Title Page

Title: Prevalence of Non-union and Delayed union in Proximal Humeral Fractures

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Abstract:

Background: Little is known about the prevalence of proximal humeral non-union. There is disagreement on what constitutes union, delayed union and non-union. Our aim was to determine the prevalence of these complications in proximal humeral fractures (PHFs) admitted to trauma hospitals.

Method: The Victorian Orthopaedic Trauma Outcomes Registry (VOTOR) identified 419 cases of proximal humeral fractures, of which 306 were analysed. Three upper limb orthopaedic surgeons used x-rays to classify fractures according to the Neer classification and determine union. SF-12 scores were used to assess patient health and wellbeing.

Results: Of 306 cases 49.4% reached union. Median time to union was 100 days (CI 90-121). Of these, 17.0% united by 60 days, 8.5% united by 89 days and 23.9% united after 90 days,

demonstrating ‘prolonged delayed union’. There were 25 non-unions with a prevalence of 8.2%, most occurring in 2-part surgical neck fractures.

Conclusion: Our cohort of largely displaced PHFs admitted to trauma hospitals had a non-union prevalence of 8.2% and an overall delayed union prevalence of 32.4%. Consensus is required on definitions of non-union and delayed union timeframes.

Keywords: shoulder fractures, humerus, non-union, delayed union, prevalence

Manuscript - Body

Introduction

Proximal humeral fractures (PHFs) account for 4-5% of all fractures [1-3]. While 85% of these will be minimally displaced, not require operative fixation, and have good outcomes [4, 5], complications such as non-union do occur. Although the treatment of this complication has been the subject of much research, little is known about the prevalence of non-union and delayed union in PHFs.

Earlier literature suggested the occurrence of PHF non-union was infrequent [6-13]. In 32 operatively managed PHFs with severe displacement, Kristiansen and Christensen reported no non-unions as did Hawkins *et al* who operatively managed 15 3-part fractures [14] [15]. Martin *et al* and Jacob *et al* had similar results [3] [16].

By 1983 only 29 PHF non-unions had been recorded [17]. Yet by that year Neer had collected a series of 50 [18]. Neer reported the incidence as 13.7% in 117 3- and 4-part fractures, all occurring at the surgical neck. [5]. The finding of non-unions occurring at the surgical neck was confirmed by others [7, 11, 19].

Prevalence of PHF non-union was reported by Court-Brown *et al* at 1.1% in a series of 1027 consecutive fractures. They described an increase in non-union to 8% if metaphyseal comminution was present and 10% with significant translation of the surgical neck [20]. Hanson *et al* reported a delayed union and non-union prevalence of 7% in their series of 160 non operative fractures [21].

Definitions of non-union and delayed union are difficult given there is no consensus about their timing. Normal fracture healing varies from 6 weeks to 3 months [3] [22]. Sheck defined non-union as occurring after 8 weeks [22] while Cadet *et al* defined it as the lack of interval healing on radiographs 6-8 weeks apart [18]. Others defined non-union as established at 3 months [20, 23, 24] or 6 months [25].

The prevalence of delayed union and non-union in PHFs isn't well established and there is disagreement on what constitutes union, delayed union and non-union. These points must be clarified as they guide management. The aim of this study was to determine the prevalence of non-union and delayed union in cases of PHFs admitted to trauma hospitals.

Method

Ethics approval was granted at four trauma hospitals in Victoria (Alfred Hospital, Royal Melbourne Hospital, Northern Hospital and University Hospital Geelong) which participate in the Victorian Orthopaedic Trauma Outcomes Registry (VOTOR). VOTOR registers information on new orthopaedic admissions with a length of stay >24 hours and in this way, forms a comprehensive database of orthopaedic injuries, treatments, complications and outcomes. Information is prospectively collected from patients who can opt-out at any time. Patients <16 years or with pathologic fractures are excluded.

The registry identified 419 cases of PHFs between September 2003 and July 2008. Medical and radiological records were reviewed retrospectively. Excluded were 49 cases with no retrievable x-rays, 16 with fractures of the proximal diaphysis, 5 with no fracture, 29 with primary hemiarthroplasties and 14 unclassified due to poor quality x-rays. This left 306 PHFs for analysis.

Digital and hardcopy X-rays were used to classify fractures and assess union. Series included AP and lateral views. Some severely traumatised participants only had AP x-rays.

Three upper limb orthopaedic surgeons with 2-15 years experience classified the fractures using the full Neer classification [4] (including the valgus impacted 4-part fracture described by Jakob [16]). Radiological union was reported when 3 cortices had bone bridging. Normal union was defined as occurring by 60 days, delayed union between 61 - 89 days and non-

union when fractures had not united by 90 days, on the basis of current norms in the literature [3, 22].

Health and wellbeing of participants was measured utilizing the 12-item Short Form Health Survey (SF-12) and its two summary scales, the Physical (PCS) and Mental Component Summary (MCS). This survey was obtained by telephone interview 12 months post injury. The higher the PCS and MCS scores, the better the outcome [26].

Chi-squared tests were used to evaluate associations between union, delayed union and non-union groups and other categorical patient variables. Univariate analysis was used to assess the relationship between union groups, patient demographics and injury characteristics.

Results

A summary of patient demographics is presented in *table 1*. Almost half (47.1%) sustained SNOHs while only 4.3% had minimally displaced fractures. Of 306 cases, 151 (49.4%) reached union. Median time to union was 100 days (CI 90-121). Fifty two fractures (17.0%) united by 60 days and 26 (8.5%) united by 89 days falling into a '*delayed union*' category. Seventy three fractures (23.9%) united after 90 days, demonstrating '*prolonged delayed union*' with some taking 14 months to unite.

The 155 fractures which didn't reach union included 130 cases with <90 days radiological follow up that couldn't be assessed further or included as non-unions. Twenty five cases received radiological follow up >90 days (range, 91 days - 3.5yrs) and were classified as non-unions with an overall prevalence of 8.2% (or 14.2% prevalence with exclusions for 130 participants lost to follow up).

There was no significant difference (p value ≤ 0.05) in union between age, sex, Neer classification or treatment. A decrease in length to union was found when fractures resulted from push-bike accidents (median 56.3 days, p=0.004) while discharge to a rehabilitation unit was associated with prolonged time to union (restricted mean 183.6 days, p=0.04) *(table 1).*

When comparing the 3 union groups amongst each other (union, delayed union, prolonged delayed union), SNOH's made up the largest proportion in the 'union' and 'prolonged delayed union' groups (40.38% and 49.31%). In the 'delayed union' group 3-part GT fractures were more prevalent (42.31%). Over half of fractures in all union groups were sustained by falls <1m (53.85%-57.69%). Operative management and plate and screw osteosynthesis were more frequent in the 'prolonged delayed union' group although there was no significant association between union and treatment (p = 0.52) *(table 2).*

Regarding non-unions, 60.0% were sustained by falls <1m followed by pedestrian accidents (20.0%). While 68% were SNOH's the actual non-union occurred at the surgical neck in 84.0% of cases. Non-operative management made up 52.0% of non-unions, 20.0% occurred

post plate and screw osteosynthesis and 12.0% after IM nailing *(table 3).* Concurrent injuries were associated with non-union (p value=0.026) and were seen in 36.0% of participants in this group. There was no association between non-union and age (p = 0.203), sex (p = 0.854), mechanism (p = 0.329), fracture type (p = 0.243), treatment (p = 0.143) and discharge destination (p = 0.061). Participants with non-union had worse PCS scores (mean 34.6, p=0.026) than those with united fractures. No difference was seen in MCS scores *(table 4).*

Discussion

Findings reveal a longer time to union than other studies. Median time to union was 100 days compared to 6-12 weeks in the literature [3, 20, 22-24]. Faster union in push-bike accidents (mean 56.3 days, CI 31 – 81 days) and longer union for discharge to a rehabilitation unit (restricted mean 183.6 days, CI 130 – 236 days) possibly reflects age differences in these groups (average 49.6 years vs. 72.0). Only 17.0% of fractures united by 60 days and a further 8.5% by 90 days, the "roughly" agreed upon times to normal union and 'delayed union'. Most united after 90 days, demonstrating 'prolonged delayed union'. This group represented 23.9% of all fractures and 48.3% of all unions. Overall, delayed unions made up 32.4% of all fractures and 65.6% of unions.

Non-unions were not uncommon with an 8.2% prevalence. This figure may be inaccurately high as it includes un-united fractures in participants who may have been lost to follow up after 90 days, while the 'prolonged delayed union' group includes cases not lost to radiological follow up after 90 days. Nonetheless, reasons potentially explaining the

prolonged times to union and non-union rate include our patient population comprising only of cases admitted to trauma hospitals, contrasting with other studies which include outpatients [20, 27, 28]. The literature outlines that medical problems, certain medications, smoking, excessive alcohol and polytrauma can predispose to delayed fracture healing and non-union

[7, 9-13, 22, 29, 30]. Compared to their outpatient counterparts, our cohort possibly had greater trauma or disease burden necessitating hospital admission and likely represented a sicker group, though specific data on participant comorbidities was not collected. In this setting, the traditional definitions of union in PHFs may be inaccurate.

Another factor is that only 4.3% of fractures were minimally displaced compared to 49% reported by Court-Brown *et al* [28] and 80%-85% reported by Neer [4, 12]. The overwhelming 95.8% of fractures were displaced reflecting greater force transmission through the fracture site and soft tissues affecting the biology of the healing bone. Displaced fractures may require operative intervention which can further disrupt the soft tissues and periosteum. Despite the expectation that the high number of displaced fractures in our series would have resulted from high energy injuries, this was not the case. Falls <1m were the most common cause of 141 fractures (46.1%). While there was no statistically significant association between union and treatment, there was a slight increase towards operative management and the use of plate and screw osteosynthesis in the '*delayed*', '*prolonged delayed'* and non-union groups.

Although fracture type did not affect union, 68% of non-unions were SNOH's, which were over-represented given they accounted for 47.1% of all fractures. When comparing SNOH's to all other 2-part PHFs, they demonstrated more 'delayed union', 'prolonged delayed union' and non-union. Only 14.6% of SNOH's (compared to 24.2%) united by 60 days and the non-union rate in SNOH's was almost double that of all other 2-part fractures (11.8% vs. 6.5%).

SNOH's may be predisposed to non-union because the distal fragment which is cortical, lacks the healing qualities of cancellous bone [7, 17]. The surgical neck fracture line, usually of transverse or short oblique configuration, reduces the contact area of fracture fragments. Furthermore, when this complication is observed in any proximal humeral fracture, the actual non-union usually occurs at the surgical neck [5, 7, 11, 30]. Of 25 non-unions 84% occurred at the surgical neck. Of these 66.7% were transverse fractures, 14.3% were oblique and 19.0% had metaphyseal comminution. Further analysis could not be performed.

Given SNOH's have longer union times it may be useful to consider them as humeral shaft fractures. Shaft union ranges from 8 to 32 weeks [31, 32]. Mahabier *et al* found the median union time for oblique (fracture line >30 degrees) and transverse fractures (line <30 degrees), to be 11 and 15weeks respectively. Humeral shaft delayed union was defined at 24 weeks and non-union at 6 months [33].

It may be necessary to change the way PHFs are defined and treated. Some suggest treatment for non-union should commence by 3 months [20, 23]. In this study it would be counterintuitive as the majority of fractures united after 3 months. In our specific cohort, timeframes for union, delayed union and non-union should resemble those of shaft fractures.

Conclusion

Results support more recent literature highlighting that non-union and delayed union of proximal humeral fractures are more frequent than previously believed. This holds true in our cohort of largely displaced fractures admitted to trauma hospitals where a non-union prevalence of 8.2% and an overall delayed union prevalence of 32.4% were observed. Consensus is required on definitions of non-union and delayed union timeframes.

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Declaration

No conflict of interest is declared.

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Table 1

Baseline characteristics and Average Union

	Total % n=306	Median/Mean Union days	P value

Gender	Male	124 (40.5)	104/200.8	
	Female	182 (59.5)	95/146.3	0.763
Age	16-60	110 (35.9)	104/184.5	
	61-79	105 (34.3)	98/127.9	0.507
	≥80	91 (29.7)	93/192.1	0.296
Mechanism of injury	MVA	32 (10.5)	127/164.3	
	MBA	13 (4.2)	183/194.4	0.913
	Pedestrian Accident	33 (10.8)	134/141.6	0.922
	Push Bike Accident	8 (2.6)	42/56.3	0.004*
	Fall <1m	166 (54.2)	100/194.2	0.556
	Fall >1m	33 (10.8)	71/143.1	0.090
	Other	21 (6.9)	82/137	
Neer classification	1-Part	13 (4.2)	121/170.8	
	2-Part *(SNOH)*	180 (58.8) (*144(47.1)*)	106/216.9	0.870
	3-Part	73 (23.9)	82/115.4	0.225
	4-Part	7 (2.3)	104/132.9	0.851
	Fracture/Dislocation	32 (10.5)	91/194.4	0.845
	Articular surface	1 (0.3)	-/-	0.863
Concurrent injury	None	189 (61.8)	93/185.3	
	Fracture	71 (23.2)	100/134.2	0.964
	Intracranial injury	8 (2.6)	90/110.25	0.945
	Fracture + Intracranial	15 (4.9)	208/149.3	0.302
	Other	23 (7.5)	-/-	-
Treatment	Conservative	186 (60.8)	93/138.6	
	Plate and screw	75 (24.5)	103/162.2	0.344
	IM nail	11 (3.6)	250/199.8	0.065
	Other	34 (11.1)	146/285.9	0.293
Discharge destination	Home	130 (42.5)	93/146.0	
	Rehab	96 (31.4)	108/183.6	0.039*
	Nursing home	6 (2.0)	91/111.2	0.817
	Hospital	29 (9.5)	133/171.9	0.253
	Other	11 (3.6)	401/239.8	0.167
	Unaccounted	34 (11.1)	-/-	-

*$p<0.05$

Table 2

Union Groups and their Characteristics

Group		Fracture Type				Mechanism					Treatment			
	No.	**SNOH**	**2-pt GT**	**3-pt GT**	**Other**	**Fall <1m**	**Fall >1m**	**MVA**	**Pede-strian**	**Other**	**Non-Op.**	**Plate + Screw**	**IMN**	**Other**
Union	**52**	21	9	12	10	28	8	3	1	12	21	15	1	15
Delayed Union	**26**	9	4	11	2	15	4	3	3	1	15	10	1	0
Prolonged Delayed Union	**73**	36	6	18	13	41	2	13	6	11	36	30	3	4

IMN = intramedullary nail

Table 3

Non-union Characteristics

Non Unions							
Case No.	**Sex**	**Age**	**Neer Classification**	**Site of Nonunion**	**Fracture Configuration**	**Mechanism**	**Treatment**
1	M	20	2-part anterior fracture/dislocation	GT	-	Pedestrian Accident	Conservative
2	F	77	SNOH	SNOH	Transverse	Fall <1m	Plate and Screw
3	M	50	2-part GT	GT	-	Fall <1m	Other
4	M	93	SNOH	SNOH	Oblique	Fall <1m	Conservative
5	F	80	SNOH	SNOH	Transverse	Fall <1m	Conservative
6	F	94	3-part GT	SNOH	Transverse	Fall <1m	Conservative
7	M	32	SNOH	SNOH	Transverse	MVA	Plate and Screw
8	M	63	SNOH	SNOH	Transverse	Fall >1m	Plate and Screw
9	M	24	SNOH	SNOH	Transverse	Not Stated	Other
10	F	67	4-part classic	SNOH	Transverse	Pedestian Accident	Conservative
11	M	84	SNOH	SNOH	Transverse	Fall <1m	Other
12	F	80	SNOH	SNOH	Transverse	Fall <1m	Conservative
13	F	79	SNOH	SNOH	Oblique	Fall <1m	IMN
14	M	43	SNOH	SNOH	Metaphyseal Comminution	MBA	Conservative
15	M	58	3-part anterior fracture/dislocation	SNOH	Metaphyseal Comminution	Fall <1m	Plate and Screw
16	F	71	3-part GT	SNOH	Metaphyseal Comminution	Fall <1m	Conservative
17	M	55	SNOH	SNOH	Transverse	Pedestrian Accident	Conservative
18	F	82	SNOH	SNOH	Metaphyseal Comminution	Fall <1m	IMN
19	M	62	SNOH	SNOH	Transverse	Fall <1m	Conservative
20	M	19	SNOH	SNOH	Transverse	Pedestrian Accident	IMN
21	F	80	SNOH	SNOH	Transverse	Pedestrian Accident	Conservative
22	F	81	SNOH	SNOH	Transverse	Not Stated	Plate and Screw
23	F	75	2-part anterior fracture/dislocation	GT	-	Fall <1m	Conservative
24	F	83	SNOH	SNOH	Oblique	Fall <1m	Conservative
25	F	74	2-part GT	GT	-	Fall <1m	Other

Table 4

PCS and MCS

PCS and MCS Scores in United Fractures					
		N	**Mean**	**P-value**	**CI**
PCS	Union	26	41.4		
	Delayed Union	17	41.2	0.971	-8.24, 7.94
	Prolonged Delayed Union	51	42.1	0.821	-5.53, 6.96
MCS	Union	26	54.2		
	Delayed Union	17	51.2	0.360	-9.53, 3.50
	Prolonged Delayed Union	51	50.7	0.168	-8.56, 1.51
PCS and MCS Scores – Union vs. Non-union					
		N	**Mean**	**P-value**	**CI**
PCS	Union	94	41.7		
	Non Union	18	34.6	0.026*	-13.39, -0.88
MCS	Union	94	51.7		
	Non Union	18	47.6	0.159	-10.01, 1.65

*$p<0.05$

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