DISLOCATION OF THE ATLAS ON THE AXIS
THE VALUE OF EARLY FUSION OF C1, C2, AND C3*

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The odontoid process of the axis owes its importance to its anatomical location high in the cervical spine. Since fractures of this small process are associated with dislocations of the atlas on the axis, which in turn compress the upper cervical spinal cord, it is not surprising that both morbidity and mortality are high with these injuries. Geoffrey Jefferson in 1920 and Osgood and Lund in 1928 surveyed 55 of the fractures of the odontoid process reported to that time, the mortality being about 50 per cent. In at least 10 of the fatal cases reviewed by Osgood and Lund death was not immediate but occurred in patients who had become increasingly disabled over weeks, months, or years. Possibly a tendency to report fatal cases at that time made the mortality more apparent than real. By 1945 Hinchey and Bickel surveyed the previous literature and added 8 cases of their own, making a total of 120.

Osgood and Lund in 1928 discussed a fracture of the odontoid process received by Dr. Lund himself in 1925. His injury was the forerunner to the great increase in the number of fractured odontoid processes reported since then. Dr. Lund’s accident occurred in a Model-T Ford; the tremendous advances in power and speed of automobiles since 1928 are a matter of record. As a result there is an increase in fractures and dislocations of the upper cervical spine associated with severe trauma. Undoubtedly the increasing use of roentgenograms taken of areas in which injury is suspected results in more frequent recognition of abnormalities in the cervical region.

Embryologically the odontoid process arises as a part of the body of the atlas but later fuses with the upper portion of the body of the axis and articulates with the posterior surface of the small body of the atlas. It is held firmly in place dorsally by the transverse ligament of the atlas. In about 25 per cent of people 30 to 50 years old there is an incomplete union of the odontoid process with the axis. A small island of cartilage, the vestige of the original intervertebral disc, remains at the base of the odontoid process. This island of cartilage in some cases may contribute to the case with which dislocations of the odontoid process occur. Under certain circumstances, as in chronic rheumatoid arthritis and in acute pyogenic infec-

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tions around the neck, as well as in trauma, the transverse ligament may rupture, allowing forward dislocation of the atlas on the axis. Congenital absence of the odontoid process with excessive mobility of the atlas on the axis has been reported a few times.

Reliable information is not available concerning the frequency of trauma to the upper cervical spine as the cause of immediate death. Life is incompatible with a severe crushing injury to the cervical spinal cord at the level of the atlas and axis; hence, if fractures of the odontoid process cause damage to the spinal cord, such injured patients do not ordinarily come under medical surveillance. The majority of surviving patients with acute fracture of the odontoid process have little or no neurologic disability, and, except for the frequency of associated injuries, the mortality from these lesions, if properly treated, should be negligible. Many patients actually walk into the emergency room.

Plaut, Schwarz and Wigton, and others maintain that solid healing of a fractured odontoid process does not occur. Osgood and Lund stated that 2 patients with such fractures, who died of intercurrent disease, showed firm union of the odontoid process at autopsy. Cone and Turner reported that 1 patient on whom they performed a fusion of the upper cervical spine displayed firm union of the fractured odontoid process several months later.

Hinchey and Bickel, however, believed that fractures of the odontoid process rarely unite but there is usually no resultant disability. Cone and Turner and Osgood and Lund thought that difficulties commonly arise when there is failure of proper union of these fractures. In 1948 Crutchfield wrote that fractures of the odontoid process with dislocation do not heal satisfactorily and advised cervical fusion; later he treated his patients conservatively by maintaining skeletal traction for several weeks, then by using rigid support for about 6 or 8 months.

More recently Amyes and Anderson surveyed 63 cases of fractures of the odontoid process seen at Los Angeles County Hospital and in their private practice. Their patients were treated by various methods, some by use of skeletal traction and others by application of plaster cast to the neck. They used no set form of therapy in the group, although a rigid steel-reinforced leather collar was recommended after traction was discontinued—"... there was a great deal of variation in the length of time the neck support was worn. Each patient was instructed to continue wearing his brace until healing was demonstrated by x-ray." Although they advised follow-up for at least a year, they apparently lost sight of many of their patients before a year had passed. They did not record any late complications, and they considered that only 3 of their patients needed cervical fusion for stabilization of the fracture-dislocation. They frequently used lamiographs, both to confirm the fracture of the odontoid process and to determine the progress of healing.

Undoubtedly some fractures of the odontoid process do heal solidly when patients are treated by maintaining skeletal traction for 3 months,
followed by their wearing a rigid external support for another 3 to 6 months. These cases have been reported and there is at least 1 in our series (Fig. 1).

The literature is replete with reports of late complications of nonunited fractures of the odontoid process, chiefly recurrent stiffness of the neck, episodes of complete or partial tetraplegia resulting from relatively minor trauma, and eventually production of a picture of chronically progressive compression of the high cervical spinal cord.\textsuperscript{3, 35} Frequently death has resulted from mild secondary trauma as in the case reported by Austin Flint, Sr., in 1869.\textsuperscript{16} The most dramatic report is that of Elliot and Sachs\textsuperscript{14} of a man who survived four episodes of compression of the spinal cord with varying degrees of paralysis over a period of almost 35 years until he died from compression of the upper spinal cord. His cervical spine and spinal cord were studied by Dr. Ernest Sachs and the cause of death—the fracture-dislocation of the odontoid process with compression of the spinal cord—was illustrated in their publication in 1912. Mixter and Osgood,\textsuperscript{20} Pilcher,\textsuperscript{29} Wilson,\textsuperscript{40} Rogers,\textsuperscript{24} Cone and Turner,\textsuperscript{9, 39} Kamman,\textsuperscript{23} Kahn and Yglesias,\textsuperscript{22} Craig,\textsuperscript{10} Schwarz and Wigton,\textsuperscript{36} Brookes,\textsuperscript{7} Jefferson,\textsuperscript{21} Blockey and Purser,\textsuperscript{3} and Alexander et al.\textsuperscript{1} presented similar stories of patients who showed serious neurologic disorders or who died as the result of nonunited fractures of the odontoid process.

Cone and Turner,\textsuperscript{9} and Gallie,\textsuperscript{18} concluded many years ago that all patients with fractures of the odontoid process should be treated by performing open operation and cervical fusion. Their results were excellent and the mortality was low. A similar policy was followed with some of the patients presented in this paper; others, for various reasons, were treated conservatively. A modification of operative procedure and other significant details in the management of these cases are considered sufficiently important to warrant further emphasis.

Although there has been no special reference to it in the medical literature, our experience gained in a few cases led us to the tentative conclusion that fractures of the odontoid process that break well into the body of the axis rather than breaking at the base of the odontoid process may heal satisfactorily without operative fusion if reduction by traction is accomplished.

Several surgical approaches to fractures of the odontoid process have been made in the last 60 years. Church and Eisendrath\textsuperscript{3} in 1892 and Brokaw\textsuperscript{6} in 1898 described methods of fixation of fractures of the spine by tying spinous processes and laminae together with various materials, including silk, silkworm gut, and kangaroo gut. Their publications did not deal with fractures or dislocations high in the cervical spine. Later Mixter and Osgood\textsuperscript{25} in 1910 and Ely\textsuperscript{15} in 1911 reported securing dislocations of the atlas and axis together with heavy silk sutures under the lamina of C1 and around the spinous process of C2.

With improved roentgenographic techniques making easier recognition
of fracture-dislocations and the treatment more certain of success, most of these lesions—particularly those discovered soon after injury—were treated by manipulation, brief traction, and immobilization with plaster cast. The report of Osgood and Lund is an excellent example of such successful treatment. The popularity of manipulative reductions and immobilization with plaster cast attended by few complications, is attested to by the publications of Brookes and Roberts. They suggested, however, that chronic dislocations of the upper cervical spine might be treated better with surgical fusion.

Nevertheless, as laminectomy became a well recognized procedure, carried out with low mortality, the immediate problem of compression of the spinal cord was attacked directly by performing laminectomy and suboccipital craniectomy. A case was described by Craig in which the patient’s chronic neurologic disability was much improved by decompression without fusion. Kahn and Yglesias, and Rogers also decompressed the spinal cord by performing laminectomy and enlarging the foramen magnum, but at the same time they did an extensive fusion of the cervical spine to the occiput. One of the early cases of Turner and Cone was handled in a similar way with success.

With the introduction of skeletal traction advocated by Crutchfield and by Barton, by inserting metal tongs into the skull, the ease of reducing dislocations of the atlas on the axis became apparent—even when done months or years after injury.

A satisfactory regime for treatment of these patients was outlined with various detailed modifications by Cone and Turner, Gallic, and Winant. After the fracture-dislocation is confirmed by a satisfactory roentgenogram, Crutchfield tongs are applied and the dislocation is reduced. The general condition of the patient dictates the time to do a surgical fusion, following reduction of the dislocation. If the patient has no associated injuries and his general condition is satisfactory, early fusion is done in the first days or weeks after injury without decompressive laminectomy. After healing of the wound, the patient is allowed to be up with external support of plaster cast or a brace. It is doubtful if the late neurologic complications of chronic atlo-axial dislocation are so often caused by callus described in the older literature as by the excessive mobility of the upper cervical spine which repeatedly injures the cervical spinal cord. There is, therefore, no logical rationale for not treating the chronic lesions by reduction and fusion as done in the acute cases.

The methods of fixation of atlo-axial dislocations have varied widely. If a laminectomy of the atlas has been done previously, a more complex method of fusion is necessary: the lateral facets are utilized and the occiput is often fused to the lower cervical spine. Cone and Turner, Winant, Kahn and Yglesias, and others, wired fragments of bone between the occiput and the atlas and/or axis. Gallic used a simple fusion of the arch of the atlas to the arch of the axis.
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ANALYSIS OF CASE MATERIAL

Twenty-five patients are in the group, ranging in age from 21 months to 75 years. There were 22 men, 2 women and 1 child. Sixteen of the injuries were the direct result of motor-vehicle accidents; 8 patients were drivers, 6 were passengers, and it is uncertain whether or not 2 patients were drivers or passengers. Three of the injured were asleep at the time of the accident. Falls from a height were the cause of 5 of the fractures; 1 patient was thrown against a building by a cow; 1 fracture was the result of metastasis of a prostatic carcinoma to the body of the axis. The 21-month-old infant either had trauma to the neck at birth or an infection about the neck. One fracture appeared spontaneously in association with severe rheumatoid arthritis.

DEATHS

(1) #114489. A 21-month-old child died the day after decompressive laminectomy was done under local anesthesia with the aid of electrophrenic stimulation. At necropsy the cervical spinal cord was observed to be only a ribbon.

(2) #167647. A 58-year-old man with metastasis of a prostatic carcinoma to the atlas died on the 14th day after operative fusion of the occipitocervical region. However, he died of a pulmonary embolus and no neurologic deficit was noted either before or after surgery.

(3) #168587. A 70-year-old man with severe tetraparesis died at home 9 months after injury, apparently of complications of the urinary tract. He was treated by use of skeletal traction with Crutchfield tongs for 25 days in the hospital, then by rest in bed at home. His physician reported that he showed slow but progressive improvement in neurologic function during the 9 months he survived. No surgical procedure was performed.

(4) #176053. A 47-year-old man with severe cerebral contusion, acute subdural hematoma, a fracture of one hip, and an injury of the brachial plexus, died about 9 months after injury in another hospital. The fracture of the odontoid process had been treated by the use of skeletal traction in the hospital and by rest in bed elsewhere. The amount of recovery of neurologic function was uncertain because of his prolonged coma from injuries of the head. No surgery was performed for the fractured odontoid process.

(5) #231761. A 23-year-old man was in an automobile accident in which he received severe cerebral contusion, an injury of the chest requiring thoracostomy and tracheostomy, and other injuries. Roentgenograms showed fracture-dislocation of the odontoid process which was reduced by traction applied with Crutchfield tongs. The patient lived for 13 days in a state of decerebrate rigidity, never regaining consciousness. No operative treatment of the fractured odontoid process was carried out. At necropsy no compression of the cervical spinal cord was seen and his death was attributed to the head injuries.

Comment. There is one lesson to be learned from studying these 5 deaths: The infant treated by removal of the posterior rim of the foramen magnum at laminectomy would have been treated more satisfactorily by application
of skeletal traction in order to reduce the dislocation. Then, if neurologic improvement had occurred, possibly a fusion could have been performed later. The difficulty in recognizing the normal configuration of the cervical spine in the child led the surgeon to suppose that he was dealing with a neoplasm rather than with an anterior dislocation of the atlas on the axis.

**SURVIVING PATIENTS TREATED CONSERVATIVELY**

There were 4 patients treated by traction followed by further rigid immobilization for varying lengths of time. In all of these, followed from 10 months to 6 years, the neurologic function remained normal.

The late follow-up studies in 3 patients are sufficiently complete to be valuable in this investigation. The fourth patient has moved to another state and was returning to work when last heard from 10 months after his injury.

(1) #139842. A 75-year-old man with fracture of the odontoid process and dislocation of the atlas on the axis was treated by application of skeletal traction and rest in bed. The urinary bladder became obstructed associated with benign prostatic hypertrophy and azotemia. The obstruction was not relieved by drainage with catheter until he was allowed to get out of bed. He was able to walk with a modified brace to which traction was applied through two sets of Crutchfield tongs for 28 days. The patient wore his brace only sporadically after removal of the tongs, and he has not wanted further treatment. There was excessive mobility of the atlas on the axis with nonunion of the fractured odontoid process. No neurologic deficit was present but he suffered from some stiffness and discomfort of the neck.

(2) #100277. A 31-year-old man was injured July 15, 1949. In addition to a fracture of the odontoid process, he had multiple fractures of the mandible, cerebral contusion with prolonged coma lasting several weeks, a fracture of the right radius and ulna, and contusion of the right lung and right kidney. Of necessity he was treated by using skeletal traction with Crutchfield tongs for 10 weeks on a Foster turning frame. He was immobilized in bed without traction for several weeks thereafter without other support to his neck. Roentgenograms of his cervical spine 6 years later showed excellent solid bony healing of the fracture of the odontoid process although it was displaced slightly forward to the right (Fig. 1). There were arthritic changes in the atllo-occipital joints and in the atllo-axial joints. Motion of his neck was moderately limited and somewhat painful but there was no neurologic deficit.
Comment. This is a striking example of a fractured odontoid process that has healed without fusion, but it is the only one in this series that has definitely done so. The patient also showed solid union in malposition of the fractures of the right radius and ulna and of the multiple fractures of the mandible. Satisfactory reduction of the fractures was necessarily delayed for several weeks because of his other injuries and the seriousness of his general condition.

(3) #234418. A 29-year-old Negro was injured when he fell down a flight of stairs on June 6, 1956. He suffered with pain in his neck, and although he is not clear about incidents immediately following the accident, he thought that his right side was very weak for several hours afterwards.

He reported to the emergency room of a hospital where roentgenograms showed a fracture of the odontoid process visible only in the anteroposterior view, with no displacement and no evidence of a fracture in the lateral view. Halter traction was applied with about 7 pounds' weight for 8 days, followed by a "cast," the extent of which is not known, for 18 days. Since he had residual stiffness of the neck following this treatment, he was referred to a neurosurgeon for the first time on Sept. 21, 1956.

At that time his neck showed some stiffness; the neurologic findings were considered to be within normal limits. Roentgenograms taken in the lateral projection of the upper cervical spine in flexion and extension revealed movement of about 6 mm. forward of the atlas on the axis in forward flexion. He was, therefore, referred to a veterans' hospital for fusion of the cervical spine at his request because of financial circumstances. There, roentgenograms were said not to show any instability of the fracture, and he was discharged without operation or external support to his neck.

Because of our interest in this problem and in following the patient, he was seen again on April 5, 1957. He had no physical complaints and was working in a restaurant. He admitted that there was some limitation of movements of his neck but denied weakness of his extremities or other significant symptoms.

Examination showed about 30 per cent limitation of flexion and extension of the neck, about 50 per cent limitation of rotation of the head, and about 60 per cent limitation of lateral bending of the head. The right biceps reflex was more active than the left, the left knee jerk was more active than the right, but there were no other abnormalities.

Roentgenograms of the cervical spine revealed continued evidence of the fracture of the odontoid process at its base in the anteroposterior view, but the most striking finding was marked forward dislocation of the atlas on the axis of about 1 cm. in forward flexion, with tilting forward of the atlas (Fig. 2). The patient was advised to have operative fusion of the cervical spine because of the instability, but to this date has not made a decision.

SURVIVING PATIENTS UNTREATED

There were 2 patients who had no specific treatment—immobilization, traction, or surgery—for fracture of the odontoid process:

(1) #214500. A 36-year-old man was in an automobile accident in which he thinks his head was thrown against the rear-view mirror above the windshield. He had severe stiffness and limitation of motion of his neck but returned to work
several weeks after the accident. He was able to do only limited physical work, however, because of pain in his neck. He was first seen at the North Carolina Baptist Hospital 2 years after his injury. There was limitation of all the motions of his back and he complained of a "popping" sensation of his neck on certain movements. There was no weakness of the arms or legs and the neurologic findings were considered to be normal.

Roentgenograms of the cervical spine disclosed a nonunited fracture of the odontoid process. Lateral films made in flexion and extension of the neck revealed anterior dislocation of C1 on C2 with further movement forward on flexion of the neck (Fig. 3). The body of the
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Fig. 4. Anteroposterior and lateral roentgenograms, the lateral films taken in flexion and extension 5½ years after fracture-dislocation of odontoid process treated by brace for 3 months after injury. Fracture still evident and there is excessive mobility of C1 on C0.

atlas protruded into the posterior pharyngeal shadow of air on forward flexion of the neck. He refused hospitalization for surgical fusion of the upper cervical spine.

(2) #115136. A 34-year-old man was examined first 3 months after an injury which occurred when the trailer-truck he was driving jack-knifed, pinning him in the cab of the truck. He complained of stiffness of his neck but no other serious disability. Three months later roentgenograms showed a fracture of the odontoid process. A brace was applied to his neck which he wore intermittently for several months. He returned to his occupation of driving a truck and, with the exception of fairly frequent headaches and limitation of motion of his neck, he was not aware of any other impairment of function. He did not seek medical aid but returned for examination in response to a letter written to him in preparation for this paper. Roentgenograms taken in the lateral projection showed the fracture of the odontoid process still to be nonunited and there was 6 to 7 mm. of mobility on flexion and extension of his neck (Fig. 4). No further treatment has been given to him.

ANALYSIS OF SURGICALLY TREATED CASES

DECOMPRESSIVE LAMINECTOMY

(1) #114489. This 21-month-old child was discussed previously under “Deaths” (1). The dislocation of the atlas was not recognized with certainty before surgery. Skeletal traction would have been the preferred treatment, followed later by fusion if the child had survived.

FUSION OF OCCIPUT TO C3

(1) #167647. This patient, also previously referred to under “Deaths” (2), had metastatic carcinoma of the prostate to the atlas with dislocation of C1 on C2. Wiring of fragments of bone from the occipital bone to C3 successfully held the dislocation in the position of satisfactory reduction already attained by skeletal traction. The patient died of pulmonary embolus on the 14th postoperative day. At
necropsy the operative fixation was found to be solid by virtue of firm wiring of fragments of bone. Though perhaps effective, this type of fusion is unduly arduous and no more stable than fixation of the atlas to the axis.

**Fusion of Atlas to Axis**

Two patients were treated in 1949 and 1950 by surgical fusion between the axis and atlas only:

(1) #113411. A 28-year-old woman was first seen 3 weeks after an automobile accident in another city. There was no neurologic disability. She had extreme pain in her neck and mobility of the neck was restricted. The dislocation was reduced satisfactorily by application of skeletal traction, after which fusion was performed of C1 to C2 by ilial grafts wired to the laminae of C1 and C2. There was definite forward displacement of the atlas on the axis 3 months after operation. Although her symptoms were considerably improved, this method of fusion was not considered satisfactory. She was seen last in March, 1956, 5 years and 9 months after operation, when she had some soreness in her neck, limitation of movement of the neck of about 15 per cent, but no neurologic disability. The range of motion in the fusion in flexion and extension of the neck was about 1 mm., but there was still slight anterior dislocation of C1 on C2.

(2) #93205. A 67-year-old man walked into the emergency room following a fall down a flight of stairs while under the influence of intoxicants. The posterior dislocation of the atlas on the axis was so pronounced on the first lateral films of the cervical spine (Fig. 5, left) that it was amazing to those in attendance that he showed no neurologic disability. Immediate complete reduction of the dislocation was obtained by the use of skeletal traction, and 8 days later a fusion was performed of the laminae and spinous processes of C1 and C2 with wiring of the fragments of bone. Because of his age he was gotten out of bed almost immediately with traction applied by rubber straps between the Crutchfield tongs and an external metal support attached to a plaster jacket. There was no further follow-up until he returned in response to a letter during the preparation of this paper. At the age of 78 years he showed no neurologic disability. The movements of his neck were somewhat limited but not more than commonly seen in a person of his age. Roentgenograms showed slight posterior dislocation of 2 to 3 mm. of the atlas on the axis with apparent healing of the fractured odontoid process (Fig. 5, right).

**Fusion of C1, C2, C3**

The operative method of fusion using iliac bone for grafting, and, more recently, using ribs from a bone bank, was used in 12 cases. The operations were performed from 8 days to 3 months after injury.

Since roentgenograms are of such vital importance in reaching a diagnosis of fracture of the odontoid process, some attention should be devoted here to the technique of taking the films. The conscious or unconscious patient who is suspected of having an injury of the cervical spine—including all serious injuries of the head—is not moved to the diagnostic roentgenographic table until a horizontal-beam lateral film of the cervical spine is taken to rule out a fracture-dislocation. If a high cervical lesion is indicated, either clinically or in the initial films, a special small cone is used to see the C1–C3
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Fig. 5. Man, aged 67 years, with no neurologic deficit. (Left) Posterior dislocation of C1 on C2. This was reduced by traction. (Right) Film 6 years later shows solid fusion.

Fig. 6. Special small cone for obtaining anteroposterior views of odontoid process through open mouth.

area. A cone small enough to be inserted into the mouth may be used in order to obtain a clear anteroposterior view of the odontoid process (Fig. 6).

OPERATIVE TECHNIQUE

Crutchfield tongs are inserted as soon as a diagnosis of fracture of the cervical spine is made. Enough traction (up to 20 or 25 pounds for a few minutes) is used to reduce the dislocation. After reduction is accomplished, the weight is reduced to about 5 to 10 pounds, and the position of the dislocation is checked by lateral-view roentgenograms.
As soon as the general condition of the patient permits it, operation is done under general anesthesia. An endotracheal tube is inserted blindly by the intranasal route, with the patient’s head in traction and without dorsi-flexion of his neck. He is then placed in the prone position in the cerebellar head-rest without flexion or extension of the neck (Fig. 7). About 10 pounds’ traction is maintained during the exposure which is accomplished by sharp dissection, clearly exposing the occipital bone, foramen magnum, arches of the atlas and axis, and the 3rd and 4th cervical vertebrae. Exposure is carried out to the facets on both sides.

If the procedure is performed within 10 days of the injury, discoloration usually will be seen of the deep muscles of the neck and occasionally also of the dorsal surface of the dura mater. Later there may be no abnormality evident in the exposed field except for unusual mobility of the axis.

All ligamentous attachments to C1, C2, and C3 out to the facets are removed with rongeurs. The cortex of the laminæ of C1, C2, and C3 is removed by multiple small bites with a rongeur until medullary bone is exposed. A small motor-driven burr would be ideal but is considered hazardous. Care must be taken at this stage of the procedure to avoid breaking through the thin laminæ of C1 and C3, but C2 is usually thick enough for the cortex to be removed easily. In order to facilitate the passage of wires
beneath the laminae, they are made narrower in the cephalad-caudad dimensions by removing small portions of the upper and lower edges with rongeurs.

Stainless-steel wires, #20 gauge, are passed beneath the laminae of C1, C2, and C3, using a curved needle large enough to accommodate the wire. The heavy wire is bent sharply as it passes through the eye of the needle in order to reduce the bulk of the needle and wire passing between the lamina and dura mater. Occasionally the wire may be passed without a needle but, of course, caution must be taken not to penetrate or encroach on the dura mater which is left intact throughout the procedure. Two wires are passed laterally under the right and left laminae of C1, C2, and C3, and another strand of wire is passed beneath the midportion of the atlas. This wire is looped around the heavy spinous process of the axis. It is tied after traction is reduced to 5 pounds and, if necessary, the neck is extended slightly.

Ribs obtained from sterile thoracic procedures and preserved in the bone bank are used as grafting material, or an iliac graft may be taken from the patient at the time of surgery. The short fragment of rib to be used is cut to the appropriate length to extend from the cephalad edge of the lamina of the atlas to the caudad edge of the lamina of the 3rd cervical vertebra (Fig. 8). The side of the rib opposite to the underlying laminae is prepared by removing the cortex of the rib to fit the similarly denuded laminae. The rib on each side is then tied in place with three wires. At times additional

Fig. 8. Artist's conception of graft using short fragment of rib extending from cephalad edge of the lamina of atlas to caudad edge of lamina of 3rd cervical vertebra.
chips of bone are placed in the wound in contact with the denuded laminae and over the exposed facets, but this is not considered essential. The wound is closed in multiple layers with interrupted sutures of silk.

DISCUSSION

Of the 12 operations performed by fusing C1, C2, and C3 with bone graft, 1 was done over 6 years ago, 2 over 2 years ago, 5 over a year ago, and the other 4 from 3 to 12 months ago.

Only 3 of these patients showed any neurologic disability from the injury of the odontoid process:

One of these, on whom operation was performed over 6 years ago, sustained a severe injury of his head together with multiple contusions and abrasions. He had multiple subcutaneous abscesses, and it was difficult to maintain his neck in proper traction because of his restlessness. He became totally tetraplegic, but in spite of the known abscesses elsewhere in his body, fusion of C1, C2, and C3 was performed. Except for one superficial abscess at the site of a suture, the wound healed by primary intention. He made a steady recovery and was last examined 1 year postoperatively. There was slight hyperactivity of the deep tendon reflexes on the left side as compared with the right, the motions of the neck were limited about 20 per cent, and he was going to school regularly. Roentgenograms showed his neck to be in normal position with solid healing of the grafts of bone (Fig. 9).

A second patient had some weakness of the left arm and leg as a direct result of the injury. The weakness improved before surgery was performed but was accentuated by the surgical procedure for 5 days postoperatively. After operation he continued to improve and 8 months later his neurologic findings were normal.

Although there was considerable neurologic disability immediately after injury, a third patient recovered completely and returned to his occupation of teaching school.

Three other patients of the group presented specific problems:

A 22-year-old man was thrown from an automobile in an accident. He showed no neurologic abnormality but roentgenograms disclosed a fracture of the odontoid process, backward dislocation of the atlas on the axis, and marked lateral dislocation of the atlas on the axis to the right. Crutchfield tongs were inserted and the dislocation was reduced by application of 30 pounds of skeletal traction without manipulation. He was transported in skeletal traction to the North Carolina Baptist Hospital where cervical fusion was performed on the 8th day after injury (Fig. 10). Four months after operation he was doing light work, wearing a Thomas brace on his neck. Eight months later he returned to work with no pain of his neck. There was about 15 per cent limitation of rotation and lateral bending of his neck.

A 63-year-old Negro man was injured when thrown against a barn by a cow. Some days later satisfactory roentgenograms in the lateral and anterior position showed anterior dislocation of the atlas on the axis without fracture of the odontoid process. The anteroposterior films were taken through the open mouth. Fusion was performed 1 month after injury, the wound healed satisfactorily, and the patient
Fig. 9. Fracture-dislocation of odontoid process associated with severe injury of head and extreme restlessness. Separation of fragments by traction was necessary to overcome progressive tetraplegia. Film on right, 41 days postoperatively, shows beginning healing of fracture. Patient made almost complete neurologic recovery following fusion.

Fig. 10. Films on left and in center show posterior and lateral dislocation of C1 on C2 with fracture of odontoid process. No neurologic deficit. Dislocation readily reduced by skeletal traction with 30 pounds of weight for 30 minutes. On right, immediate postoperative fusion.
was fitted with a Thomas brace on his neck at the time of discharge. This case, covered by a Compensation Commission, was punctuated by considerable unpleasantness between employee and employer, and it has been difficult to determine whether or not his continued complaint of pain in his neck is valid. Roentgenograms 10 months later showed the atlas and axis maintained in the same position as fused, but anteroposterior films showed a clear line of decreased density across the base of the odontoid process, probably representing a fracture. There was no displacement of the odontoid process from the axis (Fig. 11).

A 47-year-old man with a past history of severe rheumatoid arthritis several weeks before admission began to have increased pain in the neck and increasing clumsiness of the arms. A roentgenogram showed a forward dislocation of the atlas on the axis without fracture of the odontoid process. This was reduced easily by application of traction and subsequently fusion of C1, C2, and C3 was carried out. The function of his arms improved postoperatively.

Of the 3 patients who had rupture of the transverse ligament, in 2 it was caused by trauma and in the third it was associated with severe rheumatoid arthritis. Although the forward dislocation of the atlas on the axis was marked in each of the 2 patients who had been injured, there was no movement on flexion and extension of the neck. Furthermore, at operation in each case the atlas was firmly fixed in its forward position and could not be moved by gentle manipulation with rongeurs as in the other patients with fracture of the odontoid process. In the patient with rheumatoid arthritis there was free mobility between the atlas and axis, and complete reduction was accomplished by traction before surgical fusion was done.

In all but 1 of the patients on whom fusion of C1, C2, and C3 was done, the grafts of bone were clearly visible and solid as long as over 6 years after operation. In the 2 patients in whom only C1 and C2 were fused, slight mobility of the atlas on the axis was revealed on films taken in flexion and extension of the neck, but there was no detectable movement in patients with fusion of C1, C2, and C3. Most of the patients were free of significant pain or discomfort within 30 days after fusion, although the rotary movement of the cervical spine was limited 15 to 30 per cent. Some patients returned to light work wearing a brace 2 months after operation (Fig. 12).

One man with a fractured odontoid process treated by fusion of C1, C2, and C3 had a rather severe episode of pain in his neck with limitation of all movements of the neck about 18 months after surgery was done. Roentgenograms repeated then showed the grafts of bone and wires in place, and no cause was found for his pain, from which he recovered spontaneously.

SUMMARY

1. Fractures of the odontoid process carry a high mortality if associated with acute injury to the cervical spinal cord.

2. The immediate mortality is low if there is no severe injury to the cervical spinal cord—that is, if the patient reaches the hospital in satisfactory neurologic condition.
Fig. 11. Man, aged 63 years. (Left) Postoperative fusion of C1, C2, and C3. Forward dislocation of C1 on C2 brought about by rupture of transverse ligament. Preoperative films disclosed no fracture of odontoid process in the anteroposterior or lateral views. (Right) Anteroposterior film 1 year after operation shows fracture of base of odontoid process. Fusion solid.

Fig. 12. Roentgenograms in anteroposterior and lateral projections showing fracture through base of odontoid process without significant displacement. On right, 1 month after fusion, patient was ambulatory, wearing adjustable Thomas collar.
3. With prolonged immobilization of the head and neck, some fractures of the odontoid process do undergo solid healing apparently, but the period of disability is lengthened.

4. Late neurologic complications with eventual death up to 30 years after unsatisfactory healing of a fractured odontoid process have been reported frequently in the past and are serious enough to warrant operative fusion to prevent future dislocation of the atlas on the axis.

5. The lessons learned from experience with 25 fractures of the odontoid process are reviewed.

6. Operative fusion was done on 15 patients with only 1 death from pulmonary embolus on the 14th postoperative day of a patient with metastatic carcinoma of the prostate.

7. A detailed technique of performing cervical fusion is discussed and the method of fusion of C1, C2, and C3 is described. This proved satisfactory in 12 patients seen over a number of years.

8. Experience gained from this relatively large group of surgically treated patients, all carefully followed postoperatively, leads to the conclusion that early surgical fusion in cases of fracture of the odontoid process protects the patient from the late sequelae of atlanto-axial dislocation. Fusion can be done with much shorter hospitalization and earlier return to useful employment than with prolonged traction and immobilization which does not assure solid healing of the fractured odontoid process.

REFERENCES


DISLOCATION OF THE ATLAS ON THE AXIS