Original article

Conservative versus surgical treatment for type II odontoid fractures in the elderly: Grading the evidence through a meta-analysis

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ABSTRACT

Background: Odontoid fractures are common C-spine fractures in the elderly. However, the optimal treatment of odontoid fractures in the elderly is still subject to controversy.

Hypothesis: Surgical treatment has several advantages on conservative treatment, such as reduced mortality and lower incidence of non-union. This meta-analysis was performed to identify the efficacy of conservative treatment compared with surgical treatment and provides recommendations for using these procedures to treat type II odontoid fractures in the elderly.

Materials and methods: A systematic search of all studies published was conducted using the PubMed, EMBASE, OVID, ScienceDirect and Cochrane CENTRAL databases. The randomized controlled trials (RCTs) and non-randomized controlled trials (non-RCTs) that compared conservative treatment with surgical treatment and provided data on clinical effects were identified. The included trials were screened out strictly based on the criterion of inclusion and exclusion. The quality of included trials was evaluated. RevMan 5.1 was used for data analysis.

Results: Twelve studies involving 730 patients met the inclusion criteria. There were 441 patients with conservative treatment and 289 with surgical treatment. The results of meta-analysis indicated that no difference with regard to the mortality was noted (P > 0.05) between the two procedures. However, there was statistically significant difference with respect to the non-union numbers (P < 0.05) between the two procedures.

Discussion: Conservative treatment and surgical treatment are both effective procedures for treating type II odontoid fractures in the elderly. Compared with surgical treatment, there is no significant difference in mortality. With respect to non-union numbers, conservative treatment numbers are higher than surgical treatment. Due to the poor quality of the evidence currently available, high quality RCTs are required.

Level of evidence Level II: low-powered prospective randomized trial meta-analysis.

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1. Introduction

Odontoid fractures count to nearly 20% of all cervical fractures. Among these, 65–74% are type II fractures according to Anderson and D’Alonzo. They are the most common cervical fractures in the elderly [1,2]. Currently, the treatment of type II odontoid fractures remains a challenging problem, particularly in geriatric population [3].

The treatment of odontoid fractures mainly involves conservative treatment and surgical treatment. Both conservative treatment and surgical treatment have advantages and disadvantages for treating odontoid fractures. The patients typically suffer from an increased risk of operation complications when treated surgically as well as from an increased risk of second surgery and prolonged treatment duration when treated conservatively [4]. Although there are a limited number of studies have been published, the optimal treatment of odontoid fractures in the elderly is, however, still subject to controversy [5,6].

The purpose of this meta-analysis is to evaluate the evidence from RCT and non-RCT studies that compared the efficacy of conservative treatment and surgical treatment for treating odontoid fractures patients and to provide recommendations for using the procedures to treat odontoid fractures.

2. Materials and methods

2.1. Search strategy

A systematic search of all studies published was conducted using the PubMed, EMBASE, OVID, ScienceDirect and Cochrane CENTRAL...
databases from their inception to January 2015. Other Internet databases were also performed to identify trials according to the Cochrane Collaboration guidelines. The following search terms were used to maximize the search specificity: odontoid fracture, dens fracture, surgery and conservative treatment. The reference lists of all the full-text papers were examined to identify any initially omitted studies. We made no restrictions on the publication language.

2.2. Inclusion criteria

The following inclusion criteria were applied:

- study design: interventional studies (RCTs or non-RCTs);
- population: elderly patients (> 60 or older) with type II odontoid fractures;
- intervention: conservative treatment (collar, cast or halo-vest);
- comparator: surgical treatment (anterior or posterior operation);
- case series: study of > 10 cases;
- outcomes: reported at least one of the mortality and non-union numbers.

2.3. Exclusion criteria

The following exclusion criteria were applied:

- no separate analysis of type II odontoid fractures;
- elderly group not analysed separately or not identifiable in the paper;
- case series < 10 cases;
- review articles or experimental studies.

2.4. Study selection

Two reviewers (ZY and ZZY) independently screened the titles and abstracts for the eligibility criteria. Subsequently, the full-text of the studies that potentially met the inclusion criteria were read and the literature was reviewed to determine the final inclusion. We resolved disagreements by reaching a consensus through discussion.

2.5. Data extraction

Two of the authors (ZY and ZZY) independently extracted the relevant data from each full-text report using a standard data extraction form. The data extracted from studies included the title, authors, year of publication, study design, sample size, population, age, gender, type of interventions, surgical procedures, duration of follow-up and outcomes parameters. The corresponding authors of the included studies were contacted to obtain any required information that was missing. The extracted data were verified by XLM.

2.6. Methodological quality assessment

We evaluated the RCTs using the “Cochrane collaboration’s tool” for assessing the risk of bias. Non-RCT [i.e., retrospective comparative study (RCS) and prospective comparative study (PCS)] methodological quality was assessed using the Methodological Index for Non-Randomized Studies (MINORS) form[7], which was a valid instrument designed to assess the quality of comparative or non-comparative non-RCT studies.

2.7. Data analysis and statistical methods

The meta-analysis was undertaken using RevMan 5.1 for Windows (The Cochrane Collaboration, Oxford, United Kingdom). We assessed statistical heterogeneity for each study with the use of a standard Chi² test (for heterogeneity, a level of P<0.1 was considered significant) and the I² statistic. An I² statistic value of 50% was considered to indicate substantial heterogeneity. In comparing trials showing heterogeneity, pooled data were meta-analyzed using a random-effects model. Otherwise, a fixed-effects model was used for the analysis. Odds ratio (OR) and 95% confidence intervals (CIs) were calculated for dichotomous outcomes and mean differences (MDs) and 95% CIs for continuous outcomes. Publication bias was estimated by funnel plot, and asymmetry in the funnel was present if publication bias existed.

2.8. Evidence synthesis

The evidence grade was determined using the guidelines of the GRADE (Grading of Recommendations, Assessment, Development, and Evaluation) working group. The GRADE system uses a sequential assessment of the evidence quality followed by an assessment of the risk–benefit balance and a subsequent judgment on the strength of the recommendations. The evidence grades are divided into the following categories:

- high, which indicates that further research is unlikely to alter confidence in the effect estimate;
- moderate, which indicates that further research is likely to significantly alter confidence in the effect estimate and may change the estimate;
- low, which indicates that further research is likely to significantly alter confidence in the effect estimate and to change the estimate;
- very low, which indicates that any effect estimate is uncertain.

Study limitations, results inconsistency, indirectness, imprecision and publication bias may lower the grade of the quality of evidence. The reasons for increasing the quality of evidence include a large effect, presentation of a dose–response gradient and plausible confounders that would decrease an apparent treatment effect. As recommended by the GRADE working group, the lowest evidence quality for any of the outcomes was used to rate the overall evidence quality. The evidence quality was graded using the GRADEpro Version 3.6 software. The strengths of the recommendations were based on the quality of the evidence.

3. Results

3.1. Search results

A total of 1258 titles and abstracts were preliminarily reviewed, of which 12 studies eventually satisfied the eligibility criteria [8–19] (Fig. 1). These studies included 11 RCS [8–18] and 1 PCS [19]. In total, 730 patients and were included in the 12 studies. There were 441 patients with conservative treatment and 289 with surgical treatment. The basic information of included studies was presented in Table 1.

3.2. Quality assessment

Among the 12 included studies, only 1 PCS had a low risk of bias, and the remaining 11 RCS studies had a high risk of bias resulting from study design limitations. The MINORS quality scores of the non-RCTs are presented in Table 1. The mean score was 13.0 (range, 11–18), which corresponded to a 54% score. This result indicated that there was considerable variability in the evidence base.
3.3. Demographic characteristics

In total, 1 PCS and 11 RCS with 730 patients were eligible for inclusion. The individual sample sizes ranged from 16 to 159 patients. A total of 441 patients underwent conservative treatment, and the remaining 289 received surgical treatment. All of the included studies had defined eligibility criteria. Two articles compared one conservative approach with one surgical approach, five articles compared two conservative approaches with one surgical approach, three articles compared two conservative approaches with two surgical approaches, one article compared three conservative approaches with one surgical approach and one article compared one conservative approach with two surgical approaches.

Table 1
Characteristics of included studies.

<table>
<thead>
<tr>
<th>Study</th>
<th>Years</th>
<th>Country</th>
<th>Study design</th>
<th>Age</th>
<th>No. of patients (conservative treatment)</th>
<th>No. of patients (surgical treatment)</th>
<th>Minimum follow-up (months)</th>
<th>MINORS Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hanigan et al. [8]</td>
<td>1993</td>
<td>USA</td>
<td>RCS</td>
<td>&gt; 80</td>
<td>11</td>
<td>5</td>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>Ryan et al. [9]</td>
<td>1993</td>
<td>Australia</td>
<td>RCS</td>
<td>&gt; 60</td>
<td>29</td>
<td>1</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Seybold et al. [10]</td>
<td>1998</td>
<td>USA</td>
<td>RCS</td>
<td>&gt; 60</td>
<td>12</td>
<td>7</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Müller et al. [11]</td>
<td>1999</td>
<td>Germany</td>
<td>RCS</td>
<td>&gt; 70</td>
<td>17</td>
<td>5</td>
<td>18</td>
<td>14</td>
</tr>
<tr>
<td>Andersson et al. [12]</td>
<td>2000</td>
<td>Sweden</td>
<td>RCS</td>
<td>&gt; 65</td>
<td>7</td>
<td>17</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>Kuntz et al. [13]</td>
<td>2000</td>
<td>USA</td>
<td>RCS</td>
<td>&gt; 65</td>
<td>14</td>
<td>6</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Zai et al. [14]</td>
<td>2000</td>
<td>Canada</td>
<td>RCS</td>
<td>&gt; 65</td>
<td>64</td>
<td>20</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>Smith et al. [15]</td>
<td>2008</td>
<td>USA</td>
<td>RCS</td>
<td>&gt; 80</td>
<td>40</td>
<td>32</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Chaudhary et al. [16]</td>
<td>2010</td>
<td>Canada</td>
<td>RCS</td>
<td>&gt; 70</td>
<td>9</td>
<td>11</td>
<td>3</td>
<td>13</td>
</tr>
<tr>
<td>Fagin et al. [17]</td>
<td>2010</td>
<td>USA</td>
<td>RCS</td>
<td>&gt; 60</td>
<td>68</td>
<td>40</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Schoenfeld et al. [18]</td>
<td>2011</td>
<td>USA</td>
<td>RCS</td>
<td>&gt; 65</td>
<td>112</td>
<td>44</td>
<td>36</td>
<td>14</td>
</tr>
<tr>
<td>Fehlings et al. [19]</td>
<td>2013</td>
<td>Canada</td>
<td>PCS</td>
<td>&gt; 65</td>
<td>58</td>
<td>101</td>
<td>24</td>
<td>18</td>
</tr>
</tbody>
</table>

3.4. Quality of the evidence and recommendation strengths

Two outcomes in this meta-analysis were evaluated using the GRADE system. The following two outcomes were important: mortality and non-union numbers. The evidence quality for each outcome was very low (Table 2). Therefore, we agreed that the overall evidence quality was very low. This finding may lower the confidence in any recommendations.

3.5. Meta-analysis results

3.5.1. Mortality

Eleven studies reported the mortality. The pooled results of the studies showed that conservative treatment did not increase the
Table 2: The GRADE evidence quality for each outcome.

<table>
<thead>
<tr>
<th>Outcome</th>
<th>No of studies</th>
<th>Risk of bias</th>
<th>Inconsistency</th>
<th>Indirectness</th>
<th>Imprecision</th>
<th>Other considerations</th>
<th>No. of patients</th>
<th>Effect</th>
<th>Quality</th>
<th>Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality</td>
<td>11</td>
<td>Serious</td>
<td>Serious</td>
<td>Serious</td>
<td>None</td>
<td>None</td>
<td>70/383 (18.3%)</td>
<td>OR 0.99 (0.41–2.39)</td>
<td>++++++</td>
<td>Important</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very low</td>
<td></td>
</tr>
<tr>
<td>Numbers</td>
<td>10</td>
<td>Serious</td>
<td>Serious</td>
<td>Serious</td>
<td>None</td>
<td>Large effect</td>
<td>68/289 (23.5%)</td>
<td>OR 0.65 (1.93–7.27)</td>
<td>++++++</td>
<td>Important</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very low</td>
<td></td>
</tr>
</tbody>
</table>

3.5.2. Non-union numbers

Ten studies reported non-union numbers. The pooled results of the studies showed that conservative treatment increase the risk of non-union numbers (OR = 3.75, 95% CI: 1.93–7.27, P < 0.0001). There was no significant heterogeneity ($\chi^2 = 12.25, df = 9, I^2 = 27\%$, $P = 0.20$; Fig. 3). A fixed-effects effects model was used.

3.5.3. Publication bias

The funnel plot of non-union numbers demonstrated limited evidence of small study exclusion and publication bias. The diagram was asymmetrical, and few studies were plotted on the left side of the funnel (Fig. 4).

4. Discussion

Clinically, odontoid fractures are not uncommon. When treated inappropriately or without treatment, the elderly patients suffer from an increased risk of non-union. Simultaneously, there is potential atlantoaxial instability. Once it occurs displacement, this may lead to an acute or chronic injury of brain stem, spinal cord or nerve root causing severe quadriplegia, respiratory dysfunction or death. Therefore, the treatment for patients with odontoid fractures should be based on fracture pattern, patient age, neurological deficits and the patient's medical condition. Many factors have to be taken into account to find the right balance between fracture healing and treatment complications. Based on these factors, the decision for either conservative or surgical treatment is made [20].

Where treatment of type II odontoid fractures in the elderly is controversial, no single approach of management is universally accepted. Because the variable anatomy and diminished bone quality with increased age makes surgery technically challenging, Ryan et al. [21] recommended in their study that conservative treatment should be the first choice for the treatment of odontoid fractures. However, in several studies, increased morbidity and mortality rates and a high rate of non-union have been reported in the conservatively treated group, whereas acceptably low morbidity and mortality rates with a high rate of union were found in the surgically treated group [22–24]. Schoenfeld et al. [18] through multivariate analysis found that surgical treatment can reduce the mortality rate of the elderly patients. Borm et al. [25] reported the patients over 70

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![Fig. 2](image_url). The odds ratio (OR) estimate for mortality.
years with type II odontoid fractures who were treated with cervical anterior surgery, the healing rate was 73.3%, while the mortality and complication rates were not significantly higher than younger patients.

The results of meta-analysis indicated that no difference with regard to the mortality was noted (P > 0.05) between the two procedures. However, there was statistically significant difference between the two procedures with respect to non-union numbers (OR = 3.75, 95% CI (1.93–7.27), Z = 3.91, P < 0.0001). The elderly patients with type II odontoid fractures suffered from an increased risk of non-union when treated inappropriately or without treatment. There may be four main causes as follow:

- the external fixation was not really fixed, cervical was instable;
- osteoporosis was common in the elderly, the effects of external fixation was poor;
- there was cervical degeneration in the elderly, stress concentrated in the fracture site was not conducive to fracture healing;
- osteogenic ability was weak in the elderly.

There are several potential limitations of this meta-analysis:

- only non-RCT reports were included, and their sample sizes were relatively small, which may have affected our conclusions;
- the follow-up period of patients in some trials was unclear. Many patients were followed up in the short-term. This may have resulted in under-reporting;
- the existence of a publication bias also affects the analysis; it is a limitation in all meta-analysis;
- the overall GRADE quality of evidence was very low, which lowers confidence in any subsequent recommendations.

Therefore, the conclusions obtained in this meta-analysis should be treated with caution.

5. Conclusion

This meta-analysis demonstrates that conservative treatment and surgical treatment are both effective procedures for treating type II odontoid fractures in the elderly. Compared with surgical treatment, there is no significant difference in mortality. However, conservative treatment has higher non-union numbers than surgical treatment, which could negatively affect conservative treatment utilization. The overall evidence quality was very low; therefore, high quality RCTs are required.

Disclosure of interest

The authors declare that they have no competing interest.

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