Hangman’s fracture: the relationship between asymmetry and instability
C. Samaha, J. Y. Lazennec, C. Laporte, G. Saillant
From the Pierre et Marie Curie University, Paris, France

There is ambiguity concerning the nomenclature and classification of fractures of the ring of the second cervical vertebra (C2). Disruption of the pars interarticularis which defines true traumatic spondylolisthesis of C2, is often wrongly called a pedicle fracture. Our aim in this study was to assess the influence of asymmetry on the anatomical and functional outcome and to evaluate the criteria of instability established by Roy-Camille et al. We studied the plain radiographs and CT scans of 24 patients: 13 were judged to be asymmetrical, ten were considered unstable and 14 stable.

Treatment was with a Minerva jacket in 15 fractures and by operation in nine. Surgery was undertaken in patients with severe C2 to C3 sprains. One patient with an unstable lesion refused operation and was treated conservatively with a poor radiological result.

Our study showed that asymmetry of the fracture did not affect the outcomes of treatment and should not therefore influence decisions in treatment. The criteria of Roy-Camille seem to be reliable and useful. We prefer the posterior approach to the cervical spine, which allows both stabilisation of the fracture and correction of a local kyphosis.

Patients and Methods

Of 45 patients treated between January 1986 and December 1996, 24 had had CT with three-dimensional reconstruction giving details of the lines of fracture and of displacement. There were 13 men and 11 women with a mean age of 40 years (18 to 75). The cause of the fracture was a fall in eight patients and a motor-vehicle accident in 16, of whom eight had multiple injuries. Two of the 24 patients were not available for physical examination, but were included in the analysis of the initial radiological findings. Abnormal neurological signs were observed on admission in six patients, with occipital neuralgia in two and nerve lesions unrelated to the C2 injury in four.

Plain radiography and CT were performed routinely. Sagittal and coronal reconstruction of the CT images was done only in the more recent cases (Fig. 1). Tomography was performed in ten patients. The criteria of Roy-Camille et al. for instability were evaluated on all lateral images (Fig. 2). These included the width of the fracture line, regional angulation (RA) in degrees, defined as positive for kyphotic deformities and negative for lordotic deform-
This classification was used to categorise patients into three groups based on the severity of the anatomical lesion. Group 1 was defined as having little or no displacement, even on dynamic films with AT < 2 mm, and RA < 5° in either direction. In experimental studies these findings indicated that ligaments were intact or that the anterior longitudinal ligament alone was damaged. Patients were ascribed to group 2 when the AT was more than 2 mm but not greater than 8 mm, and the RA was more than 5° but not greater than 15° in either direction. These features implied disruption of the anterior longitudinal ligament and disc. Group 3 included severely displaced fractures with an AT greater than 8 mm and an RA greater than 15° in either direction, indicating complete disruption of all disc and ligament attachments between C2 and C3.

According to Roy-Camille et al., fractures of the middle column of C2 can be divided into four groups: type 1, a stable fracture (group 1); type 2, an unstable fracture (groups 2 and 3); type 3, a middle-column fracture with dislocation of the facet joint of C2-C3; and type 4, a middle-column fracture with a fracture of the dens (Fig. 3).

Concomitant lesions at sites other than the cervical spine included a head injury with or without initial loss of consciousness (15 patients), a chest injury with rib fractures (5), limb fractures (3) and fractures of the thoracolumbar spine (2). Concomitant lesions of the cervical spine included a fracture of C1 in one patient, of C3 in two and fractures of other cervical vertebrae in three.
A Minerva jacket was used in patients with a gap of no more than 3 mm between fragments, no angulation of C2-C3 in kyphosis or lordosis and no evidence of instability on dynamic flexion-extension radiographs taken on the eighth day with the patient awake.

Surgery was carried out in patients with severe lesions of the mobile segment of C2-C3 with displacement with more than 3 mm of AT and a local kyphosis greater than 15° or a lordosis of more than 5°. Halo traction was used to stabilise the fracture of the neck until operation was carried out. In

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**Fig. 3**

Diagram showing the Roy-Camille classification for fractures of the pedicle of C2.

**Fig. 4**

Diagram showing a symmetrical fracture of the pars interarticularis of C2 with a lesion of the C2-C3 disc. Note the position of the 3.5 mm screws for bridging the fracture associated with plates for stabilisation of C2-C3.
every case but one, this consisted of posterior fixation alone; the exception was a patient treated by an isolated anterior graft at C2-C3.

Internal fixation was achieved using posterior plates (Howmedica-Stryker, France) with the lower screws inserted into the articular processes of C3 and the upper one placed in order to stabilise the fracture of C2. In patients with typical symmetrical fractures, stabilisation was achieved by direct bilateral compression provided by upper screws inserted into the isthmus on both sides (Fig. 4). In those with asymmetrical fractures, stabilisation was by the insertion of an upper screw into the fractured isthmus on one side and by posterior stabilisation into the articular processes of C2 and C3 on the other (Fig. 5). Decortication of C2-C3 was carried out routinely without bone grafting. Treatment was conservative in 15 patients and surgical in nine. The mean follow-up was 13 months (6 to 96).

The clinical results were divided into three categories as follows: very good, defined as a normal range of movement and resumption of work, with no pain or neurological abnormality; fairly good, as occasional pain with a decreased range of movement, resumption of work, and absence of neurological abnormality related to treatment; and poor, with permanent pain, complete loss of movement, neurological abnormalities related to treatment, and inability to return to work.

The radiological result was considered good or very good if the AT was less than 3 mm and the RA less than 5° in either direction. A fair radiological result was an AT greater than 3 mm but unchanged or decreased compared with admission, and with the RA ≤15° in either direction. A poor radiological result was defined as an AT greater than 3 mm or more than on admission, with an RA greater than 15° in either direction.

Results

Radiological. The mean AT in the 24 patients at admission was 3.5 mm (0 to 12), the mean RA was 5° (-10 to +26), and the mean gap between fragments was 2.95 mm (0 to 9).

According to the criteria of Roy-Camille et al.¹⁰ ten fractures were considered unstable and 14 stable. None of the patients had dislocation of the C2-C3 facet joints or fracture of the dens (i.e., there were no type-3 or type-4 fractures). The lesions of the middle column of C2 were rarely symmetrical (Figs 6 and 7). In 13 of the 24 patients

Fig. 5

Diagram showing a typical asymmetrical lesion of the pars interarticularis of C2: 1, classical fracture of the pars interarticularis of C2; 2, fracture of C2 vertebral body; 3, fracture with separation of the superior articular facet. Note the direction of the fracture down to the C2-C3 disc inducing kyphosis and rotation. Plating must bridge C2-C3.
with a fracture of the pars interarticularis on one side, the other side showed a fracture through the body of C2 with various associated lesions such as in the superior articular process of C2, the foramen transversarium, and/or the lamina of C2.

Of the ten unstable fractures, seven were asymmetrical and of the 14 stable fractures, six were asymmetrical.

Non-surgical cases. Of the 15 patients treated conservatively, 13 had a very good clinical result and two poor. The radiological result was very good in 14; 9 fractures were symmetrical. The remaining patient was referred to our institution after initial treatment on traction and had a symmetrical fracture with disruption of the C2-C3 disc, indicating potential instability. The patient refused operation, and the traction was replaced by a Minerva jacket. The fracture healed but with displacement, resulting in an angular kyphosis of 17° at C2-C3.

Surgical cases. Of the nine patients treated by operation, the clinical result was very good in seven, fair in one and poor in one. Two of the fractures were symmetrical. The patient with a poor result was an alcoholic with an asymmetrical fracture treated by posterior fixation; he developed an episode of agitation which caused partial disassembly of the internal fixation. The radiological result was judged poor.

On average, healing occurred within three months. Of the nine patients, seven had a very good radiological result. Of the two patients with a poor result, one was the alcoholic mentioned above; the healed fracture showed anterior translation of 10 mm and kyphosis of 15°. The other patient was the only one treated by grafting, through an anterior approach. The fracture was asymmetrical. Displacement occurred during removal of the halo cast on the eighth postoperative day. Subsequent radiographs showed 10 mm of anterior translation and 10° of kyphosis. The clinical result in this patient was fair.

Discussion

Most systems of classification of fractures of C2 are based on lesions of the C2-C3 disc, ligaments, and facet joints. Fractures of the pars interarticularis on both sides of C2 can be considered stable if there are no other lesions, but concomitant injury to the discs and ligaments of the mobile segment can cause instability.\textsuperscript{10,16}

In 1981, Effendi et al\textsuperscript{17} observed that fractures of the pars interarticularis of C2 are often asymmetrical which they attributed to rotational forces together with hyperextension and axial compression. They suggested a classification system based on the mechanism of injury and the characteristics of the displacement. Type-I fractures are due to axial compression with hyperextension and are characterised by little or no displacement. The posterior wall of C2 may show an oblique fracture through one, or rarely both, posteroinferior corners of the body of C2. The C2-C3 disc is normal. Type-II fractures result from initial hyperextension with axial compression followed by severe hyperflexion of the neck. The C2-C3 disc is disrupted and the body of C2 is displaced in extension, flexion, or anterior listhesis. Type-III fractures are due to a combination of flexion and compression responsible for dislocation of the C2-C3 facet joints with anterior displacement of C2 in flexion. Levine and Edwards\textsuperscript{18} added to this classification a variant of type II, called type IIa, due to flexion and distraction of the neck; anterior translation is minimal, but there is significant displacement of the body of C2 in lordosis.
In clinical studies, healing of the fracture has occurred in many patients with isolated symmetrical fractures of the pars interarticularis of C2. Asymmetrical fractures, with or without disruption of the disc and ligament, were often suggested as a possible cause of nonunion but have not been analysed. Most authors recommended that surgery be reserved for failures of conservative treatment, but nonunion and considerable kyphosis have been reported, suggesting the need for early operation in patients presenting with instability.

Benzel et al. advocated the use of a combination of diagnostic investigations in order to classify fractures of C2. According to this concept, fractures of the pars interarticularis of C2 are part of a broader category of injuries defined as disruption of the ring of C2. Some studies report the proportion of asymmetrical fractures without, however, assessing the potential effect of asymmetry on outcomes of treatment.

Current classifications do not relate rotational disorders to decisions on treatment. Of our 24 patients routinely investigated by CT, 60% had asymmetrical fractures compared with 18% in the study by Burke and Harris. The frequency of asymmetrical fractures was undoubtedly underestimated before the introduction of CT. Such fractures are associated with rotational disorders which hinder reduction even under traction. There may be an increase in the width of the fracture line on one side or disruption of the foramen transversarium, placing the vertebral artery in jeopardy. Furthermore, fixed rotation due to an asymmetrical fracture may be responsible for errors in radiological evaluation of translation and angulation.

All published systems of classification rely on displacement of the fracture, although the criteria used to evaluate the mobile spinal segment vary widely. In one system, instability is defined as more than 6 mm of anterior translation and more than 2 mm of mobility on dynamic films. The criteria described by White and Panjabi and their variant developed by Francis et al. define instability as anterior translation of 3.5 mm or more, with regional angulation of 11° or more. These criteria are similar to those published in 1977 by Roy-Camille et al.

Asymmetry of fractures was found in 13 of our 24 patients and instability in ten. The 14 patients with stable fractures were treated conservatively; none developed mechanical complications or nonunion and eight of these fractures were symmetrical. Of the ten patients with unstable fractures, one was seen first at a primary hospital where he was treated by traction and referred later to our institution. All the other nine patients with unstable fracture were treated surgically and seven of the fractures were asymmetrical.

Of the two postoperative complications, the patient treated by anterior grafting probably suffered displacement for lack of complementary fixation. Of the 13 patients with asymmetrical lesions, seven were treated conservatively and six by operation.

The respective indications for operative and conservative treatment remain controversial. The proportion of cases treated by surgery varies widely from one series to the next, and most publications fail to provide a detailed description of the radiological criteria used to define the type of fracture and the degree of instability. Furthermore, most series include cases managed before CT with 3-D reconstruction was available.

Coric et al. reported a series of 64 fractures of the pedicle of C2 of which most, even those with displacement, were treated by non-rigid immobilisation. The clinical results at 14 months were satisfactory, although the mean residual anterior translation was 5 mm and residual angulation was not reported. Vichard et al. identified 229 cases of fracture of the pars interarticularis of C2 in the literature before 1981, but did not specify whether they were symmetrical or not. Treatment was non-surgical in 165 and surgical in 64. Of the surgical procedures, 25 comprised posterior fusion, 14 anterior fusion, and 25 had simple screw fixation of the pedicles. There is general agreement that non-surgical treatment is indicated in patients with undisplaced fractures which demonstrate stability on dynamic radiographs. In fractures with dislocation of the facet joints of C2-C3 operation is recommended if reduction by traction fails. In fractures which are unstable and/or displaced, conservative treatment by either traction followed by immobilisation in a Minerva jacket or hyper-extension followed by immobilisation has been recommended by some authors, although others have advocated intermediate operative treatment by the anterior or posterior route.

Francis et al. suggested that all fractures of the pars interarticularis of C2 should be treated initially by traction followed by a halo cast, and that surgery should be reserved for those patients with chronic instability or nonunion. Effendi et al. recommended that operation should only be undertaken in patients with nonunion or dislocation of the facet joints at C2-C3 and should consist of a wiring procedure.

Levine and Edwards reported a study of halo traction reduction followed by halo cast immobilisation in fractures with more than 3 mm of anterior translation. Although anterior translation and regional angulation decreased by 65% during traction, change to the halo cast was followed by a recurrence of anterior translation of 60% and of regional angulation of 40%. Furthermore, the morbidity in patients treated by halocast has varied between 12% and 36%, with complications including osteomyelitis, septicaemia, leakage of CSF and subdural abscess. Levine and Edwards recommended that very unstable fractures with dislocation of the facet joints be treated immediately by posterior fixation.

In 1984, Roy-Camille et al. reported a series of 104 cases. The results showed clearly that simple screw fixation of the pars interarticularis was inadequate in patients with instability of the C2-C3 mobile segment due to injury to the
disc and ligament because it failed to prevent loss of disc height and kyphosis. Their study did not specify whether the fractures were asymmetrical or not and, consequently, did not relate asymmetry to fixation.

Mangione et al. carried out surgery in only four of 100 patients. They treated unstable fractures by hyperextension for 15 days followed by immobilisation in a Minerva jacket with occipital and chin support for three months. All the fractures united. Surgery was undertaken in one patient seen late and in three whose fracture was not reduced after traction. Anterior grafts were applied at C2-C3 with plate fixation. Loss of AT and RA correction at the last follow-up were not reported. The rates of reduction obtained by simple traction in a number of other studies seem high. They were assessed on lateral plain radiographs, which we believe are not reliable for the detection of rotational displacement. Thus, AT and RA do not provide enough information about the quality of reduction.

Treatment decisions in our series were based on the principles set down by Roy-Camille et al. which have been followed at our institution since their publication in 1984. Thus, we do not use simple screw fixation of the pars interarticularis. Fractures without concomitant lesions of the mobile segment of C2-C3 are treated conservatively, and fractures with such lesions by fixation with a posterior plate fixation. We believe that the Roy-Camille criteria, which are similar to those developed by White and Panjabi, are reliable in the selection of patients for surgical treatment. Whether the fracture was symmetrical or asymmetrical did not influence decisions in treatment. In every case, the upper screws were placed so as to bridge the fracture of the pars interarticularis, regardless of whether it was symmetrical or not. Our comparison of outcomes in patients with each type of injury showed that this factor had no significant influence on healing of the fracture.

When criteria for instability are met, indicating a need for surgery, the presence of an asymmetrical fracture raises a number of technical problems. A fracture detaching a corner of the body of C2 on the side opposite a fracture of the pars interarticularis, indicates a risk of poor stability for an anterior graft. We have persisted with the posterior route, which facilitates correction of a kyphosis and stabilisation of the fractures. Posterior fixation can be achieved by a plate secured to C3 by screws into the articular processes. In symmetrical fractures of the pars interarticularis of C2, placement of screws through the fracture line ensures stability. In asymmetrical fractures, placement of the upper screw through the fracture in the pars interarticularis provides excellent stability; on the other side, the fracture line is anterior to the pars interarticularis and can be stabilised adequately only by inserting the upper screw squarely into the superior articular process.

The widespread use of CT in recent years has shown that many fractures of C2 involve the radiological pars interarticularis on one side only. These fractures, which result from rotational forces, can be difficult to evaluate on lateral plain radiographs and even the classical parameters of AT and RA may prove unreliable because they do not take into account the effect of rotation. Our study of 24 patients, investigated by plain radiography and CT, showed that asymmetry of the fracture did not affect outcome and should not, therefore, influence decisions in treatment. The parameters identified by Roy-Camille et al. as indicating instability, namely AT and RA, are valid regardless of whether the fracture is symmetrical or not.

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References