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**Journal Title:** Orthopedic Reviews  
**Volume:** Volume 10, Number 4  
**Publisher:** PAGEpress | 2018-12-06, Pages 7834-7834  
**Type of Work:** Article | Final Publisher PDF  
**Publisher DOI:** 10.4081/or.2018.7834  
**Permanent URL:** <https://pid.emory.edu/ark:/25593/tn5qj>

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Final published version: <http://dx.doi.org/10.4081/or.2018.7834>

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Accessed November 28, 2021 4:21 AM EST

# Variations in treatment of C1 fractures by time, age, and geographic region in the United States: An analysis of 985 patients

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## Abstract

The purpose of this investigation was to evaluate the variations in the treatment of C1 fractures over time, by age group, and by geographic region using a nationwide database. The Nationwide Emergency Department Sample (NEDS) database was queried to identify patients  $\geq 18$  years who sustained C1 fracture from 2006-2012. Patients were filtered based on the intervention they received: collar, halo, or surgery. Regions of hospital used in analysis were defined as Northeast, Midwest, South, and West. Surgical intervention for C1 fracture increased from 27.1% of cases in 2006 to 55.4% of cases in 2012 ( $P < 0.001$ ). The rate of collar treatment increased with increasing age. In contrast, rate of halo use decreased with increasing age. A greater proportion of patients in the Northeast were treated by collar compared to all other regions ( $P < 0.001$ ). We can conclude that there is considerable variation in the treatment of C1 fractures with regards to age and geographic region. Surgical treatment of these fractures is increasing over time. Future considerations should be given to developing treatment guidelines to decrease variation and potentially create cost-savings.

## Introduction

The prevalence of upper cervical spine fractures is increasing over time.<sup>1-3</sup> Fractures of C1 are responsible for up to 5-15% of all cervical spine injuries<sup>2,4-7</sup> and the diagnosis can be frequently missed.<sup>8</sup> Although these fractures are becoming increasingly more common, optimal management of C1 fractures remains controversial.<sup>4,6,9-12</sup> Treatment of C1 fractures may

include surgery, halo vest placement, or rigid cervical collar. However, no evidence-based treatment algorithm exists for treating these fractures which has led to wide variations in management. Furthermore, the aforementioned treatment options have only been evaluated in small studies that rarely assess all three potential modalities.<sup>6,13</sup>

Regional variations in treatment strategies have been observed when a clear consensus does not exist.<sup>14-16</sup> However, regional differences in the treatment of C1 spine fractures has not yet been evaluated as a potential predictor of treatment.

There is a paucity of data regarding factors that influence the treatment of C1 fractures. This study analyzed patients with C1 fractures who were admitted to the hospital through the emergency department (ED) to evaluate the variations in treatment of C1 fractures over time, by age group, and by geographic location. Since there is no consensus on optimal form of management for these fractures, we expect to find variations in treatment based on time, age, and region. Specifically, we hypothesize that surgical management of C1 fractures is increasing over time, halo orthosis use has decreased over time, and that there are regional differences in treatment patterns.

## Materials and Methods

### Data source

Data was obtained from the Nationwide Emergency Department Sample (NEDS) compiled as part of the Healthcare Cost and Utilization Project. In brief, the NEDS is the largest all-payer emergency department (ED) database in the U.S., which combines data from the State Inpatient Databases (SID) and State Emergency Department Databases (SEDD) and capture patients who were seen in the ED and admitted to the hospital. Variables included in the database are patient demographics, diagnostic and procedural *International Classification of Disease (ICD-9)* codes, inpatient charges, length of stay, and hospital region.

The NEDS database was queried to identify patients 18 years and older who were diagnosed with C1 fracture without neurological injury from 2006-2012 (ICD-9 codes 805.01). Patients with spinal cord involvement and polytrauma injuries, including concomitant cervical spine injuries, were excluded. The rationale for this exclusion criteria is that the presence of neurologic deficits and concomitant injuries are generally accepted indications for surgical management.<sup>9</sup> Subsequently patients were further filtered based on the interven-

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Key words: C1 fracture, treatment variations, halo, cervical collar.

Contributions: SJA: substantial contribution to conception, design, analysis, interpretation of data, critical revision; ZJG: substantial contribution to drafting the article and critical revisions; CV: substantial contribution to analysis, interpretation of data; STY: substantial contribution to critical revisions, final approval of the version to be published.

Conflict of interest/funding: SJA, ZJG and CV have no conflicts of interest. STY has received royalties from Stryker Spine and Meditech Spine; research grants from NIH, Biomet, and AO Spine; stock ownership in Phyggen, Meditech, and Medyssey.

Received for publication: 18 August 2018.  
Accepted for publication: 20 October 2018.

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Orthopedic Reviews 2018;10:7834  
doi:10.4081/or.2018.7834

tion they received: collar (ICD-9 codes 93.52), halo (ICD-9 codes 02.94, 93.41), and cervical fusion (ICD-9 codes 81.01, 81.02, 81.03, 03.53). Patients who had multiple interventions were re-categorized according to the more invasive procedure. Regions of hospital used in analysis were defined as Northeast, Midwest, South, and West.

### Statistical analysis

Univariate analysis was performed for patient characteristics stratified by type of intervention. Linear regression models were used to analyze trends for C1 incidence rates and treatment type over the six-year study period. Analysis of variance (ANOVA) tests were used to determine differences among procedure groups when stratified by region and age group.

Multivariate logistic regression models were created to determine the independent effect of the covariates of interest on type of intervention received if significant after analysis of variance. This was done by first including all feasible explanatory variables and then using backward elimination to obtain a minimal model. Statistical analysis

was performed using SAS 9.4 (Cary, NC). All P values less than 0.05 was considered statistically significant.

## Results

### Demographics of cohort and incidence of C2 fracture

From 2006-2012, 985 patients with the diagnosis of C1 fracture with documented intervention were identified in the NEDS database. Amongst this cohort, 36.9% were female, 63.1% were male and the mean age was 51.2 (Table 1). The incidence of C1 fractures increased from 2006-2008. From 2008-2009, the incidence of C1 fractures decreased to a similar rate seen in 2006. The incidence peaked in 2010 (6.2 cases per 100,000) and only slightly decreased in 2012 (5.8 cases per 100,000) (Figure 1).

Overall, the majority of patients received halo or surgery for C1 fractures (87.9%). A greater proportion of patients treated by collar were female compared to the halo and surgery groups, respectively (49.6% vs. 34.4%, 35.7%,  $P=0.0083$ ). In addition, the mean age of patients treated by collar was higher than the mean age of those treated with halo or surgery, respectively (62.6 vs. 48.8 or 50.5,  $P<0.001$ ) (Table 1).

### Rate of interventions over time

Surgical intervention for C1 fracture increased from 27.1% of cases in 2006 to 55.4% of cases in 2012 ( $r=0.128$ ,  $P<0.001$ ) (Figure 2). Contrastingly, the rate of halo use decreased from 61.4% in 2006 to 35.4% in 2012 ( $r=-0.125$ ,  $P<0.001$ ) with the rate in 2006 being significantly higher compared to other years (95%CI: 49.7-75.9,  $P=0.023$ ). Rigid cervical collar was the least utilized intervention throughout the study period. The rate of collar use did not significantly

change during study period ( $r=-0.0051$ ,  $P=0.819$ ) (Table 2).

### Intervention by age group

The rate of surgery did not significantly change between age groups ( $P=0.410$ ). In contrast, the rate of halo use decreased with increasing age (Figure 3). The rate of halo used in patients age 18-49 was 45.3% (95%

CI: 39.7-51.7) compared to 23.1% in patients over the age 85 (95% CI: 13.9-38.3,  $P=0.009$ ) (Table 3). The odds ratio of receiving a halo is reflected in Table 4. The rate of collar treatment increased with age. 7.3% of cases received collars in patients age 18-49 compared to 41.5% of cases in patients who were 85 and older ( $P<0.001$ ) (Table 3). Furthermore, there was increased

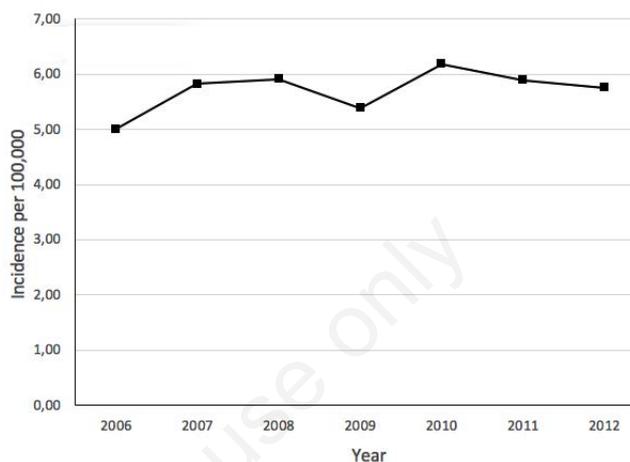


Figure 1. Incidence of C1 fracture per 100,000 hospitalizations from 2006-2012.

Table 1. Characteristics of patients with C1 fracture who received intervention.

Characteristic	Total	Collar	Halo	Surgery	P value
N (%)	985	119 (12.1)	421 (42.7)	445 (45.2)	-
Female	363 (36.9%)	59 (49.6%)	145 (34.4%)	159 (35.7%)	0.008
Age (% SD)	51.2 (20.8)	62.6 (22.7)	48.8 (19.3)	50.5 (20.8)	<0.001
18-49	490 (49.8)	36 (7.4)	222 (45.3)	232 (47.4)	
50-64	214 (21.7)	21 (9.8)	106 (49.5)	87 (40.7)	
65-74	101 (10.3)	16 (15.8)	41 (40.6)	44 (43.6)	
65-84	115 (11.7)	19 (16.5)	37 (32.2)	59 (51.3)	
85+	65 (6.6)	27 (41.5)	15 (23.1)	23 (35.4)	

Table 2. Intervention for C1 fracture from 2006-2012 (N=985).

	2006		2007		2008		2009		2010		2011		2012		P value
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	
Collar	16	11.4	20	12.7	16	11.1	19	14.5	16	10.7	20	15	12	9.2	0.819
Halo	86	61.4	66	42.0	56	38.9	61	46.6	56	37.3	50	37.6	46	35.4	0.023
Surgery	38	27.1	71	45.2	72	50.0	51	38.9	78	52.0	63	47.4	72	55.4	0.006
Total	140		157		144		131		150		133		130		

Table 3. Intervention for C1 fracture by age group (N=985).

	18-49		50-64		65-74		75-84		85+		P value
	n	%	n	%	n	%	n	%	n	%	
Collar	36	7.3	21	9.8	16	15.8	19	16.5	27	41.5	<0.001
Halo	222	45.3	106	49.5	41	40.6	37	32.2	15	23.1	0.009
Surgery	232	47.3	87	40.7	44	43.6	59	51.3	23	35.4	0.410
Total	490		214		101		115		65		

odds of receiving a collar in older patients (OR 1.04, 95% CI: 1.02-1.05,  $P < 0.001$ ) (Table 5).

### Intervention by hospital region

The rate of surgical intervention was similar across all four regions ( $P = 0.127$ ). However, the rates of halo and collar use varied among the four regions (Table 6). Halo use was highest in the West (51.4%) and this differed significantly from use in the Northeast (33.5%) and Midwest (37.3%) ( $P = 0.025$ ). Specifically, the odds of receiving halo intervention in the West were 100% higher than the odds of patients in the Northeast (OR 2.00, 95% CI: 1.31-3.06,  $P = 0.001$ ) (Table 4). In contrast, a greater proportion of patients in the Northeast (24.2%) were treated by collar compared to all other regions ( $P < .001$ ). The lowest proportion of patients treated by collar was in the South (7.5%), followed by the West (11.3%) and Midwest (11.5%). The odds of receiving a collar for patients in the Northeast were 260% higher than for patients in the South (95% CI: 2.07-6.25,  $P < 0.001$ ) (Table 5).

### Discussion

Although upper cervical spine fractures are increasing over time,<sup>1-3</sup> there is no current treatment algorithm for these injuries. As such, optimal management of these fractures remains controversial. A recent study by the senior author evaluated trends in treatment of C2 fractures.<sup>17</sup> However, to our knowledge, trends in treatment of C1 fractures have not been reported in the literature. This study sought to observe differences in treatment of C1 fractures over time, by age, and across geographic regions using a national data base. Understanding treatment trends of C1 fractures may help guide future recommendations for the optimal management of these injuries.

In this study of 985 patients admitted from the ED with C1 fractures, we observed significant differences in treatment over time, by age, and across geographic regions. Between 2006-2012, the rate of surgical treatment for C1 fractures increased approximately 30%. Surgical treatment of C1 fractures generally involves C1-C2 stabilization,<sup>4,6,9-12</sup> but occasionally requires occipital-cervical fusion.<sup>18</sup> Despite being associated with increased complications and mortality compared to conservative measures,<sup>3</sup> surgical treatment of C1 fractures was not only found to be increasing significantly over time but was also the most common treatment in all years evaluated except 2006 and 2009. There are sever-

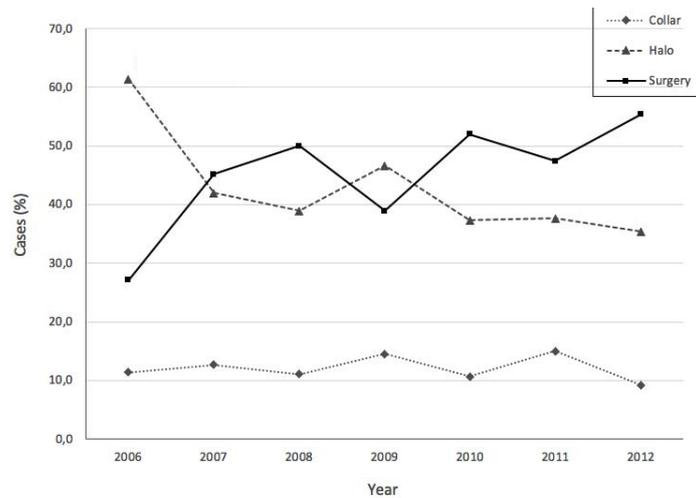


Figure 2. Percentage of C1 fractures stratified by intervention from 2006-2012.

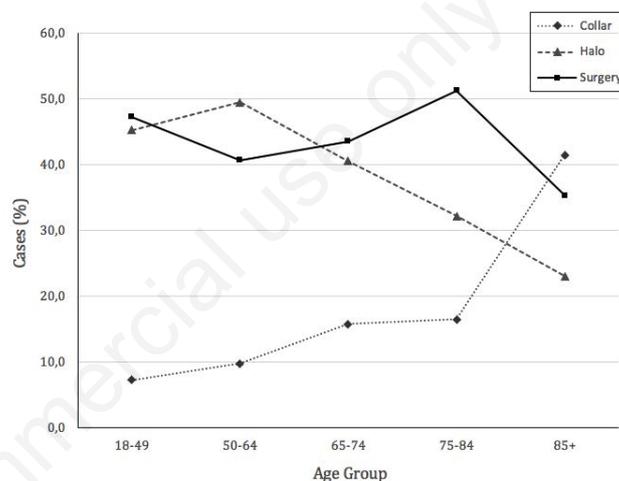


Figure 3. Intervention for C1 fractures by age group.

Table 4. Multivariable logistic regression for halo use in C1 fracture.

Predictors	Odds Ratio	95% CI	P value
Age	0.99	0.98-0.99	0.030
Gender*	0.86	0.66-1.13	0.275
Hospital region**			
Midwest	1.13	0.74-1.72	0.563
South	1.56	1.06-2.31	0.026
West	2.00	1.31-3.06	0.001
Chronic conditions	0.99	0.93-1.05	0.657

\*Reference: male; \*\*Reference=Northeast.

Table 5. Multivariable logistic regression for collar use in C1 fracture.

Predictors	Odds Ratio	95% CI	P value
Age	1.04	1.02-1.05	<0.001
Gender*	1.55	1.04-2.33	0.034
Hospital region**			
Northeast	3.60	2.07-6.25	<0.001
Midwest	1.62	0.92-2.87	0.095
West	1.57	0.87-2.81	0.132
Chronic conditions	0.90	0.82-0.98	0.016

\*Reference=male; \*\*Reference=South.

**Table 6. Intervention for C1 fracture by hospital region (N=985).**

	Northeast		Midwest		South		West		P value
	n	%	n	%	n	%	n	%	
Collar	39	24.2	28	11.5	27	7.5	25	11.3	<0.001
Halo	54	33.5	91	37.3	162	45.3	114	51.4	0.025
Surgery	68	42.2	125	51.2	169	47.2	83	37.4	0.127
Total	161		244		358		222		

al reasons that may explain our findings. First, surgical stabilization of these fractures allows for early mobilization and is associated with higher union rates compared to non-operative treatment. Also, surgery avoids the additional morbidity of pressure ulcers seen with collar use and increased falls seen with halos.<sup>3,5</sup> Furthermore, we believe advancements in surgical techniques, instrumentation, and surgical training in cervical fixation makes surgery a more appealing option.

Halo use decreased by approximately 25% from 2006-2012. This may be attributed to literature during this time period that suggested that halo use in the elderly was associated with increased morbidity and mortality.<sup>19,20</sup> Meanwhile, collar use stayed consistent over the study period and was the least utilized of the treatments evaluated.

In the elderly, conservative management with a rigid cervical collar may lead to decreased morbidity when compared to halo use or surgery<sup>3,19,20</sup> despite greater risk of nonunion.<sup>3</sup> We found that as patients increase in age, the rate of collar utilization increased significantly and was the most common treatment in patients over 85 years old. In contrast, halo use decreased significantly with increased patient age. Jubert *et al.*<sup>21</sup> performed a systemic review of the complications of cervical spine trauma in the elderly. They found that the majority of patients received surgical management for upper cervical spine fractures with decreased mortality when compared to non-operative care. Delcourt *et al.*<sup>3</sup> also reviewed the treatment and complications of upper cervical spine fractures but found higher complication rates and mortality when compared to non-operative measures. These discrepancies are likely related to the lack of studies that include large numbers of patients. Despite analyzing a national database, we were only able to fully evaluate 281 patients over the age of 65 and only 65 patients over the age of 85. Nevertheless, our findings more closely align with Delcourt *et al.*<sup>3</sup> We believe that conservative treatments were more commonly chosen in the elderly population because the morbidity of surgery in this patient population is

greater and less well tolerated.

While regional difference in treatment of various spine pathologies have been reported,<sup>26</sup> this is the first study to assess variations in treatment of C1 fractures by region. There were no significant differences in surgical rates per region, though the greatest trend towards surgery was in the Midwest. Interestingly, there was a trend towards halo orthosis use over surgery in the West, however, this was not significant. Halo use was highest in the West and lowest in the Northeast and collar use was highest in the Northeast and lowest in the South. In fact, we found that patients in the Northeast had a 260% greater chance of being treated with a collar than in the South (Table 5). However, it is important to note that collar use was still the least used treatment modality evaluated, regardless of region. Additionally, we found that the odds of treatment in a halo vest was 100% higher in the West and 56% higher in the South compared to the Northeast (Table 4). It is possible that these regional variations in treatment are secondary to variations in age within each geographic region. However, the U.S. Census Age and Sex Composition 2010,<sup>27</sup> which illustrates population data by age group in the regions examined in our study (Northeast, South, Midwest, and West), reveals very little variation in the proportion of people per age group by region. Since each age group appears to be represented equally in the four regions studied, it is likely that the variations in treatment by region are independent of age. We believe these regional variations reflect geographic biases in training as well as the lack of consensus in treatment for C1 fractures. Unlike the subaxial<sup>28</sup> and thoracolumbar spine,<sup>29</sup> there are few<sup>9</sup> validated scoring systems that clinicians can use as a guide for treatment of C1 fractures. Joaquim *et al.*<sup>30</sup> prospectively validated their previously described algorithm for treatment of upper cervical spine fractures<sup>9</sup> but the study only evaluated 38 patients.

One of the strengths of this study is that it is the first study to examine geographic variations in treatment of C1 fractures. Additionally, this study used a large nation-

wide database to obtain patient data that could not otherwise have been obtained at the institutional level, especially since C1 fractures are relatively rare compared to other spine fractures. However, there were several limitations in the present study. Patient data was compiled using the ICD-9 code for C1 fractures. This code does not differentiate between morphologically different C1 fracture types (*i.e.* isolated anterior or posterior arch fracture *vs.* Jefferson fracture *vs.* lateral mass fracture, *ect.*). However, it is unclear that differentiating morphology of these fractures would alter our results since there is no literature to support a treatment algorithm based on C1 fracture morphology. Additionally, patient reported outcomes were not available in this study. However, this study evaluated the trends in management of C1 fractures rather than the efficacy of management making patient reported outcomes less applicable.

## Conclusions

This study evaluated the variations in treatment of C1 fractures over time, by age and by region. The investigation demonstrated that surgical management of C1 fractures is increasing in frequency over time. Halo use has decreased over time while the frequency of collar use has remained the same over time. Halo was employed much less frequently in the elderly population, whereas collar use significantly increased with age. Furthermore, the treatment of these fractures varies by region – the Northeast had the highest incidence of collar use and the lowest rate of halo use. It is our hope that understanding the treatment trends of C1 fractures will lead to future recommendations regarding optimal management of these injuries.

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