Unstable odontoid fracture: Surgical strategy in a 22-case series, and literature review

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Summary  Surgical treatment of unstable odontoid fracture (type II OBAR or HTAL) has progressed, with a range of techniques, the specificities of which need to be known so as to determine their respective roles in the therapeutic arsenal now available. A retrospective study of 22 patients operated on in our center for odontoid fracture between 2005 and 2010 examined the operative techniques employed and analyzed results in the light of the literature, so as to construct an updated decision tree. Two populations could be distinguished: elderly victims of simple fall (mean age, 82.1 years), and younger victims of high-energy trauma (mean age, 42.6 years). Surgical techniques comprised: anterior odontoid screwing (n = 14), transarticular C1-C2 screwing on the posterior Magerl (n = 3) or anterior Vaccaro approach (n = 1), Harms’ posterior C1-C2 arthrodesis (n = 3), and occipitocervical arthrodesis (n = 3). The overall complications rate for the series was 28%, including one case of non-union, at a mean 11 months’ follow-up. The risk/benefit ratio may be hard to assess in elderly patients. However, anterior screwing restores odontoid anatomy and is the technique of choice in first intention for reducible fracture. In second intention, transarticular C1-C2 arthrodesis may be performed on an anterior or posterior approach, depending on local vertebral artery anatomy. Harms’ posterior C1-C2 arthrodesis allows fixation of non-reduced fractures. Occipitocervical arthrodesis is a last resort, as the associated morbidity rate is higher.

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Introduction

Odontoid fractures represent 5 to 15% of spinal fractures as a whole and are the most frequent form of cervical spine fracture in the elderly [1—4]. They are potentially serious due to the life-threatening neurologic risk entailed by the proximity of the medulla oblongata and the great mobility of the cranio-cervical junction (C1-C2 axial rotation), exposing it to a specific risk of instability. They are thus associated with elevated morbidity and mortality [5].

The culprit mechanism is mainly (in 80% of cases) cervical spine hyperflexion, inducing anterior displacement of the odontoid; hyperextension induces posterior displacement [6]. The associated rate of neurologic complications ranges from 2% to 27%, threatening survival and function [6,7]. There are two typical victim populations: elderly subjects sustaining low-energy trauma, and young subjects in whom road accidents are most often implicated; it is no exaggeration to say that the medical issues, comorbidities, bone quality and thus indications are usually diametrically opposite.

The literature reports various treatment options: conservative, by external fixation, soft cervical collar, Minerva corset or cranial halo, or surgical by osteosynthesis. Surgery may be indicated in unstable odontoid fracture with associated neurologic risk, where non-union rates are high in case of abstention. Roy-Camille stressed the combined influence of fracture-line direction and initial displacement direction [8] for classification in terms of biomechanical stability and for surgical indications. Instability is nowadays agreed to concern type II and rostral type III fractures on the Anderson-Alonzo classification [6,9,10].

Progress in surgical techniques has reduced non-union rates, which were high (26—80%) using conservative treatments [11—17]. In young patients, anterior screw fixation is now the reference attitude in unstable odontoid fracture, restoring normal anatomy and C1-C2 function. Non-union rates are low, with 83—100% fusion in reported series. The technique is, however, demanding and not always feasible; the complications rate may be as high as 24% according to Arand et al. [9,18—21]. In elderly patients, the classical attitude is cautious and based on conservative treatments, although several recent comparative studies have reported significantly improved non-union rates and especially lower mortality with surgery [22—26].

The present study takes a few cases operated on in our department, to review current surgical management of odontoid fractures and draw up a decision tree for the various surgical techniques.

Study series

Patients

Between 1st January 2005 and 31st December 2010, 22 odontoid fractures were operated on in the orthopedic and traumatologic surgery department of La Pitie-Salpêtrière Hospital in Paris, France. There were 15 men and seven women. Mean age was 60.1 years (range, 18—86 years), with a bimodal distribution: ten patients were aged over 70 years (mean, 81.2 years) and 12 under 70 years (mean, 42.6 years). Mechanisms were low-energy trauma (fall from body-height) in 41% of cases and high-energy trauma (road accident) in 59%, corresponding more or less exactly to the two age groups (Table 1). Radiologically, the fracture site was classified according to Anderson and Alonzo [27]: 19 type II (86%) and three type III (14%). Fracture-line direction, relevant to stability, was classified according to Roy-Camille [8]: nine of the type-II fractures were horizontal (HTAL) and ten oblique down and back (OBAR, for “oblique en bas et en arrière”); there were no oblique down and forward (OBAV) fractures in the present series, as such patients were managed conservatively. Eight patients (36.4%) had Frankel D neurologic disorder preoperatively.

Surgical techniques

Anterior screw fixation

Fourteen patients underwent osteosynthesis by anterior screwing. There were 13 type-II fractures: six OBAR and seven HTAL; eight were without displacement, and five could be reduced preoperatively. One non-displaced type-III fracture was treated by osteosynthesis by anterior screwing. The anterior screw fixation technique has been described by Böhler [16]. Patients were positioned in dorsal decubitus with the head on a Mayfield headrest to achieve reuction in protraction. Positioning is a crucial step and may take time, and should be adjusted prior to incision. Two fluoroscopes, frontal and lateral, need to be used simultaneously during surgery. The C2-C3 disk was approached (usually by left cervicotomity, the surgeon’s preference) and a single non-cannulated 3.5-mm screw was inserted. From experience, our team avoids cannulated screws so as to prevent guide-wire migration toward the medulla oblongata during screwing. Using a 20/10 K-wire as drill is a trick worth mentioning, as its length and flexibility reduce difficulty due to conflict with the jugular notch (Fig. 1). It is important for the entry point to be intradiscal, posterior to the antero-inferior angle of the vertebral body, so that the screw is supported by the anterior C2 body cortical bone, which has good resistance (Fig. 2). A dedicated offset screwdriver was used in the more recent operations, and can be recommended as greatly facilitating insertion of the screw, controlling direction better than a flexible or basic cardan screwdriver. Postoperatively, the patient was immobilized in a soft cervical collar or Minerva corset, depending on primary fixation quality and patient compliance.

Posterior transarticular C1-C2 arthrodesis

Two C1-C2 arthrodoses were performed by posterior transarticular screw fixation on the Magerl technique [28]: one non-displaced type-III fracture and one type-II OBAR fracture. Patients were positioned in ventral decubitus on a Mayfield skull clamp. The median posterior approach exposed the C1-C2 joint so as to determine the entry point. Counter-incisions allowed the drill to be directed obliquely (Fig. 3). Lateral control X-ray was performed (Fig. 4).

C1-C2 Harms arthrodesis

Three C1-C2 arthrodoses were performed on a posterior approach, following Harms [29]. These were three special cases: one type-II fracture, non-reducible despite traction,
Table 1 Clinical data.

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age</th>
<th>Trauma</th>
<th>Type of fracture</th>
<th>Associated lesions</th>
<th>Treatment</th>
<th>Postoperative complications</th>
<th>Non-union</th>
</tr>
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<td>3</td>
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<td>48</td>
<td>RA</td>
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</tr>
<tr>
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<td>Type B T5</td>
<td>Harms</td>
<td>Revision for infection</td>
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<tr>
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<td>M</td>
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<td>Fall from body-height</td>
<td>III</td>
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<td>CO/C3arth + C1lam</td>
<td>Revision for infection</td>
<td>LFU</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>68</td>
<td>Fall downstairs</td>
<td>II HTAL</td>
<td>No</td>
<td>Magerl</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
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<td>II OBAR</td>
<td>No</td>
<td>Anterior screw</td>
<td>SD no revision</td>
<td>D</td>
</tr>
<tr>
<td>8</td>
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<td>Anterior screw</td>
<td>No</td>
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<td>Anterior screw</td>
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<td>No</td>
</tr>
<tr>
<td>10</td>
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<td>RA</td>
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<td>CO/C5 arthrodesis</td>
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<tr>
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<tr>
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<td>C1-C2 dislocation</td>
<td>Harms</td>
<td>No</td>
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</tr>
<tr>
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<td>24</td>
<td>RA</td>
<td>II HTAL</td>
<td>No</td>
<td>Anterior screw</td>
<td>SD no revision</td>
<td>No</td>
</tr>
<tr>
<td>17</td>
<td>M</td>
<td>52</td>
<td>Fall downstairs</td>
<td>II HTAL</td>
<td>No</td>
<td>Anterior screw</td>
<td>Revision screw failure</td>
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</tr>
<tr>
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<td>83</td>
<td>Fall from body-height</td>
<td>III</td>
<td>No</td>
<td>CO/C4 arthrodesis</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
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<td>II HTAL</td>
<td>No</td>
<td>Anterior screw</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>20</td>
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<td>22</td>
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<td>Type B T12</td>
<td>Anterior screw</td>
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<td>No</td>
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<tr>
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<td>45</td>
<td>RA</td>
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</tr>
<tr>
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<td>25</td>
<td>RA</td>
<td>II OBAR</td>
<td>C5-C6 dislocation</td>
<td>Magerl</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

LFU: lost to follow-up; D: deceased; SD: secondary displacement; RA: road accident.

One type-II fracture with associated rotational dislocation of C1-C2, and one fracture initially osteosynthesized by anterior screwing. In this third case, posterior arthrodesis was performed as revision for insufficient initial reduction with poor screw positioning (Fig. 5). The medial approach exposed the C1-C2 joint. The lateral C1 bone was exposed taking care to respect the vertebral artery loop. On either side, a 2-hole RRC plate (Stryker, USA) was fixed with one 3.5-mm screw in the lateral C1 bone and one in the C2 joint bone. The procedure was performed under lateral fluoroscopy. For this procedure, it is essential to determine vertebral artery anatomy, which shows variations, preoperatively.

**Anterior transarticular C1-C2 arthrodesis**
Anterior C1-C2 arthrodesis by joint bone screw fixation following Vaccaro [30] was performed in a patient with odontoid fracture associated with Jefferson fracture: classical anterior screw fixation proved unsatisfactory due to poor primary fixation of the C2 odontoid screw and the associated C1-C2 lesion (Fig. 6). The patient underwent high left cervicotom. For the lateral bones, cannulated screws were used. The C2 joint bone entry was performed via the longus colli under frontal and lateral fluoroscopy. The divergent screws terminated in the lateral C1 bone. Like in posterior transarticular C1-C2 arthrodesis, vertebral artery anatomy needs to be determined in advance, with CT-assisted planning.

**Occipitocervical arthrodesis**
Occipital-C3 arthrodesis was performed for one displaced type-III fracture with associated neurologic disorder requiring laminectomy. Occipital-C5 arthrodesis was performed for one non-reducible type-II fracture. And occipital-C4 arthrodesis was performed for one other displaced type-III fracture.
Results

Postoperative morbidity

The overall postoperative complications rate was 28% (six patients).

Mechanical complications included secondary anterior screw displacement in two patients aged over 80 with type-II OBAR fracture. Displacement was moderate and did not require surgical revision. Revision was performed in two cases of patent failure of anterior screw fixation. In one long-standing (6 months) fracture, reduction was insufficient and the screw was too posterior; revision failed to achieve reduction and Harms C1-C2 arthrodesis was performed. Revision in the second case was performed at two days postoperatively, for defective screw positioning seen on control CT; secondary anterior screw fixation was satisfactory.

Revision surgery was performed in two cases of local infection. Both patients had been operated on with a posterior approach, one for occipitocervical arthrodesis and the other for Harms C1-C2 arthrodesis. Simple lavage without change of material, with prolonged (3 months) antibiotic therapy, achieved resolution without sequelae.

Mortality

One-year mortality was 19%: four patients aged over 80 years at trauma, treated by anterior screw fixation. One died in the immediate postoperative phase, due to respiratory distress. Two died at 6 months. The fourth died at 1 year from respiratory failure secondary to amyotrophic lateral sclerosis. Only one death (4%) was thus specifically related to the odontoid fracture.

Non-union

There was only one case of non-union, in a patient operated on for type-II HTAL fracture by anterior screw fixation. The fusion rate for the series was thus 96%.

Discussion

Management of odontoid fracture has greatly evolved since the first surgical fixation, described by Mixter and Osgood in 1910 [31]. In unstable fracture, elevated rates of non-union and complications associated with prolonged immobilization [32–34] limit conservative approaches. Surgical treatment, on the other hand, has greatly diversified since the series reported by Fourniols et al. [35], with the advent of innovative C1-C2 arthrodesis techniques. Attitudes in odontoid fracture also appear to be increasingly surgical [36], even in the elderly. The mean age of the 1995 Pitié Salpêtrière series was 50 years [35], compared to 60 in the present series. This may reflect epidemiological changes (age pyramid,

Figure 1 Diagram of anterior screw fixation, stressing certain tricks and tips: protraction, K-wire, antero-inferior edge entry point.

Figure 2 Radiographs of odontoid anterior screw fixation.
Figure 3  Diagrams of posterior screw fixation on direct posterior medial cervical approach to control right and left K-wire entry in C2 joint bone, with two more caudal incisions (right and left) to allow correct trajectory without hindrance by soft tissue. A. Lateral view. B. Three-quarter view.

Figure 4  Radiographs of transarticular screw fixation on posterior approach, following Magerl.
elderly, better non-union from anesthesiological indications, leading to complementary Vaccaro arthrodesis in the same operative time.

accidentology) and also evolution of indications in parallel to surgical and anesthesiological techniques.

It seems immediately clear that a distinction is to be made between older and younger patients. In the elderly, a recent meta-analysis failed to resolve the surgical/conservative issue [36]; all that can be said is that the literature data argue for abandoning halo-vest immobilization, found to aggravate mortality and morbidity in geriatric contexts significantly [11,37,38], in favor of the better tolerated and equally effective simple flexible cervical collar. Elderly subjects’ relatively good tolerance of non-union is to be weighed with the frequent risks associated with anesthesia and the poor bone quality affecting 50% of over-80 year-olds [39]. Depending how one looks at it, surgical management in the elderly may seem fairly innocuous or fairly pointless [16,40]. At all events, the rate of complications associated with anterior screw fixation seems to be higher than in younger patients [41], probably due to local bone demineralization; it varies greatly, however, from series to series [40,42,43]. Anderson et al. therefore recommend first-line C1-C2 arthrodesis, due to the rates of complications and of non-union that are lower than with anterior screw fixation [44]. Although seemingly logical, this argument loses weight considering that non-union may be a tolerable compromise. In the present series, eight in ten over-70 year-olds underwent anterior screw fixation; there were two moderate secondary displacement, not requiring revision surgery, and one early death. The present findings suggest that anterior odontoid screw fixation may be indicated in elderly patients, having the advantages of effective primary stabilization and good recovery of independence. There is a bias, however, inasmuch as the present series was strictly surgical, with patients with non favorable terrain having been managed conservatively. It should be borne in mind that it is always possible to go back on the surgical option in an elderly patient, and that it is physiological age, estimated on a case-by-case basis, that counts.

In younger adults, indications are found on the mechanical aspect, and debate largely concerns technique. In reduced or reducible type-II OBAR fracture, the indication of

Figure 5  Radiographs of C1-C2 arthrodesis following Vaccaro. Mechanical fixation of the odontoid screw was found to be defective peroperatively, leading to complementary Vaccaro arthrodesis in the same operative time.

Figure 6  Radiographs of C1-C2 arthrodesis following Harms. Odontoid screw malpositioning found on postoperative control; reduction defect indicated revision by Harms arthrodesis.

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choice is anterior screw fixation: it restores normal anatomy, and the literature testifies to its being the technique that provides the best functional recovery in terms of range of motion, with low mortality and morbidity. The rate of complications varies, and reaches 20% for Anderson [44], comparably to the present findings, with three revision surgeries for 14 anterior screw fixations. It is a demanding technique, requiring an experienced surgeon. In his princes description of 1982, Bölher [16] used two screws, to enhance solidity of assembly; several biomechanical studies, however, subsequently demonstrated that using two screws does not reduce the incidence of non-union or the risk of secondary displacement [45, 46]. We therefore recommend protecting the osteosynthesis by means of a temporary cervical collar. Moreover, it is not always possible to implant two screws, when the odontoid is narrow [45, 46]. Our recent experience, reported above, systematically used a single screw. The posterior transarticular Magerl, anterior transarticular Vaccaro or the Harms technique are interesting C1-C2 arthrodeses, but incurring a specific risk of vertebral artery lesion [47]; depending on individual anatomy, bone capital may indicate upward front-to-back or back-to-front transarticular screwing, the biomechanical principle of transarticular fixation being the same in either case. Anterior C1-C2 arthrodesis has the advantage of using the same patient positioning and approach as Bölher screw fixation, thereby offering a peroperative salvage solution. The Harms assembly screws may be replaced by supra-sub-laminar hooks in C1-C2, although we have no experience of this [29]. The literature reports fusion rates approximating 100% for transarticular screw fixation [28, 29, 48]; in the present series, there were no non-unions, technical failures or surgical revisions with the technique, even in elderly patients. The three patients managed by the Harms technique also showed no non-union. C1-C2 arthrodeses appear to be reliable, although range of motion is reduced in rotation [49, 50].

Fig. 7 presents the treatment attitude and surgical decision tree derived from our experience of unstable odontoid fracture. Other than patient age and fracture-line direction, which may argue for conservative management (advanced physiological age, OBAV fracture), C1-C2 arthrodesis is our second choice when anterior screw fixation is contra-indicated, impossible or has failed, considering impact on range of motion [30, 44, 46]. Like odontoid screw fixation, transarticular screwing (anterior to posterior) requires perfect prior reduction of C1 on C2 before screw insertion. Only the Harms plate assembly by screwing into the lateral C1 bone and C2 pedicle [32] is feasible in non-reduced fracture, and should therefore be part of the surgeon’s arsenal.

Vascular risk varies from 1.3% to 5.8%, depending on the series [51–53], making vascular assessment indispensable to preoperative planning for C1-C2 arthrodesis. This requires anatomic analysis of the vertebral arteries, C2 pedicles and lateral C1 bone mass ahead of transarticular screw fixation, whether anterior or posterior, or Harms’ arthrodesis, and indeed by precaution ahead of anterior screw fixation in anticipation of possible peroperative cross-over. Vascular lesions, nevertheless, are not necessarily complications with real impact: a report of 1318 transarticular C1-C2 screw fixations by the American Association of Neurosurgery found a 4.1% rate of isolated lesion to one or both vertebral arteries, with neurologic sequelae in only two patients [53]. The risk is mainly of vertebral artery embolism, ischemia risk being manageable by means of the Willis polygon.

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Finally, in type-III fracture, indications for surgery remain a matter of debate. Treatment is classically conservative, with high rates of fusion [6, 12, 32, 54]. The halo vest used to be considered to provide optimal fusion, but was associated with a non-negligible rate of complications (mediocre tolerance) so that cervical collars are now preferred [23, 37]. In the present series, three type-III fractures were managed surgically: these were borderline cases, with relatively high and displaced fractures assimilable to type II and accessible to anterior screwing; this drawback in the Anderson-Alonso classification has been previously highlighted [55].

Conclusion

Indications for surgery should be discussed in case of unstable odontoid fracture [22]. Victims are mainly elderly, and physiological age and comorbidity are the decisive factors. No age limit has been able to be set: rather, it is general status that should be taken into account [24]. Other than age, fracture-line direction is a decision factor, conservative management being suited to OAVB fracture in our view. When surgery is indicated, anterior screw fixation is our attitude of choice when feasible, due to its radiologic and clinical results, but depends on operator experience. C1-C2 arthrodesis provides acceptable functional results but remains an option of second intention due to loss of axial rotation. The Magerl technique is classical, but we would stress the interest of Vaccaro’s technique, performed in dorsal decubitus via cervicalotomy, and Harms’s, a possible solution in case of non-reduction. Preoperative imaging assessment of bone capital and vertebral artery trajectory is mandatory. Occipitocervical arthrodesis is indicated only as a salvage technique, due to the elevated associated morbidity.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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Odontoid fracture surgery


