Challenges and opportunities in trauma research: study designs and patient-reported outcome measures

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CHAPTER 9

Patient-reported and clinical outcomes after proximal humeral fractures

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Abstract

Background

The aim of this study was to assess Patient-Reported Outcomes Measurement Information System (PROMIS) scores after nonoperative and operative treatment of proximal humeral fractures. Second, to assess the correlation between the PROMIS physical function (PF), PROMIS Upper Extremity (UE), and QuickDASH (the shortened version of the Disabilities of the Arm, Shoulder, and Hand). Third, the association between objective clinical outcome and Patient-reported outcome measures (PROMs) was assessed.

Methods

A retrospective cohort study was performed using data from two American College of Surgeons (ACS) level I trauma centers. All adult patients with proximal humeral fractures who were admitted between January 2016 and March 2018 with a minimum of 3 months clinical or functional follow-up were eligible for inclusion. Functional outcome was assessed using the PROMIS PF, PROMIS UE and/or the QuickDASH. Clinical outcome measures included occurrence of complications, need for subsequent surgery, and degree of flexion and abduction.

Results

In total, 249 patients were included. The mean age was 65.53 years (SD 14.98) and 183 patients (73.5%) were female. Operative treatment was performed in 92 patients (37%). There were no differences in PROMs between nonoperative and operative treated patients, PROMIS PF (adjusted mean difference -1.50; 95% CI -5.20 – 2.19; p= 0.426), PROMIS UE (adjusted mean difference -0.27; 95% CI -6.66; 6.11; p= 0.933), and QuickDASH (adjusted mean difference -2.33; 95% CI -6.72; 2.05; p= 0.299). Also, there was no difference in complication rate (9.6% versus 12%, p= 0.701) and subsequent surgery rate (6.4% versus 12%, p= 0.195). PROMIS PF was associated with PROMIS UE (correlation (r) 0.83; 95% CI 0.76; 0.88; p <0.001), and QuickDASH (r -0.47; 95% CI -0.62; -0.29; p<0.001). The PROMIS UE was also associated with the QuickDASH (r -0.70; 95% CI -0.81; -0.55; p<0.001). The degree of flexion was associated with all PROMs, PROMIS PF (r 0.43; 95% CI 0.26; 0.58; p <0.001), PROMIS UE (r 0.27; 95% CI 0.04; 0.47; p= 0.019), and QuickDASH (r -0.25.; 95% CI -0.44; -0.04; p= 0.021).

Conclusion

There were no significant differences in outcomes between operative and nonoperative treatment of proximal humeral fractures. The PROMIS PF, PROMIS UE, and QuickDASH score showed a high mutual correlation, as well as a moderate correlation with flexion degree. The correlations found in this study suggest the PROMIS PF and PROMIS UE can be considered similarly useful as a measure for evaluating shoulder function after proximal humeral fractures.

Introduction

The fracture of the proximal humerus is a frequently encountered injury, accounting for 5.7% of all fractures. Proximal humeral fractures are the seventh most common fracture type in adults and the third most common fracture type in the elderly population.[1,2] The management of acute proximal fractures consists of operative or nonoperative treatment.[3] The optimal management of these fractures remains a significant challenge and is much debated.[4] Several meta-analyses have been published on the comparison between operative or nonoperative treatment; however, no consensus has been reached regarding the optimal treatment.[5,6]

The lack of treatment consensus is partly due to the wide range of outcome measures presented in different studies.[4] There is no agreement on the optimal outcome measures for the evaluation of proximal humeral fracture treatment, which has made it difficult to compare outcomes across studies. To accurately evaluate patients after treatment, the chosen outcome measures need to have good measurement properties (validity, reliability, and responsiveness).[4] These properties may differ across setting and patient populations. It is therefore important to evaluate different available patient-reported outcome measures (PROMs) in specific patient populations.[4]

To counter these challenges, the Patient-Reported Outcomes Measurement Information System (PROMIS) questionnaires were developed. In the field of orthopedics, the most common used PROMIS is the PROMIS physical function (PF) score. There has been considerable research that has focused on the performance of the PROMIS compared to various legacy "traditional" outcome measures across various conditions. These studies showed that PROMIS correlates well with legacy outcome measures frequently used in orthopedic outcome studies.[7-13] One of those legacy outcome measures is the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire which is used to evaluate various upper extremity disorders and is, although not developed specifically for proximal humerus fractures, the most commonly used PROM for these fractures.[4] However, despite these early promising results, the widespread use of PROMIS has not been adopted in most orthopedic literature. Furthermore, there is a lack of evidence on PROMIS specifically for orthopedic trauma.[11] There is one previous study that has evaluated the correlation between the PROMIS PF and DASH scores in the proximal humeral fracture population, which has shown encouraging results regarding correlation.[13] However, the more recently developed PROMIS Upper Extremity (UE), the PROMIS PF, and the QuickDASH (shortened version of the DASH) have not been specifically assessed in the proximal humeral

fracture population. Furthermore, discordance between objective clinical outcomes and patient-reported outcome measures (PROMs) is a common phenomenon for several UE injuries.[14] Although several studies have evaluated the association of different PROMs of proximal humeral fractures, fewer studies have explored the association between clinical outcome and PROMs.

The aim of this study was to establish benchmark PROMIS data after nonoperative and operative treatment of proximal humeral fractures. Secondly, this study sought to evaluate the correlation between the PROMIS PF, PROMIS UE, and QuickDASH scores. Finally, we aimed to explore the association between objectively measured clinical outcomes and PROMs.

Methods

Study design

A retrospective cohort study was performed using data from two American College of Surgeons (ACS) level I trauma centers. All adult patients with proximal humeral fractures who were treated with between January 2016 and March 2018 were eligible for inclusion. Eligible patients were identified by searching for Current Procedure Terminology (CPT) codes and International Classification of Diseases (ICD) codes. Inclusion criteria were: (1) age 18 years or older, proximal humeral fracture, and (3) minimum of 3 months clinical or functional follow-up. Exclusion criteria were: (1) treatment for fracture at an outside facility, (2) pathologic fracture, or (3) periprosthetic fracture. Baseline demographic characteristics, clinical and functional data were identified using the institutions' detailed Enterprise Data Warehouse and electronic medical records. Informed consent was obtained from all subjects and approval was granted by the Institutional Review Board.

Patient and treatment characteristics

Electronic medical records were reviewed to collect baseline demographic characteristics regarding age, sex, trauma mechanism, open fracture, AO-classification, number of fractures, number of UE fractures, ASA classification, hospital length of stay (HLOS), operative treatment method, and nonoperative treatment method. Injury mechanisms were further subdivided into high-energy trauma (HET) and classified according to the Advanced Trauma Life Support guidelines. HET mechanisms were defined as falls from height, crush injuries, motor vehicle and motorcycle accidents.[15,16] The AO classification was confirmed by two orthopedic surgeons in the treating institutions. Nonoperative treatment methods included closed reduction and sling

treatment. Operative treatment included Open Reduction and Internal Fixation (ORIF), hemiarthroplasty, and reversed shoulder arthroplasty.

PROMs

The collection of PROMs was standardized in both trauma centers since January 2016. Physical function and upper extremity disability were evaluated using the PROMIS physical function (PF) 10a, PROMIS Upper Extremity (UE) 16a, and/or the QuickDASH. Patients completed the questionnaires on a tablet device as part of their routine follow-up visit at the trauma centers. The PROMIS questionnaire assess limitation and difficulty with certain physical activities with scores ranging from 0 to 100, with higher scores representing higher physical function, and a mean score of 50 for the general population of the United States.[7] The QuickDASH is a validated and shortened version of the Disabilities of the Arm, Shoulder and Hand questionnaire (DASH). The QuickDASH is developed to measure UE disability and symptoms, resulting in a score ranging from 0 (no disability) to 100 (most severe disability), and a mean of 10 points reflecting the general US population average.[17] The time from treatment to questionnaire in months was available for all PROMs.

Clinical outcomes

Clinical outcome measures included occurrence of complications, need for subsequent surgery, flexion and abduction degree during clinical follow-up. Complications included nonunion, malunion, arthrosis, infection, dislocation, implant failure, and avascular necrosis. Subsequent surgery was defined as the need for additional surgery other than implant removal. Flexion and abduction were measured in degrees and were assessed by the treating physician during the last outpatient follow-up visit. The time from treatment to last clinical follow-up in months was available for all patients.

Statistical analyses

Descriptive results are presented as mean values with standard deviations (SD) or absolute numbers and percentages (%). The relation between the treatment method (operative or nonoperative) and PROMs was assessed using linear regression analysis. Regression analysis was performed with and without adjustment for baseline information and presented as crude and adjusted mean difference with 95% confidence interval (CI). Adjustment was made for baseline and clinical factors that might confound the relationship between treatment method and

functional outcome including the time from treatment to questionnaire, age, AO classification, and occurrence of multiple UE fractures. Categorical outcomes were compared using the Pearson's chi-squared test. Pearson's correlation (r) was used to assess the relationship between PROMIS PF, PROMIS UE, and QuickDASH to validate our data against previous studies.[7-11] Furthermore, Pearson's correlation (r) was used to assess the relationship between the two physical exam measurements, flexion and abduction degree, and the different PROMs. The significance level was defined as a p value <0.05. All analyses were performed in R version 3.6.1 (R Development Core Team, Released 2013, Vienna, Austria: R Foundation for Statistical Computing).[18]

Results

Study population

In total, 249 patients met the inclusion criteria. The baseline characteristics stratified by treatment method are shown in Table 1. The mean age was 65.53 years (SD 14.98) and 183 patients (73.5%) were female. In most cases, patients sustained a proximal humeral fracture during a low-energy fall (83.9%). Fourteen patients (5.6%) were involved in a HET. Open fractures were sustained by 3 patients (1.2%). The most common AO classification was type B1 (35.7%). There were 6 patients (2.3%) that sustained multiple UE fractures. Nonoperative treatment was performed in 157 patients (63%), with the majority treated with a sling (86.6%). Of the 92 patients (37%) who received operative treatment, the majority was treated with ORIF (61%). The majority of operative patients had an ASA classification of 2 (63%). The mean HLOS was 1.3 days (SD 2.8).

Relation between treatment method and outcomes

There were 26 complications (10.4%). Subsequent surgery was performed in 21 patients (8.4%). The mean flexion was 125 degrees (SD 37.9) and mean abduction was 104.8 degrees (SD 42.2). The mean duration of time from treatment to last clinical follow-up was 8.2 months (SD 6.8). The mean PROMIS PF was 25.4 (SD 10.10), the mean PROMIS UE was 34.95 (SD 14.93), and the mean QuickDASH was 17.02 (SD 11.08).

Clinical and functional outcome measures stratified by treatment method are shown in Table 2. The results of the crude and adjusted regression analyses of the relation between treatment method and PROMs are shown in Table 3. There were no differences in PROMs, crude as well as adjusted, between nonoperative and operative treatment; PROMIS PF adjusted mean

Table 1. Characteristics of 249 proximal humeral fracture patients

	Overall	**Nonoperative**	**Operative**
Patients	249	157 (63.0)	92 (37.0)
Age	64.53 (14.89)	65.43 (15.05)	62.99 (14.55)
Sex (%)			
Female	183 (73.5)	120 (76.4)	63 (68.5)
Male	66 (26.5)	37 (23.6)	29 (31.5)
Trauma mechanism (%)			
Fall-low energy	209 (83.9)	132 (84.1)	77 (83.7)
Fall-high energy	7 (2.8)	5 (3.2)	2 (2.2)
Motor vehicle crash	6 (2.4)	4 (2.5)	2 (2.2)
Motorcycle crash	2 (0.8)	2 (1.3)	0 (0.0)
Bicycle accident	6 (2.4)	3 (1.9)	3 (3.3)
Sports-related	14 (5.6)	8 (5.1)	6 (6.5)
Other	5 (2.0)	3 (1.9)	2 (2.2)
HET (%)			
No	235 (94.4)	147 (93.6)	88 (95.7)
Yes	14 (5.6)	10 (6.4)	4 (4.3)
Open fracture (%)			
No	246 (98.8)	157 (100.0)	89 (96.7)
Yes	3 (1.2)	0 (0.0)	3 (3.3)
AO classification (%)			
A1	41 (16.5)	29 (18.5)	12 (13.0)
A2	24 (9.6)	23 (14.6)	1 (1.1)
A3	14 (5.6)	8 (5.1)	6 (6.5)
B1	89 (35.7)	78 (49.7)	11 (12.0)
B2	16 (6.4)	9 (5.7)	7 (7.6)
B3	19 (7.6)	2 (1.3)	17 (18.5)
C1	12 (4.8)	5 (3.2)	7 (7.6)
C2	21 (8.4)	3 (1.9)	18 (19.6)
C3	13 (5.2)	0 (0.0)	13 (14.1)
Multiple UE fractures (%)			
No	243 (97.6)	154 (98.1)	89 (96.7)
Yes	6 (2.4)	3 (1.9)	3 (3.3)
Number of UE fractures (%)			
1	243 (97.6)	154 (98.1)	89 (96.7)
2	5 (2.0)	2 (1.3)	3 (3.3)
3	1 (0.4)	1 (0.6)	0 (0.0)
ASA classification (%)*			
1			7 (9.2)
2			48 (63.2)
3			21 (27.6)
Operative method (%)			
ORIF			56 (60.9)
Hemiarthroplasty			3 (3.3)
Reversed shoulder arthroplasty			29 (31.5)
Other			4 (4.3)
Nonoperative method (%)			
Closed reduction + sling		20 (12.7)	
Sling		136 (86.6)	
Other		1 (0.6)	
HLOS (days)	1.32 (2.79)	0.56 (1.43)	2.62 (3.86)

Continuous variables presented as mean (SD); HET high-energy trauma; UE upper extremity; ORIF open reduction and internal fixation; * ASA classification, collected for surgical patients, was known for 76 of operative patients (83%); HLOS Hospital length of stay

difference -1.50; 95% CI -5.20; 2.19; p= 0.426), PROMIS UE adjusted mean difference -0.27; 95% CI -6.66; 6.11; p= 0.933), and QuickDASH adjusted mean difference -2.33; 95% CI -6.72 – 2.05; p= 0.299). Also, there were no differences in complication rate (9.6% versus 12%, p= 0.701) and subsequent surgery rate (6.4% versus 12%, p= 0.195) between treatment methods.

Table 2. Clinical and patient-reported outcomes of 249 proximal humeral fracture patients, stratified by treatment

	Overall	Nonoperative	Operative
Clinical outcomes			
Complications (%)			
No	223 (89.6)	142 (90.4)	81 (88.0)
Yes	26 (10.4)	15 (9.6)	11 (12.0)
Complication classification (%)			
Nonunion	9 (34.6)	5 (33.3)	4 (36.4)
Malunion	2 (7.7)	2 (13.3)	0 (0.0)
Arthrosis	2 (7.7)	2 (13.3)	0 (0.0)
Infection	1 (3.8)	1 (6.7)	0 (0.0)
Dislocation	4 (15.4)	2 (13.3)	2 (18.2)
Implant failure	0 (0.0)	0 (0.0)	0 (0.0)
Chronic pain	4 (15.4)	1 (6.7)	3 (11.5)
Avascular necrosis	2 (7.7)	0 (0.0)	2 (18.2)
Other	2 (7.7)	2 (13.3)	0 (0.0)
Subsequent surgery (%)			
No	228 (91.6)	147 (93.6)	81 (88.0)
Yes	21 (8.4)	10 (6.4)	11 (12.0)
Flexion (degrees) (n=168, 68%)	124.96 (37.91)	123.78 (36.21)	126.69 (40.49)
Abduction (degrees) (n=142, 57%)	104.81 (42.23)	101.88 (42.76)	109.05 (41.45)
Time treatment to clinical FU (months)	8.20 (6.82)	6.35 (5.80)	11.36 (7.29)
PROMs			
PROMIS PF (n=164, 66%)	25.37 (10.10)	24.37 (10.78)	27.52 (8.13)
PROMIS UE (n=126, 51%)	34.95 (14.93)	34.16 (15.89)	36.43 (12.98)
QuickDASH (n=120, 48%)	17.02 (11.08)	16.67 (11.22)	17.50 (10.98)
Time treatment to PROMIS PF (months)	7.34 (5.43)	6.33 (4.60)	9.51 (6.42)
Time treatment to PROMIS UE (months)	7.42 (5.13)	6.43 (4.22)	9.27 (6.14)
Time treatment to QuickDASH (months)	6.38 (5.55)	5.49 (4.68)	7.64 (6.41)

Continuous variables presented as mean (SD); FU follow-up; PROMs Patient-Reported Outcome Measures; PROMIS Patient-Reported Outcomes Measurement Information System; PF physical function; UE upper extremity; DASH Disabilities of the Arm, Shoulder, and Hand

Table 3. Differences in patient-reported outcomes, operative and nonoperative treatment of proximal humeral fracture

	Non		Op		Crude				Adjusted			
	Mean	SD	Mean	SD	MD	95%CI		p-value	MD	95%CI		p-value
PROMIS PF	24.37	10.78	27.52	8.13	-3.15	-6.45	0.14	0.063	-1.50	-5.20	2.19	0.426
PROMIS UE	34.16	15.89	36.43	12.98	-2.27	-7.75	3.20	0.417	-0.27	-6.66	6.11	0.933
QuickDASH	16.67	11.22	17.50	10.98	-0.83	-4.86	3.21	0.688	-2.33	-6.72	2.05	0.299

Non Nonoperative; Op Operative; MD Mean difference; PROMs Patient-Reported Outcome Measures; CI Confidence Interval; PROMIS Patient-Reported Outcomes Measurement Information System; PF physical function; UE upper extremity; DASH Disabilities of the Arm, Shoulder, and Hand. Adjustment was made for baseline and clinical factors that might confound the relationship between treatment method and functional outcome including the time from treatment to questionnaire, age, AO classification, and occurrence of multiple UE fractures.

Associations between outcome measures

PROMIS PF was associated with PROMIS UE (r 0.83; 95% CI 0.76; 0.88; p<0.001), and QuickDASH (r -0.47; 95%CI -0.62; -0.29; p<0.001). The PROMIS UE was also associated with the QuickDASH (r -0.70; 95%CI -0.81; -0.55; p<0.001).

PROMIS PF was associated with flexion degree (r 0.43; 95% CI 0.26; 0.58; p<0.001), however, there was no association with abduction degree (r 0.12; 95%CI -0.09; 0.31; p= 0.269). PROMIS UE was associated with flexion degree (r 0.27; 95% CI 0.04; 0.47; p= 0.019), yet there was no association with abduction degree (r -0.14.; 95%CI -0.37; 0.11; p= 0.281). QuickDASH was

negatively associated with flexion degree (r -0.25.; 95% CI -0.44; -0.04; p= 0.021), however, there was no association with abduction degree (r -0.02; 95%CI -0.26; 0.23; p= 0.876).

Discussion

In this observational study of operative versus nonoperative treatment of proximal humeral fractures, no differences in PROMs nor in clinical outcomes were observed. In patients with a proximal humeral fracture, the PROMIS PF, PROMIS UE, and QuickDASH scores showed a high mutual correlation, as well as a moderate correlation with flexion degree.

Several meta-analyses have been inconclusive as to whether operative treatment of proximal humeral fractures is superior to nonoperative treatment, reporting no clinically relevant differences in outcomes between treatment groups.[5,6] The patient characteristics (i.e. age, sex, injury mechanism, fracture classification) of the studies reported in these meta-analyses are comparable to those of the patients included in the current study. However, due to difference in outcome measures and in duration of follow-up, a direct comparison of results is not possible. In accordance with the previous literature this study found no difference in functional outcomes and complication rates between operative and nonoperative treatment. [5,6] Regardless of treatment method, disappointing functional outcomes including residual shoulder pain, limitations in shoulder motion, and decreased quality of life after proximal humeral fractures have been reported.[19,20] Furthermore, the results in this study emphasize the overall poor outcome following proximal humeral treatment. However, this might be due to the relative short follow-up period in this study. There is still debate on whether further improvement of functional outcome after 12 months is expected after humeral fracture treatment.[21] The incidence of proximal humeral fracture rates will continue to increase with the aging population, causing prolonged and severe disability. In the elderly, the effect of UE fractures on functional outcome might continue for many years, and long-term evaluation is needed to accurately assess the efficacy of treatment and rehabilitation.[20]

Previous studies have shown encouraging results regarding correlation of PROMIS questionnaires with legacy outcome scores, responsiveness to treatment, and validity in orthopedics. Gausden et al.[11], evaluated the correlation of PROMIS in upper extremity fracture patients, and found a high correlation between the DASH and PROMIS PF (r -0.76) and PROMIS UE (r -0.79). Morgan et al.[13] evaluated the correlation between the PROMIS PF and

DASH (r -0.66), specifically in proximal humeral fracture patients older than 60 years. In the current study PROMIS PF (r -0.47) and PROMIS UE (r -0.70) also showed a moderate to high correlation with the QuickDASH in the evaluation of proximal humeral fracture patients. To our knowledge the QuickDASH, the validated and shortened version of the DASH, has not been previously compared to the newer PROMIS PF and PROMIS UE. The PROMIS were developed with the goal to provide standardized, valid, and flexible PROMs collection tools, which make them more useful in research and clinical practice, with features that lower response burden and make it possible to seamlessly incorporation them into patients' medical record.[7-13] However, despite early promising results, the widespread use of PROMIS has not been adopted in most orthopedic literature. Furthermore, there is a lack of evidence on PROMIS specifically for orthopedic trauma.[11] The correlations found in this study suggest the PROMIS PF and PROMIS UE can be considered similarly useful as a measure for evaluating shoulder function after proximal humeral fractures.

Clinical physical shoulder examination such as flexion and abduction are commonly used to assess patients with proximal humerus fractures. Because these fractures occur in a heterogenous group, with a wide variety of injury mechanisms, functional demands, and comorbidities, the potential for discordance between clinical outcomes and PROMs exists.[14] For patients with proximal humerus fractures, the relationship between shoulder impairment and PROMs has not been well-described. One previous study by Slobogean et al.[14], quantified the relationship between patient-reported shoulder outcome and objective shoulder impairment using regression models. They found different associations between objective shoulder impairment and the DASH score, with regression analysis suggesting that shoulder impairment (abduction, external rotation, strength) explained 50% of the DASH.[14] Furthermore, Slobogean et al.[14], reported flexion had the best discriminatory ability for identifying normal shoulder function. In the current study we evaluated this relationship and found a moderate association between all PROMs and flexion degree, however not with abduction degree. These results suggest that emphasizing efforts to improve the degree of flexion might be associated with higher PROMs. These results support a comprehensive approach to surgical quality that incorporates both clinical events and PROMs. The current study was limited due to the inclusion of less range of motion and strength measurements compared to the study by Slobogean et al.[14]. However, the study by Slobogean et al.[14], was limited by the small sample size of their cohort, which included 31 patients. For patients with proximal humerus fractures, the relationship between shoulder impairment and PROMIS

scores and the QuickDASH has not yet been well-described. A discordance between shoulder impairment and PROMs has been demonstrated and further work to identify patient, injury, or treatment factors to minimize this discrepancy is still needed. Although these measures of motion provide some degree of information on impairment, they do not provide insight into the perceived functional outcome. Hence, PROMs are used complementary to clinical examination.[14] The combined use of clinical measures of motion and PROMs allow physicians to evaluate the differences between clinical impairment and patient perceived functional outcome.

Potential limitations in this study need to be acknowledged. First, the study is limited by the retrospective nature. However, to our knowledge, with the inclusion of 249 patients, this study is one of largest cohort to establish data on characteristics and outcome after operative and nonoperative treatment, with functional outcome and range of motion (flexion/abduction) known for up till 68% of patients. Second, the different outcome measures had various endpoints. However, inclusion was limited to at least 3 months of clinical or functional follow-up. Furthermore, the time from treatment to clinical follow-up and time from treatment to questionnaire were known and analysis adjusted accordingly. Third, due to the nature of the injury in a trauma setting, it is not possible to compare and adjust PROMs with baseline scores. However, due to the extensive database adjustment was able for several baseline and clinical factors that might confound associations. Finally, results were limited regarding range of motion and strength measurements. We acknowledge that better evidence is lacking and further evaluation using PROMs and different clinical outcomes in proximal humeral fracture patients is needed. However, given the paucity of data regarding PROMIS and QuickDASH scores after proximal humerus fracture treatment, we hope these results will mainly provide benchmark data that can be used for future comparisons.

Conclusion

There was no significant difference in outcomes between operative and nonoperative treatment of proximal humeral fractures. The PROMIS PF, PROMIS UE, and QuickDASH score showed a high mutual correlation, as well as a moderate correlation with flexion degree. To our knowledge the QuickDASH has not been previously compared to the newer PROMIS PF and PROMIS UE in proximal humeral fractures. The correlations found in this study suggest the PROMIS PF and PROMIS UE can be considered similarly useful as a measure for evaluating shoulder function after proximal humeral fractures.

References:

1. Court-Brown CM, Caesar B. Epidemiology of adult fractures: A review. *Injury.* 2006;37:691-697.
2. Palvanen M, Kannus P, Niemi S, Parkkari J. Update in the epidemiology of proximal humeral fractures. *Clin Orthop Relat Res.* 2006;442:87-92.
3. Handoll HH, Brorson S. Interventions for treating proximal humeral fractures in adults. *Cochrane Database Syst Rev.* 2015(11):Cd000434.
4. Nowak LL, Davis AM, Mamdani M, Beaton D, Kennedy C, Schemitsch EH. A Systematic Review and Standardized Comparison of Available Evidence for Outcome Measures Used to Evaluate Proximal Humerus Fracture Patients. *J Orthop Trauma.* 2019;33(7):e256-e262.
5. Xie L, Ding F, Zhao Z, Chen Y, Xing D. Operative versus non-operative treatment in complex proximal humeral fractures: a meta-analysis of randomized controlled trials. *SpringerPlus.* 2015;4(1):728.
6. Beks RB, Ochen Y, Frima H, et al. Operative versus nonoperative treatment of proximal humeral fractures: a systematic review, meta-analysis, and comparison of observational studies and randomized controlled trials. *J Shoulder Elbow Surg.* 2018;27(8):1526-1534.
7. Brodke DJ, Saltzman CL, Brodke DS. PROMIS for Orthopaedic Outcomes Measurement. *J Am Acad Orthop Surg.* 2016;24(11):744-749.
8. Cheung EC, Moore LK, Flores SE, Lansdown DA, Feeley BT, Zhang AL. Correlation of PROMIS with Orthopaedic Patient-Reported Outcome Measures. *JBJS reviews.* 2019;7(8):e9.
9. Gagnier JJ. Patient reported outcomes in orthopaedics. *Journal of orthopaedic research : official publication of the Orthopaedic Research Society.* 2017;35(10):2098-2108.
10. Kaat AJ, Rothrock NE, Vrahas MS, et al. Longitudinal Validation of the PROMIS Physical Function Item Bank in Upper Extremity Trauma. *J Orthop Trauma.* 2017;31(10):e321-e326.
11. Gausden EB, Levack AE, Sin DN, et al. Validating the Patient Reported Outcomes Measurement Information System (PROMIS) computerized adaptive tests for upper extremity fracture care. *J Shoulder Elbow Surg.* 2018;27(7):1191-1197.
12. Hung M, Saltzman CL, Greene T, et al. The responsiveness of the PROMIS instruments and the qDASH in an upper extremity population. *Journal of patient-reported outcomes.* 2017;1(1):12.
13. Morgan JH, Kallen MA, Okike K, Lee OC, Vrahas MS. PROMIS Physical Function Computer Adaptive Test Compared With Other Upper Extremity Outcome Measures in the Evaluation of Proximal Humerus Fractures in Patients Older Than 60 Years. *J Orthop Trauma.* 2015;29(6):257-263.
14. Slobogean GP, Noonan VK, Famuyide A, O'Brien PJ. Does objective shoulder impairment explain patient-reported functional outcome? A study of proximal humerus fractures. *J Shoulder Elbow Surg.* 2011;20(2):267-272.
15. Advanced trauma life support (ATLS®): the ninth edition. *The journal of trauma and acute care surgery.* 2013;74(5):1363-1366.
16. Linder F, Mani K, Juhlin C, Eklöf H. Routine whole body CT of high energy trauma patients leads to excessive radiation exposure. *Scandinavian journal of trauma, resuscitation and emergency medicine.* 2016;24:7.
17. Hunsaker FG, Cioffi DA, Amadio PC, Wright JG, Caughlin B. The American academy of orthopaedic surgeons outcomes instruments: normative values from the general population. *J Bone Joint Surg Am.* 2002;84(2):208-215.
18. Team R. R Development Core Team. *R: A Language and Environment for Statistical Computing.* 2013.
19. Slobogean GP, Johal H, Lefaivre KA, et al. A scoping review of the proximal humerus fracture literature. *BMC Musculoskelet Disord.* 2015;16:112.
20. Hodgson S. Proximal humerus fracture rehabilitation. *Clin Orthop Relat Res.* 2006;442:131-138.
21. Frima H, Michelitsch C, Beks RB, Houwert RM, Acklin YP, Sommer C. Long-term follow-up after MIPO Philos plating for proximal humerus fractures. *Archives of orthopaedic and trauma surgery.* 2019;139(2):203-209.