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ORIGINAL ARTICLE

Identifying factors influencing mortality in patients aged over 65 following an acute type II odontoid process fracture. A retrospective cohort study

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Abstract

Objective Compare short-term mortality rates following operative and nonoperative management of geriatric patients following an acute type II odontoid process fracture.

Methods One hundred forty-one patients with a type II odontoid fracture were identified from a single centre between 2002 and 2018. Patient demographics, details of injury and management, plus mortality data were collected. The incidence of mortality at 3 and 12 months was calculated, and a multivariate model built which included the treatment modality variable and allowed adjustment for six individual confounders.

Results Of the 141 patients with a type II odontoid process fracture, 39 were managed operatively, while 102 were managed nonoperatively. Relative to the nonoperative group, the operative group was younger (79.0 ± 7.0 vs. 83.7 ± 7.6), more likely to have odontoid angulation > 15° (74.4% vs. 43.1%, $p < 0.01$), and a greater proportion having fracture displacement > 2 mm (74.4% vs. 31.4%, $p < 0.01$). Both groups were comparable for gender, comorbidities, and associated injuries. On univariate analysis of treatment modality, the odds ratio of 3-month mortality with nonoperative management was 2.55 (95% CI: 0.82–7.92; $p = 0.08$), whilst at 12-months it was 3.12 (95% CI: 1.11–8.69; $p = 0.02$). On multivariate analysis of 12-month mortality, however, treatment modality was not found to be significant. This multivariate analysis suggested that increasing age, male gender, and injury severity were significant predictors of 12-month mortality.

Conclusion In contrast to the findings of a number of previous studies, operative management may not influence survival at 3- and 12-months.

Keywords Odontoid process · Spinal fracture · Aged · Mortality

Introduction

Odontoid fractures are the most common cervical spine fracture in the elderly population and are associated with significant morbidity and mortality [1, 2]. Although concerns exist about inter-observer variability of fracture classification assignment, it remains a key determinant of management [3]. Type III fractures and the rare, type I fractures typically heal with nonoperative treatment (NOP) [4–6]. Type II fractures, however, have a high rate of non-union and can be associated with delayed complications when treated NOP [1, 7–14]. Operative treatment (OP) is usually undertaken through odontoid screw or posterior C1-2 fixation [4]. According to Grauer et al., type IIB may be better suited to odontoid screw, while type IIC may be better suited to posterior C1/2 stabilisation [15].

Existing literature directly comparing OP and NOP is dominated by retrospective studies with inconsistent results [7–10, 12, 14]. The largest studies are derived from North American centres and demonstrate a short-term survival benefit from OP; however, with increasing age, this survival benefit becomes less evident [7–10, 12].

This single centre retrospective study was designed to validate the hypothesis that OP is associated with greater short-term survival than NOP. Secondary outcomes were to assess the influence on mortality of the following variables: age, sex, fracture morphology, injury severity score (ISS) [16], and Charlson comorbidity index (CCI) [17]. It is the

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largest comparative series outside of North America, and the third largest series reported.

Methods

The study conduct adhered to the STROBE guidelines for the reporting of an observational study [18].

Patient population

A single centre, tertiary hospital, admission coding system was used to identify all patients with fractures of C2, from July 2002 to June 2018. The same codes were used in each referral hospital within the catchment network to include patients whose treatment did not require transfer to the tertiary hospital. Patients younger than 65 were excluded, as were those patients with a concomitant traumatic brain injury. A consultant radiologist and the lead author reviewed the initial computed tomography (CT) scan for all patients, and all non-type II fractures were excluded.

Data Acquisition

Approval was obtained from the Hunter New England Human Research Ethics Committee. Patient characteristics including age, comorbidities, date of injury, injury severity score, and treatment modality were determined from the records. Patient comorbidities were used to calculate the CCI. Furthermore, fracture morphology (including displacement and angulation of the dens from the C2 body) was determined from the non-enhanced, multi-planar CT of the cervical spine performed at the time of injury. Patient mortality as of 12th July 2019 was ascertained using the Australian Registry of Births, Deaths, and Marriages.

Statistical analysis

All statistical analyses were performed using Stata Statistical Software (Version 16.2) [19]. Baseline comparisons between treatment groups were performed using the Student's t-test for continues variables, and chi-squared test for categorical variables. There was no missing data to impute.

The incidence of mortality within 3 and 12 months was calculated, and a logistic regression analysis performed to assess the association with treatment modality at each timepoint. Univariate logistic regression analyses were performed to assess the impact of the 6 secondary factors on mortality. Those with a p-value of less than 0.2 were added to a multivariate model which included the treatment variable. Thus, the key objective of the model was to determine if treatment effect was significant following adjustment by the potential confounders.

Results

Of 231 patients over 65 years with an acute odontoid fracture, 141 (61%) were classified as type II, which included 60 females and 81 males. Thirty-nine patients (27.7%) underwent OP management (26/39 anterior odontoid screw; 13/39 posterior C1/2 stabilisation), whilst 102 patients (72.3%) were managed NOP (semi-rigid collar (99/102); halo vest (3/102).

Allocation to either OP or NOP was non-randomised, and depended on individual factors including age, comorbidities, fracture morphology, and their injury severity. Patients allocated to OP tended to be younger, with fewer comorbidities, and greater displacement and angulation at their fracture site.

The baseline characteristics of each group are illustrated in Table 1. Significant differences between OP and NOP groups at baseline were seen in average age, odontoid tip displacement of > 2 mm, odontoid angulation of < 15°, and CCI. There was no significant difference in sex or mean injury severity score.

Overall mortality at 3 months for OP and NOP cohorts was 11% and 23%, respectively. Analysis of 3-month mortality was conducted using univariate logistic regression. Although the odds ratio (OR) of death within three months was 2.5 times higher for patients who did not have an operation, the result was not significant ($p = 0.08$). Thus, no further analysis of mortality at this point was performed.

Overall mortality at 12 months for OP and NOP cohorts was 13% and 31%, respectively. A similar univariate logistic regression analysis was used to explore the relationship between treatment modality and 12-month mortality, which demonstrated an OR of 3.11 associated with NOP ($p = 0.02$).

Table 1 Demographics and mortality for 141 patients with type II odontoid fracture, stratified by treatment modality. Avg = average

	Operative (OP) ($n = 39$)	Non-operative (NOP) ($n = 102$)	p value
Sex			
Male	26 (66.7%)	55 (53.9%)	0.17
Age			
65–75	12 (30.8%)	15 (14.7%)	0.03
75–85	19 (48.7%)	33 (32.4%)	0.07
> 85	8 (20.5%)	54 (52.9%)	< 0.01
Avg. ± SD	79.0 ± 7.0	83.7 ± 7.6	< 0.01
Comorbidities (CCI)	5.0 ± 0.6	5.8 ± 0.4	0.02
Displacement > 2 mm	29 (74.4%)	32 (31.4%)	< 0.01
Angulation > 15°	29 (74.4%)	44 (43.1%)	< 0.01
Injury severity score	13.2 ± 3.4	12.6 ± 1.9	0.77

Further univariate analyses were then performed to study the relationship of 12-month mortality with each of the following variables: sex, age, odontoid displacement, odontoid angulation, comorbidities, and ISS. Variables related to 12-month mortality at a p-value ≤ 0.20 were added to a multivariate model which included the treatment variable. The results of these analyses can be found in Table 2. As shown, age and ISS were significantly associated with 12-month mortality, while gender and CCI were borderline significant. Thus, these four variables were included in the multivariate analysis to determine whether there was any influence on the treatment effect. Fracture morphology, including odontoid angulation and displacement, was found not to be significantly associated with mortality, and hence removed from the model.

A model building procedure was then used whereby the five predictors (treatment, gender, age, CCI, and ISS) were included in the model, which was subsequently refined by removing insignificant predictors one at a time (least significant first) (Table 3). The likelihood ratio chi-square ($p<0.01$) suggested that this model represented a statistically significant improvement over a model with no predictors (i.e. a null model). Although a univariate logistic regression analysis suggested that treatment modality was significantly associated with 12-month mortality, when additional variables were added to the model, treatment modality was no longer a significant factor. Therefore, it was dropped from the model. The following significant results were found:

1. A male is 3.24 times more likely to have had mortality within 12 months than a female.
2. An 85-year-old patient is 3.68 times more likely to die within 12 months than a person aged 75–84.
3. For every unit increase in injury severity score, the odds of mortality increased by a multiple of 1.19.

After exclusion of in-hospital mortalities, there was no statistically significant difference of in-hospital morbidity rate between OP (42%) and NOP (38%). Airway complications, including aspiration and/or pneumonia occurred in 10% and 5%, respectively. 8.3% of OP patients required readmission for acute pain management. Early crossover from NOP to OP (within 6 weeks of injury) did occur in three patients for persistent, severe, mechanical neck pain.

Discussion

This study further elucidates the experience in treating this common fracture. In this study, treatment modality, comorbidities, and fracture morphology were not independent predictors of survival, while younger age, female gender, and lower injury severity score were. Patients who underwent OP were more likely to be younger, have fewer comorbidities and with greater displacement and angulation at their fracture site. The "Hannigan threshold" of 5 mm is often quoted as being an independent indication for OP, as those with greater than 5 mm are less likely to achieve bony fusion without fixation [20]. This principle was generally adopted at our centre, as reflected in the relatively greater displacement and angulation in the patients undergoing OP. The selected surgical technique was generally guided by Gauer et al.'s recommendations outlined in the introduction.

A number of large studies have advocated for OP in this elderly population, based on a statistically greater risk of death and treatment failure associated with NOP [7, 8]. These findings were not repeated in our study.

In our study, the mortality rates for OP and NOP at 3 months were 11% and 23%, and at 12 months 13% and 31%, respectively. These mortality rates are consistent with

Table 2 Results of univariate logistic regression analyses for treatment modality and of the six pre-specified risk factors against mortality

	Odds ratio (95% CIs)	*p* value
NOP treatment		
3-month	2.55 (0.82–7.92)	0.08
12-month	3.12 (1.11–8.69)	0.02
Gender—male	2.1 (0.94–4.70)	0.06
Age		
75–85	0.92 (0.28–3.08)	0.03
> 85	2.59 (0.86–7.79)	
Displacement > 2 mm	1.16 (0.55–2.47)	0.70
Angulation		
15–29	1.08 (0.42–2.77)	0.38
30–44	1.99 (0.78–5.07)	
> 45	0.46 (0.05–4.06)	
CCI	1.20 (0.99–1.47)	0.06
ISS	1.11 (1.02–1.21)	< 0.01

Table 3 The significant results from multivariate regression analysis which included treatment modality, against 12-month mortality

	Odds ratio	95% CI	*p* value
Gender—male	3.24	1.24–8.46	0.016
Age			
75–84			
65–74	0.32	0.07–1.61	0.19
> 85	3.68	1.39–9.69	0.008
ISS (per unit)	1.19	1.05–1.35	0.006

those reported in other trials, where published 3 month mortality rates range from 7 to 27%, and 12 month rates from 21 to 45% [4, 8, 9, 12, 21].

Unfortunately, it is not possible to make comparisons with the earlier studies that showed favourable OP outcomes, as they have not described selection criteria. They report that the only difference between the OP and NOP patients was age and mechanism of injury, with no difference between cohorts for CCI, and no discussion about fracture morphology influencing treatment strategy. We have attempted to report our selection criteria for OP, such that meaningful comparisons and outcomes can be made with future datasets.

Our finding that treatment modality does not significantly influence mortality in the geriatric population is supported by several earlier studies [9, 10, 12, 14]. This statement has been shown to be especially true of patients aged over 80 years [9, 10]. However, there may be a survival advantage for operatively managed patients at the younger end of the geriatric spectrum [12].

Our finding that male sex was independently associated with increased mortality does not necessarily infer that these patients are less appropriate for OP; however, survival beyond injury is a consideration in cost–benefit analyses. This finding was also noted in previous studies [8, 14].

ISS demonstrated an association with increased mortality at 12 months. This finding is concordant with previous studies, which have specifically identified the presence of neurological injury as being associated with higher mortality [9, 10]. This study was not powered to demonstrate whether this mortality association was mitigated by surgical intervention. Regardless of this, an acute neurological deficit remains one of the strongest indicators for OP.

Although a significant impact was not seen with CCI on survival, the association was borderline ($p=0.06$). A significant correlation between CCI and mortality was expected, which would be in accordance with earlier findings [7, 8, 12, 22]. The significant between-group difference at baseline supports the statement that patients with better overall health were generally more likely to be offered OP. However, the fact that OP was thus not shown to be associated with superior survival may, in fact, reflect a true harmful effect of OP in the patients with lower CCI.

The evaluation of morbidity associated with treatment modality is compromised in retrospective series. While a primary outcome assessing mortality is a valid one, it only represents part of the picture. Similar to previous studies [14, 21], our study did not reveal any statistically significant differences in morbidity associated with treatment modality and confirms that morbidity rates are high irrespective of treatment.

Despite the limitations of this study, it remains the third largest series addressing this question, and the largest outside of North America [7, 8, 12, 14]. Although the study design is non-randomised and retrospective, it adjusts for baseline differences between cohorts and thus enables comparisons to be made.

Like the existing published literature, it is limited by its retrospective design, a relatively small number of operative cases, and a variable operative approach. Furthermore, the assignment of odontoid fractures into subtypes on the basis of CT findings has traditionally proven challenging due to inter-observer variability. This is made even harder in the geriatric cohort, whose fracture configuration often does not neatly fit this classification. We attempted to account for this by only including patients with CT imaging rather than radiographs and having all imaging reviewed by two independent specialists who reached a consensus on each case.

Conclusion

The findings that increasing age, male sex, and higher injury severity scores are significantly associated with 12-month mortality, independent of treatment modality, have been described previously. The authors had hypothesised that mortality would also be influenced by higher CCI, and greater displacement and angulation at the fracture site; however, this was not the case.

This Australian experience demonstrates that the proportion of patients allocated to OP is less, however, the outcomes achieved are similar to those seen in North America. Type II odontoid fractures in the elderly, most often resulting from a low force mechanism, continue to be associated with a high risk of mortality, regardless of treatment modality.

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Availability of data and materials The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Code availability Not applicable.

Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflict of interest.

Ethical approval Permission granted to reproduce copyrighted materials.

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