JSES International 6 (2022) 942–947

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

Rotator cuff repair in upper extremity ambulators: an assessment of longitudinal outcomes

Andrew M. Valiquette, MD, MBA*, Alexander R. Graf, MD, Dara J. Mickschl, PA-C, Andrew J. Zganjar, MD, Steven I. Grindel, MD

Department of Orthopaedic Surgery, Medical College of Wisconsin, Milwaukee, WI, USA

ARTICLE INFO

Keywords:
Weight-bearing shoulder
Upper extremity ambulator
Arthroscopic rotator cuff repair
Assistive device
Rotator cuff tear
Wheelchair
Supraspinatus
Acromioclavicular joint

Level of evidence: Level IV; Case Series; Treatment Study

Background: Individuals who rely on wheelchairs, walkers, and crutches for ambulation have an increased incidence of rotator cuff tears due to altered shoulder biomechanics and increased force transmission across the shoulder joint. The purpose of our study is to review our longitudinal outcomes treating upper extremity ambulators to guide patient expectations and identify risk factors for rotator cuff repair failure.

Methods: A total of fifteen patients were included after a cohort of thirty-nine patients were identified. The mean age was 54.9 years at the time of index rotator cuff repair, with each patient requiring either wheelchair, cane, walker, or crutches for ambulation. Clinical outcomes were measured (strength, range of motion, and pain scores), and patient-reported outcome scores (American Shoulder and Elbow Surgeons, Simple Shoulder Test, and University of California Los Angeles functional shoulder assessment tool) were obtained. No follow-up imaging was obtained unless indicated by a change in clinical status.

Results: Within our cohort, 14 of 15 (93%) presented with supraspinatus tears, 7 of 15 (47%) with infraspinatus tears, and only 3 of 15 (20%) with subscapularis pathology. Additionally, the rates of concurrent biceps pathology or acromioclavicular joint pathology were significant at 53% and 73%, respectively. Only one patient in our cohort experienced known failure of cuff repair, despite longitudinal follow-up at an average of 97 months following surgery, however, routine follow-up imaging was not obtained. There were statistically significant improvements in visual analog scale pain scores, forward flexion ROM and strength, and abduction ROM. Additionally, statistically significant improvements were noted in all patient-reported outcome scores measured.

Conclusion: Despite the apparent risks associated in rotator cuff repair in upper extremity ambulators, these patients demonstrate clinically significant improvements following surgery. Appreciating additional pathology beyond the rotator cuff is important in formulating a treatment plan.

Individuals who rely on wheelchairs, walkers, and crutches for ambulation have an increased incidence of rotator cuff tears due to altered shoulder biomechanics and increased force transmission across the shoulder joint.[3] Previous studies have shown a four-fold increase in the incidence of rotator cuff tears in wheelchair-bound patients compared to age and comorbidity-matched peers (63% vs 15 %).[1] Several authors have described the outcomes of rotator cuff repair in this population, although the data are quite limited, especially in long-term results. Kerr et al described a 33% retear rate, but satisfactory results with a mean follow-up of 46 months.[13] Jung et al found a retear rate of 12% with improvement in ASES and Constant scores at a mean of 31 months.[12] In addition, this relatively high incidence of rotator cuff pathology, coupled with a greater reliance on upper extremity function to perform activities of daily living, has been shown to delay presentation for treatment and have a profound negative impact on psychological well-being.[8,18,23,24]

While previously studies having described the incidence of rotator cuff pathology and outcomes following rotator cuff repair in upper extremity ambulators (UEA) patients, to date no other studies have reported other associated shoulder pathology in this cohort and the impact of associated comorbidities. Therefore, the purpose of our study is to review our longitudinal outcomes treating UEA patients to guide patient expectations and identify risk factors for treatment failure. We hypothesize that in addition to rotator cuff tears there will be a high incidence of concomitant shoulder joint pathology and that outcomes will deteriorate over time given the high demand placed on the shoulder unique to this patient population.

The Medical College of Wisconsin/Froedtert Health Institutional Review Board #5 granted approval for the study #PRO00014024, Rotator Cuff Repair in Upper Extremity Ambulators, effective 2/11/2011.

*Corresponding author: Andrew M. Valiquette, MD, MBA, Medical College of Wisconsin Department of Orthopaedic Surgery, 9200 W. Wisconsin Ave. P.O. Box 26099, Milwaukee, WI 53226-0099, USA.

E-mail address: avaliquette@mcw.edu (A.M. Valiquette).

https://doi.org/10.1016/j.jseint.2022.08.015
2666-6383/

Table I
Patient inclusion and exclusion criteria.

Inclusion criteria
- Underwent shoulder surgery—surgical codes for rotator cuff repair (29827), sub-acromial decompression (29826) or acromioclavicular joint resection (29824).
- Reliance on assisted walking devices (wheelchair, walker, cane, or crutches) for >6 months.
- Aged >18 years.

Exclusion criteria
- Previous surgery to the affected shoulder.
- Neurologic impairment of affected shoulder (known cervical disc herniation, cervical or thoracic syringomyelia or tetraplegia).
- Active shoulder infection at time of surgery.

Table II
Patient demographics.

Sex	
Male	8 (53%)
Female	7 (47%)
Age (y)	
Mean and SD	54.9 ± 9.12
Median	54
Range	44-75
Dominant hand injured?	
Yes	11 (80%)
No	4 (20%)
Smoking status	
Smoker	7 (47%)
Nonsmoker	8 (53%)
Diabetes status	
Diabetic	4 (27%)
Nondiabetic	11 (73%)
Reason for assistive device use	
SCI	4 (27%)
CVA	5 (33%)
Knee OA	2 (13%)
Other	4 (27%)

SCI, spinal cord injury; *CVA*, cerebrovascular accident/stroke; *OA*, osteoarthritis; *SD*, standard deviation.

Materials and methods

An institutional review board-approved retrospective chart review was performed on all patients who underwent rotator cuff repair by the senior author (S.G.) at our institution from 2002 to 2013. Adult patients that were reliant on wheelchairs, walkers, or crutches for ambulation for a minimum of 6 months prior to surgery were considered UEA and included in the study. Patients with neurologic shoulder impairment and previous shoulder surgery were excluded (Table I). Demographic data, medical, and surgical history and operative reports were reviewed (Table II). In addition, preoperative radiographs and magnetic resonance imaging (MRI) were also reviewed to determine rotator cuff tear size, thickness, chronicity, location, and presence of fatty infiltration using the Goutallier grading system. MRI and clinical examination were used to identify concomitant shoulder pathology, including symptomatic acromioclavicular (AC) joint, labral, glenohumeral, and biceps pathology.

All patients underwent surgical treatment after failure of conservative treatment consisting of rest, physical therapy, and/or corticosteroid injection. For rotator cuff repair, all surgeries were performed arthroscopically by the senior author utilizing single or multiple Bio-corkscrew anchor(s) (Arthrex, Naples, FL, USA) with #2 FiberWire suture in a single row with horizontal mattress technique. The appearance of the cuff tears in each patient varied, and the technique of repair was at the discretion of the treating surgeon. If the patient was found to have tenderness over the AC joint, pain elicited with cross arm adduction on exam or imaging consistent with AC joint arthrosis, an arthroscopic distal clavicle excision was performed. If the patient was found to have intra-articular degeneration of the long head biceps tendon intraoperatively, an arthroscopic biceps tenotomy was performed at the discretion of the surgeon. Degenerative labral débridement was performed at the discretion of the surgeon based on intraoperative findings, as well.

Postoperatively, patients were seen at regular intervals of 2, 6, and 12 weeks. Additional follow-up appointments were also scheduled for 6 months and 1 year postoperatively as needed. All patients completed a standardized therapy protocol (Table III). Three shoulder assessment scores were used to determine functionality at the initial preoperative visit and end-of-care visit: University of California Los Angeles (UCLA) functional shoulder assessment tool, American Shoulder and Elbow Surgeons Evaluation Form (ASES), and Simple Shoulder Test (SST). The questionnaires involved with the ASES and SST scores were available at the initial visit, end-of-care visit, and an additional long-term follow-up conducted over the phone, while the other measurements were taken at each follow-up visit whenever possible. Range of motion and strength was determined by the surgeon using a goniometer and Medical Research Council (MRC) 5-point scale, respectively. End of care was defined as clinic visit where therapist, surgeon, and patient agreed maximal functional outcome had been attained. Failure of repair was defined clinically by worsening pain, acute onset of weakness, or loss of function. Imaging studies were not routinely obtained at the final follow-up. Statistical analysis was performed using linear regression (analysis of covariance) which modeled the outcomes of change in UCLA score, pain, forward flexion, and flexion strength (final − initial). The alpha value was set at 0.05. Two predictors were used in the analysis of covariance models: initial value of an outcome and a group indicator (for example, presence of diabetes mellitus). Linear mixed models (LMMs), accounting for repeated observations within a subject, were used for modeling change in SST and ASES over time. LMM explored the effect of a variable of interest (such as diabetes mellitus) at both follow-ups controlling for baseline effect at each follow-up visit. Boxplots are presented for SST and ASES over time (Figs. 1-9). Separate models investigated the effects of diabetes mellitus, smoking, acute versus chronic tear, and Goutallier classification separately (Figs. 1-9). Summary statistics are provided for each outcome by covariates. Analysis was done using SAS V9.4 (SAS Institute, Cary, NC, USA).

Results

A total of 15 patients met the inclusion criteria. Patients' ages ranged from 44 to 75, with a mean age of 54.9 years. All 15 patients required the use of an assistive device for ambulation both preoperatively and postoperatively, with 4 of the patients requiring use of a wheelchair, 5 requiring a walker, 4 requiring a cane, and 2 requiring crutches. Reasons for requiring assistive device for ambulation varied, but included prior stroke, spinal cord injury, lower extremity osteoarthritis, and chronic low back pain. Final clinic follow-up ranged from 5-40 months, and final phone follow-up ranged from 57-149 months.

Eleven of the 15 patients experienced a rotator cuff injury of their dominant extremity (Table II). The average Goutallier grade for our patient cohort was 2.64, which is higher than many other published studies. The value for Goutallier grade was calculated by taking an average of the torn tendons for each patient. The rate of biceps tendinopathy was 53%, with those same 8 patients receiving a biceps tenotomy. One superior labrum from anterior to posterior tear was noted, a biceps

Table III
Rotator cuff repair therapy protocol.

Follow-up week	Protection	Exercises
Week 1	Wear sling at all times, off for exercises and bathing	• Passive ROM only for shoulder (flexion, abduction, ER/IR) as pain tolerates 3x daily. • Flexion = 90°, ER = 40°, IR = 40° • Slow progress to full passive ROM by 3 weeks • Active ROM to scapula, elbow, wrist, and hand • Scapular stabilization using manual resistance and proper mechanics • Pendulum - 5x daily
Week 6	Discontinue sling	• Passive ROM as tolerated • Active/Assisted shoulder ROM (wall walk, cane) • Emphasize scapular stabilization/proper mechanics
Week 8	None	• Passive, full ROM • Active shoulder ROM • Submaximal isometrics to shoulder
Week 10	None	• Active/Passive ROM • Strengthening -slow steady progression • Ensure scapular stabilization/proper mechanics when strengthening

ROM, range of motion; *ER*, external rotation; *IR*, internal rotation.

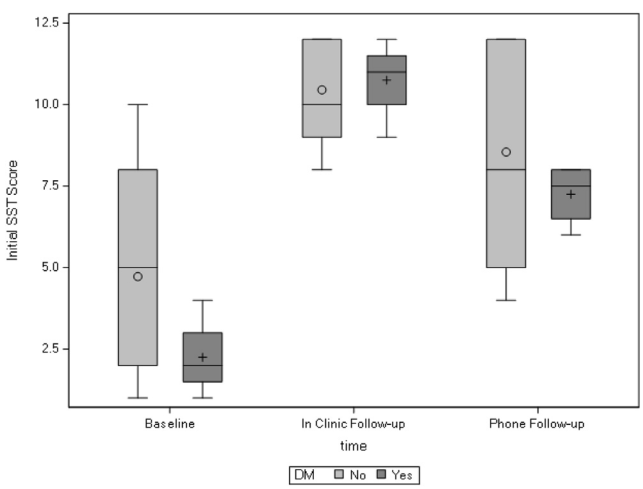

Figure 1 Linear mixed model representing SST scores at baseline, at final clinic follow-up, and in phone follow-up with relation to the presence or absence of diabetes mellitus. The presence of diabetes as a comorbidity does not appear to have influenced SST scores during the course of follow-up. *SST*, Simple Shoulder Test.

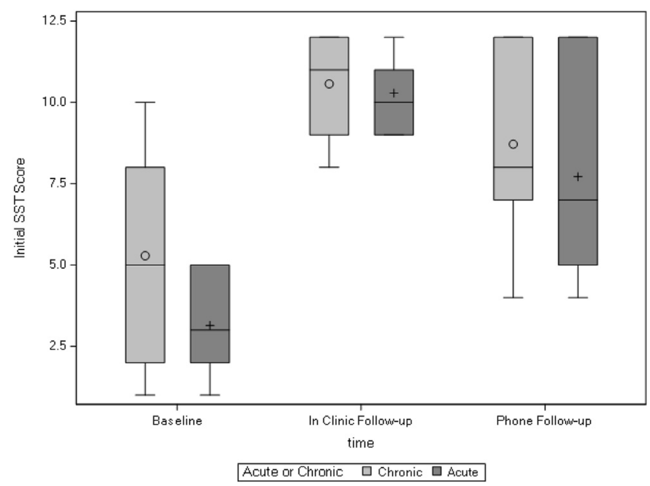

Figure 3 Linear mixed model representing SST scores at baseline, at final clinic follow-up, and in phone follow-up with relation to the chronicity of rotator cuff tear. The chronicity of the tear does not appear to have influenced SST scores during the course of follow-up. *SST*, Simple Shoulder Test.

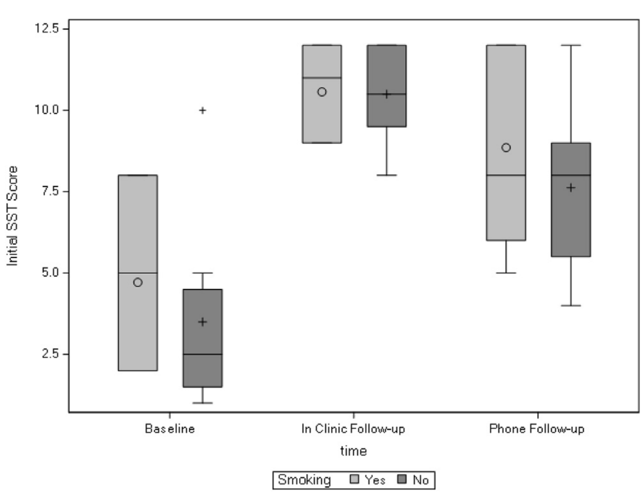

Figure 2 Linear mixed model representing SST scores at baseline, at final clinic follow-up, and in phone follow-up with relation to the presence or absence of smoking. The presence of smoking as a comorbidity does not appear to have influenced SST scores during the course of follow-up. *SST*, Simple Shoulder Test.

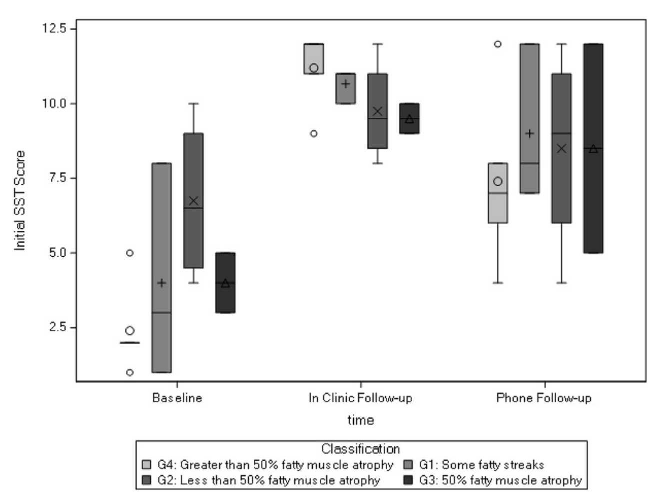

Figure 4 Linear mixed model representing SST scores at baseline, at final clinic follow-up, and in phone follow-up with relation to Goutallier classification as determined by preoperative MRI. The Goutallier classification of the rotator cuff pathology does not appear to have influenced SST scores during the course of follow-up. *MRI*, magnetic resonance imaging; *SST*, Simple Shoulder Test.

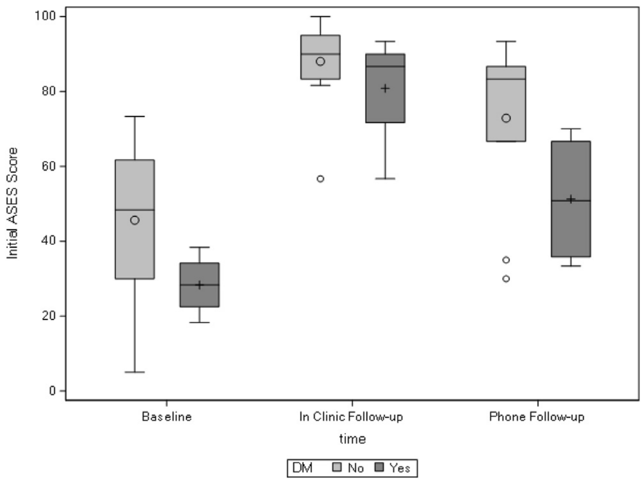

Figure 5 Linear mixed model representing ASES scores at baseline, at final clinic follow-up, and in phone follow-up with relation to the presence or absence of diabetes mellitus. The presence of diabetes as a comorbidity does not appear to have influenced ASES scores during the course of follow-up. *ASES*, American Shoulder and Elbow Surgeons.

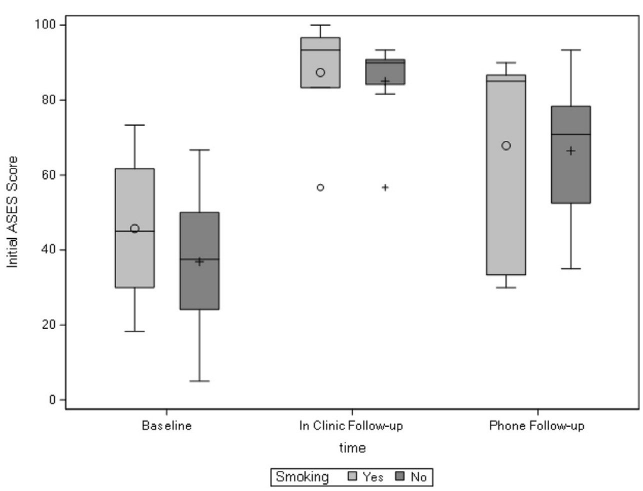

Figure 6 Linear mixed model representing ASES scores at baseline, at final clinic follow-up, and in phone follow-up with relation to the presence or absence of smoking. The presence of smoking as a comorbidity does not appear to have influenced ASES scores during the course of follow-up. *ASES*, American Shoulder and Elbow Surgeons.

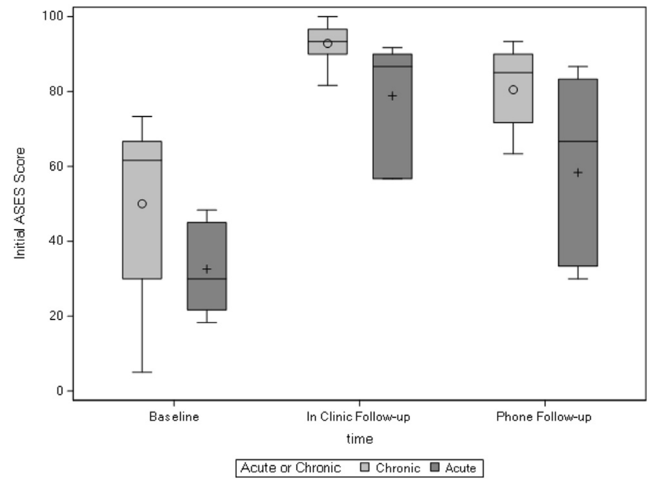

Figure 7 Linear mixed model representing ASES scores at baseline, at final clinic follow-up, and in phone follow-up with relation to the chronicity of rotator cuff tear. The chronicity of the tear does not appear to have influenced ASES scores during the course of follow-up. *ASES*, American Shoulder and Elbow Surgeons.

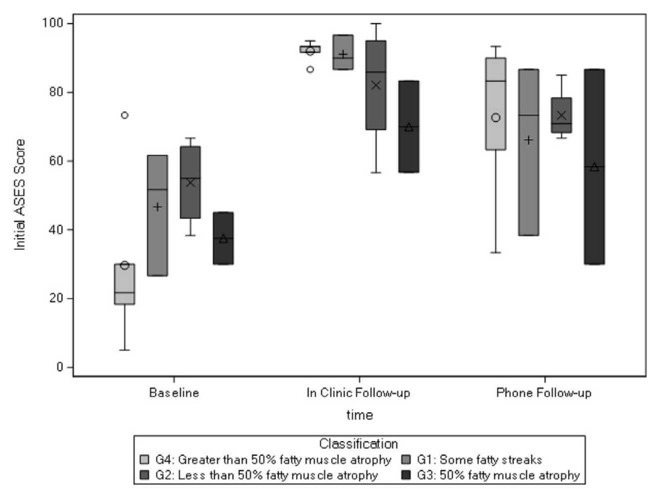

Figure 8 Linear mixed model representing ASES scores at baseline, at final clinic follow-up, and in phone follow-up with relation to Goutallier classification as determined by preoperative MRI. The Goutallier classification of the rotator cuff pathology does not appear to have influenced SST scores during the course of follow-up. *MRI*, magnetic resonance imaging; *ASES*, American Shoulder and Elbow Surgeons; *SST*, Simple Shoulder Test.

tenotomy was performed in this patient and the superior labrum was débrided. Seventy-three percent of patients exhibited symptomatic AC joint degeneration, and 100% of our cohort received a subacromial decompression, and 73% of the patients underwent distal clavicle excision. Sixty-seven percent of patients required glenohumeral/labral degeneration débridement.

Overall, all patients showed a significant improvement in pain and clinical outcome scores (Table IV). Improvement in pain from preoperative to end-of-care appointment (average 12 months postoperative; range 5-40 months) was 5 visual analog scale points ($P \leq .001$). Average improvement in forward flexion was 35 degrees ($P \leq .001$) and abduction was 30 degrees ($P = .002$). Average improvement in forward flexion strength was 0.8 MRC grades ($P = .01$). Average functional improvements were also significant as measured by UCLA (14.8 points, $P < .001$), SST (6.47 points, $P < .001$), and ASES scores (45.11 points, $P < .001$). Long-term functional scores obtained from phone interviews conducted at an average of 97 months postoperatively (range, 57-149 months) showed decreased SST (2.3 points, $P = .01$) and ASES (19 points, $P = .01$) from initial postoperative measurements but maintained improvement relative to preoperative values ($P < .001$).

Assessment of medical comorbidities and rotator cuff characteristics on rotator cuff repair outcome at the end of healing was equivocal. In patients with diabetes, there was no statistically significant difference in final pain, range of motion or UCLA, SST, or ASES scores compared to patients without diabetes. Similarly, in patients with a chronic as opposed to an acute tear there were no statistically significant differences. However, in patients with smoking history, the difference in gain of flexion strength was statistically significant (0.56 ± 0.20 $P = .0186$). One patient did demonstrate new onset weakness and pain at follow-up, an MRI was performed, and a retear was identified. The patient underwent conservative treatment with physical therapy and was able to continue use of a wheelchair for ambulation. We are unable to

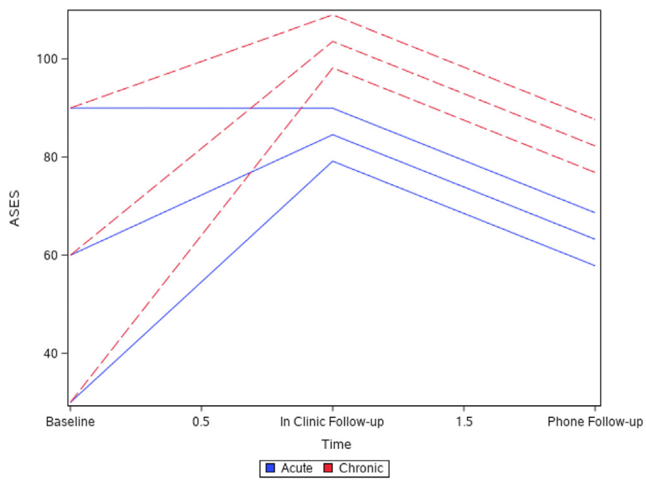

Figure 9 ASES scores in relation to acute or chronic tears demonstrate that for both acute and chronic tears, there is an improvement from baseline in final clinic follow-up, but this effect does appear to diminish by the final phone follow-up. *ASES*, American Shoulder and Elbow Surgeons.

determine if other asymptomatic retears occurred as final follow-up imaging was not routinely obtained.

Discussion

Our study found satisfactory patient-reported outcomes at final clinic follow-up (5-40 months), and long-term phone follow-up (57-149 months). Based on clinical examination, only one presumed retear is reported in our cohort of 15 patients. Overall, there was attrition in outcomes over time, with decreased ASES and SST scores at phone follow-up compared to final clinic follow-up. However, these scores were still improved as compared to the preoperative baseline.

Historically, rotator cuff repair in UEA patients was controversial due to the high risk of retear and complex tear patterns. However, more recent studies have demonstrated short-term success for rotator cuff repair in UEA patients.[6,9,11-13,17,19] Nevertheless, studies assessing long-term outcomes of rotator cuff repair in UEA have remained elusive in part due to the relatively small patient population and lack of standardized long-term functional assessments.

In the present study, despite the increased functional demands of the shoulder postoperatively in UEA patients, we found a significant improvement in pain, range of motion, and strength at final clinic follow-up, and patient-reported outcomes demonstrate long-term function improvements. However, over time we did see a decrease relative to initial end of healing outcome measurements. This attrition over time could be secondary to known age-related changes in cuff quality as well as increased wear due to the unique biomechanical stresses on the shoulder when the upper extremity is used for ambulation.[14] Specifically, biomechanical data demonstrate that during the push phase of wheelchair propulsion, the infraspinatus, anterior deltoid, and pectoralis major provide power and are most prone to fatigue.[20] It should be noted, however, the significant heterogeneity in our study and that only 4 of 15 participants utilized wheelchair as the primary modality of ambulation. Routine surveillance MRI could possibly detect these changes over time and could be considered an area for further research moving forward.[10]

The majority of our patients had supraspinatus tears (93%), which is consistent with previous studies, including a 2013 systematic review performed by Mall et al examining tear characteristics in all populations found that 84% of patients with a rotator cuff tear had a supraspinatus tear, 39% had an infraspinatus tear, and 78% demonstrated tears of the subscapularis.[15] Our incidence was slightly higher for supraspinatus involvement; however, the rate of subscapularis tears was far greater in the general RCT population, only 3 of 15 patients in our group of UEAs. Akbar et al compared 100 paraplegic, wheelchair-bound patients with 100 age matched controls and performed MRI of the shoulder. In comparing the wheelchair-dependent group to the control group, the rate of supraspinatus tears was 61% vs. 14%, subscapularis tears 12% vs. 2%, and infraspinatus tears 19% vs. 3%, respectively.[1] Based on these findings, and biomechanical studies of UEAs that demonstrate increased stress on the anterosuperior rotator cuff, our rates of specific tendons torn redemonstrate the findings from these prior studies, despite limited sample size.[16]

In addition to rotator cuff tears, our study also revealed a high incidence of concomitant shoulder pathology in the UEA population. The majority of our patients (73%) also had symptomatic AC arthritis, highlighting the importance of comprehensive approach to shoulder treatment. Much like rotator cuff tears in the general population, concomitant shoulder pathology is quite common among UEAs. Specifically, biceps tendinopathy (including appears quite common, with incidence between 40% and 83%).[10,13] Additionally, AC joint arthritis, CA ligament thickening, and bursitis appear quite frequently.[10]

Although multiple studies exist following longitudinal outcomes of rotator cuff repair in UEAs, few have documented this extended amount of follow-up or used standard reproducible outcome measures. Kerr et al had an average final follow-up of 46 months (24-82 months) but determined outcome based on clinical in-office examination and ultrasound evaluation.[13] Jung et al had an average final follow-up of 32.1 months, but in their final visit they assessed rotator cuff repair integrity via MRI.[12] Fattal et al had an average follow-up of 18 months.[6] Our study included phone follow-up at an average of 97 months demonstrates that not only do these patients improve in the 1-2-year postoperative timeframe but they also experience improvement compared to preoperative functional status, although this effect does appear to diminish over time. We only report one known retear in our cohort of 15 patients, although without MRI or ultrasound evaluation of each patient, we cannot confirm that this was the single retear in our cohort.

Table IV
Outcomes after rotator cuff repair at final in-office follow up visit.

Measurement	Baseline	Final follow-up	Average change from preoperative baseline	Level of significance
VAS pain score	5.9	0.9	−5.0	$P \leq .001$
Forward flexion	112	147	+35	$P = .003$
Forward flexion strength*	3.6	4.4	+0.8	$P = .01$
Abduction	108	138	+30	$P = .002$
UCLA score	14.4	29.2	+14.8	$P \leq .001$
SST score	4.06	10.53	+6.47	$P \leq .001$
ASES score	41.0	86.11	+45.11	$P \leq .001$

VAS, visual analog scale; *UCLA*, University of California Los Angeles; *SST*, simple shoulder test; *ASES*, American Shoulder and Elbow Surgeons; *MRC*, Medical Research Council.
*Measured in MRC (0-5 scale, with 0 = paralysis, and 5 = normal strength).

With the exception of Goldstein et al, other studies regarding rotator cuff repair in this population have not accounted for the impact of comorbidities on outcomes.[7] It is well-documented that both diabetes and smoking increase the risk of rotator cuff tear and prevent tendon-bone healing following repair.[4,5,21,22] Smoking also exhibits a dose and time-dependent relationship with cuff tears.[2] Although 47% of our study population smoked and 27% had diabetes, we were unable to identify a statistically significant difference in SST or ASES scores in the diabetic or smoking patients within our population. On further analysis, UEA patients who smoked were found to have a statistically significant difference in gain of flexion strength, compared with those that were nonsmokers. This could be explained by previously exhibited poor tendon healing in smokers.[21] However, given the small sample size and confounding variables such as variable follow-up and concomitant shoulder pathology these results should be interpreted with caution.

Limitations of this study include the retrospective nature of the study and small sample size (n = 15), which limit the generalizability of our findings. However, our findings are consistent with other studies' findings with regard to cuff tendon involved and functional outcomes.[6,12,13] In addition to small sample size, there was significant heterogeneity of our study population with regard to UEA type and overall shoulder pathology. Although the majority of literature on rotator cuff repair in UEA patients has focused on wheelchair ambulation, our study featured a significant proportion of patients who utilize other ambulatory devices such as crutches, canes, and walkers. Although each of these increase force transmission across the shoulder joint, there are likely different biomechanical implications which alter specific rotator cuff tear injury pattern and retear rate. Furthermore, there is evidence to suggest the size of rotator cuff tear is greater in those with prolonged use of crutches preoperatively; however, there is little evidence available regarding tear rates in those with prolonged use of walkers. A future prospective study with more patients would enable greater intergroup comparisons and may ultimately influence treatment and postoperative rehabilitation. Our study did not include final follow-up imaging studies (ultrasound or MRI), which significantly limits our ability to conclude true retear rate. Although only one symptomatic retear was identified, the actual retear rate could be much higher.

Conclusion

Although our sample size limits generalizability, our results confirm previous reports that rotator cuff repair in UEAs is associated with long-term improvements in pain and patient-reported functional outcomes. Appreciating additional pathology beyond the rotator cuff is important in formulating treatment plan. Comparing an age and comorbidity-matched cohort that does not require assistive devices for ambulation could provide further insight into outcomes of UEAs following rotator cuff repair.

Acknowledgments

The authors would like to acknowledge Armaan Haleem for his efforts in the data collection process of this project.

Disclaimers:

Funding: No funding or grants were received from any internal or outside source for this project.
Conflicts of interest: The authors, their immediate families, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

References

1. Akbar M, Balean G, Brunner M, Seyler TM, Bruckner T, Munzinger J, et al. Prevalence of rotator cuff tear in paraplegic patients compared with controls. J Bone Joint Surg Am 2010;92:23-30. https://doi.org/10.2106/JBJS.H.01373.
2. Baumgarten KM, Gerlach D, Galatz LM, Teefey SA, Middleton WD, Ditsios K, et al. Cigarette smoking increases the risk for rotator cuff tears. Clin Orthop Relat Res 2010;468:1534-41. https://doi.org/10.1007/s11999-009-0781-2.
3. Bayley JC, Cochran TP, Sledge CB. The weight-bearing shoulder. The impingement syndrome in paraplegics. J Bone Joint Surg Am 1987;69:676-8.
4. Bedi A, Fox AJ, Harris PE, Deng XH, Ying L, Warren RF, et al. Diabetes mellitus impairs tendon-bone healing after rotator cuff repair. J Shoulder Elbow Surg 2010;19:978-88. https://doi.org/10.1016/j.jse.2009.11.045.
5. Cho NS, Moon SC, Jeon JW, Rhee YG. The influence of diabetes mellitus on clinical and structural outcomes after arthroscopic rotator cuff repair. Am J Sports Med 2015;43:991-7. https://doi.org/10.1177/0363546514565097.
6. Fattal C, Coulet B, Gelis A, Rouays-Mabit H, Verollet C, Mauri C, et al. Rotator cuff surgery in persons with spinal cord injury: relevance of a multidisciplinary approach. J Shoulder Elbow Surg 2014;23:1263-71. https://doi.org/10.1016/j.jse.2014.01.011.
7. Goldstein B, Young J, Escobedo EM. Rotator cuff repairs in individuals with paraplegia. Am J Phys Med Rehabil 1997;76:316-22.
8. Gutierrez DD, Thompson L, Kemp B, Mulroy SJ. Physical therapy clinical research network; rehabilitation research and training center on aging-related changes in impairment for persons living with physical disabilities. The relationship of shoulder pain intensity to quality of life, physical activity, and community participation in persons with paraplegia. J Spinal Cord Med 2007;30:251-5. https://doi.org/10.1080/10790268.2007.11753933.
9. Hanada K, Fukuda H, Hamada K, Nakajima T. Rotator cuff tears in the patient with paraplegia. J Shoulder Elbow Surg 1993;2:64-9.
10. Jahanian O, Van Straaten MG, Goodwin BM, Lennon RJ, Barlow JD, Murthy NS, et al. Shoulder magnetic resonance imaging findings in manual wheelchair users with spinal cord injury. J Spinal Cord Med 2020;45:1-11. https://doi.org/10.1080/10790268.2020.1834774.
11. Jordan RW, Sloan R, Saithna A. Should we avoid shoulder surgery in wheelchair users? A systematic review of outcomes and complications. Orthop Traumatol Surg Res 2018;104:839-46. https://doi.org/10.1016/j.otsr.2018.03.011.
12. Jung HJ, Sim GB, Jeon IH, Kekatpure AL, Sun JH, Chun JM. Reconstruction of rotator cuff tears in wheelchair-bound paraplegic patients. J Shoulder Elbow Surg 2015;24:601-5. https://doi.org/10.1016/j.jse.2014.09.028.
13. Kerr J, Borbas P, Meyer DC, Gerber C, Buitrago Téllez C, Wieser K. Arthroscopic rotator cuff repair in the weight-bearing shoulder. J Shoulder Elbow Surg 2015;24:1894-9. https://doi.org/10.1016/j.jse.2015.05.051.
14. Kulig K, Rao SS, Mulroy SJ, Newsam CJ, Gronley JK, Bontrager EL, et al. Shoulder joint kinetics during the push phase of wheelchair propulsion. Clin Orthop Relat Res 1998:132-43.
15. Mall NA, Lee AS, Chahal J, Sherman SL, Romeo AA, Verma NN, et al. An evidenced-based examination of the epidemiology and outcomes of traumatic rotator cuff tears. Arthroscopy 2013;29:366-76. https://doi.org/10.1016/j.arthro.2012.06.024.
16. Morrow MMB, Van Straaten MG, Murthy NS, Braman JP, Zanella E, Zhao KD. Detailed shoulder MRI findings in manual wheelchair users with shoulder pain. Biomed Res Int 2014;2014:769649. https://doi.org/10.1155/2014/769649.
17. Oh JH, Kim W, Kim JY, Rhee YG. Outcomes of rotator cuff repair in patients with comorbid disability in the extremities. Clin Orthop Surg 2017;9:77-82. https://doi.org/10.4055/cios.2017.9.1.77.
18. Papp M, Russell I, Requejo PS, Furumasu J, McNitt-Gray JL. "Reaction force generation and mechanical demand imposed on the shoulder when initiating manual wheelchair propulsion and at self-selected fast speeds." ASME. J Biomech Eng 2019;141:124505. https://doi.org/10.1115/1.4045492.
19. Popowitz RL, Zvijac JE, Uribe JW, Hechtman KS, Schürhoff MR, Green JB. Rotator cuff repair in spinal cord injury patients. J Shoulder Elbow Surg 2003;12:327-32. https://doi.org/10.1016/s1058-2746(03)00035-1.
20. Rankin JW, Richter WM, Neptune RR. Individual muscle contributions to push and recovery subtasks during wheelchair propulsion. J Biomech 2011;44:1246-52. https://doi.org/10.1016/j.jbiomech.2011.02.073.
21. Santiago-Torres J, Flanigan DC, Butler RB, Bishop JY. The effect of smoking on rotator cuff and glenoid labrum surgery: a systematic review. Am J Sports Med 2015;43:745-51. https://doi.org/10.1177/0363546514533776.
22. Titchener AG, White JJ, Hinchliffe SR, Tambe AA, Hubbard RB, Clark DI. Comorbidities in rotator cuff disease: a case-control study. J Shoulder Elbow Surg 2014;23:1282-8. https://doi.org/10.1016/j.jse.2013.12.019.
23. Van Drongelen S, Van der Woude LH, Janssen TW, Angenot EL, Chadwick EK, Veeger DH. Mechanical load on the upper extremity during wheelchair activities. Arch Phys Med Rehabil 2005;86:1214-20. https://doi.org/10.1016/j.apmr.2004.09.023.
24. Wang JC, Chan RC, Tsai YA, Huang WC, Cheng H, Wu HL, et al. The influence of shoulder pain on functional limitation, perceived health, and depressive mood in patients with traumatic paraplegia. J Spinal Cord Med 2015;38:587-92. https://doi.org/10.1179/2045772314Y.0000000271.