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CASE REPORT

Manual wheelchair use leads to a series of failed shoulder replacements: A case report and literature review

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Abstract
Manual wheelchair users place high stress on their shoulders. We describe a 69-year-old male who developed end-stage shoulder osteoarthritis from chronic manual wheelchair (MW) use. Three prosthetic total shoulder replacements failed, reflecting his refusal to transition to an electric wheelchair. MW use must be avoided in some of these patients.

KEYWORDS
electric wheelchair, failed shoulder arthroplasty, manual wheelchair, reverse shoulder arthroplasty, shoulder infection, total shoulder arthroplasty

1 | INTRODUCTION

Nearly four million people use a wheelchair in the United States, of which approximately 90% are manual wheelchair users (MWUs).[1,2] Full-time MWUs perform about 14–18 wheelchair transfers per day that, when coupled with typical daily wheelchair use, place high weight-bearing demands on the shoulders leading to increased incidence of chronic shoulder pain.[3–6] Shoulder pain in MWUs is associated with unfavorable reduced variability in the peak resultant force on the upper limb during wheelchair propulsion.[7] There is also the unfavorable higher kinematic spatial variability in the recovery phase of wheelchair propulsion in MWUs with shoulder pain when compared to those without shoulder pain.[8] Consequently, it is not surprising that approximately 30%–75% MWUs report significant shoulder pain.[9–13] Even the seemingly innocuous weight-relief maneuver (i.e., pressing upward on the wheelchair arms) commonly performed by MWUs to reduce pressure on the buttocks results in higher-than-normal shoulder loading and narrowing of the acromion-humeral distance, the latter correlating strongly with shoulder pain.[14] For these various reasons, MWUs (including the large majority who are non-athletes) often have chronic shoulder pain that can be attributed to various conditions, including subacromial impingement, rotator cuff tear, ischemic osteonecrosis of the humeral head, distal clavicular osteolysis, tendinitis, and degenerative arthritis.[11,15–17]

We report the case of a 69-year-old right-hand-dominant paraplegic male who developed chronic shoulder pain after 30 years of manual wheelchair (MW) use, especially on the left side. An anatomic total shoulder arthroplasty (ATSA) was performed for end-stage osteoarthritis, but this failed within 1 year due to glenohumeral instability associated with aseptic loosening of the glenoid component. Revision surgery included a bipolar hemiarthroplasty (HemiA). To reduce pain and enhance implant longevity, the patient also received a power-assisted wheelchair to assist with propulsion on inclines and with turning. However, he did not use it. Progressive pain and shoulder subluxations associated with non-compliant/continual MW use then led to a reverse total shoulder arthroplasty (RTSA). The patient again failed to comply with the recommendation to stop MW use even though an electric wheelchair had been provided to him. The RTSA ultimately failed from excessive MW use and a concomitant anaerobic infection. He was ultimately treated with a permanent antibiotic-containing spacer and thereafter he used an electric wheelchair.

We report this case in the perspective of a literature review to emphasize that (1) MWUs have higher rates major complications of shoulder arthroplasties that may not be adequately emphasized in several studies, (2) there is high variability in published postoperative protocols for resuming manual transfers and propulsion for MWUs after shoulder arthroplasty, and (3) some MWUs requiring an index or revision RTSA should first have, and agree to use, an electric or power-assisted wheelchair to reduce mechanical stress on their shoulders.

1.1 | Informed consent

The patient was informed and consented that data concerning his case would be submitted for publication.

2 | CASE REPORT

The patient is a 69-year-old right-hand-dominant paraplegic male MWU (height: 183 cm; weight: 91 kg; BMI: 27) that presented to our clinic in December of 2013 with a two-year history of left shoulder pain associated with activities of daily living and was especially high with wheelchair transfers. Thirty years prior to this visit, he was in a work-related vehicle rollover accident. This caused a left acromioclavicular separation (grade 3) and a thoracolumbar spine injury that left him permanently paraplegic, leading to his permanent MW use. He had successful repair of a degenerative rotator cuff tear on the same shoulder 5 years prior to this clinic visit. The patient worked at home as a certified public accountant and was married. He had hypertension and depression, which were treated with medications.

Manual muscle testing showed normal strength of his shoulder muscles. Active and passive motions of the left shoulder were 140° flexion, 105° abduction, 70° external rotation, and 40° internal rotation. Impingement and Hawkins-Kennedy maneuvers, and shoulder rotation with the elbow at his side caused moderate pain. Radiographs showed moderate glenohumeral osteoarthritis and humeral osteophytes, and no rotator cuff tear on magnetic resonance images. The impingement pain was temporarily relieved with physical therapy and subacromial corticosteroid injections. In May of 2013, he had an arthroscopic acromioplasty with bursectomy and debridement of a degenerative labrum tear.

Because of persistent pain, he sought opinions from two surgeons who recommended a ATSA. This was performed in December 2013 by JGS and included a non-cemented humeral stem and a cemented diverging pegged all-polyethylene glenoid component (Stryker Solar® Shoulder System). Rotator interval plication addressed the subluxation.[15,16] We instituted a postoperative protocol (as in[16]); however, the patient failed to adhere to this, starting transfers and propulsion much sooner than recommended (Table 1).

Six months after the ATSA, he reported high pain with routine MW use (Figure 1). Physical examination showed humeral subluxation in the anterior-superior direction, indicating failure of the rotator interval plication. Recommendations included (1) physical therapy tailored to avoid this subluxation and (2) use of a wheelchair with geared wheels or the possibility of ratcheting handles for propulsion.[2] Although his Worker's Compensation insurance agreed to cover the costs, the patient refused wheelchair modification.

By 9 months after the ATSA, his shoulder pain was significant only when propelling his wheelchair up an incline. By 11 months after the ATSA, he returned with complaints of increasing left shoulder pain and crepitus, which were attributed to anterior-superior glenohumeral instability and a loose glenoid component. On February 18, 2015, revision shoulder surgery was done by JGS, which was 14 months after the index ATSA. A new glenoid component was not implanted. The humeral head was removed and replaced with a bipolar head (Stryker Solar® Shoulder System).[18] An irreparable subscapularis tendon with anterior glenohumeral instability was addressed with a pectoralis major tendon transfer.[19] Tissue cultures showed no growth at 14 days. Although either an electric, geared manual, or power-assisted wheelchair were prospectively deemed essential, he again refused these recommendations despite being told unequivocally that he otherwise would have persistent or worsening shoulder pain because he now had a HemiA.

TABLE 1 Shoulder arthroplasty in wheelchair-dependent patients

Reference	No. Patients, Average Age (years) (range)	Means of ambulation	Transition to electric wheelchair	Type of Shoulder Arthroplasty	Average months follow-up (range)	post-operative Protocol	Permanent Spacer	Outcome
Anatomic Total Shoulder Arthroplasty (ATSA) and Hemiarthroplasty (HemiA)								
Garreau De Loubresse et al. 2004	5, 70 years (61–88)	Wheelchair (No distinction between electric and manual)	NA	4 ATSA, 1 HemiA	30 (24–36)	NA	NA	1 failed (glenoid component migration)
Hattrup and Cofield 2010	6, 68 years (54–87)	Wheelchair (No distinction between electric and manual)	NA	5 ATSA, 1 HemiA	84 (24–200)	Passive motion first 6 weeks, active-assisted motion 6 weeks, transfers 8–10 weeks, limited ambulation 12 weeks	NA	1 excellent, 4 satisfactory, 1 unsatisfactory
Reverse Total Shoulder Arthroplasty (RTSA) and Anatomic Total Shoulder Arthroplasty (ATSA) [4 HemiA in Chiche et al. and one Bipolar HemiA in our patient]								
Ueblacker et al. 2007	1, 62 years	Wheelchair (No distinction between electric and manual)	NA	Bilateral RTSA	30 (right prosthesis), 26 (left prosthesis)	Active-assisted ROM with gradual weekly increases	NA	1 revision for loose screw then results were satisfactory
Romine et al. 2015	11, 63 years (44–81)	6 wheelchairs (No distinction between electric and manual), 5 walkers	NA	RTSA	19 (12–37)	Full weight 12 weeks	NA	No baseplate loosening, 85% satisfaction with surgery
Kemp et al. 2016	10 (19), 71 years (59–84)[a]	Wheelchair (No distinction between electric and manual)	NA	RTSA	40 (22–66)	Passive ROM 3 weeks, active-assisted ROM 6 weeks, weight bearing and transfers 12 weeks	Yes (one patient; not known if permanent)	1 periprosthetic FX and infection treated with spacer, 1 persistent pain
Skedros et al. 2017	1, 70 years	MWU	Yes, 12 months after surgery	RTSA	24	Passive motion first 6 weeks active-assisted motion 6 weeks, transfers 8–10 weeks, limited ambulation 12 weeks	NA	No pain and good functional outcome

(Continues)

TABLE 1 (Continued)

Reference	No. Patients, Average Age (years) (range)	Means of ambulation	Transition to electric wheelchair	Type of Shoulder Arthroplasty	Average months follow-up (range)	post-operative Protocol	Permanent Spacer	Outcome
Cuff and Santoni 2018	21, 68 years (58–75)	16 wheelchairs (No distinction between electric and manual), 5 walkers	NA	RTSA	73 (62–98)	Transfers 6 weeks	NA	12% complication rate, 92% satisfaction
Boettcher et al. 2021	79, 65 years (NA-NA)	NA (states “paraplegia”)	NA	26 ATSA, 53 RTSA	NA	NA	NA	No difference in rate of revision between paraplegic and non-paraplegic patients
Chiche et al. 2021	11, 64 years (23–85)	7 MWU, 3 electric, 1 unclear (MWU likely)	Yes (5/8 patients)	4 ATSA, 5 RTSA, 4 HemiA	34 (13–86)	Transfers 4 months	NA	1 dislocation of TSA revised to RTSA, 1 infection (removed from final analysis)
Calek et al. 2022	17, 72 years (49–80)	15 MWU, 2 electrics	NA	RTSA	50 (25–120)	Transfers 4–8 weeks	NA	2 baseplate dislocations
Our case 2022	1, 69 years ATSA (72 years RTSA)	MWU	Yes (after spacer)	ATSA, HemiA, RTSA	120	5 weeks Transfers, 7 weeks Propulsion	Yes	Explanted, permanent spacer

Abbreviation: NA = not available/not reported.

[a] Kemp et al. excluded three "early failures" from their analysis and an additional four due to inadequate follow-up, leaving 12 RTSAs in 10 patients. However, it is unclear how many patients vs. shoulders were included in their initial cohort (i.e., prior to excluding seven [?] patients).

FIGURE 1 A photograph of our patient showing the typical amount of his left shoulder extension just prior to pushing the wheels forward.

One year after this revision surgery, he reported high pain with MW use. He sought a second opinion from a surgeon at a nearby academic medical center who recommended revision to a RTSA, with bone grafting of the glenoid surface to increase lateral offset. Although outcome data for RTSAs in MWUs were not available in the peer-reviewed literature at the time (2015), we again informed our patient that we would only perform this surgery if he obtained an electric wheelchair. He agreed to this plan. Notably, there was no evidence that his underlying depression, which can correlate with increased noncompliance,[20] had worsened.

A RTSA was implanted by JGS in February 2016. A 10 mm thick segment of a fresh-frozen femoral head allograft was placed on the concentrically worn glenoid surface, and the glenoid baseplate was fixed to the scapula with five screws that traversed through the graft.[21,22] After 3 months with limited shoulder motion,[16] the patient started to strengthen his shoulder and participate in progressive training for transfers. By the fourth postoperative month, he was transferring independently and had no complaints at 6 months after implantation. There was no evidence of glenohumeral instability (Figure 2). Although an electric wheelchair was available for him at no cost, he

FIGURE 2 Anterior–posterior radiograph of the patient's RTS prosthesis at 6 months after implantation. He had no complaints at this time.

refused to use it. He then made clear to us for the first time that when he used anything other than a MW he “felt disabled.”

By August 2016, after missing several scheduled clinic appointments, he returned with complaints of pain; radiographic lucency also was detected at the base of the allograft suggesting poor incorporation. Worsening pain with continued unadvised MW use led to computed tomography scanning in January 2017 that revealed dislodgement of the glenoid component and dissociation of the peripheral locked screws from the baseplate (Figure 3). All infection markers (CRP, ESR, and WBC) were normal, and glenohumeral joint aspiration yielded mildly cloudy fluid with no evidence of infection at 14 days of incubation. The RTSA was removed in February 2017 and replaced with a handmade antibiotic-containing cement spacer because of concern for an anaerobic infection. Operative findings included substantial metallosis and

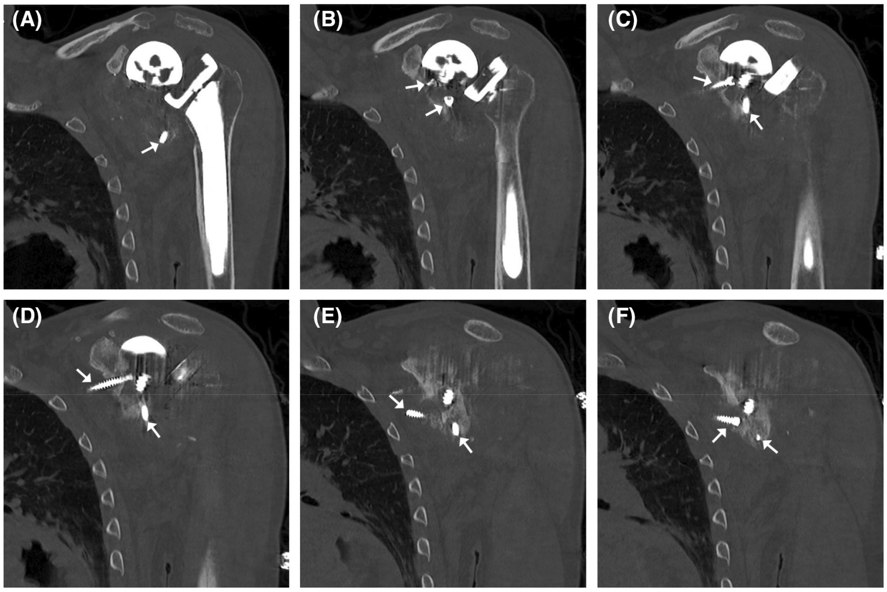

FIGURE 3 A series of anterior-to-posterior CT scan images showing dislodgement of the baseplate with upward rotation of the glenosphere and dissociation of all peripheral locking screws (arrows indicate two of the dissociated screws). The distance between images (A) and (B) is 4 mm and is also 4 mm between images (E and F). The distance is 2 mm between each remaining pair of adjacent images. Images C and D show the dislodged glenoid component and screws.

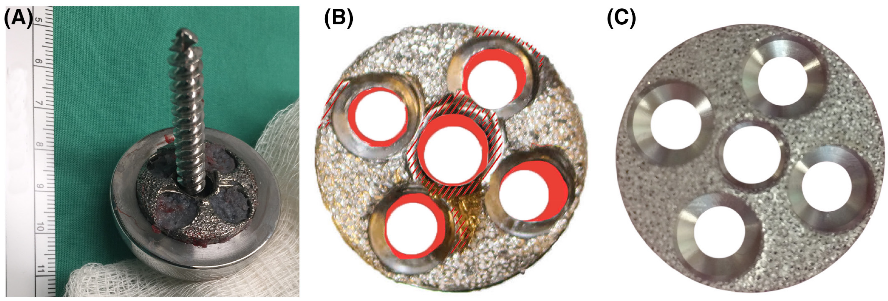

FIGURE 4 Photographs of our patient's RTSA baseplate (A and B) with the loose, but not dislodged central locking screw, and a pristine baseplate (C) that had never been implanted (provided by Stryker Corporation): (A) The patient's baseplate at the time of its removal shows grayish tissue filling the holes where the four peripheral screws had worn through and completely dissociated from the baseplate. When compared to the un-implanted/pristine implant shown in (C), the red color in image (B) shows the amount of metal that had completely worn away and the parallel red lines in (B) show additional peripheral wear.

wear-related dissociation of the peripheral screws from the baseplate (Figure 4). *Cutibacterium acnes* grew from all three tissue cultures, and a repeat surgical debridement was done 3 weeks later with removal of the handmade spacer and replacement with an injection-modeled antibiotic-containing spacer (Stage One™ Cement Spacer Molds, Zimmer Biomet, Warsaw, Indiana, USA).

He then began using an electric wheelchair and was told that revision arthroplasty surgery would not be possible. Radiographs at 24 months after the placement of the final spacer are shown in Figure 5. At that time, he reported cervical disk degeneration that exacerbated his shoulder pain; treatment was with chronic narcotic pain medication. Active ranges of left shoulder motion were 70° forward flexion, 60° abduction, 50° external rotation, and 20° internal rotation. The medication and dose for his depression had not been adjusted over the seven-year period described in this report, and his left shoulder function remained the same at final follow-up at 5 years after implantation of the spacer.

3 | DISCUSSION

The series of failed prosthetic arthroplasties in this case demonstrates the importance of ensuring that MWUs undergoing shoulder arthroplasty strictly adhere to post-operative protocols and, in some cases, switch from a manual to an electric or power-assisted wheelchair (especially prior to revision arthroplasty). We believe that our patient would have had a better outcome had these principles been followed. Recent studies showing relatively higher prosthetic shoulder failures in MWUs vs. non-wheelchair users[17,23–25] further substantiate this approach. Studies that have explored reasons for the reluctance of some MWUs to transition to power wheelchairs can help healthcare providers identify potential physical, psychosocial, and financial barriers that might be at play.[26,27] In the perspective of these reports and our own experience,[28] we will not revise shoulder prostheses in MWUs until they establish the preoperative use of an electric or power-assisted wheelchair. This approach can

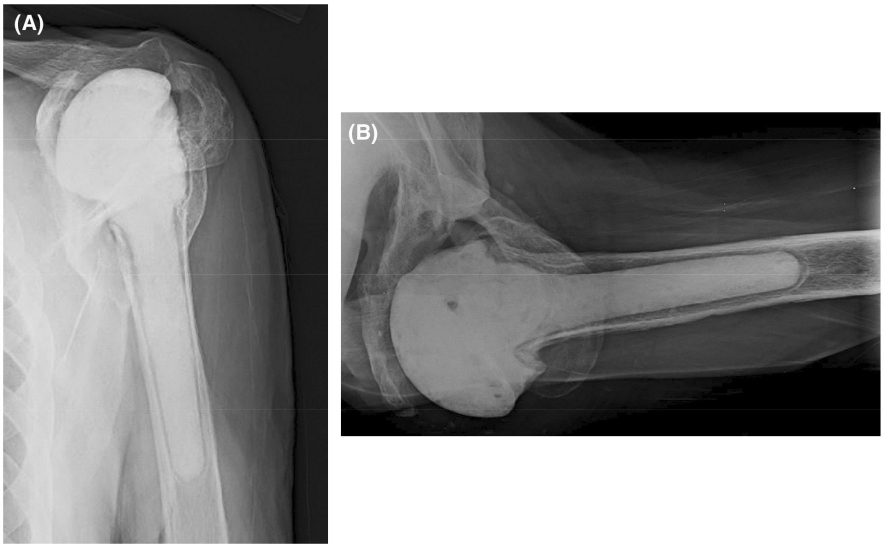

FIGURE 5 Anterior–posterior (A) and axillary-lateral (B), anterior is at the bottom of the image radiographs of the patient's injection-molded cement spacer at 18 months after implantation. Note that to enhance stability, additional cement was applied into the metaphyseal region of the bone just before insertion of the spacer.

also be beneficial for some MWUs who are undergoing an index shoulder arthroplasty.[29] For patients who desire maintaining some manual propulsion, geared manual or power-assisted wheelchairs could be used.[1,2,30,31] Some patients might agree to this transition if they realize that this could be part-time use, where a power wheelchair might be needed only for ambulation outside the home or facility where they live.[26]

MWUs commonly develop shoulder disorders due to weight-bearing and chronic overuse,[11,15,32] but only some might be viable candidates for shoulder arthroplasty. Although generally deemed unfavorable by the orthopedic community at the time of our patient's index arthroplasty,[33] a few studies prior to 2013 supported using an ATSA in MWUs[15,16] (Table 1). We were not aware of any data that would help surgeons and other healthcare providers identify MWUs who, due to their habitual propulsion/transfer demands, would be at increased risk of failure of a shoulder arthroplasty. In all patients, a successful ATSA is highly dependent on a functional rotator cuff. While this might be a desirable choice for some wheelchair users, RTSAs are more appropriate for patients (including selected wheelchair users) with glenohumeral arthritis and significant rotator cuff dysfunction and/or shoulder instability. This is because RTSAs do not rely on the rotator cuff muscles for overhead arm elevation (the deltoid muscle performs this function) and the ball-in-socket design provides a high degree of intrinsic stability.[28,34,35] In 2015, when we performed our patient's RTSA there was limited data that supported this application, including one unpublished study[36] and one case report.[37] Following the RTSA in our patient, several studies have been published that further support using this procedure in MWUs (Table 1). Prior to these publications, anecdotal reports of shoulder surgeons and unpublished results presented at orthopedic/shoulder meetings indicated that the short-term success rate of RTSAs in MWUs was approximately 75%.

Several studies[17,23,24,29,38] now confirm that nearly one in four wheelchair-dependent patients is at substantial risk of arthroplasty failure. The recent study of Chiche et al.[29] suggests that this could likely be minimized with prospective modifications of wheelchair ambulation. In 2021, they reported on the outcomes of 13 shoulder arthroplasties (4 ATSA, 5 RTSA, 4 HemiA) in 11 patients who were chronic wheelchair users (three patients were using an electric wheelchair at the time of surgery). Of the eight patients who were MWUs, five (63%) postoperatively had to change from a manual to an electric wheelchair (they did not specify the types of shoulder arthroplasties in these patients). They concluded that "...the fear to doing a reverse shoulder arthroplasty in this [chronic MWU] population is not justified if adaptations to the transfers and means of locomotion are implemented." We find the percentage (63%) of MWU transitioning to an electric wheelchair to be astonishingly high. Could it be that some prior studies of shoulder arthroplasty in MWUs had patients that also transitioned to electric wheelchairs but were not reported simply because "wheelchair use" (without specifying the "type" wheelchair) continued? Identifying outcomes of shoulder arthroplasties in patients who maintained MW use vs. those that transitioned to power wheelchairs is an important distinction that should be made in future studies.

Although in the United States RTSAs are now common, accounting for nearly 40% of all shoulder arthroplasties in 2011,[34,39] a broad range of complications can occur following this procedure. In fact, reported complication rates range from 10% to 68% in non-wheelchair users.[40–42] However, the adverse consequences of implant failure by early loosening, or otherwise unsatisfactory results of RTSAs in MWUs seem to be understated by some investigators.[17,23,24,38,43] For example, although four of the 19 patients (21%) described by Alentorn-Geli et al.[23] had unsatisfactory results, they concluded that "RTSA is a safe and effective procedure in wheelchair-dependent patients who use their shoulders for weight-bearing purposes." The study of Kemp et al.[17] suggests that approximately 25% of their patients (all MWUs with RTSA) had major complications (e.g., falls, dislocation, and periprosthetic humeral fracture). We emphasize "suggests" and "approximately" because several patients in their initial cohort of 19 MWUs were excluded because of inadequate follow-up (see footnote in Table 1). Nevertheless, similar to Hattrup and Cofield,[16] Kemp et al. stated that "patients must be willing to fully cooperate with the postoperative therapy protocol, including no weight bearing transfers with the operative arm for 12 weeks." Kemp et al.[17] and Calek et al.[24] also prospectively tell their patients that they must accept a higher complication rate.

The infection rate following a RTSA is reported to range from 1% to 10%.[40] Wiater et al.[44] reported on 19 of 50 RTSAs (all non-wheelchair users) that were revised for infection, with *Propionibacterium acnes* (*P. acnes*) being the most common organism. (In 2016, the taxonomic affiliation of *P. acnes* was changed to *Cutibacterium acnes* (*C. acnes*).[45]) Infection coupled with excessive loading was the most important factors in the failure of our patient's RTSA. As in our patient, articulating antibiotic-loaded spacers are commonly used in these cases, and they can be left in the shoulder as a permanent prosthesis. For example, Stine et al.[46] reported on 30 non-wheelchair patients with chronic shoulder sepsis (18 had arthroplasties) that were treated with cement spacers, and 50% of the patients ($n = 15$) used the spacer as a permanent prosthesis. Although permanent retention of a cement spacer has been reported by others as a salvage procedure for infected shoulder arthroplasties in non-wheelchair users,[47–49] we did not locate a prior report of the permanent retention of a bone-cement spacer in a MWU after a shoulder arthroplasty of any type.

In contrast to our current protocol and the high MW-to-electric wheelchair postoperative transition reported by Chiche et al.,[29] we located only one other mention of a MWU that transitioned to a power wheelchair after a RTSA.[28] Additionally, we did not locate any report stating that this is a preoperative recommendation for some patients. Our literature review also revealed high variability in postoperative rehabilitation protocols after shoulder arthroplasty in wheelchair-dependent patients (Table 1). For example, two studies reporting timeframes for when ambulation and transfers are allowed in MWUs after a RTSA, ATSA, or HemiA recommend that transfers should wait 8–12 weeks, and full-strength manual propulsion should wait at least 12 weeks.[16,17] One study reported that transfers are not allowed until 4 months after RTSA,[29] which differs markedly from another where transfers were allowed at 6 weeks.[25] In view of this variability, additional research is needed to develop evidence-based guidelines for commencing transfers and propulsion for MWUs after shoulder arthroplasty, especially with RTSA because of marked increased likelihood of the specific complication of glenoid dislodgement/loosening.[24] Otherwise, robust data sets in non-wheelchair patients show similar revision rates (for all reasons) in ATSA vs. RTSA[50,51]; comparatively limited data suggest that this is also the case in most wheelchair-dependent patients.[24]

It is possible our patient's non-compliance, at least in part, stemmed from his depression because this condition can increase medical non-compliance by as much as three-fold.[20] Surveys and educational interventions that are used for other musculoskeletal disorders or circumstances[52–55] could help develop methods for determining preoperatively which MWUs are at increased risk of shoulder arthroplasty failures due to non-compliance. Established survey-type instruments, like the Minnesota Multiphasic Personality Inventory (MMPI),[56,57] could also help explore the dimensions of personality characteristics that correlate with non-compliance. Surveys and educational interventions specific to MWUs who are candidates for a shoulder arthroplasty are needed especially considering that preoperative educational materials geared toward non-MWUs have been shown to be somewhat ineffective at enhancing compliance with postoperative protocols.[58] A study by Domingues et al.[27] helps pave the way for more specific assessment of the psychosocial and participation impact of MWU vs. powered wheelchair use in patients with diverse medical/physical conditions who will undergo a shoulder arthroplasty. The various surveys that they employed could be used to preoperatively identify psychosocial factors that might cause some MWUs to not comply with postoperative protocols and/or resist transitioning from MW use to a power wheelchair.

In addition to using survey-type instruments to explore a patient's psychological/behavioral propensity for non-compliance/reluctance with recommended wheelchair use after a shoulder arthroplasty, novel strategies should also be considered for identifying those at risk for failure simply from their habitual upper extremity use. For example, Dysterheft et al.[59] studied 14 adults with spinal cord injury (mean age: 30 ± 11 years) who used a manual wheelchair for >80% of daily ambulation and were free of any condition that could be worsened by physical activity. Physical activity was measured using the Physical Activity Scale for Individuals with Physical Disabilities (PASIPD), and shoulder pain was measured using the Wheelchair User's Shoulder Pain Index (WUSPI) survey. Mean and intraindividual variability propulsion measurements showed that participants with higher PASIPD scores used a more "injurious stroke technique" when propelling at higher speeds. It is likely that these individuals are at a higher risk of sustaining shoulder injuries. A strong association was also found between peak propulsion forces and shoulder pain. They concluded that rehabilitation professionals should emphasize the use of a "protective stroke technique" in both less active and highly active MWUs during exercise and faster propulsion. This type of analysis holds promise for identifying MWUs who might be at higher risk of shoulder prosthesis failure.

Sonenblum et al.[60] measured aspects of 28 MWUs' (20 had spinal cord injuries) everyday mobility with a wheel-mounted accelerometer and seat occupancy switch for 1–2 weeks, and bouts of mobility were recorded and characterized (distance, duration, and velocity). They found that 1 week of measurements was sufficient to give an accurate appraisal of activities when compared to longer durations. These types of measurements warrant study in MWUs that plan to have shoulder arthroplasty, especially in view of their data showing a broad range of these important characteristics of daily use. A scoring system could be devised for identifying patients with high/frequent habitual activities and psychosocial factors that correlate with high failures and/or other complications after shoulder arthroplasty. In turn, pre-operative education could then be instituted to help reduce risk in these patients. Although all established wheelchair users have some degree of training when they began wheelchair use, additional training might be needed for some patients who will have a shoulder arthroplasty. The future could be that individuals identified in the moderate-to-high postoperative risk category are preoperatively evaluated by physical therapists or others who provide this training. Virtual reality (VR)-based training that is being pioneered for all types of wheelchairs and wheelchair users[61] could help high-postoperative-risk patients recognize the need for modifying their maneuvering and other activities that produce loads that are deleterious for shoulder prostheses. As access to these technologies and the aforementioned survey instruments are improved and become more widely available, they should prove useful in reducing complications by optimizing preoperative preparation and postoperative rehabilitation of MWUs.

4 | CONCLUSION

Many lessons can be learned from our patient's tumultuous course and poor outcome, especially when considered in the context of a literature review and in the perspective of validated surveys and emerging technologies that hold promise for reducing failure of shoulder prostheses in MWUs. As exemplified by our case and several recent studies, MWUs can incur high failure rates after shoulder arthroplasty. To help avoid implant loosening, postoperative protocols that include modified propulsive techniques or electric wheelchairs should be considered for some patients. Additional research is needed to help guide surgeons and other healthcare providers in this decision-making process. Studies are also needed that are aimed at optimizing the time course of postoperative rehabilitation for MWUs and prospectively identifying patients that are at risk of shoulder arthroplasty failure.

AUTHOR CONTRIBUTIONS

Dr. John G. Skedros provided medical and surgical care to the patient, led the literature search, and led the writing of the case report. John T. Cronin helped with the literature search, writing of the case report, and review table preparation. Ethan D. Finlinson helped with the literature search and writing of the case report. Tanner D. Langston helped with the literature search and writing of the case report. Dr. Micheal G. Adondakis helped with the literature search and writing of the case report.

ACKNOWLEDGEMENTS

None

CONFLICTS OF INTEREST

None.

DATA AVAILABILITY STATEMENT

All data can be accessed via correspondence with the first author, Dr. John G. Skedros.

ETHICAL APPROVAL

Each author certifies that his institution has approved the reporting of this case, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

CONSENT

The patient gave consent for the writing and publication of this case report.

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