however, retained any particular disability or had signs of neurologic disorders. All patients were treated by immobilization with Crutchfield tongs for 6–7 weeks, followed by a plaster collar worn for several months. These authors emphasized that failure of bony union does not constitute a serious danger, provided adequate immobilization has been achieved by early treatment. They believed the fibrous callus to be nearly as strong as bony callus and blamed bad results on inadequate treatment.

Rogers (1957) reported 9 cases of which 2 were with forward displacement and 2 with backward displacement. The 5 patients with undisplaced fractures could all return to work 8 months after injury, on an average. He described two cases of late displacement; one patient waited 7 months before seeking treatment, the other was seen 19 years after injury. In both cases Albee's spinal fusion was performed and examination 5 years later showed the results to be satisfactory. Four of his nine patients had pseudarthrosis but were asymptomatic. From his follow-up study Rogers concluded that, provided the antero-posterior diameter of the spinal canal does not decrease more than 3 mm., there is no danger to the patient, since anatomical conditions in this region easily allow for such a displacement.

ANATOMY AND PHYSIOLOGY OF THE ODONTOID PROCESS

The odontoid process develops initially as the corpus of atlas (Brocher, 1955; Kladetzky, 1956). Two lateral ossification centers fuse together and disappear around the fifth month of intra-uterine life. An apical center is joined to the other centers between the ages of 2 and 5 years. Between the fourth and seventh year the odontoid ossifies and fuses into the body of the axis. (Fullenlove, 1954). This ossification may be delayed to a fairly late age and sometimes fails to take place altogether, in which case a separate os odontoideum develops. Amyes & Anderson believed that in as many as 25 % of all adults bony union between the odontoid and the body of the axis is incomplete; they suggested that this may predispose to both fracture and mal-union.

In my series I have been unable to verify the presence of a separate odontoid in a single instance. Numerous cases of os odontoideum have been reported in the literature (McRae 1953, Brocher 1955, Fleming & Hodson 1955). Schultz, Levy & Russo (1956) cited 14 cases of agenesis dentis, that is to say cases where the odontoid could not be discerned

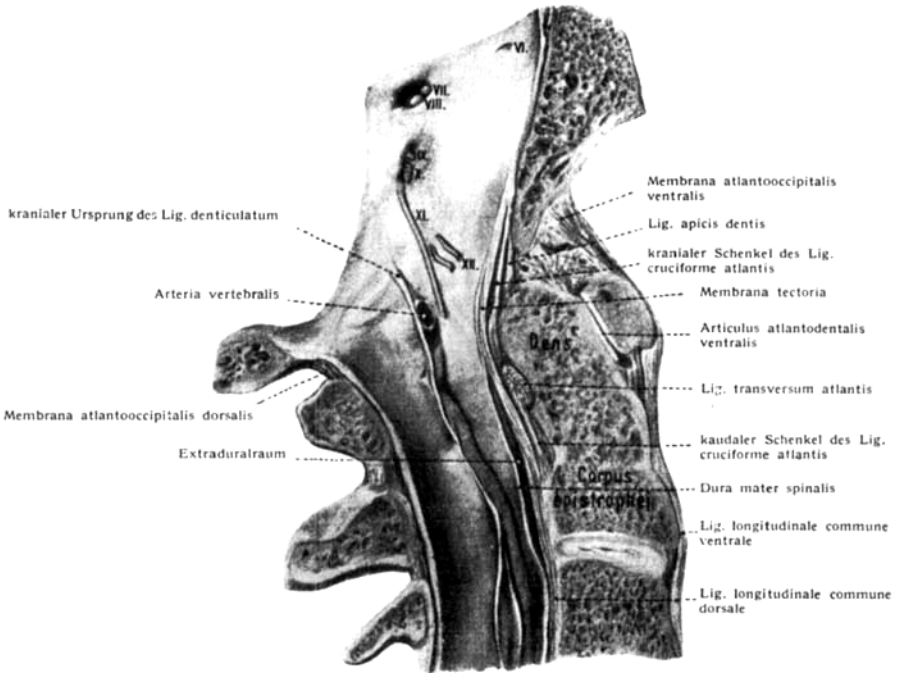

Fig. 1.
Gross anatomy of dens of axis and its ligaments (From Rauber-Kopsch).

in the roentgen picture. Brocher (1955), however, questioned the accuracy of this statement and suggested that the phenomenon could be due to difficulties in interpreting the roentgenograms, in which os odontoideum always appears smaller than a normal odontoid. Incomplete fusion is visible in the roentgen picture as a lighter zone between the odontoid and the body of the axis, indicating the presence of a residual part of the disc formed in intra-uterine life. Other skeletal anomalies, as described by Bohlig (1954), Godlewski (1955), and Schlesinger (1958), occur rarely.

The odontoid process is articulated with the posterior aspect of the anterior arch of the atlas and dorsally to the ligamentum transversum atlantis (Fig. 1), which centrally encloses a cartilaginous body. The firm ring fixing the odontoid in its position is called the annulus osteofibrosus. The alar ligaments and the membrana tectoria further stabilize the atlo-odontoid joints. The ligamentum apicis dentis is merely a rudimentary organ of chorda dorsalis. The ligamentum transversum holds the odontoid process against the atlas, whereas the lig. alare

controls rotation and lateroflexion. Both ante-retroflexion and lateroflexion occur in the occipito-atloid joint, while the atlo-axoid joint permits ante-retroflexion and rotation. Werne (1957), in his exhaustive study of the mechanics of these joints,found the total ante-retroflexion to be around 23°, lateroflexion around 10° and rotation 50°. The rotation in the atlo-axoid joint centers around the odontoid, and is limited by the alar ligaments. His investigation furthermore showed that a prerequisite for spontaneous atlas dislocation is insufficiency of the transverse ligament, a conclusion reached earlier by Davis (1951). Werne also performed post-mortem studies on a large forensic series where the victims had been exposed to acceleration violence in a horizontal direction. Of the 28 analyzed cases, five had skull fractures, three odontoid fractures, and fifteen fractures of other cervical vertebrae. In none of the cases had the ligament ruptured in the absence of skeletal injury.

The vascularization of the odontoid process is mainly supplied by art. vertebralis via the body of the axis, and by smaller vessels in ligs. apicis dentis and alaria (Fritsche, 1913; Baumecker, 1935). Magnant (1931) and Makhlouf (1958) called attention to the similarity between the caput femoris and dens axis, and cited cases of necrosis of the odontoid, although Baumecker considered the vessels in the ligaments adequate for the formation of callus.

Another important anatomical consideration is the significant difference in diameter of the spinal cord and the spinal canal in this region. The actual cord measures 11–12 mm. transversally, whereas the diameter of the spinal canal is 30 mm. transversally and 25 mm. sagitally. This explains the accounts found in the literature of cases where atlas and fractured odontoid had displaced more than 10 mm. and the patient surprisingly was asymptomatic (Böhler, J. 1948; Schlesinger, 1958). Sundelin (1938) stated as an additional reason for the integrity of the spinal cord, that the anterior or posterior arch of the atlas at the moment of forwards or backwards displacement is moved upwards, so that the spinal canal is allowed more play and is bent into an S shape instead of being crushed altogether.

PRESENTATION OF MATERIAL

The material reviewed in this paper consists of 26 cases of fracture of the odontoid treated at the University Hospital in Uppsala or at the Central Hospitals of Falun, Gävle, or Örebro, during the period between 1927 and 1956. These hospitals together serve a population of around

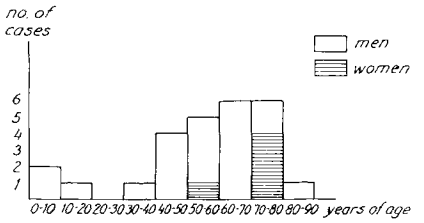

Fig. 2.
Age and sex incidence of the material.

1 million. The age and sex incidence of the material is shown in Fig. 2. At the time of this follow-up study, 18 of the patients were living. All presented themselves for examination, which included tomography. Two more patients had at an earlier date undergone a follow-up examination, but had not been examined by roentgen. They were at the time of this study dead from other causes. Information about the patients dead before this investigation was started was in part requested from the relatives and was furthermore derived from the hospital records and, in some cases, autopsy reports from later hospital stays. In all cases, a relatively clear picture could be formed with respect to the possible after-effects of the fracture. Evaluation of trauma, initial symptoms, therapy, and length of treatment was accordingly based on a study of 26 patients. 20 patients were subjected to a clinical follow-up examination, which in 18 cases included tomography.

Of the six deaths, one was due to tetraplegia immediately after injury. Diagnosis could not be ascertained from the roentgenograms, but was made on autopsy. One patient died two months after the accident. On autopsy, the cause of death was established as basal pneumonia in one of the lungs; unfortunately, the cervical spine was not completely dissected because the odontoid fracture was considered healed. Death occurred one week after the patient became ambulatory. The third patient died 3 months after injury from pernicious anaemia while still hospitalized. Of the remaining deaths, 2 were due to cancer ventriculi, 6 and 7 years after injury. One patient died 4 years after fracture of the odontoid from heart failure at the age of 82, and one at age 85 from metastatizing cancer, 6 years after injury. The primary tumour could not be localized. One patient, finally, died 11 years after injury in a mental hospital; the cause of death was given as marasmus senilis + ganggraena senilis. Two of the deceased patients had previously been subjected to a follow-up examination, but were not examined with roentgen.

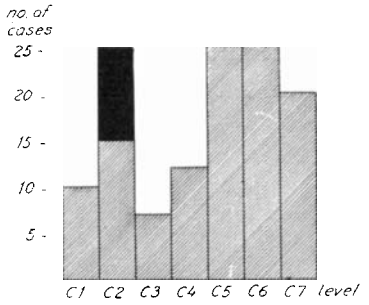

Fig. 3.
Localization of 124 fractures involving cervical vertebrae; 94 patients treated at the Surgical Dept of Uppsala 1927–56. *Black:* Fractures of the odontoid.

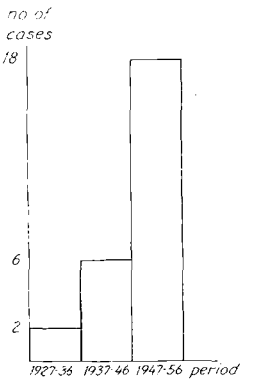

Fig. 4.
Distribution of cases by decades.

Of the 26 patients, only one therefore had died from tetraplegia as an immediate effect of the injury. This implies a total mortality rate of 4 % for this series. In none of the other seven cases can death be attributed directly to the odontoid fracture. Two patients died 2 and 3 months after the accident, but death was not due to the odontoid fracture.

Frequency. In the period between 1927 and 1956 a total of 614 patients with one or more fractures of the spine were admitted to the Surgical Department of the University Hospital; they included 94 patients with a total of 127 fractures of the upper cervical spine. Ten of these were odontoid fractures (Fig. 3). This incidence roughly agrees with that reported in the literature. Osgood & Lund found 1–2 odontoid fractures among 100 traumatic lesions of the vertebrae, whereas Magnant reported 3–4. Amyes & Anderson had a 13 % incidence among fractures of the cervical spine, Crooks & Birkett 7 %.

Fig. 4 shows an increase in incidence during the past decade, which should in part be ascribed to increasing accuracy of roentgen diagnosis. A further contributing factor is the increasing number of traffic accidents.

Trauma, mechanism of injury, and associated injuries. As shown in Table 1, most cases of fracture of the odontoid are the result of falls from heights. In 8 cases the height was recorded as 2–3 mm., in one case as 10 mm.; in the remaining cases this information was lacking. All seven vehicular accidents occurred during the past 9 years. Osgood & Lund (1928) reported that 60 % of the fractures were caused by falls

TABLE 1
Means of injury.

	Number of patients
Fall on head from height	13
(From hay load 7)	
Motor vehicle accident	7
Fall on ground	3
Fall with bicycle	3
Total	26

on the head. Amyes & Anderson (1956) found vehicular accidents to be the predominant cause (36/63) in their investigation. Jefferson (1928) contended that fracture of the odontoid is caused by an impact against the neck when it is in a fixed position. Mere flexion of the neck due to a strong dynamic force applied to the head, usually results in dislocation of the vertebrae between the middle and lower third of the cervical spine. Blockey & Purser (1956) stated that any impact on the head throwing it into extreme flexion, extension, or rotation, may fracture the odontoid. Grogono (1954), quoting Wood-Jones, pointed out that the ideal lesion on hanging by no means is fracture of the odontoid, but snapping of the lower processes of the axis which causes immediate spinal cord injury.

Among the injuries often seen in association with odontoid fracture, Blockey & Purser considered fractura mandibulae the most common (10 %). Of the 26 cases reported here, fractura dens axis was diagnosed as the sole lesion in 12, whereas 11 patients had injuries to the skull, consisting of large compression wounds, commotio cerebri, and fractura cranii. Other associated injuries were, in 4 cases, fracture of the atlas and, in 3 cases, multiple traumatic lesions. Only one patient had a fracture of the mandible (Table 2).

TABLE 2
Associated injuries.

(Fractura dens axis only 12)	
Vuln. contus. capellit. + commotio cerebri + fract. cranii ...	11
Fractura atlantis	4
Fractures outside the cervical spine	3
(Fract. mandibulae 1)	

TABLE 3
Initial symptoms.
(26 patients)

Painful neck	26
Stiff neck	20
Pathologic mobility-sensation of instability	6
Spasm or numbness in arms and hands	4
Neurologic disorders	3
Dysphagia	2

Symptoms. Table 3 shows the initial symptoms displayed by the 26 patients. It is remarkable, that only 17 of the 26 patients consulted a doctor immediately after injury. Four of them were discharged without treatment, in two cases after roentgen examination had failed to disclose the fracture. Nine patients waited to consult a doctor until several days after the accident, by which time the symptoms had increased in intensity. Blockey & Purser furthermore found that the symptoms are often so negligible that the diagnosis may easily be missed. The immediate pain is severe but subsides quickly. The classic "pathognomonic" picture of a man supporting his head with his hands, is not so common; in this material it was seen in only 6 cases, the identical figure reported by Fritsche (6/26). Crooks & Birkett stated that the first and often only symptom is a certain stiffness and tenderness on palpation, in some cases in combination with torticollis. Difficulty in swallowing was noted by Sundelin as a common symptom.

In Amyes & Anderson's serier, 5 of 58 surviving patients suffered from weakness of the extremities due to spinal cord compression. Other symptoms encountered in these patients were hyperreflexia, positive extensor plantar reflex, and loss of pain and temperature sensation. Additional features were hyperaesthesia in the occipital region, and paraesthesia or hyperaesthesia of the hands and fingers. These symptoms indicate the damage to the spinal cord to be most severe anteriorly. Grogono published a more detailed description of the most common symptoms caused by incomplete spinal cord injury in this region. They appear to be: 1) motor weakness or complete paralysis of the arms and legs, 2) exaggerated reflexes, with extensor plantar response, 3) paralysis of bladder with retention of urine, 4) impairment of pain and temperature sense, 5) nerve root lesions with hyperaesthesia in the area of C1 and C2 and occipital neuralgia, 6) paraesthesia and hyperaesthesia of hands and fingers. He reached the same conclusion, there-

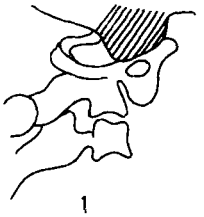

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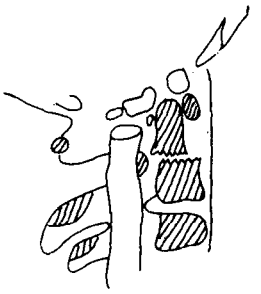
Fig. 5.
Schematic drawing from the roentgenplate of a male age 53, four months after injury. Forward luxation of the odontoid and atlas. The first picture, taken at the time of injury, was considered negative.



2

Fig. 6.
Schematic drawing from the roentgenplate of a male age 41, who six months earlier had sustained a fracture of the odontoid at which time no dislocation was seen. Backward dislocation of the odontoid and atlas with neurological symptoms.

fore, that the damage to the spinal cord must be most pronounced anteriorly. He attributed the neurologic features with symptoms in the arms and fingers to damage to the anterior spinal artery.

In the present series, 3 patients showed immediate symptoms of neurologic disorders. One patient complained of numbness in the neck, another showed weakness of the right arm, extensor plantar response, and general spasticity. The third patient had on admission a distinct tetraplegia with loss of sensation below the mammillary line. Although no skeletal injury could be detected in the roentgenograms, Crutchfield traction was applied, but the patient died three days later. The odontoid fracture was detected at autopsy.

Diagnosis. From the preceding account it is clear that it is not posible to rely on clinical symptoms alone for diagnosis of an odontoid fracture. As a curiosity it may be mentioned that during the 19th century stethoscopy was used to auscultate the crepitations over the suspected odontoid fracture. It needs no comment that the method is hardly suitable. The only reliable means of diagnosis is a careful roentgen examination.

In this series of 26 patients, the initial roentgen examination was negative in 4 cases, one of them the patient who died from tetraplegia 3 days after injury; in this case autopsy revealed fracture of the odontoid with haematoma. In the remaining three cases, increasing severity

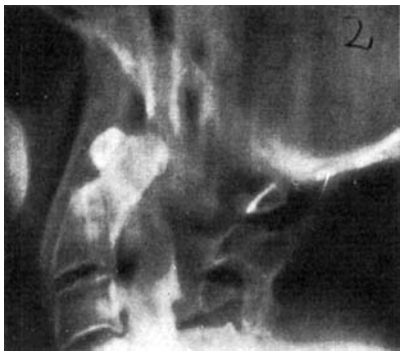


Fig. 7.
Same case as in fig. 6. Roentgenological appearance nineteen years after operation ad modum Albee. The fracture has healed in spite of the lack of incorporation of the graft.

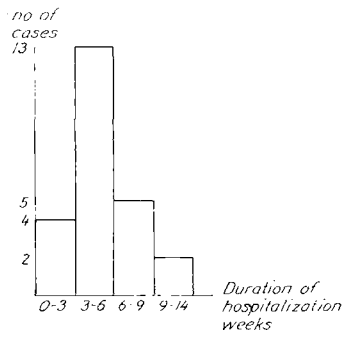


Fig. 8.
Duration of hospitalization in weeks.

of the symptoms led to a new roentgen examination; in one case, however, this was postponed until 4 months after injury when a forward displacement was thought to have occurred (Fig. 5). Roentgen examination was made in all cases with both a lateral and an antero-posterior projection, the latter through the open mouth. Voutilainen (1955) reported two cases in which the diagnosis was missed on ordinary roentgen examination but tomography some years later showed pseudarthrosis. He emphasized the importance of tomography in the follow-up of odontoid fractures, as this permits evaluation of the degree of callus formation. Other authors who have recommended tomographic examination are Amyes & Anderson, Rogers, Fischedick, and Schlesinger. As mentioned before, analysis of the 17 cases in this series for which the original roentgenograms were available, failed to establish a single case of os odontoideum. In the remaining nine cases drawings were available instead; these showed irregular fracture lines.

Therapy. As can be seen in Table 4, treatment of the patients included in this series has been somewhat heterogeneous. It was conservative, however, in all cases but one where Albee's operative fusion was performed with a tibial bone graft placed between the occipital bone and the spinous processes of C3. Half a year after the initial treatment, which had consisted solely of bedrest for one month, this patient had been readmitted to hospital with pronounced weakness in the arms

TABLE 4
Age, therapy, tomographic findings

Case nr.	Age	Initial therapy	Additional therapy
1	53	(None)	(After 4 m.) Glisson's sling 1 w., 1 kg.
2	41	(Bedrest + massage 5 w.)	Support 2½ m. Op.Plaster bed 1 m. Support 3 m.
3	75	(Glisson's sling 3 w., 1 kg.)	Bed rest 1 w.
4	7	Sandbags 3 w.	Bed rest 1 w.
5	61	Glisson's sling 5 w., 1 kg.	Support 1 m.
6	66	Glisson's sling 1 m.	
7	9	Glisson's sling 6 w.	Bed rest 1 m.
8	57	(None)	(After 14 d.) Support 1 w.
9	32	Plaster bed 1 m.	Support 1 m.
10	17	Glisson's sling 3 w.	Plaster collar 1 m. Plastic collar 3½ m.
11	65	Crutchfield tongs 4 d., 8 kg.	Sandbags 2 w. Plaster collar 2 m.
12	68	Crutchfield tongs 4 w., 8 kg.	Sandbags 3 w. Plaster collar 2 m.
13	57	Crutchfield tongs 3 d., 3 kg.	
14	78	Sandbags 5 w.	
15	42	(None, pat. confined to bed for 5 m. for fractured femur. Diagn. after 4 m.).	
16	57	Sandbags 5 w.	
17	52	Sandbags 3 w.	Plaster collar 4 w.
18	79	Sandbags 3 w.	Plaster collar 2 w.
19	73	Glisson's sling 3 w., 1½ kg.	Plaster collar 1 w. Bed rest 4 w.
20	73	Sandbags 1 m.	
21	68	Glisson's sling 1 d.	Sandbags 1 w. Support 3 w.
22	41	Sandbags 6 w.	Plaster collar 2 w.
23	43	Sandbags 2 w.	
24	69	Sandbags 6 w.	
25	85	Sandbags 4 w.	
26	78	Bed rest 2 w.	

and legs, severe pain, and limitation of movement. The roentgenogram showed a posterior displacement of the odontoid and atlas (Fig. 6). Although postoperative examination showed failure of the graft to take anywhere but in the spinous process of C3, protracted postoperative immobilization in plaster led to healing of the odontoid fracture (Fig. 7). If the patient who died as a direct result of the fracture is excluded, the total hospitalization time for the remaining 25 patients was 167 weeks, implying an average of approximately 7 weeks. By excluding one patient who was hospitalized for 5 months because of a

TABLE 4
and disability in the material.

Comment	Tomographic findings	Permanent disability except for limitation of movement
Not immediately diagnosed	–	25 % disab.
Only atlas fracture initially diagnosed	Bony healing (graft did not take)	25 % disab.
	–	None
	Bony healing	None
	Pseudarthrosis	None
	Bony healing	100 % disab.
	Bony healing	None
Not immediately diagnosed	Pseudarthrosis	None
	Bony healing	None
After 1 y. no healing; union after 1½ y.	Bony healing	None
	Bony healing	None
	Pseudarthrosis	None
Dead of tetraplegia after 3 d.	–	–
	Bony healing	None
	Pseudarthrosis	None
	Bony healing	None
	Pseudarthrosis	None
Dead of malignant tumour after 7 y.	–	None
Dead of pneumonia 9 w. after injury	–	–
Dead of pern. anaemia + thrombosis 3 m. after injury	–	–
	Pseudarthrosis	None
	Bony healing	None
	Pseudarthrosis	None
	Pseudarthrosis	None
Dead after 7 y. of ca. ventriculi	–	None
Dead after 4 y. of cardiac failure	–	None

fractured femur and during that time was not treated for his odontoid fracture, this figure is reduced to 6 weeks (Max. 9 w., min. 1 w.) (Fig. 8).

As mentioned before, there is a fairly high degree of disparity in the choice of treatment for these fractures. From a rewiev of the literature it appears, however, that the various authors predominantly adhere to three separate lines of thought:

1. *Exclusively conservative treatment.* Both Osgood, Lund & Hambly (1944) think immobilization in plaster alone sufficient treatment, provided the cast, which should go over the head and down to the lower

part of the chest, is worn for at least three months. So-called skeletal traction is recommended by Baumecker (1955) and Crutchfield (1954). The latter applies 2–5 Kg. of pull for 4–5 weeks, with frequent roentgen checks in order to avoid over-traction and to permit exact reduction. This is followed by an additional 6 months immobilization in plaster. Böhler also recommends Crutchfield tongs, but applies as much as 5 Kg. of pull. He rejects Glisson's sling as being too uncomfortable and painful for the patient. By placing the patient's head on a board run on ball-bearings, a frictionless support can be achieved. In this way the pull in Glisson's sling can be considerably reduced without impairment to the traction force along the longitudinal axis of the head (Hultén, 1958). A weight of ½ Kg. has proved quite adequate and easily tolerated by the patient, even for longer periods of time. Blockey & Purser also apply Crutchfield tongs, for 5 weeks, followed by a plaster collar to be worn for another 2–3 months. They consider this treatment adequate even if the fracture fails to unite during this time, on condition, however, that treatment is not delayed. Ziegler (1958) points out that healing of an odontoid fracture is not necessarily dependent on immobilization. The last-mentioned authors consequently consider the fibrous union which sometimes results, equally strong as bony healing.

2. *Conservative treatment with complementary operative treatment of fractures showing no tendency to heal and of redislocated fractures.* This therapeutic trend predominates. The various methods of conservative treatment with immobilization in plaster or some form of skeletal traction have been described in the preceding paragraph. The available surgical techniques are numerous, but on the whole most surgeons proceed along one of the following two lines:

a) operative stabilization with foreign material

b) operative fusion with bone.

Mixter & Osgood (1910) described some cases where they had operated upon the patients using strong silk which was wound around the posterior arch of the atlas and tied under the spinous process of the axis. Guillaume & Lubin (1941) bored two holes in the os occipitale and through them introduced a kangaroo tendon which was guided downwards around the dorsal arch of the atlas and under the spinal processes of the axis. They later changed to metal wire. (Guillaume, 1952). Crooks & Birkett uset fascia lata in an identical technique. Nicol (1952) used metal wire which was first tied around the spinous processes of the axis and then fixed under the spinous processes of the third vertebra. In his opinion, the head would be able to move more

freely after such an operation than after occipitocervical fusion. He did use a bone peg, however, in cases where the arch was fractured posteriorly. Occipitocervical fusion with bone grafts, as recommended by Albee, Adson, or Hibbs, has been practiced by Kahn & Yglesias (1935), Cone & Turner (1937), Charbonnel & Sicard (1938), Hambly (1944), Brussatis & Müller (1953), Bodart (1956), Libscomb (1957), Schlesinger (1958), and Makhlouf (1958). Grogono (1954) considered fusion of the first two vertebrae sufficient, while Schlesinger used a specially constructed H-clamp in this operation.

Charbonnel & Sicard regarded redislocation as the sole indication for surgical intervention. They prescribed continuous traction followed by immobilization in plaster for three months. All patients with pseudarthrosis were treated operatively by Libscomb & Makhlouf, the latter indicating the minimal interval before operation as 1½–2 years. Nicol & Javalet (1957), on the other hand, advocated operation in all cases where union had not occurred after three months. They believed that only 50 % of the fractures can be reduced or kept in reduced position by closed treatment. If surgical treatment for some reason should be contra-indicated, they prescribe two years of immobilization in plaster. Surgical intervention in cases of late displacement has been advised by numerous authors, Brussatis & Müller, Watson-Jones, Rogers, and Schlesinger. Amyes & Anderson recommended skeletal traction and immobilization in plaster for 6 months, and believed that the patient should be followed for another year. They find operative treatment indicated in cases where during or after this time a tendency towards displacement is observed. Watson-Jones gave general anaesthesia when reducing the fracture and applying the plaster. He considered operative treatment indicated also for irreducible fractures. Rogers (1957) adheres to the same opinion and considers a displacement exceeding 3 mm. indicative if attempts at reduction with Barton's tongs have failed.

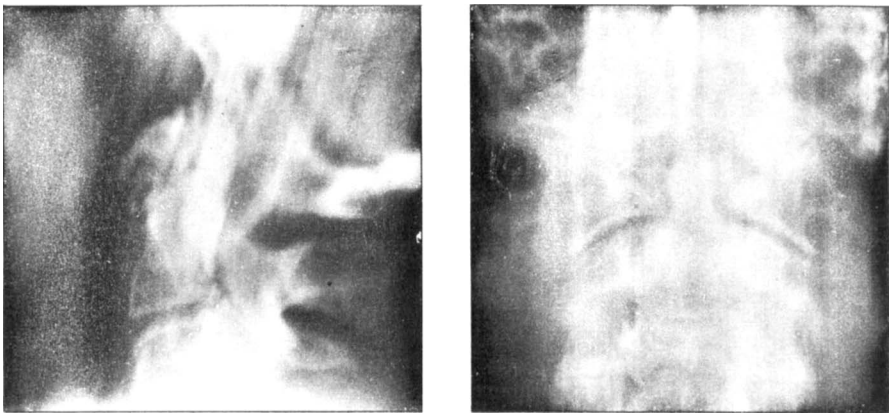
3. *Operative treatment in all cases.* This principle has been advocated by Kahn & Yglesias, Cone & Turner, Guillaume & Lubin, Guillaume, and Nicol, who all considered the risk of redislocation so real that surgical intervention is always indicated. Crooks & Birkett performed laminectomy and recommed it in all cases with acute or gradual signs of cord compression.

Complications. Redislocation, which in the literature is considered extremely dangerous, occurred in this series in two cases. In both cases, the initial treatment had been neglected. One of these patients was the 41-year old man who was operated upon as described in the fore-

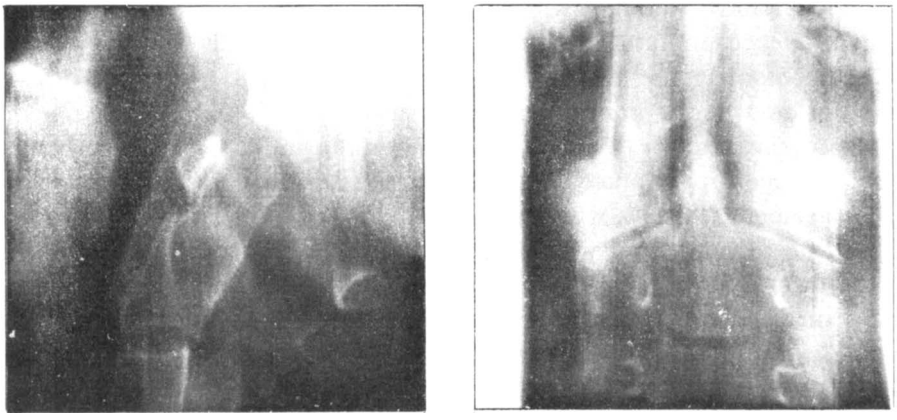
going. The other was a man included in the group with initially negative roentgenograms, who was discharged after a week's hospitalization for suspected commotio cerebri. On renewed examination when the patient was readmitted after 4 months, the posterior arch of the atlas could be palpated against the back wall of the pharynx. In the meantime the patient had, among other things, been employed in carrying tiles with a belt over the forehead which resulted in strong aggravation of his symptoms, consisting of pain, stiffness, numbness in one hand, and dysphagia. Roentgen examination at that time showed a pronounced forward displacement of the odontoid and atlas (Fig. 5). Attempts at reduction with Glisson's sling were unsuccessful because of the patient's unwillingness to submit to this treatment. After two months he returned to heavy manual work, although he received 25 % disability compensation because of stiffness and a slight loss of strength in the arms. The patient died of cancer ventriculi 6 years afterwards and the records show him to have continued with heavy manual work up to the time he became weakened by the metastatizing cancer.

The importance of immediate treatment is duly stressed by the fact that these two patients constitute two-thirds of all those in this series whose symptoms persisted and made them eligible for disability compensation (25 %). The third patient in this group was a 66 year old man who on admission displayed no signs of neurologic complications. Roentgen examination revealed a fracture through the base of the odontoid, which together with the atlas had displaced 6 mm. backwards. The patient was put in Glisson's sling but became psychotic and unruly after a few days, loosened the sling several times and got out of bed. These manoeuvres led to a general spasticity with bilateral extensor plantar reflex as well as numbness and loss of strength in the left arm and leg. This patient was awarded 100 % disability compensation. On examination 9 years after the accident there was scarcely any improvement in his condition, although tomograms showed the fracture to have healed (Fig. 9a and b).

One more patient included in this series had neurologic symptoms. This was a man, at the time of injury 41 years old, who was admitted with slight numbness in the arms and after a few days displayed general hyperreflexia, loss of strength in the right arm, and positive extensor plantar reflex on that side. Although treatment was restricted to immobilization with sandbags, his condition improved fairly rapidly and he could be discharged with a plaster collar after 8 weeks. The only persisting symptom at that time was a slight numbness in the



Figs. 9 a and b.
Tomogram of the odontoid of a male, age 75, who nine years earlier fractured his odontoid. The fracture has healed, but the patient still suffers from neurological symptoms, grave enough to make him unfit for work.



Figs. 10 a and b.
Tomogram of the odontoid of a male, age 52, who eleven years earlier fractured his odontoid and had neurological symptoms. Now the fracture has healed and the patient is asymptomatic.

right hand. The patient was convalescent for 8 months. On examination 10½ years later, he was completely asymptomatic and fully able to perform his job as a forester. Tomographic examination showed that the fracture had healed (Fig. 10a and b).

These four patients are the only ones in this series who had so-called late complications.

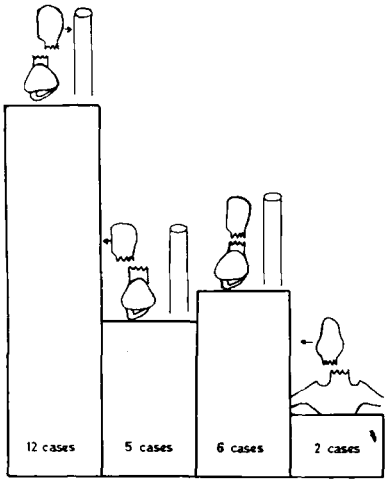


Fig. 11.
Direction of dislocation.

Fig. 11 shows that backwards displacement of the atlas and fractured odontoid predominated in this series (12 cases). Whether there was displacement in the case of the patient who died 3 days after injury cannot be deduced from the autopsy report.

Numerous authors have observed that the most serious symptoms and the most pronounced disability are found in cases of backwards displacement. Table 5, which gives the duration of disability in relation to the direction of displacement, shows that this trend was hardly present in this series. One of five patients with backwards displacement and three of twelve with forwards displacement had manifest neurologic symptoms, which in one case in the latter group subsequently disappeared completely.

Osgood & Lund (1928) found in the literature 10 cases of patients described, who had at a late stage become paralyzed following some minute trauma, such as sneezing or sudden motion of the head. Blockey & Purser, in agreement with most other authors, regarded late paraplegia as due to poor healing and gradual or sudden displacement. Mixter & Osgood, on the other hand, contended that myelitis could result from irritation of the spinal cord caused by a prolonged abnormal position, trauma, abnormal mobility, or compression as a result of excessive callus formation. They also maintained that late neurologic disorders may be due to chronic hypertrophia of the meninges and to damage to the marrow as a result of scar tissue development with

TABLE 5

Duration of disability in relation to direction of displacement.

Anterior displacement	No displacement	Posterior displacement	Lateral displacement
7 weeks	8 weeks	12 weeks	57 weeks
12 weeks	15 weeks	22 weeks	14 weeks
9 weeks	11 weeks	20 weeks	
25 % permanent disability	52 weeks	6 weeks	
	26 weeks	24 weeks	
		25 % permanent disability	
		100 % permanent disability	

compression of and alterations in the vascularization of the medulla. Amyes & Anderson distinguished between immediate and late complications and considered the former to be due to displacement, compression of the spinal cord, compression of one or more arteries, haemorrhage and compression of nerves, and contusion of muscles. The delayed complications were caused by displacement due to poor healing, with subsequent compression and gradual atrophy of the crossed pyramidal tracts, or with local necrosis of the spinal cord. They also mentioned excessive callus formation at the fracture site, osteomyelitis, chronic adhesive arachnoiditis and, finally, avascular necrosis of the odontoid as contributory factors to late complications.

RESULTS OF THE FOLLOW-UP

In the total series of 26 patients, 20 were subjected to a follow-up examination which in 18 cases included tomography. The remaining 6 patients had died before this investigation was started. In these cases, evaluation of working capacity, appreciable limitation of movement, and neurologic manifestations was based on hospital records and autopsy reports, supplemented by information obtained from the relatives.

The follow-up examination of the other 20 patients took place on an average 8½ years after injury (Fig. 12). Therapy, complications and roentgen findings are tabulated in Table 6.

The period of disability is shown in Table 7. This does not include patients over 70 years of age. By excluding both the patients who

TABLE 6

Results of follow-up examination.

Case nr.	Interval between injury & follow-up	Persisting Symptoms	Limitation of movement (+ = 25%; ++ = 25-75%; +++ = >75)	Healing
1	3 years 8 months	Severe pains in the neck, dysphagia, movement greatly limited (25 % disability)	+++	No roentgen examin.
2	19 „	Pains, loss of strength in arms and hands (25 % disability)	++	Bony healing
3	3 „ 6 „	Slight limitation of movement	+	No roentgen examin.
4	15 „ 6 „	Completely asymptomatic	—	Bony healing
5	12 „ 4 „	Slight limitation of movement	+	Pseudarthrosis
6	9 „	Tremor, loss of strength & numbness in left arm and hand and in both legs, stiffness (100 % disab.)	++	Bony healing
7	8 „ 6 „	Completely asymptomatic	—	Bony healing
8	5 „ 6 „	Slight pains, no other symptoms except limitation of movement	++	Pseudarthrosis
9	1 „ 7 „	Slight limitation of movement	+	Bony healing
10	1 „ 6 „	Slight limitation of movement	+	Bony healing
11	3 „ 6 „	Slight limitation of movement	+	Bony healing
12	3 „ 6 „	Slight limitation of movement	+	Pseudarthrosis
14	4 „ 3 „	Slight pains, in addition to limitation of movement	++	Bony healing
15	27 „ 5 „	Slight limitation of movement	+	Pseudarthrosis
16	5 „ 4 „	Slight limitation of movement	+	Bony healing
17	9 „	Slight limitation of movement	+	Pseudarthrosis
21	20 „ 4 „	Limitation of movement	++	Pseudarthrosis
22	10 „ 5 „	Slight limitation of movement	+	Bony healing
23	4 „ 7 „	Slight pains and slight limitation of movement	+	Pseudarthrosis
24	4 „ 9 „	Slight limitation of movement	+	Pseudarthrosis

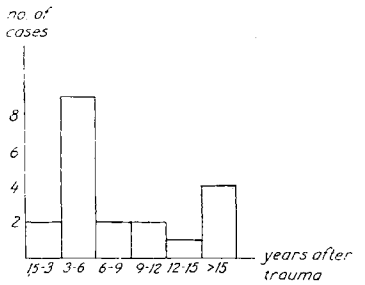


Fig. 12
Interval between injury and follow-up examination.

became eligible for permanent disability compensation and the case with fractura femoris, the average disability period for the remaining 15 patients is 20 weeks (max. 57 w., min. 6 w.). Rogers found an average of 8 months for his 9 patients, Charbonnel & Sicard 6 months.

At the time of this investigation serious symptoms persisted in three cases, without exception due to late complications. They are therefore grouped under that heading. As shown in Table 6, all others were at the time of examination in good condition, although in all but two cases movement was somewhat limited, generally to a very slight extent. The two patients who were found to be completely asymptomatic had at the time of accident been 7 and 9 years old, respectively.

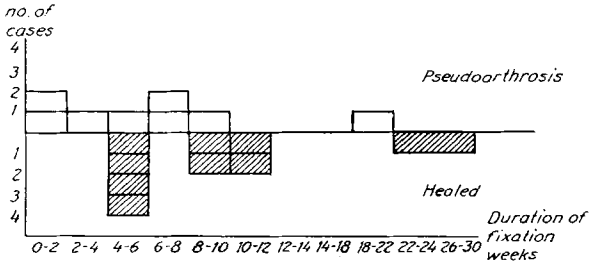


Fig. 13.
Duration of immobilization of healed and pseudarthrosis cases.

Of the 18 patients examined with tomography, 8 were found to have pseudarthrosis. As shown in Table 6, these patients had no symptoms other than the limitation of movement mentioned above. From this table one can furthermore deduce a certain difference in immobilization

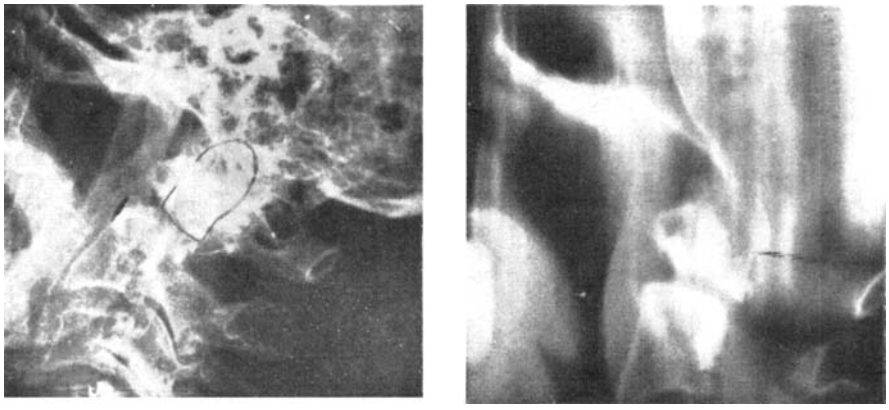
TABLE 7
Disability.
Not included are patients over 70 years of age.

Case nr.	Duration	Comment	Direction of displacement	Length of displacement > 3 mm.
1	7 w.	25 % permanent disability	Anterior	++
2	2 yrs.	50 % disability for 5 yrs., 25 % permanent disability	Posterior	+
3	7 w.	–	Anterior	—
4	8 w.	–	–	—
5	57 w.	–	Lateral	—
6		100 % permanent disability	Posterior	+
7	12 w.	–	Posterior	—
8	15 w.	–	–	—
9	11 w.	–	–	—
10	52 w.	–	–	—
11	22 w.	–	Posterior	+
12	20 w.	–	Posterior	+
15	15 mths. because of fractura femoris		Posterior	—
16	6 w.	–	Posterior	—
17	14 w.	–	Lateral	—
21	26 w.	–	–	—
22	34 w.	–	Posterior	+
23	12 w.	–	Anterior	—
24	9 w.	–	Anterior	—

time between the unhealed and the healed fractures; the former had been immobilized for 6 weeks on an average, the healed fractures for 11 weeks. The difference is not significant, however, ($M = 6.2 \pm 2.3$; $M = 10.8 \pm 4.4$; $D = 4.62 \pm 4.97$) (Fig. 13).

DISCUSSION

From the preceding account it is clear that fracture of the odontoid is no uncommon injury. Odontoid fracture may be expected to constitute 1–2 % of all vertebral fractures. Fig. 4 shows the increase in incidence during the past decade. Meyerding (1955) observed that more cases of fracture of the odontoid would be diagnosed if roentgen examination was performed in all cases of even moderate pain after some trauma against the head. The present material supports this be-

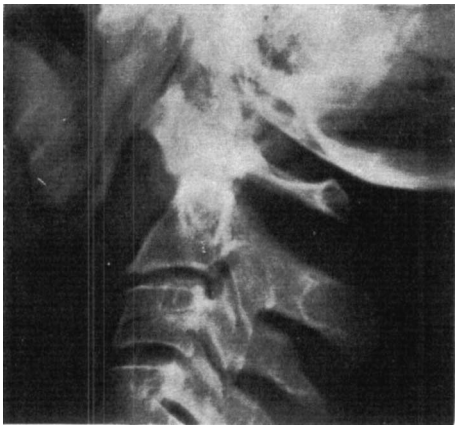


Figs. 14 a and b.
Initial (a) and follow-up (b) pictures four years after fracture of the odontoid process in a male, age 68. Pseudarthrosis is clearly visible on the tomogram. He is still fully employed and able to pursue his hobby of bicycle racing.

lief. Two patients were discharged without treatment, one of them after roentgen examination had proved negative. In two more cases the initial roentgenogram was considered negative. Not less than 9 patients considered their symptoms so negligible that they did not immediately consult a doctor.

The increasing frequency during the past decade is mainly due to traffic accidents. The patients with fractures due to this kind of accident were all admitted to hospital in the period between 1946–1957. Consequently, a further increase must be expected in the future.

The two patients in this series with late displacement at first went untreated. Of the 18 patients who were examined with tomography, no less than 8 were found to have pseudarthrosis. The period of observation of these patients was 11 years on an average. None of them had any persisting symptoms at the time of examination other than limitation of movement; nor had they in the interval before noticed any symptoms which could be attributed to a displacement of the fracture; this despite the fact that many of them had performed heavy manual work and in the course of it had even sustained fairly strong traumata to the head (Figs. 14, 15, 16, 17). This confirms Blockey & Purser's observation that fibrous union may be as strong as bony healing. Of the 26 patients in this material, one died as a direct consequence of the injury. Of the remaining patients, neurologic disorders of varying intensity had been present in 4 cases. Only one patient had



a

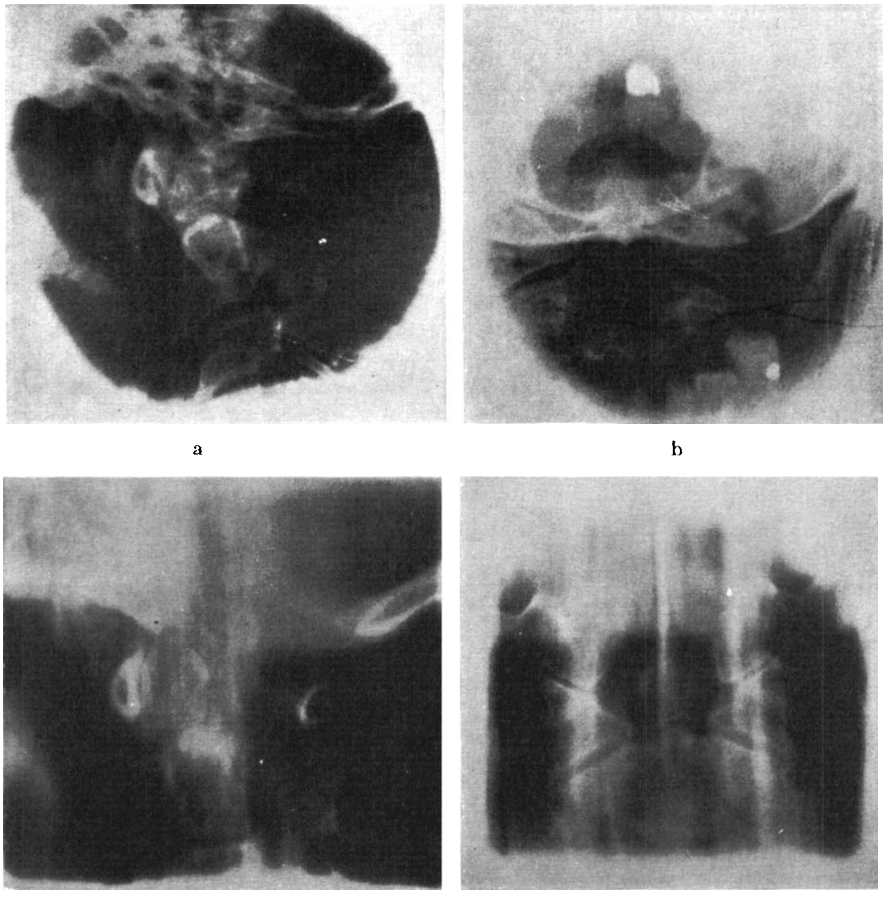
b

c

Figs. 15 a, b and c.

Initial (a) and follow-up (b and c) pictures five years after fracture of the odontoid process in a male, age 43. Pseudarthrosis is clearly visible on the tomogram. The patient does heavy labour as a farmer.

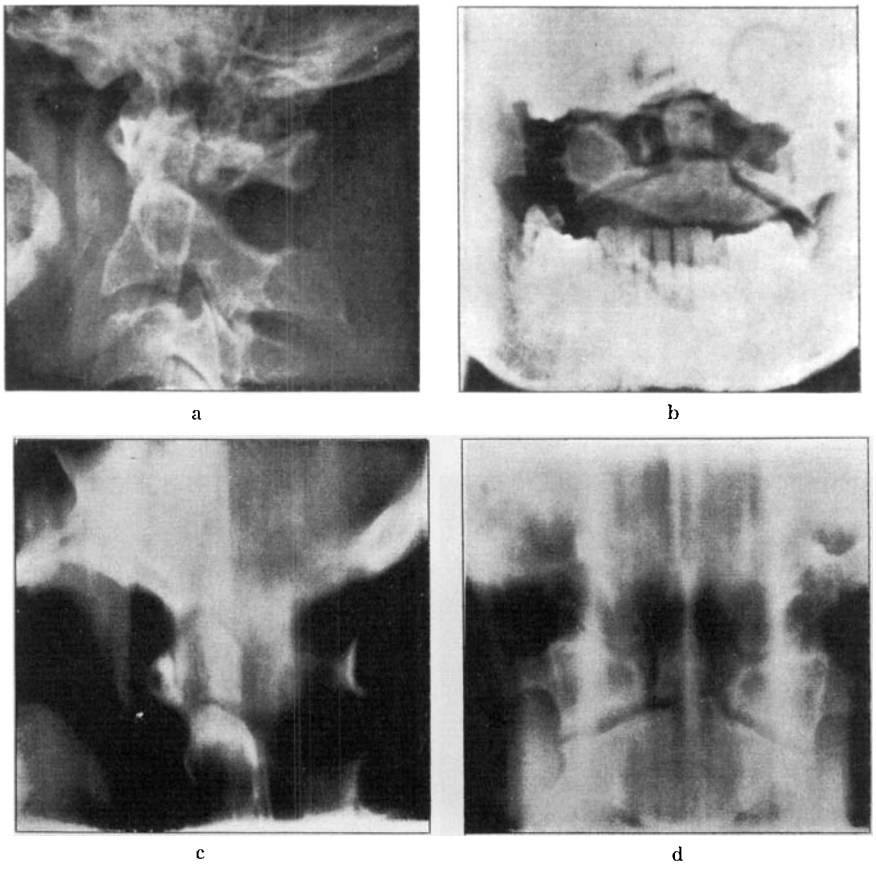
become 100 % disabled due to weakness of the arms and legs, whereas two patients had persistent symptoms entitling them to 25 % disability compensation for life. The investigation has demonstrated, therefore, that the prognosis for fracture of the odontoid is considerably more favourable than what has been generally believed. This conclusion applies to diagnosed fractures. In how many cases death is immediate and the fracture never diagnosed, is impossible to ascertain.



Figs. 16 a, b, c and d.

Initial (a and b) and follow-up (c and d) pictures five years after fracture of the odontoid process in a male, age 69. On the lateral tomogram the pseudarthrosis and forward luxation are easily seen. In spite of this, the patient has no symptoms at all from his broken and dislocated neck.

From the results of the follow-up study described in the foregoing, a conclusion may be drawn that treatment should be conservative. Only one patient in this material was operated upon because of late displacement. The results would certainly not have been worse if treatment had been restricted to immobilization in plaster or some other type of immobilization, since the follow-up examination showed that the bone graft had failed to take (Fig. 9). According to current opinion, an odontoid fracture should be immobilized for at least one year, but the results



Figs. 17 a, b, c and d.
Initial (a and b) and follow-up (c and d) pictures nine years after fracture of the odontoid process in a male, age 52, who still is a devoted tennis player. He has no persisting symptoms. Pseudarthrosis is clearly visible on the tomograms.

of the present investigation suggest that an immobilization period of around 3 months suffices (Table 6). In seven cases in this series immobilization was achieved merely with sandbags. The results for this group do not differ from those for patients treated with skeletal traction and/or immobilization in plaster. As in all fracture management, adequate reduction should of course be attempted if the fracture is displaced in one or the other direction. This procedure is most satisfactorily performed with Crutchfield tongs or similar appliances. It is questionable whether surgical intervention is ever indicated in the initial treatment. It should be considered, however, in neglected cases

with roentgenographic evidence of late displacement, but only after adequate attempts at closed reduction together with 3–4 months immobilization in a plaster collar have failed. In such cases occipito-cervical fusion is considered the method of choice.

SUMMARY

Twenty-six cases of fracture of the odontoid process of the axis are presented. Of these, twenty were subjected to a follow-up examination on an average 8 years after injury. In 18 cases this examination included tomography. The remaining 6 patients had died before this study was begun, but it was possible to evaluate these cases with respect to more serious after-effects.

Odontoid fractures constituted in this material 1–2 % of all vertebral fractures and 10 % of all fractures of the cervical spine. The most common cause was a blow to the head due to either a fall from a height or traffic accidents.

The initial symptoms were as a rule slight. In addition to pain, 20 patients were found to have a stiff neck and 6 complained of instability. Roentgen examination was required for correct diagnosis, whereas tomography was necessary for accurate evaluation of healing.

One patient died of tetraplegia. The mortality rate in this material was 4 %.

Treatment consisted of immobilization with sandbags or plaster, or skeletal traction, for 2–4 months. Complications were in this material relatively few; in all cases they were due to neglect of initial treatment. In no case where treatment had been instituted immediately could any after-effects of the injury be observed except for a slight loss of mobility. Late displacement occurred in two cases, 2 and 4 months, respectively, after injury. Neither of these patients had in the first instance received treatment, owing to the fact that it had been impossible to identify the fracture on roentgen examination. The average period of hospitalization was 7 weeks, of disability 20 weeks. Altogether, three patients had persistent symptoms consisting of weakness of the arms and hands, as well as pain and stiffness of the neck. Of 18 patients examined with tomography, 8 had pseudarthrosis after an average observation period of 11 years. These patients had fewer symptoms than those with healed fractures. The unhealed fractures had been immobilized for about 6 weeks, those that had heated for 11 weeks. Statistically, however, the difference has no certain significance ($D = 4.6 \pm 5$).

It has been demonstrated that fracture of the odontoid, if adequately treated, does not constitute a vital risk, nor causes any appreciable disability.

RESUME

Vingt-six cas de fracture de l'odontoïde de l'axis sont rapportés. Parmi ceux-ci, 20 ont été soumis à un réexamen, en moyenne 8 ans après la lésion. Dans 18 cas, cet examen a compris la tomographie. Les autres 6 malades sont morts avant que cette étude n'ait été entreprise, mais il a été possible d'évaluer ces cas en ce qui concerne les suites les plus sérieuses qui se sont manifestées.

Les fractures de l'odontoïde constituent dans ces observations 1 à 2 % de toutes les fractures vertébrales et 10 % de toutes les fractures de la colonne cervicale. La cause la plus commune a été un coup sur la tête dû à une chute d'une certaine hauteur ou à un accident de la circulation.

Les symptômes initiaux ont en général été faibles. En plus des douleurs, on a constaté chez 20 malades une raideur de la nuque, 6 se plaignant d'instabilité. L'examen radiologique était nécessaire pour corriger le diagnostic, tandis que la tomographie l'était pour évaluer minutieusement la guérison.

Un malade est mort de tétraplégie. Le taux de la mortalité dans ce matérial d'observation a été de 4 %.

Le traitement a consisté dans l'immobilisation au moyen de sachets de sable ou de plâtre ou de traction osseuse durant 2 à 4 mois. Dans ces observations, les complications ont été relativement peu nombreuses; dans tous les cas elles ont été dues au défaut de traitement initial. Dans aucun des cas où le traitement a été entrepris immédiatement, des suites de la lésion ont été observées, sauf une légère perte de la mobilité. Un déplacement tardif est apparu dans deux cas, 2 et 4 mois respectivement après la lésion. Aucun de ces malades n'avaient été mis en traitement en premier lieu du fait qu'il avait été impossible d'identifier la fracture à l'examen radiologique. La période moyenne d'hospitalisation a été de 7 semaines, d'incapacité de travail de 20 semaines. Dans l'ensemble, ces malades présentent des symptômes persistants consistant dans une faiblesse des bras et des mains, de même que douleurs et raideur de la nuque. Sur 18 des malades chez lesquels la tomographie a été pratiquée. 8 avaient une pseudarthrose après une période moyenne d'observation de 11 ans. Ces malades avaient moins de symptômes que ceux dont les fractures étaient guéries. Les fractures

non guéries ont été immobilisées pour une période d'environ 6 semaines, celles qui étaient guéries pour 11 semaines. Toutefois, au point de vue statistique, cette différence n'a aucune importance ($D = 4{,}6 \pm 5$).

Il a été démontré que les fractures de l'odontoïde, si elles sont dûment traitées, ne constituent pas un risque vital et ne causent pas non plus une incapacité appréciable.

ZUSAMMENFASSUNG

Sechsundzwanzig Brüche des Zahnfortsatzes des Epistropheus werden vorgestellt. Von diesen wurden zwanzig durchschnittlich 8 Jahre nach dem Unfall einer Nachuntersuchung unterzogen. In 18 Fällen wurde auch eine Tomographie vorgenommen. Die übrigen 6 Patienten waren gestorben ehe diese Untersuchung begonnen wurde, aber es war doch möglich diese Fälle hinsichtlich ernsterer Folgeerscheinungen zu bewerten.

Die Brüche des Zahnfortsatzes stellten in diesem Materiale 1–2 % aller Wirbelbrüche und 10 % aller Brüche der Halswirbelsäule dar. Die häufigste Ursache war ein Schlag auf den Kopf, hervorgerufen durch Fall von einer Höhe oder durch einen Verkehrsunfall.

Die Frühsymptome waren in der Regel leicht. Abgesehen von den Schmerzen hatten 20 Patienten einen Steifen Nacken und 6 klagten über mangelhafte Stabilitet. Die Röntgenuntersuchung war zur Stellung einer richtigen Diagnose erforderlich, während die Tomographie zur genauen Beurteilung des Heilungsprozesses notwendig war.

Ein Patient starb an Tetraplegie. Die Sterblichkeit in diesem Materiale war 4 %.

Die Behandlung bestand in Ruhigstellung mittels Sandsäck n und Gips oder in Extension am Skelett für 2–4 Monaten. Komplikationen traten in diesem Material verhältnismessig selten auf. In allen Fällen waren sie durch Versäumnis des Behandlungsbeginns bedingt. In keinem Falle, in dem die Behandlung sofort eingeleitet wurde, konnten irgenwelche Spätschädigungen beobachtet werden, abgesehen von einer leichten Herabsetzung der Mobilitet. Späte Verschiebungen traten in zwei Fällen, 2 beziehungsweise 4 Monate nach dem Unfalle, auf. Keiner dieser Patienten hatte unmittelbare Behandlung erhalten, da der Bruch röntgenologisch nicht gefunden werden konnte. Die durchschnittliche Zeit des Krankenhausaufenhaltes war 7 Wochen, die der Arbeitsunfähigkeit 20 Wochen. Insgesamt 3 Patienten hatten Dauersymptome, die sowohl in einer Schwäche der Arme und Hände als auch in Schmer-

zen und Steifheit des Nackens bestanden. Von den 18 mittels Tomographie untersuchten Patienten hatten 8 eine Pseudarthrose nach einer Beobachtungszeit von durchschnittlich 11 Jahren nach dem Unfall. Diese Patienten hatten weniger Symptome als jene mit geheilten Brüchen. Die ungeheilten Brüche waren für ungefähr 6 Wochen, die geheilten für 11 Wochen ruhiggestellt worden. Statistisch hat der Unterschied jedoch keine sichere Bedeutung ($D = 4{,}6 \pm 5$).

Es wurde somit nachgewiesen, dass der Bruch des Zahnfortsatzes, wenn entsprechend behandelt, weder lebensgefährlich ist, noch ausgesprochene Invaliditet hervorruft.

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