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INVITED REVIEW

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Nonoperative versus operative management of type II odontoid fracture in older adults: a systematic review and meta-analysis

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OBJECTIVE Odontoid fractures are the most common fracture of the cervical spine in adults older than 65 years of age. Fracture management remains controversial, given the inherently increased surgical risks in older patients. The objective of this study was to compare fusion rates and outcomes between operative and nonoperative treatments of type II odontoid fractures in the older population.

METHODS A systematic literature review was performed to identify studies reporting the management of type II odontoid fractures in patients older than 65 years from database inception to September 2022. A meta-analysis was performed to compare rates of fusion, stable and unstable nonunion, mortality, and complication.

RESULTS Forty-six articles were included in the final review. There were 2822 patients included in the different studies (48.9% female, 51.1% male), with a mean ± SD age of 81.5 ± 3.6 years. Patients in the operative group were significantly younger than patients in the nonoperative group (81.5 ± 3.5 vs 83.4 ± 2.5 years, $p < 0.001$). The overall (operative and nonoperative patients) fusion rate was 52.9% (720/1361). The fusion rate was higher in patients who underwent surgery (74.3%) than in those who underwent nonoperative management (40.3%) (OR 4.27, 95% CI 3.36–5.44). The likelihood of stable or unstable nonunion was lower in patients who underwent surgery (OR 0.37, 95% CI 0.28–0.49 vs OR 0.32, 95% CI 0.22–0.47). Overall, 4.8% (46/964) of nonoperatively managed patients subsequently required surgery due to treatment failure. Patient mortality across all studies was 16.6% (452/2721), lower in the operative cohort (13.2%) than the nonoperative cohort (19.0%) (OR 0.64, 95% CI 0.52–0.80). Complications were more likely in patients who underwent surgery (26.0% vs 18.5%) (OR 1.55, 95% CI 1.23–1.95). Length of stay was also higher with surgery (13.6 ± 3.8 vs 8.1 ± 1.9 days, $p < 0.001$).

CONCLUSIONS Patients older than 65 years of age with type II odontoid fractures had higher fusion rates when treated with surgery and higher stable nonunion rates when managed nonoperatively. Complications and length of stay were higher in the surgical cohort. Mortality rates were lower in patients managed with surgery, but this phenomenon could be related to surgical selection bias. Fewer than 5% of patients who underwent nonoperative treatment required revision surgery due to treatment failure, suggesting that stable nonunion is an acceptable treatment goal.

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KEYWORDS cervical collar; elderly; geriatric; odontoid fracture; spine fusion; systematic review; treatment

In the last few decades, countries around the world have experienced increasingly aging populations. It is estimated that about 17% of the world's population will be older than 65 years by 2050, equating to 1.3 billion people.[1–3] The demographic shift in age has already changed the patients for whom we care. Older patients present new challenges for healthcare practitioners and spine surgeons, who must treat multiple medical comorbidities such as osteopenia, osteoporosis, and frailty. All these conditions influence patient outcomes. The management of odontoid fractures presents a unique challenge to spine surgeons, as people live remarkably healthy and active lives well into their 80s and 90s. In many cases, these patients are able to continue to live independently.

A review of the Centers for Medicare & Medicaid Services claims database revealed that fractures of the

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odontoid process increased by 135% over a 10-year period.[4] Odontoid fractures, which are most frequently type II fractures, are now the most common type of cervical spine fracture in older adults. Different management strategies have been proposed throughout the years based on fracture morphology, degree of angulation, and, in particular, the age of the patient. Nonoperative management with external immobilization by a cervical collar or halo vest is the treatment currently recommended by evidence-based neurosurgical guidelines.[5,6] The nonoperative approach has long been favored due to increased surgical morbidity in older patients. Nonetheless, despite successful treatment with a collar or halo vest, some patients develop nonunion or progression of the fracture angulation that requires surgical consideration. Additionally, in recent years, there has been a trend to treat some older patients with type II odontoid fractures with surgery immediately rather than after failed conservative treatment measures. These studies have demonstrated that surgical fixation conferred a survival benefit compared with nonoperative treatment.[7,8] Nonetheless, performing surgery in the older population exposes patients to increased risks of perioperative complications.

Despite the commonality of type II odontoid fractures, the aging population and disagreement within the published literature continue to fuel the debate over the ideal management of these fractures. The goal of this study was to provide a systematic review comparing outcomes between surgical and conservative management of type II odontoid fractures in patients older than 65 years of age.

Methods

A systematic literature review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[9] to identify studies reporting on type II odontoid fractures in patients older than 65 years of age (Fig. 1). The search was conducted, and the results were retrieved in September 2022.

Search Strategy and Screening

The databases examined included PubMed, PubMed Central, Cochrane Library, Embase, and Ovid. The search was tailored to gather English-language articles published from the inception of each database through September 2022. Keywords included "odontoid," "fracture," "elderly," "aged," "treatment," and "treatment outcome," with the Boolean operators AND or OR (*Appendix*).

Inclusion and Exclusion Criteria

Studies written in the English language that described patients older than age 65 with type II odontoid fractures were included. These articles consisted of case series (> 5 patients) and retrospective and prospective reports. Abstracts, posters, indexes, commentaries, author notes, case reports (< 5 patients), and literature reviews were excluded. Figure 1 shows the article selection process. Operative studies included patients treated with anterior and posterior cervical fixation strategies. Nonoperative studies included patients treated with an external cervical orthosis, including rigid and soft collars and halo vests.

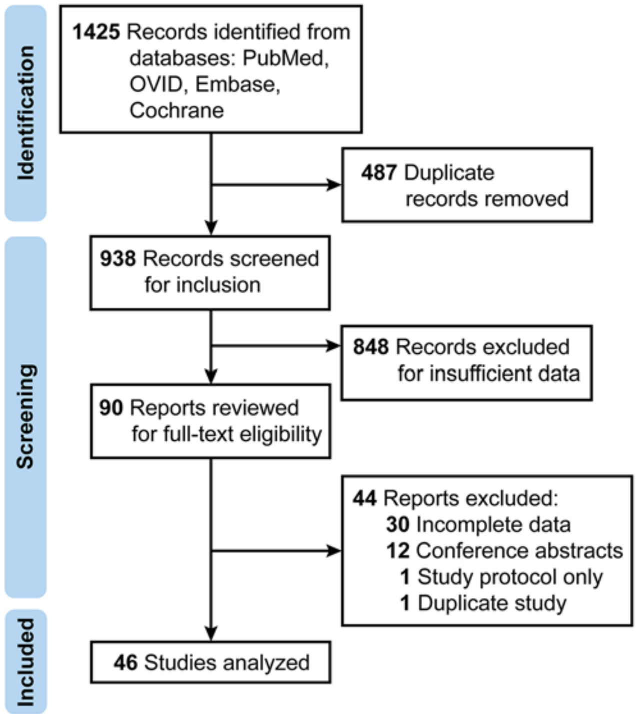

FIG. 1. PRISMA 2020 flow diagram of the search and selection process. Figure is available in color online only.

Data Extraction

All data were obtained directly from results sections, tables, figures, and texts of included articles. The relevant data were extracted and placed into a custom table that included the article's first author and year published, study type, number of patients included, demographics, type of intervention, hospital course, length of treatment, complications, overall outcome, fusion rates, and follow-up, among others. When data were unclear or unspecified, we noted this in the table. Criteria for fusion were dependent on the authors' definition in each individual study. Fusion was determined by the presence or absence of bridging bone on postoperative anteroposterior and lateral radiographs or CT images, the presence or absence of motion on dynamic cervical flexion-extension radiographs, or both.

Statistical Analysis

Independent-samples t-tests weighted by intervention sample size were used to compare age and length of stay between groups. Pooled fusion, mortality, and complication rates were calculated with 95% CIs and shown in a forest plot. Data were collected in Excel (Microsoft Corporation), and forest plots were created using MedCalc Statistical Software version 20.106 (https://www.medcalc.org).

Results

A total of 1425 results were found from the different database searches. After removing duplicates, we evaluated the titles and abstracts of 938 studies. Three independent reviewers narrowed these articles to 90, which were selected for full-text downloads and detailed reviews. Of these, 44 were excluded because they did not contain sufficient information on fracture healing, complications, or mortality. Forty-six articles[2,7,10–53] were included for data retrieval (Table 1). Of these, the specific outcomes of interest (fracture healing, mortality, and complication rates) were reported in 35, 44, and 36 studies, respectively.

There were 2822 patients included from the different studies (49% female, 51% male). The mean ± SD age of the overall cohort was 81.5 ± 3.6 years. Patients in the operative group were significantly younger than patients in the nonoperative group (81.5 ± 3.5 vs 83.4 ± 2.5 years, $p < 0.001$). Most of the studies originated in North America (n = 21) and Europe (n = 22), most frequently from the United States (n = 20) and Germany (n = 9). Three studies were prospective by design, whereas the rest were retrospective. Most of the studies were published within the past 10 years; the most common years of publication were 2013 and 2018 (n = 6 each).

The majority of the studies detailing conservative management recommended a rigid collar, but several studies reported the use of a halo vest. Conservative management was most commonly prescribed for 12 weeks but was also often prescribed for 6 weeks. Very few studies reported estimated blood loss for patients treated with surgery, but for the data available, the mean was 211 mL (range 0–450 mL). The lengths of stay for operative and nonoperative cases were reported in 6 and 15 studies, respectively. The mean ± SD length of stay for the entire data set was 11.6 ± 4.3 days. Patients treated with surgery stayed in the hospital significantly longer than those treated nonoperatively (13.6 ± 3.8 vs 8.1 ± 1.9 days, $p < 0.001$).

Fracture Healing

The fusion rate for all 1361 patients analyzed, irrespective of management, was 52.9% (720/1361) at the latest follow-up (mean 20 months, range 3–74 months). Bony fusion was higher in patients who underwent surgery (74.3%) compared with those treated conservatively (40.3%) (OR 4.27, 95% CI 3.36–5.44; $p < 0.001$) (Table 2 and Fig. 2). As a result, the incidence of both stable and unstable nonunion was lower in patients who underwent surgery (OR 0.37, 95% CI 0.28–0.49; $p < 0.001$; vs OR 0.32, 95% CI 0.22–0.47; $p < 0.001$). Overall, 4.8% (46/964) of nonoperatively managed patients subsequently required surgical intervention due to treatment failure, including fracture instability or residual neck pain.

Mortality and Complications

The incidence of patient mortality across all studies was 16.6% (452/2721). Patient mortality was lower in the operative cohort (13.2%) than in the nonoperative cohort (19.0%) (OR 0.64, 95% CI 0.52–0.80; $p < 0.001$). Not surprisingly, complications were more likely in patients who underwent surgery (26.0% vs 18.5%) (OR 1.55, 95% CI 1.23–1.95; $p < 0.001$). These complications were considered more invasive in nature than those in the nonoperative group, including tracheostomy, feeding tube placement, and reintubation versus urinary tract infection, pneumonia, and skin abrasions.

Discussion

Type II odontoid fractures remain the most common cervical spine fracture among older patients (Fig. 3). The overall mean age of the cohort was 82 years, well above the traditional threshold age of 65 years for older patients. Hence, the results we report are clinically relevant to current practice and should be generalizable. We were not surprised that the majority of studies we found were from North America and Europe, 2 regions that have the most rapidly aging populations and are projected to have 20%–25% of their populations over the age of 65 years by 2050.[1]

The debate over the most appropriate management of type II odontoid fractures in older adults spans many decades and remains without solid consensus. Historically, expectant nonoperative bracing has been the preferred treatment, given the increased relative morbidity of performing surgery in this age group.[5] Nonetheless, nonoperative management has a known risk of nonunion and neck pain, among other complications.[40,54] Concern over pseudarthrosis has led to an increase in the number of patients undergoing surgical fixation for these fractures. Alluri et al. reported that 46% of older patients with odontoid fractures underwent surgery in 2003, and this rate almost doubled to 86% in 2017, with an average increase of 3.7% per year.[55] Issa et al.[32] recently studied patients aged 90 years or older who underwent surgical fixation, demonstrating a shift in practice toward operative treatment for patients for whom surgical intervention was not historically considered safe.

For the overall cohort, we found a 53% (720/1361) fusion rate for operative and nonoperative treatments combined. We performed a meta-analysis to compare treatment options, and the data available demonstrate that surgical fixation provides a significantly higher fusion rate than nonoperative treatment for type II odontoid fractures in older adults by a factor of almost 2 (74% vs 40%). However, despite higher nonunion rates, the nonoperative group showed a higher rate of stable nonunion (39%) with good clinical outcomes, including lack of mobility on flexion-extension radiographs and lack of neck pain. Ultimately, these patients had their external braces removed successfully. A good clinical outcome, defined as fusion or stable nonunion, was achieved in 93% (466/499) of patients treated operatively and 79% (657/832) of patients treated nonoperatively. Even so, only 4.8% of the patients initially treated nonoperatively went on to require surgical intervention for treatment failure. Several authors have argued that a stable nonunion may represent a reasonable goal for these patients once the collar or brace is removed and they resume their activities of daily living.[2,5,6] Our data suggest that fracture healing is achieved in the majority of patients who undergo operative or nonoperative treatment and that only a small minority require subsequent intervention after collar removal.

A prior study suggested that, for patients with type II odontoid fractures, the following criteria should be considered for surgery: "dens displacement ≥ 5 mm, commi-

TABLE 1. Studies included in the systematic review

Authors & Year	No. of Pts		Mean	Mortality		Fusion		Stable Nonunion		Unstable Nonunion		Complications	
	Op	Nonop	Age (yrs)	Op	Nonop	Op	Nonop	Op	Nonop	Op	Nonop	Op	Nonop
Agrillo et al., 2008[10]	9	NR	73.4	0	NR	7	NR	1	NR	1	NR	0	NR
Alhashash et al., 2018[11]	20	NR	81	3	NR	15	NR	2	NR	0	NR	4	NR
Allia et al., 2020[12]	17	36	84.5	3	6	9	19	5	16	0	9	3	NR
Aquila et al., 2018[2]	NR	24	82	NR	3	NR	10	NR	NR	NR	2	NR	6
Berlemann & Schwarzenbach, 1997[13]	19	NR	75	1	NR	16	NR	2	NR	1	NR	5	NR
Börm et al., 2003[14]	15	NR	66.8	1	NR	11	NR	2	NR	2	NR	3	NR
Borsotti et al., 2020[15]	18	63	87	1	10	NR	NR	NR	NR	NR	NR	8	22
Campanelli et al., 1999[16]	7	NR	80.1	1	NR	3	NR	3	NR	0	NR	2	NR
Carlstrom et al., 2021[17]	11	86	88	5	36	NR	NR	NR	NR	NR	NR	NR	NR
Chapman et al., 2013[7]	165	157	81.8	11	35	NR	NR	NR	NR	NR	NR	NR	NR
Chaudhary et al., 2010[18]	11	9	NR	3	1	7	6	0	2	1	0	NR	NR
Chibbaro et al., 2022[19]	NR	260	83	NR	0	NR	117	NR	130	NR	13	NR	24
Clark et al., 2018[20]	43	NR	84.3	1	NR	NR	NR	NR	NR	NR	NR	18	NR
Dailey et al., 2010[21]	57	NR	81.2	5	NR	24	NR	10	NR	8	NR	20	NR
DePasse et al., 2017[22]	32	94	83.1	0	14	NR	NR	NR	NR	NR	NR	12	17
France et al., 2012[23]	12	25	81.7	2	1	NR	NR	NR	NR	NR	NR	8	9
Frangen et al., 2007[24]	27	NR	85.5	6	NR	20	NR	1	NR	0	NR	1	NR
Gembruch et al., 2019[25]	98	27	85.7	27	6	NR	NR	NR	NR	NR	NR	22	2
Gembruch et al., 2020[26]	13	NR	81.8	1	NR	9	NR	1	NR	3	NR	6	NR
Harrop et al., 2000[27]	10	NR	80	1	NR	8	NR	0	NR	1	NR	2	NR
Hénaux et al., 2012[28]	11	NR	85.4	0	NR	4	NR	5	NR	0	NR	0	NR
Hong et al., 2018[29]	NR	50	80	NR	1	NR	21	NR	8	NR	18	NR	NR
Hou et al., 2011[30]	43	NR	80.6	8	NR	36	NR	5	NR	1	NR	1	NR
Ishak et al., 2017[31]	35	NR	86.5	0	NR	35	NR	0	NR	0	NR	11	NR
Issa et al., 2021[32]	15	NR	91.4	0	NR	15	NR	0	NR	0	NR	0	NR
Joestl et al., 2016[33]	32	48	71	3	4	26	34	2	8	1	2	9	12
Koech et al., 2008[34]	NR	42	80	NR	9	NR	17	NR	24	NR	1	NR	4
Kohlhof et al., 2013[35]	24	NR	81	2	NR	18	NR	1	NR	0	NR	NR	NR
Kuntz et al., 2000[36]	6	14	80	1	3	4	3	0	2	0	4	1	NR
Lofrese et al., 2019[37]	NR	50	82.7	NR	7	NR	24	NR	26	NR	0	NR	0
Lukins et al., 2021[38]	39	102	83.7	5	24	NR	NR	NR	NR	NR	NR	NR	NR
McIlroy et al., 2020[39]	NR	125	84	NR	15	NR	36	NR	49	NR	33	NR	NR
Molinari et al., 2012[40]	NR	34	84	NR	2	NR	2	NR	9	NR	21	NR	2
Molinari et al., 2013[41]	26	NR	83.2	5	NR	7	NR	14	NR	0	NR	7	NR
Molinari et al., 2013[42]	25	33	83	5	2	7	2	13	10	0	20	6	2

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TABLE 1. Studies included in the systematic review

Authors & Year	No. of Pts		Mean	Mortality		Fusion		Stable Nonunion		Unstable Nonunion		Complications	
	Op	Nonop	Age (yrs)	Op	Nonop	Op	Nonop	Op	Nonop	Op	Nonop	Op	Nonop
Osti et al., 2011[43]	33	NR	79.6	5	NR	21	NR	4	NR	8	NR	10	NR
Perry et al., 2018[44]	17	94	83	13	67	5	3	NR	NR	NR	NR	13	28
Platzer et al., 2007[45]	41	NR	NR	4	NR	NR	NR	NR	NR	NR	NR	9	NR
Raudenbush & Molinari, 2015[46]	NR	34	83	NR	NR	NR	2	NR	6	NR	20	NR	NR
Reinhold et al., 2011[47]	31	57	81	NR	NR	16	14	5	10	1	15	NR	NR
Scheyerer et al., 2013[48]	33	14	81.2	8	11	18	0	0	8	7	0	0	NR
Schoenfeld et al., 2011[49]	44	112	82	5	28	NR	NR	NR	NR	NR	NR	NR	NR
Schwarz et al., 2018[50]	52	NR	84	5	NR	26	NR	13	NR	3	NR	0	NR
Smith et al., 2008[51]	32	40	NR	4	6	NR	NR	NR	NR	NR	NR	20	14
Smith et al., 2013[52]	NR	58	79	NR	15	NR	35	NR	4	NR	11	NR	22
Waschke et al., 2016[53]	11	NR	83	1	NR	8	NR	2	NR	0	NR	0	NR

NR = not reported; pts = patients.

nution of the odontoid fracture, and/or inability to achieve or maintain fracture alignment with external immobilization."[5] In this review, displacement of the dens was cited as one reason for choosing an operative intervention. However, a wide variety of indications were listed in the studies, and several failed to mention the specific criteria used to determine operative versus nonoperative intervention. We were unable to exclude selection bias in these studies. In our clinical experience, older and frailer patients are less likely to be offered surgical treatment. Correspondingly, our data show that patients who underwent surgery were younger than those offered conservative management. Those patients who appear to be sicker and to have a higher chance of mortality are often deemed unsuitable surgical candidates, despite what their imaging findings may show. These critical factors cannot be overlooked when choosing the appropriate management of odontoid fractures in older adults. Although this bias is almost assuredly present in the included retrospective studies in this systematic review, there is no method to control for it. Our data indicate that mortality rates are higher in the nonoperative cohort. However, there is no causal association to suggest that the operative intervention itself decreases mortality; rather, the differences in the underlying morbidity in both patient groups that cannot be controlled increase mortality. This point is demonstrated by Carlstrom et al., who showed that frailty was the main factor associated with increased mortality in octogenarians with type II odontoid fractures, regardless of operative or nonoperative intervention.[17]

It is essential to analyze the complication profiles of type II odontoid fracture treatments and look beyond radiographic fusion rates as the metric for good outcomes. Because of the heterogeneity of the complications reported, it was difficult to calculate the rates of individual complications. However, it is relevant to note that there were high in-hospital complication rates after surgical treatment, and overall complication rates were lower in the nonoperative group. Additionally, the reported complications following surgery are often of a significantly life-altering nature. For example, 25% of patients in the study by Smith et al.[51] required a tracheostomy after surgery, and 19% of patients needed a feeding tube after surgery. Similarly, the AO Spine North America Geriatric Odontoid Fracture Mortality Study reported that 18% of 165 patients required placement of a feeding tube.[7] DePasse et al.[22] reported that their surgery group had a higher rate of percutaneous endoscopic gastrostomy tube placement than the conservatively managed group (25% vs 1.2%, $p < 0.01$). Gembruch et al.[26] reported an in-hospital complication rate of 22.4% (22/98) after surgery compared with 7.4% (2/27) for nonoperative cervical collar treatment. Although these studies show that surgery is associated with a higher fusion rate, surgery also carries a higher in-hospital complication burden. In the current analysis, the patients who underwent surgery had a length of stay that was approximately 5.5 days longer than those who did not, likely related to this increased complication rate. Additionally, one must consider the effects of major and minor complications on the quality of life and outcome of older patients who undergo odontoid fracture surgery. A tracheostomy

TABLE 2. Comparison of outcomes by operative status

Outcome	Op		Nonop		OR	95% CI	p Value
	No. of Pts	%	No. of Pts	%			
Fusion	375/505	74.3	345/856	40.3	4.27	3.36–5.44	<0.001
Stable nonunion	91/499	18.2	312/832	37.5	0.37	0.28–0.49	<0.001
Unstable nonunion	38/499	7.6	169/832	20.3	0.32	0.22–0.47	<0.001
Mortality	146/1110	13.2	306/1611	19.0	0.64	0.52–0.80	<0.001
Complications	201/772	26.0	164/885	18.5	1.55	1.23–1.95	<0.001

or a feeding tube is much more life-altering for an older patient than a urinary tract infection treated with oral antibiotics or skin breakdown from collar use.

Prolonged lengths of stay associated with higher complication rates drive costs higher. As the healthcare environment continues to evolve, cost and quality of life are essential metrics to monitor. In particular, older patients are usually covered by a universal healthcare plan protected by tax contributions (Medicare) in the United States and via their socialized healthcare systems in Europe. Thus, cost-effective treatments that sustain the quality of life at equitable costs are needed for this population.

Limitations

Most of the studies reviewed were retrospective cohort studies, which resulted in low-grade evidence according to the evidence-based medicine criteria. We were unable to assess the individual patient records or radiographs to determine the surgical indications given by the studies' authors. Moreover, reporting of outcomes varied among the studies, and in some studies, interventions were grouped together, such as anterior odontoid screw placement and posterior fusion being reported in the same operative group. Rigid collars and halo vests were also commonly grouped together when reporting nonoperative management. It is difficult to compare these management paradigms individually. Similarly, we could not compare comorbidities between the 2 groups of patients we studied. As with all retrospective data, there is an inherent risk of selection bias in reporting these results, which may explain some of the findings (e.g., the higher mortality rate seen in nonoperative patients).

Future Directions

In an age of registry data, more comprehensive analyses and decision-making trees for odontoid fractures in older adults should be possible. Multi-institutional spine registries such as the American Spine Registry have the potential to provide better clarity to answer the questions posed in this article. We encourage all spine surgeons to support and contribute to these registries for better transparency and decision-making.

Conclusions

In this systematic review and meta-analysis of type II odontoid fractures in older patients, we found that fusion rates were significantly higher in patients who underwent surgery. However, fewer than 5% of nonoperative patients required subsequent surgical intervention. Mortality is higher among patients treated nonoperatively, but evidence linking death directly to conservative care is lacking because lower mortality in surgically treated patients is likely to be explained by surgical selection bias. Complication rates and length of stay were significantly higher in patients who underwent surgery. Stable nonunion is an acceptable goal in older patients with type II odontoid fractures.

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Appendix

Database Search Queries

PubMed

((“Aged”[Mesh] OR “Aged, 80 and over”[Mesh]) AND (“Spinal Fractures”[Mesh] AND “Odontoid Process”[Mesh])) AND ((((“Treatment Outcome”[Mesh]) OR “Therapeutics”[Mesh]) OR “Fracture Fixation”[Mesh]) OR “Arthrodesis”[Mesh])

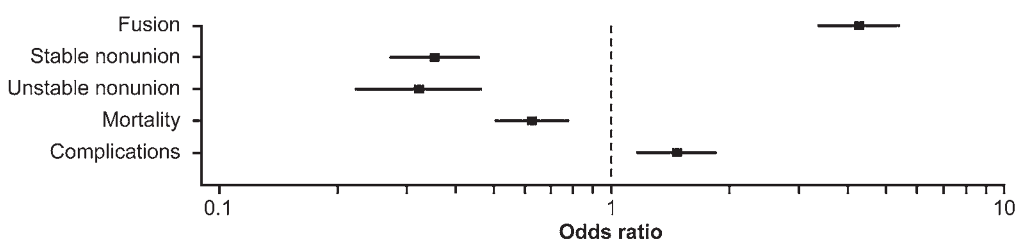

FIG. 2. Forest plot comparing the main pooled outcomes between studies that evaluated operative versus nonoperative treatment of type II odontoid fractures. *Squares* represent the odds ratios and *lines* represent the 95% CIs.

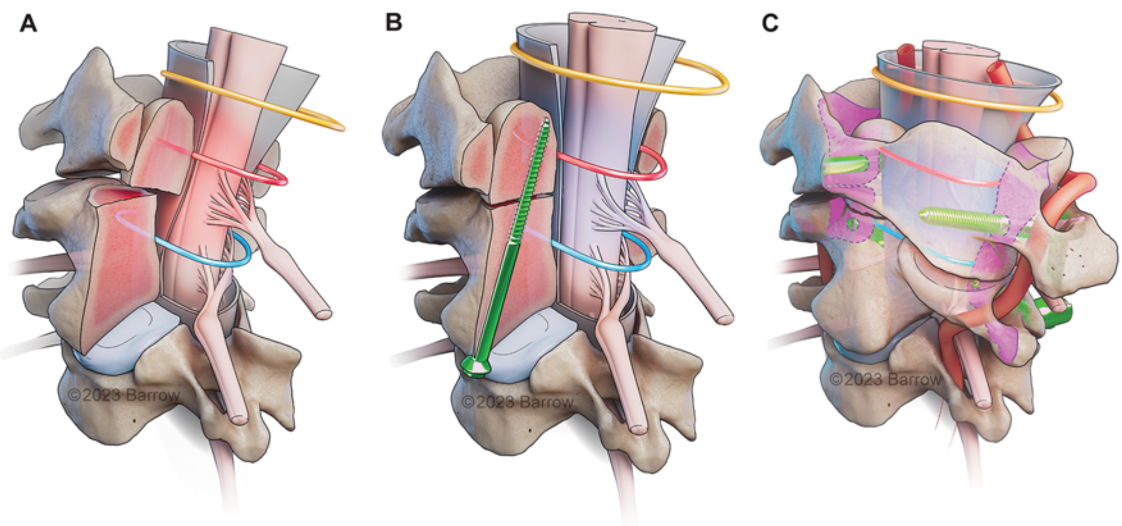

FIG. 3. Illustrations demonstrating cervicomedullary compression and the different surgical strategies to treat odontoid fractures. **A:** Type II fracture through the base of the odontoid process. Posterior displacement of the fracture causes cervicomedullary compression (*red middle ring*) relative to other levels (*blue bottom and yellow top rings*). **B:** Surgical fixation using an anterior odontoid screw reduces the fracture and restores normal odontoid alignment. Fracture reduction removes the cervicomedullary compression (*red middle ring*) and restores the central canal diameter that matches the diameter of the other levels (*yellow top and blue bottom rings*). **C:** Surgical treatment of the odontoid fracture with placement of C1 lateral mass and C2 pars interarticularis screws also restores alignment and the canal diameter, thereby alleviating the cervicomedullary compression (*red middle ring*). Used with permission from Barrow Neurological Institute, Phoenix, Arizona. Figure is available in color online only.

((elderly[MeSH Terms]) AND (odontoid process[MeSH Terms])) AND (bone fracture[MeSH Terms])

OVID

((aged or elderly) and (odontoid and fracture) and treatment)

EMBASE

('aged'/exp OR aged OR 'elderly'/exp OR elderly) AND ('odontoid'/exp OR odontoid) AND ('fracture'/exp OR fracture) AND ('treatment'/exp OR treatment)

Cochrane

((aged or elderly) and (odontoid and fracture) and treatment)

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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Conception and design: Tumialán, Avila, Hurlbert. Acquisition of data: Tumialán, Avila, Farber, Rabah, Hopp. Analysis and interpretation of data: Tumialán, Avila, Farber, Chapple, Hurlbert. Drafting the article: Tumialán, Avila, Farber. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Tumialán. Statistical analysis: Avila, Chapple. Study supervision: Tumialán, Hurlbert.

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