Original article

Trends in the surgical management of odontoid fractures in patients above 75 years of age: Retrospective study of 70 cases

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Background: Odontoid fractures are the most common upper cervical spine fracture in adults over 70 years of age. Hence, treatment of these fractures has public health implications.

Objectives: Evaluate the early complications, bone healing and mortality in patients above 75 years of age who undergo surgical treatment of an odontoid fracture. Compare the results between patients operated with the Harms technique or anterior screw fixation.

Methods: This was a retrospective study of 70 patients with an odontoid fracture who were treated surgically between 2000 and 2015 at the Hôpital de la Timone in France. The age at the time of diagnosis, comorbidities, ASA score and autonomy were evaluated. Bone healing was determined using computed tomography.

Results: In the cohort, 22 patients underwent anterior screw fixation, 38 were treated using the Harms technique and 10 with other procedures. The average age was 85.1 years. Fifty-four percent of patients had an ASA score above 3. The average follow-up was 23.4 months. An Anderson type II fracture was present in 80.6% of patients. In the anterior screw fixation group, the operative time was significantly shorter than in the Harms group and no blood transfusions were needed. However, 13.6% of these patients had to be re-operated because the initial construct was unstable; no patients in the Harms group underwent revision surgery. There were more complications in the anterior screw fixation group than in the Harms group: 41% versus 13.2% (P < 0.02). The fractures had healed in all patients reviewed after 1 year. The 3-month survival in the anterior screw fixation group was 64.7% and it was 81.3% in the Harms group. These rates were stable at 1 year with no statistical differences between groups.

Conclusion: Surgical treatment of odontoid fractures in the elderly results in an excellent union rate. The mortality rate is stable after 3 months. In our experience, the Harms technique has a lower risk of complications and better mechanical stability than anterior screw fixation. Despite the steep learning curve, we believe the Harms technique is probably the best choice for treating odontoid fractures in the elderly.

Level of evidence: IV.

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1. Introduction

Industrialized nations have an increasingly older population that is expanding in size and continues to be active. In the United States, patients older than 85 years of age are the fastest growing segment of the population and should quintuple by 2050 [1,2]. Odontoid fractures are the most common upper cervical spine fracture in adults above 70 years of age [1,2] and can occur following benign trauma. The management of upper cervical spine fractures, and particularly odontoid fractures in the elderly, is becoming a public health challenge [3].

The optimal care of these fractures is complex. It should rapidly restore adequate autonomy while limiting morbidity and mortality associated with inactivity and/or prolonged hospitalization. Various techniques have been described for treating these injuries, ranging from conservative treatment by immobilization to surgical fracture fixation techniques. The local anatomy of the upper cervical spine, the often-compromised bone quality in the elderly, and the surgical skills required mean there is currently no strong consensus on how to treat these fractures.

Recent studies have shown a theoretical advantage of surgical treatment for odontoid fractures in patients older than 65 years of age with improved quality of life and lower morbidity and
mortality [4]. These results must be weighed against the theoretical risks of surgery or mechanical complications due to the presence of osteoporotic bone. Moreover, given the demographic changes described previously, the 65-year-old threshold no longer seems to correspond to the definition of a geriatric population.

The aim of this single-centre retrospective study was to report how our surgical management of odontoid fractures has changed over time in patients above 75 years of age and how these patients fare after surgery. The outcomes were compared between two surgical techniques – posterior C1–C2 fusion with polyaxial screw and rod fixation as described by Harms and Melcher [5] and anterior screw fixation (ASF) as described by Böhler [6] – using the fusion rate as the main endpoint. In each group, early complications and the mortality rate at 1-year postoperative were also analyzed.

2. Materials and methods

2.1. Study outline

All the patients 75 years of age or older who underwent surgical treatment for an odontoid fracture between January 2000 and March 2015 at our hospital and had at least 1-year follow-up were included retrospectively. For each patient, the age at the time of diagnosis, their height and weight, significant comorbidities (high blood pressure, cardiac arrhythmia, coronary artery disease and diabetes), the American Society of Anesthesiologists (ASA) score and the surgical technique used were recorded.

2.2. Preoperative assessment

The imaging work-up in every patient consisted of a computed tomography (CT) scan of the cervical spine with reconstruction and injection of contrast product. The CT scan was used to evaluate the location of the fracture line based on the Anderson and Alonzo classification, its orientation based on the Roy-Camille classification for type II fractures, the presence of other vertebral fractures, and the degree of C2 osteoporosis according to Lakshmanan’s classification [7]. Contrast product was injected to view the trajectory of the vertebral artery – particularly when posterior screw fixation was planned – the presence of vertebral artery dissection due to trauma and the presence of persistent first intersegmental vertebral artery. Magnetic resonance imaging was also done in patients with neurological deficits.

The chosen surgical technique was analyzed retrospectively and was based on various factors, such as fracture type, fracture line orientation and surgeon experience, particularly when the Harms technique was used.

2.3. Assessment of autonomy

The patients’ autonomy level was analyzed based on their living arrangements prior to the fracture (at home or in nursing home) and the activities of daily living (ADL) scale described by Katz et al. [8]. The latter is a 12-point scale used to assess patient autonomy during ADLs. A score above 6 indicates the patient is dependent.

2.4. Postoperative follow-up

All patients were reviewed at 3 months and 1 year postoperative, and then every 2 years. During each follow-up visit, the results of the clinical examination, autonomy level and the results of the cervical spine CT assessment of fracture healing were recorded. In May 2015, all living patients were contacted by telephone and were asked to answer questions restating the various ADL scale criteria. The duration of follow-up was defined as the time elapsed between the diagnosis of the odontoid fracture and the date of last contact with the patient or his/her death. In patients with less than 1 year of follow-up, fracture union was evaluated on the 3-month CT scan. Lastly, patients with less than 3 months’ follow-up were excluded in the analysis unless they had died within this time frame.

2.5. Assessment of bone union

Bone union was evaluated on a CT scan with reconstruction at 3 months and 1 year postoperative. Union was defined as a bone bridge between the two edges of the fracture or between the C1 and C2 processes in one these examinations.

2.6. Statistical analysis

The differences between paired variables were compared using Student’s t-test with SPSS software. The significance threshold was set at 5%. Survival curves were generated using the Kaplan–Meier method and XLSTAT software.

3. Results

3.1. Demographics

The main characteristics of the study population are given in Table 1. The average age was 85.1 years [SD = 6.3]; 39% of patients had an ASA score of 2 and 54% had an ASA score of 3, which indicates the presence of comorbidities. The patients included in the Harms and ASF groups were initially comparable (P > 0.05). The average follow-up for the overall cohort was 23.4 months [SD = 25.7]; however, it varied between groups. During the initial clinical examination, more than 90% of patients had suffered a head injury with neck pain, justifying a cervical CT scan. Of the 70 included patients, 23 had a spinal cord injury (quadriplegia, tetraparesis or Brown–Séquard syndrome).

3.2. Fracture description

The main features of the odontoid fractures in this study are summarized in Table 2. Most of the fractures (80.6%) were Anderson type II fractures [9] with 73% of patients having an oblique linear fracture line that slopes backward. Based on the Lakshmanan classification [7], osteoporosis was present in the C2 vertebral in every patient; it was classified as moderate or severe in 43% of them. In 10% of patients, the fracture was discovered at the non-union stage; another fracture was also present in 20% of patients (C1 fracture in more than 50% of cases).

3.3. Surgical technique, follow-up and bone union

In the 70-patient cohort, 55% were operated using the Harms technique, 37% with anterior screw fixation and 14% using other techniques: Magerl fusion, occipital-cervical fusion and C1–C2 hook fusion. After 3 months’ follow-up, 12 patients had died (17%), 43 patients were reviewed and 15 were lost to follow-up. Among the living patients, the fracture had healed on CT scan in 86% of patients at 3 months’ postoperative. All implants were correctly positioned. At the 1-year follow-up, 41 patients were reviewed and all their fractures had healed. One patient had died and one was lost to follow-up between the 3rd and 12th month postoperative (Fig. 1).

3.4. Changes in the surgical techniques over time

Fig. 2 shows how the number of procedures done with the two main surgical techniques evolved over time. In the early 2000s, few patients above 75 years of age were operated for an odontoid
Table 1
Characteristics of the study population.

<table>
<thead>
<tr>
<th></th>
<th>Total n = 70</th>
<th>Harms n = 38</th>
<th>ASF n = 22</th>
<th>Other n = 10</th>
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<tr>
<td>Sex (M/F)</td>
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<td>11/27</td>
<td>9/13</td>
<td>4/6</td>
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<tr>
<td>Age</td>
<td>85.1 ± 6.3</td>
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<td></td>
<td>[75.1–104.2]</td>
<td>[75.1–104.2]</td>
<td>[83–92.7]</td>
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<tr>
<td>BMI</td>
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<td>22.8 ± 2.6</td>
<td>24.5 ± 3.9</td>
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<tr>
<td></td>
<td>[17.6–33.1]</td>
<td>[17.6–29.4]</td>
<td>[17.7–29.4]</td>
<td>[20.8–33.1]</td>
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<tr>
<td>ASA score</td>
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<td>17</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>20</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Follow-up (months)</td>
<td>23.4 ± 25.7</td>
<td>14.5 ± 12.7</td>
<td>26.6 ± 31.9</td>
<td>52.7 ± 28.1</td>
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<td></td>
<td>[0.2–90.5]</td>
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<td>[0.4–86.7]</td>
<td>[7.6–90.5]</td>
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<td>Home</td>
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<td>20</td>
<td>8</td>
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<tr>
<td>Nursing home</td>
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<td>9</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Anticoagulant or antiplatelet therapy</td>
<td>19</td>
<td>10</td>
<td>6</td>
<td>3</td>
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<td>History</td>
<td></td>
<td></td>
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<tr>
<td>HBP</td>
<td>43</td>
<td>23</td>
<td>13</td>
<td>7</td>
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<tr>
<td>Arrhythmia</td>
<td>14</td>
<td>6</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>CAD</td>
<td>19</td>
<td>7</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>Diabetes</td>
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<td>4</td>
<td>5</td>
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<td></td>
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<td>Head injury</td>
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<td>20</td>
<td>8</td>
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<tr>
<td>Neck pain</td>
<td>65</td>
<td>35</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Neurological deficit</td>
<td>16</td>
<td>6</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

ASA: American Society of Anesthesiologists; ASF: anterior screw fixation; BMI: body mass index; CAD: coronary artery disease; HBP: high blood pressure.

Table 2
Radiological features of the fracture line.

<table>
<thead>
<tr>
<th></th>
<th>Total n = 70</th>
<th>Harms n = 38</th>
<th>ASF n = 22</th>
<th>Other n = 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anderson and Alonzo classification</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type II fracture</td>
<td>58</td>
<td>29</td>
<td>20</td>
<td>9</td>
</tr>
<tr>
<td>Type III fracture</td>
<td>12</td>
<td>9</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Orientation of fracture line</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posterior oblique</td>
<td>13</td>
<td>8</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Anterior oblique</td>
<td>51</td>
<td>25</td>
<td>19</td>
<td>7</td>
</tr>
<tr>
<td>Horizontal</td>
<td>6</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>C2 osteoporosis based on Lakshmanan [10]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minor</td>
<td>40</td>
<td>18</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>Moderate</td>
<td>24</td>
<td>16</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Severe</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Non-union</td>
<td>7</td>
<td>3</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Associated fracture of another vertebra</td>
<td>14</td>
<td>7</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>C1</td>
<td>9</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Other vertebra</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Fig. 1. Frontal and sagittal CT reconstruction showing healing of the fracture site 1 year after posterior C1–C2 fusion as described by Harms and Melcher [5].
fracture. By 2010, the number of operated patients had increased by a factor of 2.5; most of them were operated using the Harms technique, which had been lightly used until then (1 case before 2010). In 2014, more than 80% of patients were operated using the Harms technique – independent of the fracture line orientation – as this technique stabilizes the fracture even in the presence of osteoporosis.

3.5. Autonomy level

Fig. 3 shows the patients’ autonomy based on the Katz ADL scale. There was no difference between the preoperative and postoperative ADL scores in the whole cohort or in the subgroups.

3.6. Postoperative course

Table 3 describes the main features of the early postoperative course in the cohort. The operative time was significantly shorter ($P < 0.001$) in patients who underwent ASF of the odontoid; the average time was 82 minutes [SD = 40] for the entire cohort. No vertebral artery damage was discovered in this cohort and none of the patients who underwent ASF required blood transfusion ($P < 0.05$).

3.7. Early complications

Table 4 lists two types of complications: medical complications during the hospital stay and complications requiring surgical revision, either because of a surgical site infection or because of construct failure. There were significantly more complications in the ASF group than in the Harms group: 41% versus 13.2% ($P < 0.02$). Three patients (13.6%) who initially underwent ASF of the odontoid (Fig. 4) were re-operated because of early failure of the construct. None of the patients in the Harms groups had to be re-operated because of mechanical failure ($P < 0.05$) or incorrect implant positioning.

3.8. Mortality rate and survival analysis

Fig. 5 shows the percentage of surviving patients over time for the entire cohort based on the Kaplan–Meier method. At 3 months postoperative, the cumulative survivorship was 76.3%. At 2 years, the cumulative survivorship was 67.8%. Fig. 6 shows the survival curves for the Harms and ASF subgroups up to 18 months postoperative. The 3-month survival in the ASF group was 64.7%; it was 81.3% in the Harms group. This difference between the two groups was still present at 1-year postoperative, with a 65% survival rate in

![Fig. 2. Trends over time in the surgical technique used (ASF: anterior screw fixation).](image)

![Fig. 3. Change in postoperative autonomy based on the Katz scale according to the surgical technique used (ASF: anterior screw fixation).](image)
**Fig. 4.** Example of a patient with failure of an anterior screw construct (left panel) who was revised using the Harms posterior fixation method (right panel).

**Fig. 5.** Survivorship of the entire study cohort (Kaplan–Meier curve with 95% confidence intervals).

**Fig. 6.** Survivorship of the Harms group and anterior screw fixation (ASF) groups out to 18 months postoperative (Kaplan–Meier curve with 95% confidence intervals).
the ASF group and 78% in the Harms group; however, this difference was not statistically significant ($P=0.386$).

### 4. Discussion

#### 4.1. Study population

Multiple studies have described the treatment of odontoid fractures in the elderly. However, many of these studies use 65 years of age as a threshold for an elderly patient [10,11] or even 60 years of age [12]. We feel that other than chronological age, the definition of a geriatric population must include other factors, such as incapacity and dependency, thus only patients older than 75 years of age were included in our study. As of January 1, 2015, more than 6.5 million people in France were above 75 years of age, or 10% of the entire population; this compares to 3.8% of the population in 1950 and is projected to increase 240% by 2040 [13]. The average age of our study cohort (85 years) was higher than in similar published studies: 77.2 years [14], 80 years [15] and 81 years [16].

We chose to breakdown our cases into two subgroups (Harms and ASF) based on the type of surgical technique used. This allowed us to compare the outcomes of two well-known surgical techniques: posterior C1–C2 fusion according to Harms and Melcher and anterior screw fixation of the odontoid.

#### 4.2. Clinical presentation and fracture type

The most common clinical presentation was a head injury with neck pain following low-energy trauma, highlighting the need for a cervical CT scan if there is any uncertainty about the diagnosis initially, to avoid discovering a fracture in the non-union stage and the development of neurological deficits. The type of fracture in this study is similar to published data with most being type II oblique linear fractures in which the fracture line slopes backward [1,14]. The presence of associated fractures (20%) is consistent with the rate reported in other published studies [17], which reinforces the need to evaluate the cervical spine fully.

#### 4.3. Changes in surgical techniques over time

Before 2010, only one patient in our practice was operated using Harms technique. Starting in 2010, the number of procedures increased considerably with all patients being operated using this technique between 2011 and 2013. This change can be attributed to several factors, such as the description by Harms and Melcher of their technique in 2001 [5], the learning curve for this technique in elderly and typically fragile patients, and the development of spinal instrumentation in recent years [18], particularly polyaxial screws which make it easier to implant rods between C1 and C2.

#### 4.4. Choice of surgical technique

The choice of surgical technique depends on several parameters.

##### 4.4.1. Fracture type

An oblique posterior fracture line is typically considered an indication for ASF because the perpendicular trajectory of the screw through the fracture line will compress the fracture site. However, when the fracture is considerably displaced or C1-C2 subluxation is present, it can be difficult to reduce the fracture with the patient supine. By using a MAYFIELD® skull clamp, external manoeuvres can be used to reduce the fracture under fluoroscopy guidance and stabilize the reduced fragment during fracture fixation. In our experience, the orientation of the fracture line is not a primary criterion when deciding on the treatment type.

##### 4.4.2. Bone quality

All patients in our study had C2 osteoporosis based on the CT scan criteria of Lakshmanan [7]. In a study comparing ASF with posterior fusion, Anderson reported secondary screw migration in two patients who underwent ASF, with loss of fracture reduction in one of these patients [19]. Kohlof et al. observed the same instability following ASF that required revision by the posterior approach [16]. In our study, three patients who initially underwent ASF had to be re-operated through a posterior approach because of construct instability. In these cases, there were no signs of ligament damage on the preoperative MRI that could explain this
instability. We believe that the reduced bone stock in elderly patients compromised the screw hold. Consequently, we prefer using a construct with better mechanical stability, such as the fusion procedure described by Harms and Melcher [20–22]. The main consequence of this strategy is the considerable limitation on cervical rotation postoperatively, which must be weighed against the incidence of degenerative changes in the atlantoaxial joints found in 4% to 18.2% of the elderly [23,24]. Complete fusion of the atlanto-odontoid joint space occurs in about 61% of patients above 80 years of age [25]. The benefits of maintaining cervical spine rotation by preserving C1–C2 joint mobility by ASF of the odontoid seems crucial in younger patients, but less so in elderly ones. Lastly, ASF requires minutely detailed radiographs, which can be more challenging because of bone demineralization.

4.4.3. Surgical experience

There is no consensus on the preferred surgical technique for odontoid fractures. Thus, the technique selected greatly depends on the surgeon’s skills and experience. Posterior C1–C2 fusion is a demanding technique with a long learning curve. The main technical challenge is related to bleeding due to the abundance of venous plexuses around the C2 root and over the entry point for the C1 lateral masses. Subperiosteal dissection and the use of burrs can help to control bleeding. In cases of persistent venous bleeding, extensive packing will often suppress it. Moreover, the proximity of the C2 root, which is not protected by a bone structure, means that bipolar forces are preferred over monopolar electrocautery.

4.5. Early complications

In a 2013 literature review by Jubert et al., the early complication rate ranged from 0% to 44% in patients above 60 years of age who underwent upper cervical spine surgery. Most of these complications were respiratory disorders and dysphagia [26]. Platzer et al. reported a 16% early complication rate in their study comparing ASF to posterior fusion in patients above 65 years of age: these complications included cardiovascular decompensation, thromboembolic complications, lung disorders and surgical site infections. The early complications in our study are similar to those reported in other published studies in terms of type and frequency. Conversely, the complication rate was three times higher in the ASF group than in the Harms group. This is a large difference given that these two groups were comparable initially. Because of the small sample size, we could not identify statistically significant differences in the number of medical complications between the groups. Nevertheless, there were more revisions due to mechanical instability of the construct in the ASF group.

4.5.1. Fusion rate

Osti et al. reported a 64% fusion rate in patients over 65 years of age who underwent ASF. The development of non-union is correlated with degenerative changes in the atlantoaxial joint, the degree of odontoid osteoporosis, a posterior oblique fracture line orientation, the quality of fracture reduction, the position of the screws and the degree of comminution [27]. In a level II prospective study, Vaccaro et al. reported a 95% fusion rate in a cohort of patients mainly operated with the Harms technique [28]. Molinari et al. reported only a 35% fusion rate in patients who underwent posterior fusion (Harms technique and lamellar hooks). However, they did not provide a breakdown of cases treated with each surgical technique and their method to assess bone union was not standardized: radiographs were used in some patients and CT scans in others [15]. In our study, the fusion rate was 86% at 3 months and 100% at 1 year.

4.5.2. Early mortality (< 3 months)

The survivorship of the entire cohort revealed a high early mortality rate: nearly 25% of patients died within 3 months of suffering the fracture. Molinari et al. reported a 21% mortality rate at 3 months; however, 75% of the patients in their study were treated conservatively. In their subset of operated patients, the 3-month mortality rate was 11%. The patients in the Molinari study [15] were younger than in our study and only 15 were treated surgically, whereas 70 were treated surgically in our study. The analysis of mortality based on the surgical technique found a higher mortality rate in the ASF group (35.3%) than in the Harms group (18.7%).

4.5.3. Late mortality (> 1 year)

The survivorship of our entire cohort was stable out to 2 years postoperative (32.2%). For reference, the 1-year mortality after femoral neck fracture ranges from 27% to 32% [29,30]. When the survival rate is analyzed based on surgical technique, the gap found in the 3rd month postoperative is still present at 1 year: the mortality in the ASF group was 35.3% and 22% in the Harms group. Despite the high mortality in the first 3 months postoperative, likely because of early complications related to fracture treatment, the mortality rate of operated patients is stable over time.

5. Conclusion

Surgical treatment of odontoid fractures in elderly patients is justified by the excellent fusion rate, which allows the patients to quickly regain their pre-injury autonomy, and a mortality rate comparable to patients operated because of femoral neck fracture. In our study, anterior screw fixation resulted in three times more complications than the posterior C1–C2 fusion technique described by Harms, and had a higher revision rate due to mechanical instability. However, the Harms technique has a steep learning curve before the procedure can be done in a reasonable time, given the typical fragile general health of these elderly patients. This is now our preferred technique for treating odontoid fractures in the elderly; it may evolve into minimally invasive techniques using new intramedullary CT techniques paired with a navigation system.

Disclosure of interest

B. Blondel: consultant in Medicea International/Implant/Spineguard; S. Fuentes: consultant in Medicea International/Medtronic/Stryker; S. Pesenti: consultant in Implant; P. Tropiano: consultant in Depuy-Synthes, royalties in LDR Medical and Board in Medtronic. The other authors declare that they have no competing interest.

References


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