Fractures of the Odontoid Process of the Axis*

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ABSTRACT: Odontoid fractures were classified into three types, and, in a series of forty-nine fractures, two avulsion, thirty-two body, and fifteen basilar fractures were treated and followed for an average of twenty-two months (range, six months to nineteen years). Body fractures are most prone to non-union and surgery (spine fusion) is commonly required in this group.

Fractures of the odontoid process and the body of the axis have always aroused interest but there is little agreement on the best method of treatment and the long-term prognosis of these injuries. The incidence of non-union of fractures of the odontoid process has been variously estimated to be as low as 4.8 per cent and as high as 62.8 per cent [1,2,8-10]. Osgood and Lund reviewed the relevant literature in 1928, and found only fifty-five reported cases of fracture of the odontoid process. They noted that most previous authors had found a high incidence of neurological involvement and death, but suspected that this was related to many of the reported cases being from autopsy material. However, in ten of their reported patients paralysis was not present at the time of initial injury and subsequently caused death after a second, trivial injury. Osgood and Lund did state that the general impression at the time of the 1928 article was that union rarely occurred. Until the time of their review in 1928, there were only three reported cases of operative treatment for this fracture. Two of the three had previously been reported by Mixter and Osgood in 1910.

Subsequent opinions also varied as to the frequency of neurological involvement, both at the time of initial injury and many years later as delayed myelopathy. Schwarz and Wigton reported two cases of delayed myelopathy — one some eighteen years after injury and the other five years after trauma to the head and neck. Both were thought to be secondary to an ununited fracture of the odontoid process with instability.

In our own review of the literature we found over fifty reported cases of delayed myelopathy, varying widely in degree of involvement, including spastic hemiparesis, urinary and fecal incontinence, Brown-Séquard syndrome, monoparesis, quadriplegia, dysphagia, and neuralgia of the occipital nerves. Some of the neurological defects were progressive. Others were intermittent or static. Some began at the time of injury, while others had a delayed onset as long as forty-eight years following the initial injury. Recently, Schatzker and associates reported that of thirty-seven patients with fractures of the odontoid process, non-union developed in twenty-three (63 per cent), and Roberts and Wickstrom recently reported that in a series of fifty fractures of the odontoid process, forty of which were treated conservatively, eight developed non-union (20 per cent). They thought that delay in immobilization and inadequate immobilization contributed to the rate of non-union, and concluded that fractures of the odontoid process should be immobilized for twenty weeks in traction or a Minerva cast. If union was not present at the end of that period, they recommended cervical fusion. Schatzker and associates classified the frac-

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Dallas, Texas, January 18, 1974.

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tures as high or low depending on whether the fractures were above or below the accessory ligaments, but found no difference in the rate of union. They also correlated the degree and direction of displacement and found that the rate of non-union correlated with the degree but not with the direction of displacement.

The purpose of this article is to report our experience with fractures of the odontoid process treated at the Campbell Clinic and City of Memphis Hospital during an eighteen-year period from January 1954 through June 1972. This study was undertaken to determine the results of different methods of treatment and to formulate a more scientific plan as to how they should be treated in the future.

Methods, Materials, and Results

During the period from January 1954 through June 1972, we were able to locate a total of sixty patients who had been seen at the Campbell Clinic and City of Memphis Hospital with fractures of the odontoid process. Nine patients were doing well and were neurologically intact when last seen but had too short a follow-up for the final outcome to be determined. Two patients had died within one week after injury. In one, a child, the

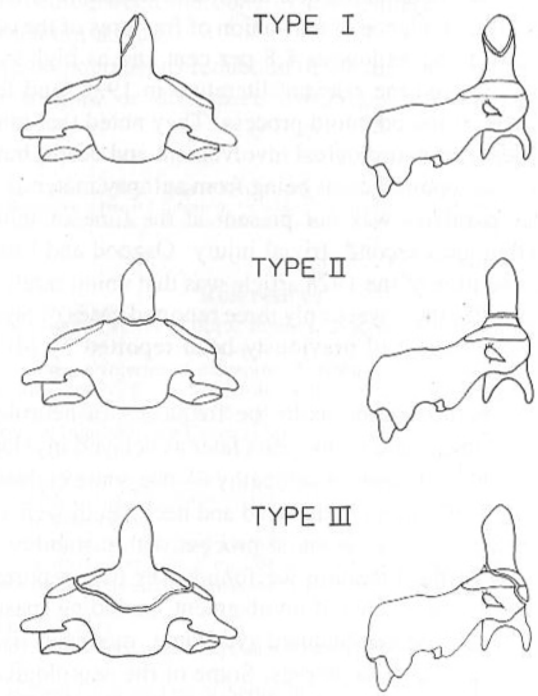

FIG. 1

Three types of odontoid fractures as seen in the anteroposterior and lateral planes. Type I is an oblique fracture through the upper part of the odontoid process itself. Type II is a fracture at the junction of the odontoid process with the vertebral body of the second cervical vertebra. Type III is really a fracture through the body of the atlas.

cause of death was an associated severe head injury. The other death was in an eighty-six-year-old man who died suddenly while in traction. Permission for autopsy was not granted and the cause of death was unknown. The remaining forty-nine patients were followed for a minimum of six months. The longest follow-up was nineteen years and the average was slightly over twenty-two months. The patients were rather evenly distributed according to age by decades; the youngest was three years old and the oldest was seventy-six, with an average of 40.7 years. Of the forty-nine patients in this series, the mechanism of injury was a vehicular accident in thirty-five. Ten patients incurred the fracture in a fall and four received blows on the back of the head.

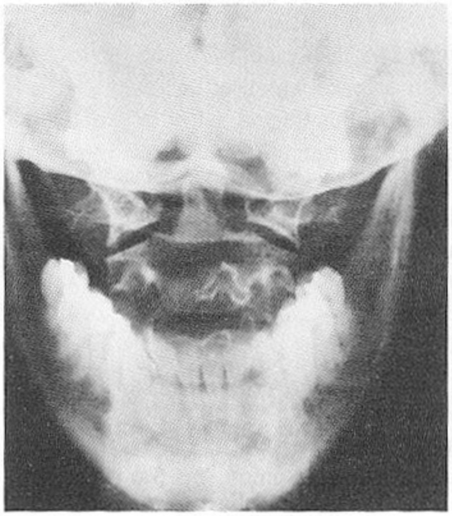

FIG. 2-A

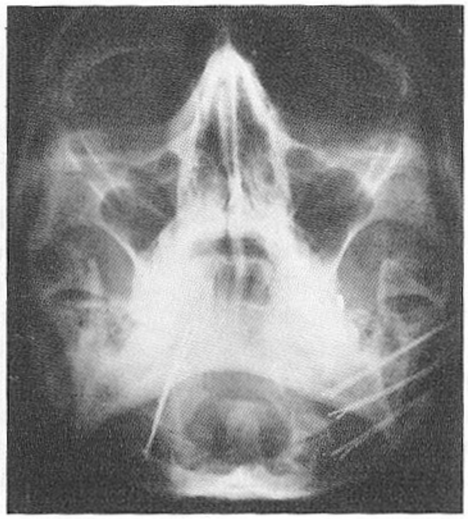

FIG. 2-B

Figs. 2-A, 2-B, and 2-C: A Type-I fracture of the odontoid process located high in the odontoid process.
Fig. 2-A: The open-mouth odontoid view.
Fig. 2-B: Water's view. The odontoid is located at the center of the foramen magnum in this view.

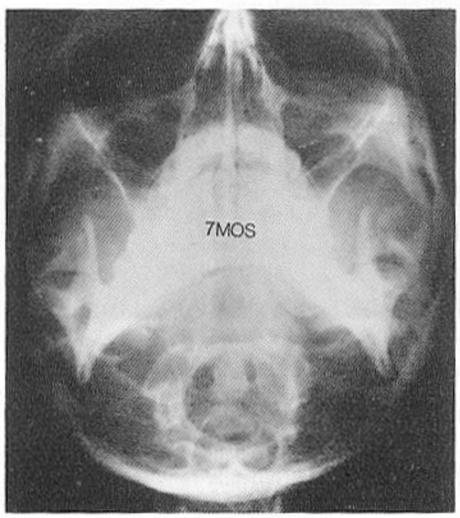

FIG. 2-C

The fracture healed by seven months with conservative treatment.

Other associated injuries were frequent in this group of patients. They included cerebral concussion in twelve, extremity fractures in ten, and fractures of the facial bones in four. Of special interest were four patients who had an associated fracture of the cervical spine.

After reviewing the roentgenograms of the patients carefully, we were able to identify three types of fractures based on the anatomical location of the fracture line (Fig. 1). Type I is an oblique fracture through the upper part of the odontoid process itself and probably represents an avulsion fracture where the alar ligament attaches to the tip of the odontoid process. Type II is a fracture occurring at the junction of the odontoid process with the body of the second cervical vertebra. In Type III, the fracture line extends downward into the cancellous portion of the body and is really a fracture through the body of the axis. We further classified each of these types as displaced or undisplaced. As far as we can determine this classification has not been published before.

Union and Non-Union

There were only two Type-I fractures (Figs. 2-A, 2-B, and 2-C), and both were undisplaced. Both healed uneventfully. A collar or a brace was used as treatment and no particular problems were encountered. The location of this fracture is too high in the odontoid process to lead to instability of the first cervical vertebra on the second even if non-union had developed.

There were a total of thirty-two Type-II fractures. Of these, fourteen were undisplaced and eighteen were displaced two millimeters or more as seen on the lateral roentgenogram. All of the fourteen undisplaced Type-II fractures were treated by traction either in a head halter or in tongs for approximately six weeks, followed by a brace. Nine of the fourteen united in an average of 6.4 months (Figs. 3-A and 3-B). Non-union developed in five of the undisplaced Type-II fractures. There were eight displaced Type-II fractures of the odontoid process treated conservatively by Crutchfield-tong traction for approximately six weeks, followed by bracing. Five united and non-union developed in three. Of the five fractures that united, the average time to union was 5.6 months.

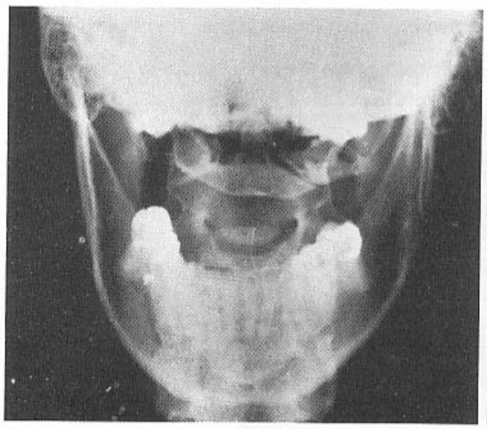

FIG. 3-A

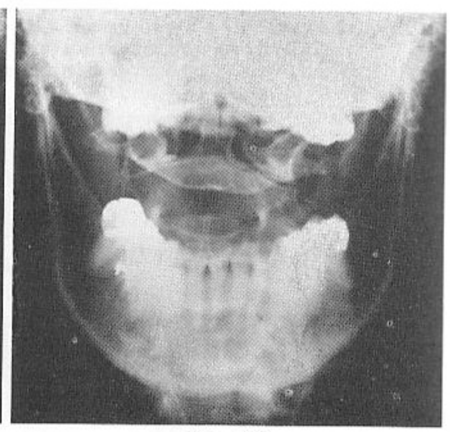

FIG. 3-B

Figs. 3-A and 3-B: A Type-II undisplaced odontoid fracture.

Fig. 3-A: The open-mouth odontoid view. The fracture could not be visualized in the lateral projection. Excellent quality roentgenograms are a necessity and tomograms should be made if ordinary roentgenograms leave any doubt.

Fig. 3-B: At four months the fracture appears to be uniting. Flexion-extension lateral views showed no change in the alignment of the first and second cervical vertebrae.

Of the eighteen displaced Type-II fractures, ten had primary wiring and fusion. The decision to carry out a fusion was made by the individual surgeon and was not based on any common rationale. Most patients had fusion from the first cervical vertebra to the second or third cervical vertebra (Figs. 4-A, 4-B, and 4-C). One patient with an associated fracture of the ring of the first cervical vertebra had fusion from the occiput to the second cervical vertebra. In eight of the ten fusions for Type-II displaced fractures, the fusion was successful without any significant problems. In one patient with delirium tremens who removed his traction, the wire pulled loose, and another fusion was carried out from the occiput to the second cervical vertebra. The fracture and fusion finally united. In one other attempted fusion in a three-year-old child with a Type-II displaced fracture, bone-bank bone was used along with wiring of the first cervical vertebra to the second. The bone was rapidly resorbed but the odontoid fracture united. The wire subsequently broke but since the fracture had united, stability had been restored.

In nine of the ten Type-II displaced fractures treated by primary fusion, the odontoid fracture united coincident with the wiring and fusion. In one patient, non-union of the odontoid process persisted in spite of a solid posterior fusion.

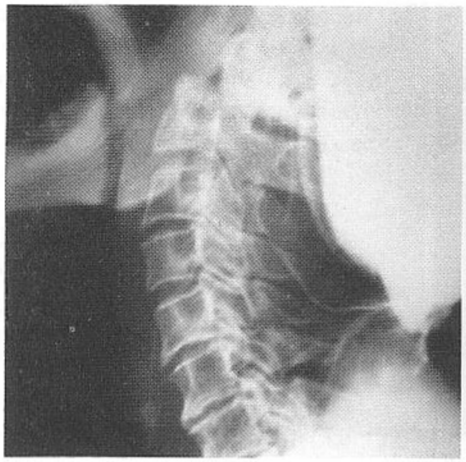

FIG. 4-A

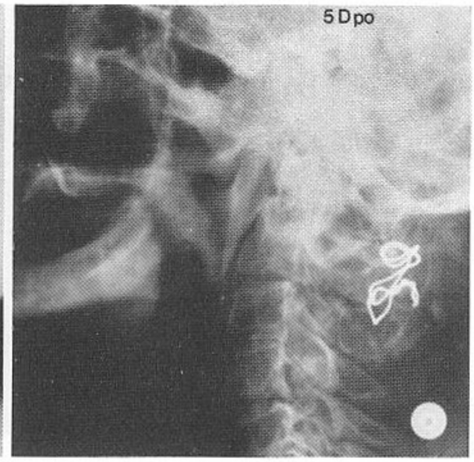

FIG. 4-B

Figs. 4-A, 4-B, and 4-C: A Type-II odontoid fracture.

Fig. 4-A: Lateral roentgenogram. Note the marked posterior displacement of the odontoid process in relation to the body of the second cervical vertebra.

Fig. 4-B: Five days after reduction of the fracture with skeletal traction, posterior wiring of the first cervical vertebra to the second, and fusion with autogenous iliac-bone grafts. Reduction prior to fusion is very important in preventing delayed long tract signs. They may develop even with a successful fusion if correct alignment is not restored.

Fig. 4-C: At five months the fusion appears solid and the fracture of the odontoid has united in good position.

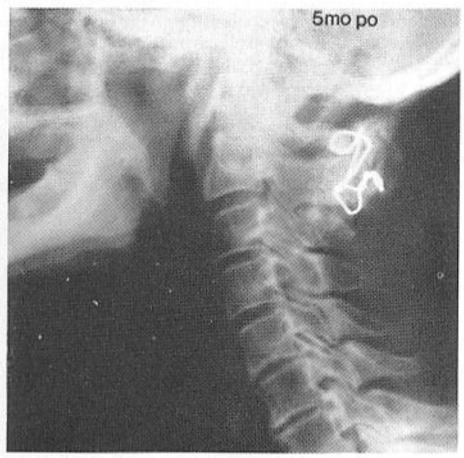

FIG. 4-C

There were fifteen Type-III fractures that extended into the body of the second cervical vertebra. Five were undisplaced. Four of the five were treated in traction followed by braces and all united without difficulty. The average time to roentgenographic union for this group was 5.5 months. One was treated by primary wiring and fusion. Both the fusion and the fracture were solidly united by twelve weeks.

There were ten Type-III fractures that were initially displaced when first seen. Nine were treated non-operatively by traction followed by the use of a brace or cast. Eight united in satisfactory position in an average of four months (Figs. 5-A and 5-B). One patient with a Type-III displaced fracture was first seen five weeks after injury and had received no previous treatment. He was then treated with a collar or a brace for eight months. When last seen, fifteen months after injury, he complained of neck pain and dysphagia with an established non-union. We were unable to locate him for additional follow-up.

The tenth patient was treated by primary fusion. An operative infection developed that was apparently related to an existing infection at the site of tong insertion. In spite of this the fracture of the odontoid process healed and the fusion solidified. The infection resolved six months after fusion, when the wire was removed. When the patient was last seen, sixteen months later, he was asymptomatic and free of infection.

For the over-all group of fractures treated initially by non-operative methods, there were two Type-I undisplaced fractures and both united. There were twenty-two Type-II

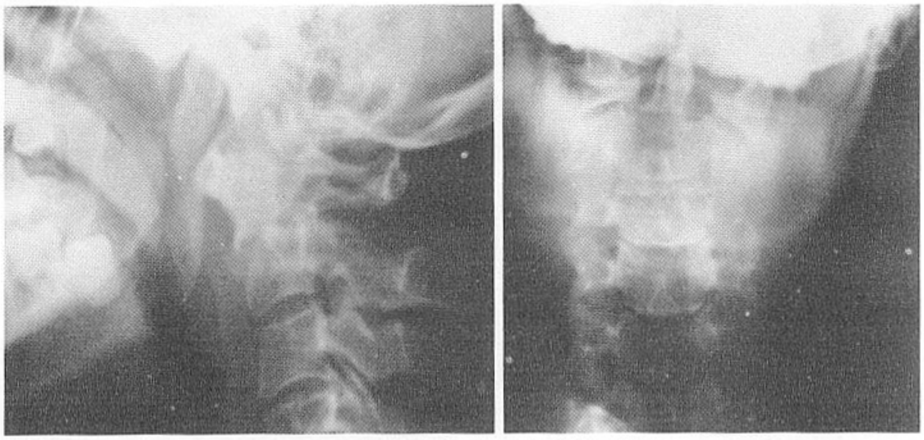

FIG. 5-A

Figs. 5-A and 5-B: A Type-III odontoid fracture.
Fig. 5-A: Lateral roentgenogram and open-mouth odontoid view. The odontoid process is displaced five millimeters anteriorly in relationship to the body of the second cervical vertebra. It was reduced almost completely with 2.6 kilograms of skeletal traction.

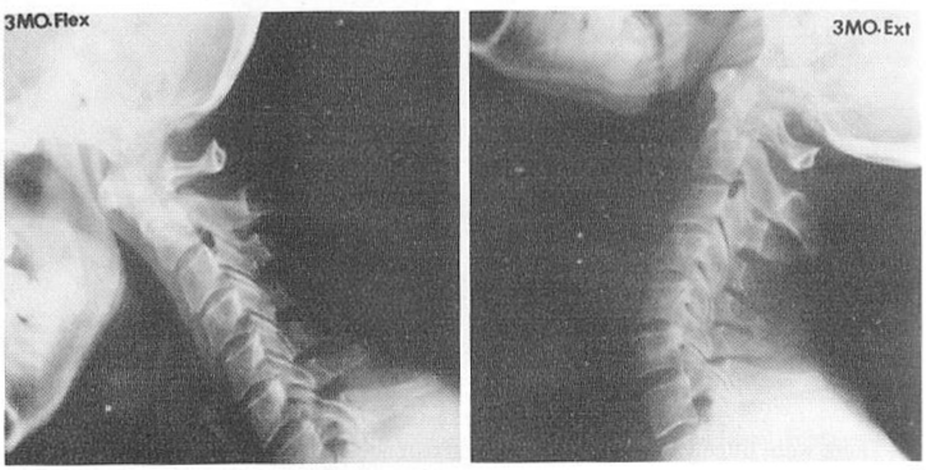

FIG. 5-B

Lateral roentgenograms in flexion and extension after three months of treatment in traction followed by bracing. The fracture has united in good position and is stable.

fractures (fourteen undisplaced and eight displaced) of which fourteen united and nonunion developed in eight. There were thirteen Type-III fractures (four undisplaced and nine displaced) of which twelve united and one did not. Thus, there appears to be a definite correlation in this series between the type of fracture and the chance of the fracture uniting. However, we could find no correlation between the degree or the direction of displacement and the percentage of fractures that united with conservative treatment.

Odontoid Fractures in Children

Five children were included in the sixty patients in the series. One, a three-year-old, was one of the two who died in the first week after injury. The other four are included in the forty-nine patients who were followed. None of the four had any neurological findings. Two of the children were five years old, one was six, and one was three. The three-year-old child, previously mentioned, was treated by primary wiring and fusion with grafts from the bone bank. The grafts resorbed and the wire broke, but the Type-II fracture that was initially displaced united in good position and was stable. The other three children were all treated in traction for six weeks followed by Minerva casts (Figs. 6-A and 6-B). Their fractures united in an average of four months and they had no further difficulty. Two of the three who were treated conservatively had displaced Type-II fractures and one had a displaced Type-III fracture.

The series is obviously too small for conclusions to be formulated as to how fractures of the odontoid process in young children should be treated. It appears, however, that the prognosis for union in Type-II lesions may be better than in adults. Possibly this is because they are epiphyseal separations, which are known to unite rapidly in other locations. We recently saw a three-year-old girl with a displaced Type-II fracture. It was reduced and treated in a halo cast. Her roentgenograms at ten weeks showed early healing of the fracture.

Probably most odontoid fractures in children under the age of ten should be given a chance to unite with conservative treatment, and fusion should be reserved for any non-unions that develop.

Early Neurological Involvement

Of the sixty patients seen with acute fractures of the odontoid process, forty-five had no neurological involvement when seen initially that was thought to be related to the fracture. Fifteen patients had some neurological defects, ranging from paraparesis to a Brown-Séquard syndrome. Ten had minor neurological findings initially, such as mild upper-extremity weakness, hyperreflexic lower extremities, and decreased sensation in the occipital area. The neurological findings in almost all of the patients with minor changes resolved with treatment. Three of the five patients with major neurological involvement had almost complete return of function after treatment. Two had very little improvement and were quadriparetic when last seen.

Late Myelopathy

Of the forty-nine patients in the series, forty either had healing of the fracture or had primary wiring and fusion. There were nine patients with non-union who did not have fusion initially, who had potential instability at the level of the first and second cervical

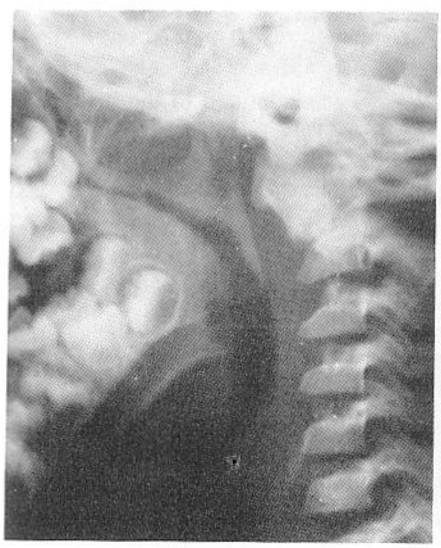

FIG. 6-A

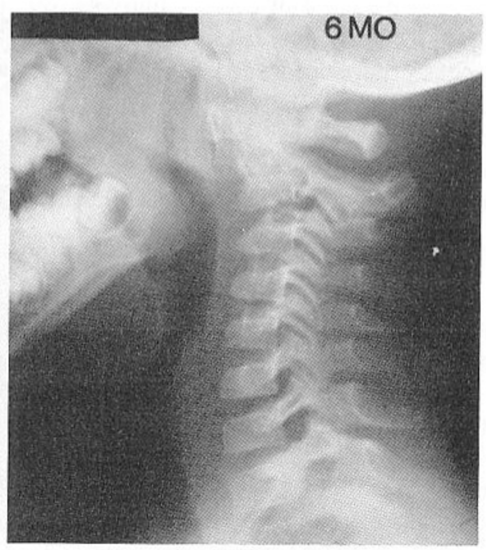

FIG. 6-B

Figs. 6-A and 6-B: A Type-II odontoid fracture with anterior displacement in a five-year-old child.

Fig. 6-A: Lateral roentgenogram. This may represent a traumatic epiphyseal separation rather than a true fracture.

Fig. 6-B: Six months after treatment in traction followed by a Minerva jacket, the fracture has united and stability has been restored.

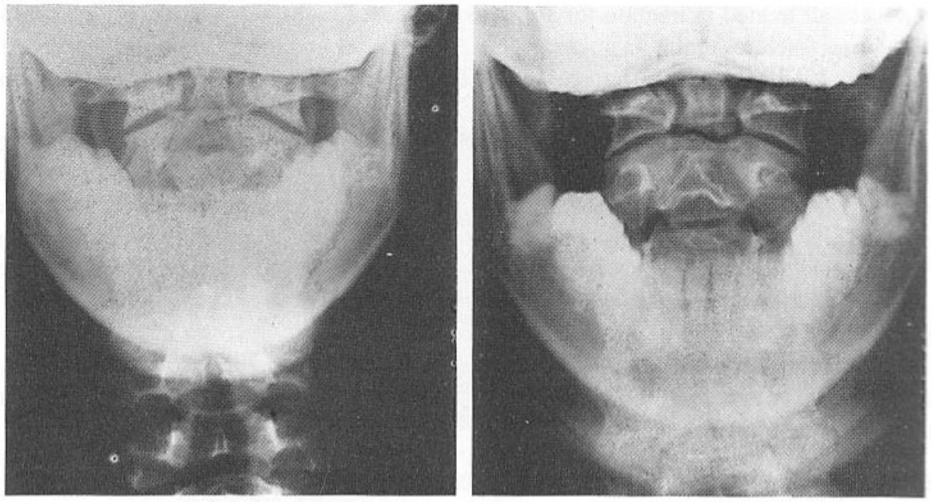

FIG. 7-A FIG. 7-B

Fig. 7-A: An undisplaced Type-II odontoid fracture in a seventeen-year-old boy. He was treated in traction followed by bracing. A non-union of the odontoid developed.

Fig. 7-B: An open-mouth odontoid view shows the obvious non-union nineteen years after injury.

vertebrae. Five of these patients underwent successful posterior fusion of the cervical spine while still being followed within the first eighteen months. All became asymptomatic.

The remaining four patients were lost to follow-up until this study was undertaken in June 1972. When three returned at our request, all complained of either neck pain or occipital neuralgia and had motion at the old fracture site of from two to five millimeters on flexion-extension roentgenograms. None, however, thought that their symptoms were severe enough for a fusion at that time. They were cautioned about the possibility of late neurological involvement with minor trauma and were told to return immediately if they developed any symptoms. In two, the symptoms had not increased and no treatment was undertaken. However, a thirty-six-year-old man who had been injured nineteen years previously returned in June 1973. He had no known recent trauma but had spontaneously developed sudden-onset upper-extremity paresthesias and decreased sensation in the index and long fingers of both hands. He was admitted to the hospital and wiring and fusion was done from the first to the second cervical vertebra with autogenous iliac-bone grafts. Six months after surgery, the neurological findings had resolved and the fusion appeared solid (Figs. 7-A through 7-D).

Discussion

After reviewing the literature and studying our patients with fractures of the odontoid process, there are areas of controversy that we still consider unresolved. On the other hand, we believe there are some problems to which the answers seem clearer.

In our series the mortality rate was certainly not as high as in some reports in the literature. This is probably because our series included no autopsy material from patients who died shortly after their injuries. Only two of the sixty patients in whom we made the diagnosis of a fracture of the odontoid process died, and in both of these the fracture of the odontoid process did not appear to be the direct cause of death.

Early neurological deficits of some degree were present in fifteen of our sixty patients (25 per cent). However, the findings were minor in ten patients and only five had serious neurological involvement. Only two had disabling neurological problems after treatment.

In establishing the prognosis as to union of the fracture, we believe it is important to classify the fractures. Type-I fractures are uncommon, but in our two patients with this

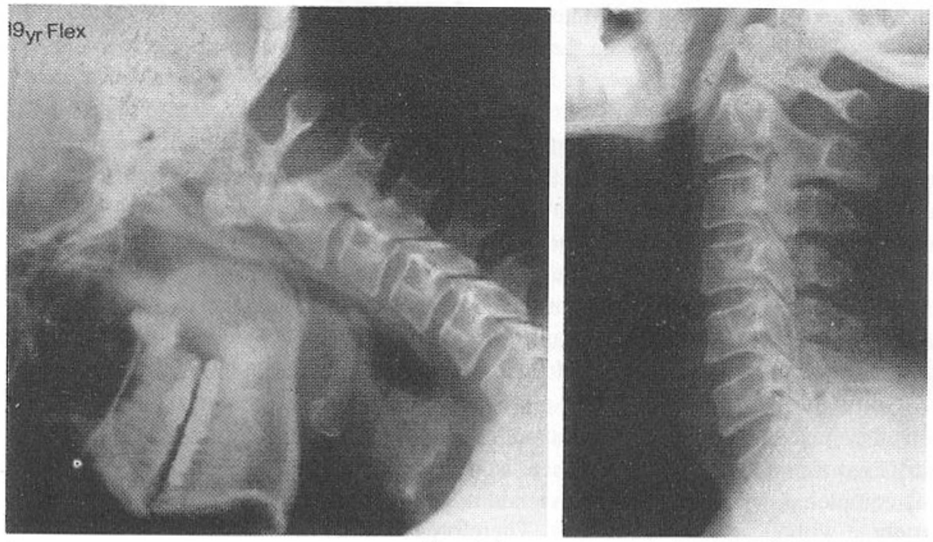

FIG. 7-C

Lateral roentgenograms made in flexion and extension nineteen years after injury. The odontoid reduces in extension and displaces anteriorly three millimeters in flexion.

type of fracture healing took place uneventfully with simple immobilization in a collar or a brace. Even if non-union should occur, it probably would not be a problem because the fracture is too high in the odontoid process to cause instability of the first cervical vertebra on the second.

Type-II fractures, those at the junction of the odontoid process with the body of the axis, are the most difficult to treat and are most prone to non-union. In our patients, the percentage of non-unions that developed with conservative treatment was almost identical for undisplaced and displaced Type-II fractures.

Several regimens of treatment of the Type-II fractures may be followed. One is that of Roberts and Wickstrom, who advised traction followed by bracing or a cast for twenty

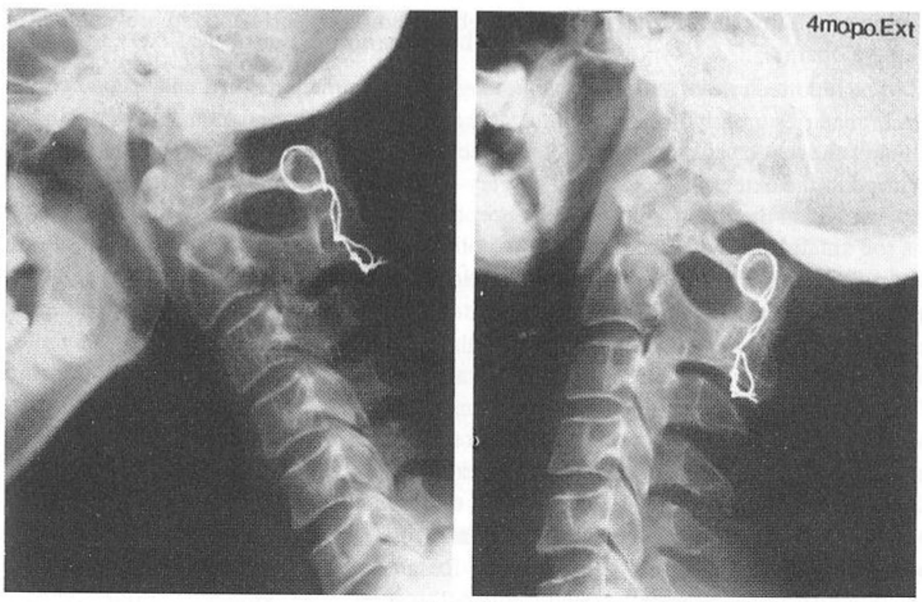

FIG. 7-D

Lateral roentgenograms made in flexion and extension four months after posterior wiring and fusion. The fusion mass appears solid between the first and second cervical vertebrae and the odontoid process is stable.

weeks. They then made flexion-extension roentgenograms, and in those patients whose fractures had not united and in whom the first cervical vertebra was unstable on the second, a fusion was recommended. Another approach is to undertake primary cervical fusion in adult patients with Type-II fractures of the odontoid process, as was done in ten patients in this series. The results of fusion in our series were good and no deaths occurred. The patients were able to leave the hospital in a brace in two or three weeks in most cases and be up and about. Perhaps the patient should be presented with the facts and have some voice in the decision. Obviously, the experience of the surgeon and the anesthesiologist, as well as the facilities available, must be considered. A patient could elect twenty weeks of traction and bracing knowing that there was a 36 per cent chance of then requiring a fusion and four to six additional months of bracing, or he could elect primary fusion. He should also be informed that he would lose some 10 to 15 per cent of rotation of the neck.

In the twelve patients who had a primary fusion, there were two surgical complications that have been previously discussed. In the total eighteen fusions done both as primary treatment and for non-union, there was one additional complication. Since this study was completed, we have done twelve additional fusions of the first and second cervical vertebrae without any complications. Therefore, in thirty such fusions the complication rate in our hands was 10 per cent. All complications occurred in patients treated early in this series. While there was some increased morbidity associated with these complications, the final outcome was successful in all three.

A third regimen is to treat Type-II fractures conservatively unless a neurological deficit develops. However, there are real dangers in this approach. Minor trauma in a patient with an ununited fracture may produce severe neurological involvement and even death.

The Type-III fractures have a large cancellous surface. One would expect them to do well with reduction and immobilization in traction followed by bracing. This proved to be the case in our series. Of the thirteen Type-III fractures treated by this method, union took place in all but one. The one patient with non-union was not seen for treatment until several weeks after injury, and this probably contributed to the failure of the fracture to unite. It appears that fusion as primary treatment is not justified when the rate of success with conservative treatment is over 90 per cent. On the other hand, if non-union does occur, a fusion of the first and second cervical vertebrae should be performed to prevent possible late myelopathy.

The reported rate of success in achieving fusion between the first and second cervical vertebrae varies greatly in the literature. Recently, Fried reported ten cases of wiring and fusion of the first cervical vertebra to the second. In eight of his ten patients, redislocation occurred to the extent that additional surgery or prolonged immobilization was necessary. It appears from the illustrations in his report that the wire used in several of these patients was too small to provide stability. On the other hand, Schatzker and associates reported fifteen patients with fractures of the odontoid process treated by primary wiring and fusion. Union was successful in thirteen with only minor redisplacement. The authors appeared concerned because the fracture of the odontoid process itself failed to unite in seven patients. We agree with Fried, who stated that while union of the odontoid process is desirable, its importance in a successful fusion has been overemphasized. If the ring of the first cervical vertebra is solidly united to the posterior elements of the second cervical vertebra, we do not see how an ununited odontoid process is of any consequence unless the dislocation was not reduced at the time of surgery.

Our results following posterior wiring and fusion of the first cervical vertebra to the second are similar to those of McGraw and Rusch, who recently reported successful fusion in fourteen of fifteen patients with instability at the first and second cervical vertebral levels. Their only failure was in a patient who had improper placement of the wire and an inadequate bone graft. The technique they recommended of fixing a rectangular bone graft in place with the wire appears to have definite advantages. Better contact between the graft and the posterior elements of the first and second cervical vertebrae is achieved and there is less chance of redislocation. We used a similar technique in several of our patients with success. Fielding also reported successful results with a similar technique.

In our series of forty-nine patients, a total of eighteen fusions was performed. Twelve patients had fusions as primary treatment and six were done for non-union that developed following conservative treatment. Sixteen patients had successful fusion following the first operation. The time required for the fusion to solidify roentgenographically was from two to eight months, with an average of 4.5 months.

The other two patients whose fractures failed to achieve fusion after the first operation have already been mentioned. One was the three-year-old child in whom grafts from the bone bank resorbed and the wire broke. He was the only patient in whom autogenous iliac-bone grafts were not used. No additional treatment was undertaken because the fracture of the odontoid process united and was stable. The other initial failure occurred in the patient in whom delirium tremens developed, who removed his traction and pulled the wire loose. A second fusion from the occiput to the second cervical vertebra was carried out and was successful.

The initial fusion level was from the first cervical vertebra to the second or third cervical vertebra in all but two patients. One patient had a fusion from the occiput to the second cervical vertebra because of an associated fracture of the ring of the first cervical vertebra. The other fusion that included the occiput was the patient just discussed who pulled the wire loose and required a second operation.

All of the sixteen patients with successful fusions of the first cervical vertebra to the second or third cervical vertebra achieved stability, and no late neurological complications have developed to date. As a result of these observations, we believe the occiput should not be included in fusions done for fractures of the odontoid process or non-union of fractures of the process unless there is a congenitally deficient ring of the first cervical vertebra or an associated fracture of the first cervical vertebra. Both of these are uncommon. McGraw and Rusch also believed that the occiput should not be included and agreed with Fielding that if the occiput is fused there is an additional loss in flexion-extension of 30 per cent.

Summary and Conclusions

1. Sixty patients with fractures of the odontoid process were studied, forty-nine of whom were followed for six months or more.

2. The fractures were classified as Type I, Type II, or Type III according to the level and configuration of the fracture.

3. Type-I fractures are uncommon. They are located high in the odontoid process, are stable, and do well with simple immobilization.

4. Type-II fractures are located at the junction of the odontoid process with the body of the second cervical vertebra and are the most common type. They are unstable, and even if initially undisplaced they frequently become displaced. Non-union developed in 36 per cent of the Type-II fractures treated conservatively. Primary fusion appears to be justified in this group of patients, although age, associated injuries, and the general condition of the patient should be considered. If conservative treatment is undertaken and non-union develops, fusion should be done to prevent late myelopathy.

5. In the Type-III fractures the fracture line extends downward into the body of the second cervical vertebra. Because of the large cancellous surface, over 90 per cent of these fractures unite and do well with traction followed by bracing. Primary fusion does not appear justified and wiring and fusion should only be done if non-union develops.

6. A total of eighteen cervical fusions were done either as primary treatment or because non-union developed. Sixteen successful fusions were achieved after the first opera-

tion. Fusion of the first cervical vertebra to the second is adequate in the vast majority of patients with fractures of the odontoid process or non-union of fractures of the process. The occiput should be included only if there is a fracture or congenital deficiency in the ring of the first cervical vertebra. The third cervical vertebra need not be included unless there is a fracture of the posterior elements of the second cervical vertebra.

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