Fractures of the odontoid process
AN ANGIOGRAPHIC AND CLINICAL STUDY
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We treated 183 patients with fractures of the odontoid process (109 type II, 74 type III) non-operatively. Union was achieved in 59 (54%) with type-II fractures. All type-III fractures united, but in 16 patients union was delayed. There was no correlation between union and the clinical or radiological outcome of the fractures. Selective vertebral angiography, carried out in 18 patients ten with acute fractures and eight with nonunion, showed that the blood supply to the odontoid process was not disrupted. Studies on ten adult axis vertebrae at post-mortem showed that the difference in the surface area between type-II and type-III fractures was statistically significant. Our findings show that an age of more than 40 years, anterior displacement of more than 4 mm, posterior displacement and late presentation contribute towards nonunion of type-II fractures.

Patients and Methods
In a prospective study, between 1988 and 1992, we treated 196 patients with fractures of the odontoid process at the King Edward VIII Hospital. We excluded 13 because of inadequate follow-up. The mean follow-up was 2.19 years (1 to 5). The mean age of the patients was 36.7 years (18 to 64) and there were 163 men. The injuries were due to motor-vehicle collisions (114), assaults (54) and falls (15). Of the 183 patients, 91 presented for treatment within 48 hours, and 92 were referred between four and 31 days after injury with a stiff, painful neck. Lateral and open-mouth views of the cervical spine were obtained in all patients, but in 57 CT was also used since the open-mouth views were inadequate. There were 109 type-II and 74 type-III fractures (Table I). Of the former, 47 were undisplaced, 59 were displaced anteriorly (2 to 6 mm) and three posteriorly (Fig. 1). Of the 74 type-III fractures, 45 were undisplaced and 29 were displaced anteriorly (2 to 6 mm) and three posteriorly (Fig. 1). The 74 type-III fractures, 45 were undisplaced and 29 were displaced anteriorly (2 to 8 mm). The fractures were reduced with 2 kg skull traction in 32 patients (52%) with type-II fractures and in 19 (65%) with type-III fractures. In the remaining 40 patients with displaced fractures partial reduction was achieved. A sterno-occipito mandibular immobiliser (SOMI) brace was used in 120 patients and a Minerva cast in 63 patients. The patients were reviewed every two weeks for a period of one month and, thereafter, at monthly intervals. The mean duration of treatment was 14 weeks (12 to 20). Two patients who had type-

Table I. The numbers of patients in each age range and their types of fracture

<table>
<thead>
<tr>
<th>Age (yrs)</th>
<th>Fracture type</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 to 30</td>
<td>II</td>
<td>III</td>
</tr>
<tr>
<td>31 to 40</td>
<td>29</td>
<td>21</td>
</tr>
<tr>
<td>41 to 50</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>51 to 64</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>109</td>
<td>74</td>
</tr>
</tbody>
</table>

Fractures of the odontoid process have been the subject of investigation and commentary for over 80 years.1-4 While most authors have agreed that those involving the body of the axis (type III) can be successfully managed non-operatively the major controversy has concerned the treatment of fractures at the base of the odontoid process (type II).5-8 The reported incidence of nonunion of type-II fractures after conservative treatment has varied from 15% to 85%.5,7,9-11 Avascular necrosis and nonunion have been attributed to disruption of the blood supply to the odontoid process.3,7,10 We have prospectively studied factors which may contribute to nonunion. The blood supply to the odontoid process in acute fractures and in nonunion is compared and also the surface area of type-II and type-III fractures.
II fractures which were displaced anteriorly by 2 mm and 4 mm, respectively, were quadriparetic at presentation.

The Ethical Committee of the Medical Faculty approved a pilot study to evaluate the blood supply to the odontoid process in a cohort of 18 patients, eight with acute type-II fractures and ten with type-II nonunion, who were neurologically intact. Standard angiographic techniques were used to catheterise selectively the vertebral and carotid arteries via the femoral artery, under sedation and local anaesthesia. Digital subtraction angiography of the carotid and vertebral arteries in the frontal and lateral projections was undertaken.

In ten adult post-mortem specimens the axis was removed and type-II and type-III fractures of the odontoid process were created with a hand saw. The surface area of each type of fracture was measured.

We used the chi-squared test to analyse the outcome and 95% confidence intervals (CI) were calculated.

**Results**

Union was confirmed when no movement was seen on flexion/extension radiographs and bony trabeculae across the fracture site were observed on tomography. Of the 109 type-II fractures, 59 (54%) united, 19 (17%) developed a fibrous union and 31 (29%) had nonunion. The difference in the rate of union between undisplaced and displaced fractures was statistically significant (chi-squared test, \( p = 0.031 \); relative risk 0.685; 95% CI 0.48 to 0.967). Union was achieved in only one patient (33%) with posterior displacement (Fig. 2). Malunion with anterior angulation occurred in ten patients (Fig. 3). The incidence of nonunion was significant (\( p < 0.0001 \); relative risk 0.318; 95% CI 0.21 to 0.49) in patients more than 40 years of age (Table II) and in those who presented more than a week after injury (\( p < 0.001 \); relative risk 15.3; 95% CI 0.97 to 239.3). All type-III fractures united, but malunion with anterior displacement occurred in 21 patients. Delayed union was seen in 16, occurring at 16 weeks in 12 and at 20 weeks in the remaining four who presented late (3 at 9 days; 1 at 10 days). The two patients with quadripareisis made a complete neurological recovery, but union was achieved in only one.

There were no correlations between range of movement (Table III), pain (Table IV) and the radiological outcome of the fracture (chi-squared test, \( p = 0.474 \)). Neck movement was not assessed in 31 patients who had nonunion. The relative risk of mild pain for union and nonunion was 1.59 (95% CI 0.85 to 2.99), that of moderate pain for union relative to nonunion when compared with no pain, was 1.04 (95% CI 0.6 to 1.76) and that for severe pain was 3.41 (95% CI 0.62 to 18.9). At long-term follow-up the fractures with nonunion had stabilised due to a fibrous union. There was no evidence of avascular necrosis or myelopathy in these patients.

The selective vertebral angiograms showed the posterior

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**Table II.** The relationship between age and nonunion in the 109 patients with type-II fractures, by number and percentage

<table>
<thead>
<tr>
<th>Age range (yrs)</th>
<th>Number of patients</th>
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<tbody>
<tr>
<td></td>
<td>Union</td>
</tr>
<tr>
<td>18 to 30</td>
<td>60</td>
</tr>
<tr>
<td>31 to 40</td>
<td>29</td>
</tr>
<tr>
<td>41 to 64</td>
<td>20</td>
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Table III. The range of movement of the patients who achieved union, 78 with type-II and 74 with type-III fractures.

<table>
<thead>
<tr>
<th>Flexion and extension of cervical spine</th>
<th>Fracture type</th>
<th>Number of patients</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Union</td>
<td>Malunion</td>
</tr>
<tr>
<td>Normal</td>
<td>II</td>
<td>27</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>27</td>
<td>11</td>
</tr>
<tr>
<td>Decreased by &lt; 25%</td>
<td>II</td>
<td>18</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>Decreased by 25 to 50%</td>
<td>II</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>15</td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 3a – Lateral radiograph at presentation showing anterior angulation of a type-II fracture. Figures 3b and 3c – Tomography showing malunion after treatment.

Figure 4
Angiogram of the right vertebral artery in the lateral projection showing the anterior ascending (open arrow) and posterior ascending arteries (closed arrow) (A, anterior arch; P, posterior arch).

Figure 5
Angiogram of the right vertebral artery in the frontal projection showing the posterior ascending artery (closed arrow) and the apical arcade (open arrow) (L, lateral mass of axis).

Figure 6
Digital subtraction angiogram in the lateral projection of the right vertebral artery and the posterior ascending artery (arrow) (A, anterior arch; P, posterior arch).
ascending artery in all acute fractures, but the anterior ascending artery with the apical arcade was seen in only three (Figs 4 and 5). In the eight patients with nonunion only the posterior ascending artery was visualised (Fig. 6). There were no branches from the internal and external carotid arteries anastomosing with branches of the vertebral artery in either the acute fractures or those with nonunion. The mean difference between the surface area of type-II and type-III fractures was 134.72 mm² (Student’s paired t-test, p < 0.0001, 95% CI 133.8 to 135.6).

Discussion

The reasons for nonunion of fractures of the odontoid process have been debated over the last few decades because of the potentially fatal instability at the atlantoaxial joint and the progressive myelopathy which may occur after nonunion. Traumatic disruption of the blood supply to the odontoid process has been cited as a contributory factor. Anatomical studies have shown a vascular arcade to the body of the axis and the odontoid process. Recent studies have shown no histological evidence of avascular necrosis in ununited fractures of the odontoid which were resected for myelopathy, and it was suggested that nonunion of type-II fractures occurred as a result of the interposition of the transverse ligament at the site of the fracture. This is the first clinical study which has shown that the blood supply to the odontoid process is not totally disrupted in acute fractures and nonunion. The posterior ascending artery, which is the larger of the two branches of the vertebral artery, was demonstrated in all cases and the anterior ascending branch, which was not observed in 15 patients, may have been damaged at the time of injury.

The anatomical differences between type-II and type-III fractures may affect the healing of the fracture. The base of the odontoid process, which consists mostly of cortical bone, is circular in cross-section and the maximum displacement compatible with union in type-II fractures is 20%. The low bone density and localisation immediately beneath the odontoid process suggests that this area transmits little load. The mean volume of trabeculae at the base of the odontoid process is 55% less than that of the axis and the odontoid process. The deficiency of both the bone mass and the number of trabeculae at the base of the odontoid process may explain the high prevalence of nonunion after type-II fractures. Cancellous bone heals faster than cortical bone and fractured trabeculae are the main starting point of reparative callus after fractures of the vertebral body. The surface area of artificially created fractures showed a statistically significant difference between type-II and type-III fractures and a predominance of cancellous bone in type-III fractures suggests that union may be more likely with these injuries.

Delay in treatment due to late presentation and missed diagnosis has been an important factor contributing to nonunion of the type-II fractures. Ryan and Taylor recommended surgery in patients who presented two weeks after injury since 80% developed nonunion after non-operative treatment. Dunn and Seljeskog reported an incidence of nonunion of 25% when the diagnosis was made within a week, increasing to 75% when treatment was commenced after one week. In our study, union occurred in 76% of type-II fractures when the presentation was within 48 hours, but decreased to 44% when patients presented at between four and seven days. Presentation after one week resulted in nonunion. It is suggested that nonunion after delayed treatment may be due to excessive movement at the site of the fracture as a result of inadequate immobilisation.

The incidence of nonunion ranged between 53% and 77% after non-operative treatment of type-II fractures in the elderly (>60 years). In a recent study, however, treatment in a halothoracic vest resulted in a rate of nonunion of 18% in elderly (54 to 79 years) patients. This lower incidence, despite a delay in the diagnosis (3 to 49 days), may be due to accurate reduction and rigid immobilisation. The significant difference in nonunion between the two age groups (18 to 40 and 41 to 64 years) in our study may be due to the increased healing potential in the younger patients.

A notable cause of fractures in our patients was a direct blow to the head with a blunt object. An experimental study has shown that fractures of the odontoid process can be produced consistently by lateral loading. Clinical studies have suggested lateral flexion as a possible mecha-

Table IV. Pain and its relationship to union, malunion, nonunion and fibrous union for the 109 patients with type-II and the 74 with type-III fractures

<table>
<thead>
<tr>
<th>Pain</th>
<th>Fracture type</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>II</td>
<td>Union</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>17</td>
</tr>
<tr>
<td>Mild</td>
<td>II</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>13</td>
</tr>
<tr>
<td>Moderate</td>
<td>II</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>16</td>
</tr>
<tr>
<td>Severe</td>
<td>II</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>III</td>
<td>7</td>
</tr>
</tbody>
</table>
nism of injury, although lateral tilt was not evident in all cases. We found lateral tilt and an oblique pattern of the fracture in only 13 patients, six of whom had been assaulted. The pattern will depend on the site of the blow, the position of the head at the time of assault and whether the patient fell.

The clinical outcome was similar to that in previous studies which found no correlation between the type of union and symptoms of pain and restriction of movement which were not significantly different between patients managed conservatively and those treated surgically. Stoney et al. showed a higher incidence of persisting pain associated with posterior malunion, but the position at union did not correlate with residual stiffness of the neck.

The blood supply to the odontoid process was not compromised in type-II fractures and the causes of nonunion did not correlate with residual stiffness of the neck.

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References