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Predictors of clavicle fixation in multiply injured patients

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Abstract

Introduction: *Clavicle fractures account for approximately 10% of all fractures in multiply injured patients. Although prevalent, there is no consistency in the current literature as to the management of these fractures. The aim of our study is to evaluate the factors associated with surgical fixation of the clavicle fracture in multiply injured patients.*

Methods: *All major trauma patients aged 16 years and over with a clavicle fracture were included in this study. Data were extracted from the Victorian State Trauma Registry (VSTR), with a date of injury from the 1st July 2005 to 30th June 2014. Univariate and multivariate statistical analysis was undertaken to determine the variables associated with clavicle fixation.*

Results: *Over the nine-year period, 1779 patients were included in this study. The patient cohort had a median age of 47 and a median Injury Severity Score of 17. Of the cohort, 273 patients underwent surgical fixation of their clavicle fracture. The following variables were associated with surgical fixation of the clavicle after considering the relevant confounders: year of presentation, younger patients, patients who had an ICU admission, or an associated injury to the humerus or scapula.*

Conclusion: *Over fifteen percent of our cohort of multiply injured patients underwent surgical fixation of their clavicle fractures, with this study being the first to report on variables associated with clavicle fixation in this setting. Further research is required to investigate the reasons for clavicle fixation and the outcomes of clavicle fracture management in multiply injured patients.*

Keywords: *clavicle fracture, multiply injured patient, operative treatment, surgical fixation, trauma, trauma registry*

Introduction

The majrity of clavicle fractures occur in isolation, and account for 2-5% of all fractures in the adult population [1,2]. As such, most of the literature surrounding clavicle fractures focuses on patients with an isolated injury [1,3-5]. However, clavicle fractures are highly prevalent in multiply injured trauma patients [2,6,7] accounting for 5-11% of all fractures in these patients, and are a useful marker indicating potential further thoracic or upper extremity injuries following significant trauma [8]. This becomes increasingly important in multiply injured patients where injuries can be commonly missed [9,10].

With the establishment of population-based trauma registries, it is possible to identify and analyse epidemiological data and factors associated with clavicle fractures in multiply injured patients. Many studies have investigated factors including mechanism of injury, fracture rates, associated injuries, in hospital mortality, and patient demographics [2,6,7,11]. The German DGU Trauma registry is one such registry, collecting data from around 600 participating trauma centres located primarily in Germany, with involvement from a number of countries around the world. Analysing DGU Trauma register data, Horst et al. [11] highlighted the importance of the presence of clavicle fractures following severe trauma. Over a twelve-year period, they included 46,565 patients aged 16+ with an Injury Severity Score (ISS) of >16, of which 4790 (11.4%) had a fracture of the clavicle. The patients with a clavicle fracture showed a significant increase in associated thoracic and scapula injuries, with longer stays in the intensive care unit (ICU) as compared with patients without a clavicle fracture.

There remains a paucity of literature pertaining to the management and outcomes of severely injured patients with clavicle fractures. While studies have assessed factors and outcomes comparing operative and non-operative management in cohorts with isolated clavicle injury [12,13], in multiply injured cohorts there is a lack of evidence available describing the factors associated with surgical fixation. The aim of this study was to identify factors associated with operative management of a clavicle fracture in a cohort of multiply injured patients via a population-based trauma registry.

Method

Setting

The Australian state of Victoria has a population of 5.8 million with an annual growth rate of 2.1% [14]. The state operates an inclusive, regionalised trauma system with three designated major trauma service (MTS) hospitals; one paediatric and two adults. The trauma system is monitored using the Victorian State Trauma Registry (VSTR), which is a state-wide population-based registry, implemented in July 2001 [15]. Data from the VSTR are used to advise the Victorian government on a best practice model of trauma service provision [16]. Data for the registry is collected from all trauma receiving hospitals in the state [17].

Descriptor		Non operative	Operative	Total	P value
		N=1,506 (84.7%)	N=273 (15.3%)	N=1779	
Age (median, 25/75 percentile) (years)		48 (34,62)	44 (32,54)		<0.001
Gender	Male	1117 (74.2%)	212 (77.7%)	1329 (74.7%)	0.223
	Female	389 (25.8%)	61 (22.3%)	450 (25.3%)	
Injury severity score (ISS) Grouping	Apr-13	238 (15.8%)	37 (13.6%)	275 (15.5%)	0.226
	14-16	271 (18.0%)	38 (13.9%)	309 (17.4%)	
	17-26	617 (41.0%)	123 (45.1%)	740 (41.6%)	
	27+	380 (25.2%)	75 (27.5%)	455 (25.6%)	
Spine	AIS <=2	1337 (88.8%)	250 (91.6%)	1587 (89.2%)	0.171
	AIS >2	169 (11.2%)	23 (8.4%)	192 (10.8%)	
Lower Limb	AIS <=2	1245 (82.7%)	210 (76.9%)	1455 (81.8%)	0.024
	AIS >2	261 (17.3%)	63 (23.1%)	324 (18.2%)	
Head	AIS <=2	997 (66.2%)	199 (72.9%)	1196 (67.2%)	0.03
	AIS >2	509 (33.8%)	74 (27.1%)	583 (32.8%)	
Thorax	AIS <=2	411 (27.3%)	51 (18.7%)	462 (26.0%)	0.003
	AIS >2	1095 (72.7%)	222 (81.3%)	1317 (74.0%)	
Other Upper Limb injury	No	1359 (90.2%)	237 (86.8%)	1596 (89.7%)	0.086
Excludes clavicle and scapula	Yes	147 (9.8%)	36 (13.2%)	183 (10.3%)	
Scapula	No	1226 (81.4%)	179 (65.6%)	1405 (79.0%)	0
	Yes	280 (18.6%)	94 (34.4%)	374 (21.0%)	
Humerus	No	1452 (96.4%)	252 (92.3%)	1704 (95.8%)	0.002
	Yes	54 (3.6%)	21 (7.7%)	75 (4.2%)	
Year of injury	2005	135 (9.0%)	28 (10.3%)	163 (9.2%)	
	2006	113 (7.5%)	49 (17.9%)	162 (9.1%)	
	2007	148 (9.8%)	32 (11.7%)	180 (10.1%)	
	2008	146 (9.7%)	17 (6.2%)	163 (9.2%)	
	2009	180 (12.0%)	19 (7.0%)	199 (11.2%)	
	2010	185 (12.3%)	29 (10.6%)	214 (12.0%)	
	2011	216 (14.3%)	30 (11.0%)	246 (13.8%)	
	2012	200 (13.3%)	34 (12.5%)	234 (13.2%)	
	2013	183 (12.2%)	35 (12.8%)	218 (12.3%)	
Charlson Comorbidity index (CCI)	CCIidx=0	1031 (68.5%)	179 (65.6%)	1210 (68.0%)	
	CCIidx=1	366 (24.3%)	83 (30.4%)	449 (25.2%)	
	CCIidx<1	109 (7.2%)	11 (4.0%)	120 (6.7%)	
Cause	MVA	447 (29.7%)	87 (31.9%)	534 (30.02%)	
	MBA	334 (22.2%)	86 (31.5%)	430 (24.17%)	
	Cyclist	211 (14.0%)	49 (17.9%)	260 (14.61%)	
	Pedestrian	123 (8.2%)	19 (7.0%)	142 (7.98%)	
	Low fall	91 (6.0%)	1 (0.4%)	92 (5.17%)	
	High Fall	194 (12.9%)	18 (6.6%)	212 (11.92%)	
	Collision with object	32 (2.1%)	3 (1.1%)	35 (1.97%)	
	Other	64 (4.2%)	10 (3.7%)	74 (4.16%)	
Fund category	TAC/WC/Other	886 (58.8%)	195 (71.4%)	1081 (61.25%)	0
	Medicare	488 (32.4%)	52 (19.0%)	540 (30.59%)	
	Private/DVA	119 (7.9%)	25 (9.2%)	144 (8.16%)	

Intensive care unit (ICU) admission	Yes	664 (44.1%)	160 (58.6%)	824 (46.3%)	0
	No	842 (55.9%)	113 (41.4%)	955 (53.7%)	
YEAR					0

Numbers is n (%) unless otherwise stated
Abbreviations: AIS = Abbreviated injury score, ISS = Injury Severity score, CCI =Charlson comorbidity index, DVA =Department of Veterans affairs, ICU = Intensive care unit, MVA = Motor vehicle accident, MBA = Motorbike accident, TAC= Traffic Accident commission, WC = work cover
In Fund category Other indicates other compensable funds

Table 1. *Factors (univariate association)*

Descriptor		Odds ratio	95% confidence interval	P value
Age group	16-30 (reference)	1		0.027
	30-40	1.45	0.94, 2.25	
	40-50	1.09	0.71, 1.67	
	50-60	1.29	0.83, 2.01	
	60-70	0.8	0.47, 1.37	
	70-80	0.34	0.15, 0.81	
	80+	0.17	0.04, 0.72	
Gender	Male (reference)	1		0.746
	Female	1.06	0.74, 1.53	
Injury severity score (ISS) Grouping	4-13 (reference)	1		0.274
	14-16	0.93	0.56, 1.55	
	17-26	1.31	0.84, 2.03	
	27+	1.04	0.57, 1.83	
Spine	AIS <=2 (reference)	1		
	AIS >2	0.75	0.46, 1.24	0.262
Lower Limb	AIS <=2 (reference)	1		
	AIS >2	1.24	0.85, 1.81	0.259
Head	AIS <=2 (reference)	1		
	AIS >2	0.77	0.52, 1.13	0.178
Thorax	AIS <=2 (reference)	1		
	AIS >2	1.25	0.85, 1.84	0.261
Other Upper Limb injury –	No (reference)	1		
Excludes clavicle and scapula.	Yes	1.1	0.71, 1.69	0.674
Scapula	No (reference)	1		
	Yes	2.11	1.54, 2.88	0
Humerus	No (reference)	1		
	Yes	1.94	1.07. 3.51	0.03
Year	2005 (reference)	1		
	2006	2.64	1.49, 4.68	0
	2007	1.29	0.71, 2.35	
	2008	0.68	0.34, 1.35	
	2009	0.58	0.30, 1.13	
	2010	0.91	0.50, 1.66	
	2011	0.8	0.44, 1.45	
	2012	0.9	0.50, 1.61	

	2013	1.15	0.64, 2.07	
Charlson Comorbidity index (CCI)	CCIidx=0 (reference)	1		0.065
	CCIidx=1	1.41	1.02, 1.95	
	CCIidx<1	0.8	0.40, 1.60	
Cause	Low fall (reference)	1		0.265
	MVA	3.2	0.40, 25.66	
	MBA	3.81	0.48, 30.41	
	Cyclist	4.93	0.63, 38.85	
	Pedestrian	1.75	0.33, 22.94	
	High Fall	2.64	0.33, 21.19	
	Collision with object	1.59	0.15, 17.22	
	Other	3.21	0.38, 27.45	
Fund category	Medicare (reference)	1		0.087
	TAC/WC/Other	1.46	0.95, 2.24	
	Private/DVA	1.7	0.98, 2.96	
Intensive care unit (ICU) admission	No (reference)	1		0.004
	Yes	1.58	1.16, 2.17	

Numbers is n (%) unless otherwise stated

Abbreviations: AIS = Abbreviated injury score, ISS = Injury Severity score, CCI =Charlson comorbidity index, DVA =Department of Veterans affairs, ICU = Intensive care unit, MVA = Motor vehicle accident, MBA = Motorbike accident, TAC= Traffic Accident commission, WC = work cover

In Fund category Other indicates other compensable funds.

Table 2. *Factors associated with surgical fixation of a clavicle fracture (Multivariate analysis)*

A patient is defined as major trauma if any of the following criteria are met: 1. Death as a result of injury; 2. Injury severity score (ISS) >12; 3. Admission to ICU for > 24 hours and requiring mechanical ventilation; and 4. Urgent surgery. The VTSR uses an opt-out method of consent with an opt-out rate of <0.5% [16]. Ethics approval for this specific project was obtained from the Monash University Human Research Ethics Committee (MUHREC).

Data

Data were extracted for eligible cases from the VSTR, with a date of injury from the 1st July 2005 to 30th June 2014. Major trauma patients captured by the VSTR were included in this study if the following criteria were over 15 year of age and had sustained an Abbreviated Injury Scale (AIS) 2005-2008 update coded clavicle fracture. The AIS is an anatomically based coding structure used to describe and classify the severity of injuries [18,19]. The AIS is one of the most common anatomic scales for traumatic injury and is widely used by trauma registries. There are four clavicle fracture groupings in the AIS - unspecified, proximal, shaft, and distal.

Data extracted from the registry included patient demographics, injury event details, ISS, AIS diagnosis codes, VTSR procedure codes, International Classification of Disease 10th Revision Australian Modification (ICD-10-AM) diagnosis and procedure codes, and in-hospital outcomes. Data categories included age, gender, ISS grouping, associated injuries (spine, lower limb, head, thorax, other upper limb injury (excluding clavicle and scapula), scapula and humerus, mechanism of injury, funding category and ICU admission. Age and ISS was categorised into groups, due to their non-linear relationship with the outcome of interest, and to improve the ease of interpretation.

Associated injuries were further divided into AIS severity score <2 and AIS severity score >2. An AIS severity score of <2 relates to a minor or moderate injury of the designated body region for example a superficial laceration, while that of >2 relates to a scale ranging from serious to maximal (untreatable) injury.

Admission funding category was divided into compensable [Transport Accident Commission [TAC]/Work Safe Victoria [WSV]/Other], Medicare (Public Universal Healthcare provider), and privately insured. Compensable patients were those covered by the state's third-party no-fault insurers work-related injury [WorkSafe Victoria (WSV)], and road traffic injury [Transport Accident Commission (TAC)].

Statistical analysis

Data were analysed using Stata Statistical Software version 14.0 (StataCorp LP. 2015, College Station, TX, USA). Descriptive statistics were used for patient demographics. Data are presented as frequencies and percentages for categorical variables, and either mean (standard deviation) or median (interquartile range) for continuous variables, depending on the distribution of the data. The baseline demographics and injury/event details for those patients who had their clavicles fixed and those who did not were compared using Chi-square ($\chi 2$) testing (for categorical variables) and Mann-Whitney U-test was performed for the continuous variable of age. A p-value of <0.05 was considered significant.

Multivariable logistic regression was then used to identify important demographic and injury factors that predict clavicle fracture proceeding to fixation. Variables demonstrating a p-value of <0.25 in the univariate analysis were entered the multivariable model. The method used was based on that described by Hosmer and Lemeshow [20]. Adjusted odds ratio (AOR) and 95% confidence intervals (CI) were reported.

Results

Over the 9-year period, there were 22,072 major trauma cases captured by the registry of which 1779 (8.9%) participants met the inclusion criteria for this study due to the presence of a clavicle fracture. Most participants were male with a median age of 47 years and a median ISS of 17 (Table 1). The most common cause of injury was a road traffic crash with the vast majority being unintentional events (Table 1). Most clavicle fractures were classified as "not further specified". Of those specified there were 30 medial, 462 midshaft and 214 lateral fractures (Table 1). Six participants had bilateral clavicle fractures and a total of 17 were classified as open fractures. Associated injuries to the chest, head, lower extremity and spine were most prevalent. Most chest injuries were serious (AIS of 3). Fifteen per cent of chest injuries and 29.4% of head injuries had an AIS score of greater than 3 (equivalent to a severe to critical injury) (Table 1).

Of the 1779 participants, 273 underwent operative fixation of the clavicle fracture. The cohort undergoing operative management of the clavicle were younger, predominantly male, and had higher incidence of regional injuries to the scapula and humerus when compared to those managed non-operatively (Table 1). The operatively managed group contained a higher proportion of road trauma incidents, particularly motor vehicle and motorcycle crashes, and a larger percentage were financially covered by either Transport Accident Commission (TAC) or WorkSafe Victoria (WSV). The prevalence of an ICU admission during their inpatient stay was higher in patients with operative clavicle fixation (Table 1). Those having sustained their injury from a fall had lower rates of surgical fixation. Injury Severity Score, gender and whether the patient had sustained a severe spinal injury were not different between the groups.

Age, gender, ISS group, associated spine, head, lower limb, thoracic, humeral, scapular, other upper limb injuries, year of presentation, cause, fund category, ICU admission, and Charlson comorbidity index all demonstrated a univariate association of $p<0.25$ with the outcome of interest (surgical management of the clavicle) and were included in the multivariable model. From the multivariate analysis (Table 2), younger age was found to be associated with higher rates of clavicular fixation. Patients with an associated humeral or scapular fracture had approximately twice the odds of undergoing surgical fixation as compared to those without whilst an ICU stay was also associated with clavicular fixation (Table 2). After adjusting for other potential confounding factors, gender, ISS, cause of injury and fund category (compensable or not) were not associated with operative fixation of the clavicle.

Discussion

This study is the first to report on factors associated with clavicle fixation in the multiply injured patient. In our population, younger patients, those with associated scapula or humeral fractures, or patients having an ICU admission had higher odds of undergoing fixation of their clavicle. It was also noted that fixation rates varied significantly based on year of presentation. The reasons behind the decision to operate remain unknown although the information in this study provides important insights into factors associated with clavicle fixation in the multiply injured patient population.

The prevalence of clavicle fracture in multiply injured patients in the state of Victoria was 8.1%, which is lower than that found in the German trauma registry (DGU) (10.3%) [11], or the Dutch trauma registry (10.7%) [2,6]. Operative fixation of the clavicle fracture was performed in 15.3% of our cohort. Current literature shows fixation rates in similar patient cohorts between 3.9% and 20.2% [5,6,21]. Previous studies reporting on patient cohorts with ISS>16 and high rates of ICU admission showed comparatively lower rates of fixation. Van Laarhoven et al. [2] showed that 4.27% of their patients with clavicle fracture underwent surgical fixation, while Ferree et al. [21] reported 3.9% of multiply injured patients proceeding to operative management.

Multiple fractures within an anatomical region may lead to increased instability and greater risk of fracture displacement and non-union. A floating shoulder is defined as an ipsilateral fracture of the neck of glenoid and midshaft clavicle [22]. Surgical fixation is often recommended given the risk of displacement of one or both fractures [23-26]. Our study showed a significant association between fixation of the clavicle fracture and the presence of a humerus or scapula fracture. While we were unable to determine if this was directly due to floating shoulders, our data suggests that this may form a part of the surgical decision making in patients with severely injured or unstable upper extremities.

Our finding of the association between ICU admission and fixation of the clavicle, differs from that reported by Ferree et al. [21]. They reported on the distribution and management of a 155-patient cohort of multiply injured patients with clavicle fracture. None of the 61 patients that required admission to ICU in their cohort underwent fixation of their clavicle. This was explained as patients admitted to ICU are more likely to be intubated and imaged supine, leading to less muscle tension and apparently un-displaced fractures. It must be noted that in multiply injured patients' injuries with life threatening factors will take priority. We hypothesise that ICU patients in our cohort may have undergone fixation to achieve decrease in pain, early mobility, to enable improved patient positioning and to stabilise upper limb injuries. It has been previously noted that in multiply injured patients, it is extremity injuries which primarily affect long term functional outcomes [27-29] and assessment and early management of these are a priority within a mature trauma system.

One factor found to be associated with clavicle fixation was the year that the patient presented. Prior to 2008, patients had higher odds of having their clavicle undergo fixation. This may be reflective of the evidence (or lack thereof) at the time, or perhaps decision making within the surgical team. It appears that from 2013, the odds of clavicle fixation are again increasing. The reasons for this are unknown.

This strength of this study includes the use of data from the VSTR, a population-based trauma registry, with an excellent follow up rate. Using a registry such as this ensures that the study is not influenced by bias of policies or preferences from any single surgeon or centre. The data collected is readily generalizable and allows for direct comparison with studies from other population-based registries. To the authors knowledge this is the largest study reporting on factors associated with clavicle fixation following severe trauma.

Using a data registry results in the limitations associated with a retrospective study. Not all factors that may be relevant to the decision-making regarding fixation of a clavicle were available. Fracture type may be an important factor in surgical decision making but was not consistently reported in our cohort with 1079 of 1779 cases listed as fracture type "not further classified". Ferree et al. [21] categorised fracture by site and displacement according to the Robinson classification and compared multiply injured patients to an isolated injury cohort. There was noted disparity between management in the separate cohorts. It is important to note that this study has established associations between factors and clavicular fixation, but a causal effect cannot be assumed.

This study is the first to show as association between younger age, associated upper limb fracture, ICU admission and year of injury with the odds of clavicle fixation in the multiply injured population. Whether these factors are specific to our cohort, or if these findings can be generalised to other populations is unknown. Further research is needed to determine why these factors affect the decision making, and if the patient outcomes are different following surgical management.

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Author contributions and conflict of interest statement

Please note that all authors have made substantial contributions to all of the following: (1) the conception and design of the study, or acquisition of data, or analysis and interpretation of data, (2) drafting the article or revising it critically for important intellectual content, (3) final approval of the version to be submitted.

The manuscript, including related data, figures and tables has not been previously published and is not under consideration elsewhere.

None of the authors have any financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work.

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