Treatment of pedicular fractures of the axis

A clinical study and screw fixation technique

GUY M. BORNE, M.D., GERARD L. BEDOU, M.D., AND MAGLOIRE PINAudeau, M.D.

Department of Neurosurgery, Central General Hospital Marechal Joffre, Perpignan, France

The authors report 18 cases of pedicular fractures of C-2. The characteristics of these fractures are discussed, and the authors conclude that these lesions are more correctly called "pedicular-isthmus" fractures. A technique of screw fixation of the pedicle is presented. This was found to be a simple and safe method of repair, giving consistently good anatomical and functional results.

KEY WORDS: axis, pedicle, cervical spine fracture, screw fixation

Although the most frequent type of fracture of the C-2 vertebra involves the odontoid process, fractures of the pedicle are not rare and may be either isolated or associated with another lesion at C-2, such as a vertebral body fracture. The special characteristics of pedicular fractures of C-2 relate to the anatomy of this vertebra, which is considered to be part of an anatomical and functional complex, the C1-2 unit.

Following trauma of the cervical spine, the neurological risks are related to instability. In the lower cervical spine, it is the fracture of the pedicle that is responsible for instability, but at the C-2 level the main cause of the instability is not the pedicular fracture but a lesion of the C2-3 intervertebral disc, which will lead to an anterior dislocation of the superior cervical spine together with the skull. Our policy has been to operate on all patients presenting with even a minimal displacement, in order to avoid the three main complications: 1) secondary displacement, seen even with skeletal traction; 2) pseudarthrosis; and 3) abnormal callus formation, leading to persistent pain.

This report describes our experience with 18 cases of pedicular fracture of the axis. Repair of these fractures is discussed and the screw fixation technique is described. All the operations were performed by the same surgeon (G.M.B.).

Characteristics of Pedicular Fractures

Anatomical Considerations

The vertebral pedicles are the bony bridges uniting the vertebral body on either side to the junction between the lamina and the articular and transverse processes. The isthmus, as indicated by its name, is the narrower part joining the complex superior articular process-pedicle-transverse process to the complex lamina-inferior articular process. It is the segment of the articular column immediately below and behind the pedicle and is best identified on an oblique x-ray picture of the lumbar region, in which it has been described as "the little dog's neck."

The true anatomical pedicles of the axis are found in the narrower portions joining the complex vertebral body-odontoid base to the superior articular process. The isthmus unites the superior and inferior articular processes. Therefore, what is commonly thought of as a pedicular fracture of C-2 involves not only the true anatomical pedicles but also the isthmus (that is, the bony portion limited anteriorly by the superior articular process, the inferior margin of the transverse foramen, and the vertebral body, and posteriorly by the inferior articular process and the lamina). It would therefore be more appropriate to label these fractures as isthmus fractures or even fractures of the pedicle-isthmus complex of C-2.

Dynamic Considerations

There are two distinct levels in what can be described as the "craniospinal hinge." and knowledge of the movements taking place at each level is important in understanding the mechanisms leading to lesions of C-2, and particularly to lesions of the pedicle-isthmus complex at this level.

Flexion-extension and lateralization movements take place at the upper level, which comprises the atlanto-
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occipital joint. Flexion beyond 20° is limited by the lateral atlanto-occipital ligament, the lateral alar-odontoid ligaments, and the vertical limb of the cruciform ligament. Extension is limited to 30° by the anterior longitudinal ligament and the contact between the occipital bone and the posterior arch of C-1. Lateral movements (that is, those in a frontal plane) greater than 20° are prevented by the lateral alar-odontoid ligaments, the horizontal limit of the cruciform ligament, and the atlanto-occipital ligaments. No rotation movements take place at the upper level due to the configuration of the junction between the occipital condyles and the superior articular facets of C-1.

Rotation occurs at the lower level at the atlantoaxial joint or, more precisely, at the lateral atlantoaxial joint. A sliding motion also occurs which leads to lateral inclination of the head toward the side opposite to that of the rotation. The extent of rotation is 40° on either side, and some movements of flexion-extension and inclination also occur here, limited to 10° and 5° respectively.²

Fracture Mechanism

There are two well defined functional units involved in fractures: a superior part, consisting of the occipital bone of the skull, the atlas, and the anterior part of C-2 (that is, the vertebral body, odontoid process, and superior articular process), and an inferior portion, formed by the posterior arch of C-2, the inferior articular process, and the remaining subjacent cervical spine. These two components are united by the posterior atlantoaxial ligaments, the anterior and posterior longitudinal ligaments, and the pedicles of C-2.

A pedicular fracture will result from a sudden forceful flexion or extension which causes the two units to separate. The classical whiplash injury may be encountered when these movements occur in succession. Hyperextension may also result, and is well documented in passengers of cars hit violently from the rear, or in pedestrians or motorcyclists falling to the ground and striking their forehead. In such cases, in addition to pedicular fractures, there may be rupture of the anterior and posterior longitudinal ligaments, leading to anterior luxation of C-2 over C-3 with crushing of the intervertebral disc, as seen in hangman's fracture. These lesions have been well described by Roy-Camille, et al.,³ who reported their experience with fresh cadavers. Marshall,⁴ in his postmortem investigations following judicial hangings, discovered radicular and cord injuries as well as lesions of the vertebral arteries.

Hyperflexion can also produce injuries, but to our knowledge this very seldom occurs. Case 16 in our series was such a case (see Table 1). The patient was a motorcyclist who fell backward, striking his occiput on the ground. We have also seen one case of pedicular fracture of C-2 (Case 6) resulting from a vertical impact: the victim's head was probably flexed when he was hit over the vertex with an iron rod.

Thus, many different mechanisms can cause a C-2 pedicular fracture, either in isolation or in association with other factors, although hyperextension is encountered most commonly.

Types of Fractures and Associated Lesions

Fractures can be separated into two types: those that can be considered isolated (that is, strictly pedicular fractures) and those associated with a vertebral body fracture.

Pedicular Fractures. The solely pedicular fractures can be subdivided into vertical fractures, which extend from the superior edge of the pedicle down to the lower edge close to the inferior articular process, and oblique fractures, which follow a course from above downward and forward. This latter type can involve the transverse foramen, sometimes detaching a segment of its posterior edge.

Vertebral Body Fractures. Vertebral body pedicular fractures are those that involve the anterior part of the pedicle and radiate toward the lateral portion of the vertebral body. They can be either single fractures or complex with splitting of the vertebral body and separation of the odontoid.

Associated Lesions. Lesions often accompany fractures and can involve the axis itself, especially the odontoid process, spinal process, or even a lamina. Additionally, one may encounter lesions of the atlas or of the spinous process of C-3, compression of C-3 alone, or compression of C-3 associated with displacement at the junction of C2-3.

Summary of Cases

Clinical Material

This series included 13 men and five women with pedicular fractures at C-2 (Fig. 1 and Table 1). The patients' ages ranged from 19 to 70 years for men (mean
### TABLE 1

Summary of clinical data in 18 cases of pedicular fracture *

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Etiology &amp; Date of Injury</th>
<th>Type of Fracture</th>
<th>Neck Pain†</th>
<th>Other Lesions</th>
<th>Traction Duration (days)‡</th>
<th>Type of Operation</th>
<th>Result§</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27, F</td>
<td>traffic accident, Feb, 1969</td>
<td>bilat pedicular oblique fracture of C-2</td>
<td>++</td>
<td>head injury, fracture of mandible, lt rib, &amp; lt leg</td>
<td>10</td>
<td>wiring of C1-3, bone graft: occiput to axis</td>
<td>good</td>
</tr>
<tr>
<td>2</td>
<td>35, F</td>
<td>traffic accident, Nov, 1971</td>
<td>bilat pedicular oblique fracture of C-2</td>
<td>+</td>
<td>head injury, fracture of hip &amp; ulna</td>
<td>6</td>
<td>wiring of C1-3, bone graft: occiput to axis</td>
<td>good</td>
</tr>
<tr>
<td>3</td>
<td>54, F</td>
<td>traffic accident, July, 1975</td>
<td>bilat pedicular fracture of C-2, odontoid fracture</td>
<td>+</td>
<td>head injury</td>
<td>7</td>
<td>wiring of C1-3, bone graft: occiput to axis</td>
<td>good</td>
</tr>
<tr>
<td>4</td>
<td>30, M</td>
<td>traffic accident, July, 1975</td>
<td>bilat pedicular oblique fracture of C-2</td>
<td>++</td>
<td>fracture of rt humerus</td>
<td>3</td>
<td>wiring of C1-3, bone graft: occiput to axis</td>
<td>good</td>
</tr>
<tr>
<td>5</td>
<td>43, M</td>
<td>traffic accident, Dec, 1975</td>
<td>rt pedicular oblique fracture of C-2</td>
<td>+</td>
<td>head injury</td>
<td>1</td>
<td>screw fixation</td>
<td>excellent</td>
</tr>
<tr>
<td>6</td>
<td>65, M</td>
<td>assault, Mar, 1976</td>
<td>bilat pedicular oblique fracture of C-2, subluxation of C-2 on C-3</td>
<td>0</td>
<td>head injury</td>
<td>8</td>
<td>screw fixation, wiring of C2-3</td>
<td>excellent</td>
</tr>
<tr>
<td>7</td>
<td>40, F</td>
<td>traffic accident, Apr, 1977</td>
<td>rt pedicular vertical fracture of C-2</td>
<td>+</td>
<td>head injury, fracture of rt femur</td>
<td>6</td>
<td>screw fixation</td>
<td>excellent</td>
</tr>
<tr>
<td>8</td>
<td>31, M</td>
<td>traffic accident, Jan, 1979</td>
<td>bilat pedicular oblique fracture of C-2, subluxation of C-2 on C-3</td>
<td>+</td>
<td>multiple lt rib fractures, fracture of lt humerus</td>
<td>12</td>
<td>screw fixation</td>
<td>excellent</td>
</tr>
<tr>
<td>9</td>
<td>40, F</td>
<td>traffic accident, Sept, 1979</td>
<td>bilat pedicular vertical fracture of C-2</td>
<td>+</td>
<td>head injury, fracture of rt wrist</td>
<td>3</td>
<td>screw fixation</td>
<td>excellent</td>
</tr>
<tr>
<td>10</td>
<td>55, M</td>
<td>fall from scaffold, Jan, 1980</td>
<td>lt pedicular vertical fracture of C-2</td>
<td>+</td>
<td>head injury</td>
<td>2</td>
<td>screw fixation</td>
<td>excellent</td>
</tr>
<tr>
<td>11</td>
<td>34, M</td>
<td>traffic accident, June, 1980</td>
<td>bilat pedicular &amp; vertebral body fracture of C-2</td>
<td>+</td>
<td>head injury</td>
<td>16</td>
<td>screw fixation</td>
<td>excellent</td>
</tr>
<tr>
<td>12</td>
<td>54, M</td>
<td>traffic accident, Aug, 1980</td>
<td>bilat pedicular oblique fracture of C-2</td>
<td>++</td>
<td>sternum fracture, head injury</td>
<td>3</td>
<td>no surgery because there was no fracture displacement</td>
<td>excellent</td>
</tr>
<tr>
<td>13</td>
<td>19, M</td>
<td>traffic accident, Dec, 1980</td>
<td>bilat pedicular oblique fracture of C-2, subluxation of C-2 on C-3</td>
<td>++</td>
<td>head injury</td>
<td>3</td>
<td>screw fixation</td>
<td>excellent</td>
</tr>
<tr>
<td>14</td>
<td>46, M</td>
<td>traffic accident, Mar, 1981</td>
<td>bilat pedicular &amp; vertebral body fracture of C-2</td>
<td>++</td>
<td>head injury, scapula &amp; clavicle fracture</td>
<td>2</td>
<td>screw fixation</td>
<td>excellent</td>
</tr>
<tr>
<td>15</td>
<td>50, M</td>
<td>traffic accident, July, 1981</td>
<td>bilat pedicular oblique fracture of C-2</td>
<td>+</td>
<td>head injury</td>
<td>11</td>
<td>screw fixation</td>
<td>excellent</td>
</tr>
<tr>
<td>16</td>
<td>67, M</td>
<td>traffic accident, July, 1981</td>
<td>bilat pedicular oblique fracture of C-2</td>
<td>+</td>
<td>head injury</td>
<td>3</td>
<td>screw fixation</td>
<td>excellent</td>
</tr>
<tr>
<td>17</td>
<td>25, M</td>
<td>traffic accident, Jan, 1983</td>
<td>bilat pedicular &amp; vertebral body fracture of C-2</td>
<td>+</td>
<td>head injury</td>
<td>2</td>
<td>screw fixation</td>
<td>excellent</td>
</tr>
<tr>
<td>18</td>
<td>70, M</td>
<td>fall to ground, Feb, 1983</td>
<td>bilat pedicular vertical fracture of C-2</td>
<td>++</td>
<td>head injury</td>
<td>3</td>
<td>screw fixation</td>
<td>excellent</td>
</tr>
</tbody>
</table>

* Only two patients exhibited neurological signs: Case 8 (paresthesia of the upper limbs) and Case 16 (sudden transitory quadriplegia). All patients had postoperative immobilization for 3 months.
† Definition of symbols: ++ = severe neck pain; + = some neck pain; 0 = no neck pain.
‡ Crutchfield tongs were used for traction.
§ Good = anatomical relationships restored, no pain, some limitation of neck movement; excellent = anatomical relationships restored, no pain, no limitation of neck movement.
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45 years) and from 27 to 54 years for women (mean 39 years). The majority of these patients were men (72.2%).

Motor-vehicle accidents were the cause of injury in 15 cases. A fall from a scaffold (Case 10), an assault (Case 6), and an accidental fall to the ground by a pedestrian (Case 18) caused the remaining injuries. It is interesting to note that 12 of the 15 road traffic accident victims (80% of cases) were in a car, although we cannot state precisely whether as a driver or a passenger. The other three cases involved motorcycles.

In all cases, the first major sign of injury was neck pain of variable intensity which led to x-ray studies of the cervical spine. In all but two of the patients (Cases 8 and 16), neurological examination at the initial admission showed no disorder. One of these patients complained of paresthesia of both lower limbs, but this problem disappeared quickly; the other presented with transitory quadriplegia.

In this series, trauma to the cervical spine was always accompanied by other lesions, usually skull and facial injury (in 16 of 18 cases). Other associated lesions were either thoracic or abdominal, or involved the extremities.

Treatment Rationale

Cord injury is not due to the pedicular fracture of C-2, as this widens the spinal canal. Injury to the cord occurs only when the C2-3 intervertebral disc is damaged, which allows C-2 to slide forward over C-3 resulting in an anterior dislocation of the upper spine and skull. Therefore, the single most important factor that must be considered in order to select the method of treatment is stability.

We consider a stable fracture to be one in which there is either no displacement or in which displacement causes an interpedicular diastasis smaller than 2 mm. We recognize that with displacement greater than 2 mm there is subluxation and that the fracture is unstable.

In the case of a stable fracture without displacement, we agree with most authors that orthopedic treatment alone is sufficient, by means of a rigid plastic or plaster of Paris collar maintained usually for 3 months. Monthly follow-up evaluation with x-ray pictures gives a good indication of the healing process. Opinion differs, however, in the cases in which there is little displacement, either minimal (less than 2 mm) with a stable fracture, or slightly wider with an unstable fracture. Various approaches have been used in these situations,1-3 and a general consensus has not been agreed upon. Some physicians advocate immediate surgical fixation instead of orthopedic immobilization in order to minimize the risks of pseudarthrosis. All agree, however, on a combined approach in cases of unstable subluxation or obvious dislocation of C-2 over C-3, first to restore the proper spinal bone axis (reduction), and second to maintain a stable reduction.

We believe that in all cases reduction should be performed as an emergency procedure. This can be done manually under general anesthesia. Although quick reduction is achieved, this method is not devoid of danger, and therefore we prefer progressive reduction by means of Crutchfield’s skeletal traction under x-ray control.

Sometimes the displacement of the posterior arch cannot be reduced by traction. We then achieve reduction surgically using a Farabeuf’s forceps to grip the spinal process of C-2, which is then pulled upward and forward to bring the bone fragments into perfect apposition (see Fig. 3 left). The best mode of surgical treatment for these unstable pedicular fractures is still a subject of controversy.

Very few surgeons still perform anterior fusion of C2-3 with an autogenous bone graft using the difficult anterior approach. However, the well known technique of posterior fusion by wiring of C-1 through C-3 and even C-4, sometimes associated with autogenous bone grafting, is very much in favor. We used it ourselves until 1975 (Cases 1 to 4), but since then we have preferred the posterior approach with screw fixation of the fractured pedicle, as first described by Judet and LeConte.4 This operation is simple, elegant, quick, and efficient, and gives consistently excellent anatomical and functional results. However, it demands a thorough knowledge of the anatomy of the area, since there is very little room to insert a screw between the vertebral artery and the spinal cord. It is mandatory to operate under direct vision at every stage of the operation, and the image intensifier can add a great deal of assurance, especially if the surgeon has little experience with the method.

Screw Fixation Procedure

The patient is positioned prone under general anesthesia, and skeletal traction by means of Crutchfield’s tongs is kept at 3 kg. The cutaneous incision starts from the external occipital protuberance and extends along the midline down to the C-6 or C-7 level. The septum nuchae is split along the midline, then the muscles are freed from the occipital bone and from the posterior arch of C-1, C-2, and C-3, care being taken not to injure the vertebral artery at C-1. At the C-2 level, exposure must reach the lateral margin of the articular process.

It is then necessary to locate precisely the entry point for the screw on the posterior surface of the inferior articular process of C-2. The pedicle is identified after detaching the atlantoaxial ligament. Its internal face is approached via the superior edge using a Creed dissector. The fracture site is often felt and identified at this stage. If it is apparent that reduction has not been achieved by means of the preoperative skeletal traction, it is done before drilling, using the Farabeuf forceps to pull the spinous process of C-2 upward toward the occipital bone (Fig. 2A). The angle of drilling is 20° inward and 20° upward (Fig. 2B and C). While the drilling is being performed, the surgeon’s assistant
maintains the dissector or a spatula at the inner aspect of the pedicle. This not only allows for direct vision but also helps to protect the spinal cord.

The drill hole is prepared using two successive drill bits of different diameter. The first has a diameter of 2.8 mm and is fitted with a stop which limits the drilling depth to 30 mm. This allows it to pass through the posterior part of the pedicle, the fracture site, and the true pedicle anteriorly, stopping within the C-2 vertebral body. The second drill bit has a diameter of 4 mm and is inserted through the previous hole only up to the fracture site. A vitallium Phillip's screw, 3.5 mm in diameter and 30 mm in length, passes freely through the posterior tunnel. Tightening the screw within the narrower anterior drill hole will allow for compression of the fragments and will secure the reduction. Recently we have added a vitallium washer to prevent the head of the screw from penetrating the bone.

The procedure is done bilaterally, with both holes drilled before any screw is placed. The screws are then inserted (Fig. 2D) and screwed down alternately to obtain simultaneous tightening and avoid any risk of secondary displacement of the fragments. In this way a very strong bony junction is realized. A suction drain is left in contact with the laminae. The muscles are reapproximated in two layers, and the aponeurosis is closed with absorbable sutures. Two-layer closure of the skin completes the operation.

Postoperatively, skeletal traction is maintained at 2 kg until the drain is removed, usually at 48 hours, and until after control x-ray films are obtained (Fig. 3). The patient is allowed to walk wearing a soft cervical collar, which is kept in place until the stitches are removed, around the 9th day. A rigid cervical collar is then fitted and worn for 3 months.

**Results and Comment**

During the period 1969 to 1983, we treated 18 cases of pedicular fracture of C-2. Only one of them (Case 12) did not undergo surgery. That patient presented with a bilateral fracture without displacement; he also had head injury and fracture of the sternum, and was
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in poor general condition. He was successfully treated with a plaster of Paris collar for 3 months, without complications.

Our earlier cases were treated by posterior fusion of C1–3 using steel wire and autogenous bone grafting. Since 1975, we have used the bilateral pedicular screw fixation technique. Immobilization has been maintained by a plaster of Paris or rigid plastic cervical collar worn for 3 months, and in all cases bone union was achieved in that time.

In the long-term follow-up studies there have been no complications, no pseudarthrosis, and no deaths. Functional results have been very good, which is not surprising since cervical spine movements should be far less impaired when very little restraining osteosynthesis material is used. Therefore, pedicular screw fixation, which leaves the joints free to move, is particularly satisfactory when compared to posterior wire fusion.

Acknowledgment

The authors thank Dr. P. Nicoleau for translating the manuscript.

References


Manuscript received February 25, 1983. Accepted in final form August 11, 1983.

Address reprint requests to: Guy M. Borne, M.D., Department of Neurosurgery, Centre Hospitalier Joffre, 66020 Perpignan, France.