EFORT open reviews

SHOULDER AND ELBOW | 7:3 | 227–239

Understanding shoulder pseudoparalysis. Part II: Treatment

Jonathon C Coward[1], Stefan Bauer[2], Stephanie M Babic[1], Charline Coron[2], Taro Okamoto[1,2] and William G Blakeney[1]

[1]Deaprtment of Orthopaedic Surgery, Royal Perth Hospital, Perth, Western Australia, Australia
[2]Chirurgie de l'Épaule, Service d'Orthopédie et Traumatologie, Ensemble Hospitalier de la Côte, Morges, Switzerland

Correspondence should be addressed to W G Blakeney
Email
blakeney@gmail.com

- Decision-making for the treatment of pseudoparalytic shoulders is complex and a high level of experience in shoulder surgery and outcome evaluation is required.
- Management and results depend on clinical findings, tear and tissue quality, patient and surgeon criteria. Clinical findings determine the exact definition and direction of pseudoparesis and pseudoparalysis.
- Tear pattern and tissue quality determine if the rotator cuff is repairable or irreparable. Age and general health are important patient factors.
- Non-operative treatment is the first option for patients with a higher risk profile for reconstruction or arthroplasty, but delineation of its value requires better evidence.
- Tendon transfers are used for irreparable loss of the horizontal force couple balance (rotation). Options include latissimus dorsi, pectoralis minor and major for loss of active internal rotation, and latissimus dorsi ± teres major and lower trapezius for loss of active external rotation (AER).
- Partial cuff repair with or without superior capsular reconstruction using allograft or biceps tendon is an option for loss of active forward elevation.
- Treatment for the combined loss of elevation and external rotation patients is still not clear. Options include lateralised reverse shoulder arthroplasty (RSA) alone or combined RSA with a tendon transfer.
- RSA with loss of AER can be revised by adding a tendon transfer.

Keywords
- pseudoparalysis
- pseudoparesis
- shoulder

EFORT Open Reviews (2022) **7**, 227–239

Introduction

Part 1 of this article defined 'pseudoparesis' and 'pseudoparalysis' in detail in relation to loss of specific shoulder functions and discussed the history and examination findings that determine these diagnoses. Part 1 also explained the biomechanics of the rotator cuff and the development of pseudoparesis and pseudoparalysis and summarised imaging and classifications of rotator cuff tears.

Part 2 describes the management options for patients with pseudoparesis and pseudoparalysis and assesses the evidence supporting each of these options. The studies included in this paper often use varying definitions of pseudoparesis or pseudoparalysis or alternately, phrase clinical findings entirely as a specific loss of function as opposed to using either of these terms. This paper maintains the definitions of pseudoparesis and pseudoparalysis used in part 1 to ensure consistency of comparison when assessing the relevant literature (1).

Non-operative treatment

There is limited evidence available on the non-operative treatment of true pseudoparesis or pseudoparalysis.

Collin *et al.* prospectively managed 45 patients with massive rotator cuff tears and patients with a mean age of 67 years using a specifically designed five-session rehabilitation programme (2). Massive rotator cuff tear was defined as full-thickness tears of two or more tendons, stage 3 or 4 Goutallier fatty muscle degeneration and shoulder active forward elevation (AFE) pseudoparesis. The programme aimed to improve the range of motion and function by increasing stability and centralisation of the humeral head on the glenoid. At 2 years post-completion, 53% of patients had greater than 160° of AFE (from a mean of 76° preprogramme). The overall Constant–Murley score (CMS) significantly improved from 43 to 56 ($P < 0.05$). Patients with the poorest outcomes had three

www.efortopenreviews.org
https://doi.org/10.1530/EOR-21-0070

or more tendons involved or had massive anterior tears, while those with the best outcomes had massive posterior tears. The limitations of this study include inadequate results reporting regarding significance levels and a lack of control group.

Levy *et al.* reported outcomes for 17 patients with massive cuff tears who were managed non-operatively secondary to medical comorbidities (3). All patients had AFE pseudoparesis with tears involving supraspinatus, infraspinatus and subscapularis (no mention was made of teres minor) and grade 4 fatty infiltration of supraspinatus on MRI. Patients were subjected to a specific anterior deltoid re-education physiotherapy programme for at least 12 weeks and were followed up for a minimum of 9 months. There was an overall improvement in the range of motion, particularly in AFE from a mean of 40°–160°. There was also an increase in mean CMS score across the cohort from 26 to 63. However, this study is limited as it involved a very small cohort of patients, the results had a large range (CMS score: 43–77) and no significance values were provided.

Agout *et al.* conducted a prospective cohort multicentre study on 68 patients with irreparable rotator cuff tears who underwent non-operative management, including analgesia use, physical rehabilitation and subacromial corticosteroid injections (4). The CMS score improved significantly from 40.7 to 57.1 at 12 months ($P < 0.0001$). However, there was no control group in this study and the treatment received by each patient was at the discretion of the surgeon, thereby meaning that the treatment protocol itself was not described. This study also made no distinction between patients with or without pseudoparesis or pseudoparalysis.

Gutiérrez-Espinoza *et al.* conducted a prospective cohort study on 92 patients with massive irreparable rotator cuffs tears who completed a 12-week physiotherapy programme using two manual therapy techniques – posterior glenohumeral mobilisation and scapular mobilisation (5). Thirty of the patients (32%) met our definition of having AFE pseudoparesis prior to treatment protocol. The range of motion was not assessed post-treatment however, making the protocol's ability to reverse pseudoparesis difficult to assess from these results. However, there was a significant improvement in functional outcomes with the CMS score improving from 38.4 at baseline to 63.3 at 12 weeks ($P < 0.01$) and the visual analog score (VAS) during activity decreasing from 5.6 at baseline to 1.9 at 12 weeks ($P < 0.01$).

Ainsworth conducted a pilot cohort study that assessed ten patients who underwent a 12-week education and rehabilitation programme that focused on posture correction, muscle re-education, strengthening, stretching, proprioception and adaptation (6). The Oxford Shoulder Score (OSS) was reported as improved from 32.2 at baseline to 24.6 at 3 months, but this does not fit with the accepted interpretation of the OSS (with a lower score indicating a higher level of disability). The 36-item Short-Form Health Survey (SF-36) showed an improvement in the pain and role limitation due to physical health categories but not in role limitation due to emotional health or perceived general health categories. Although this study showed improvements in functional outcomes, the range of motion was not documented as an outcome and neither pseudoparalysis nor pseudoparesis was mandatory inclusion criteria. It was also limited by its small sample size, short follow-up and lack of control group.

Christensen *et al.* conducted a cohort study on 30 patients with massive rotator cuff tears who underwent a lengthy education and rehabilitation programme (7). Patients performed two different exercises three times a week for 5 months in total. One session each week was supervised by a physiotherapist for the first 3 months and then one session every second week. The exercises were graduated on a weekly basis based on the patient's level of pain and whether the patient still felt challenged during the exercises. The OSS improved from 25.6 at baseline to 33.8 at 3 months ($P = 0.004$) and from baseline to 37.2 at 5 months ($P < 0.001$). The EuroQoL-5 dimension 5-level (EQ-5D-5L) functional component increased significantly from 0.671 at baseline to 0.755 at 5 months ($P = 0.009$). The EQ-5D-5L VAS component increased from 60.0 at baseline to 80.0 at 5 months ($P < 0.001$). The strength of this study lies in the standardised nature of the rehabilitation protocol undertaken by all participants. The limitations are its lack of control group and short follow-up period. In fact, patients were not followed up at all beyond the end of the rehabilitation period itself.

Shepet *et al.* completed a systematic review in 2020 on non-operative management options for massive irreparable rotator cuff tears (8). The basis of this review was to establish a protocol to guide non-operative management as there is no current gold standard in this area. Shepet *et al.* proposed a recommended rehabilitation protocol for patients with massive irreparable rotator cuff tears based on the studies by Ainsworth *et al.*, Christensen *et al.*, Gutiérrez-Espinoza *et al.* and Levy *et al.* described above (3, 5, 6, 7). The reason these studies alone were included in the protocol design is that only these four studies provided a detailed description of their rehabilitation protocol while also showing a significant improvement in functional outcome scores. The fundamental elements of the rehabilitation protocol designed by Shepet *et al.* can be summarised as follows:

(a) Quality – supervised physical therapy to ensure that the exercises are performed correctly.
(b) Quantity – two to three exercise sessions per week.

(c) Progression – first, focus on improving the range of motion by practising passive forward flexion and external rotation within the limits of pain; secondly, incorporate strengthening exercises using deltoid and teres minor exercises; and finally, improve scapular stabilisation and proprioception.
(d) Adjuncts – subacromial corticosteroid injections prior to commencing rehabilitation were considered reasonable and the use of non-steroidal anti-inflammatory drugs during rehabilitation was also allowed in the programme.

Overall, the evidence for non-operative management of massive irreparable rotator cuff tears is insufficient, particularly for its role in the reversal of pseudoparesis or pseudoparalysis. The recent systematic review conducted by Shepet *et al.* quotes an overall success rate for non-operative management of 32–96% and demonstrates that there are various rehabilitation programme approaches that hold promise (8). These programmes for non-operative management are the first options for patients with higher risk profiles for complications/adverse events prior to surgical reconstruction or arthroplasty. Scientific evidence of higher quality is required to further define their exact value. In younger patients with repairable cuff tears, it may be advisable to proceed directly to operative repair.

Operative repair

One key and challenging question for deciding on the best management is determining whether the cuff tear is repairable or irreparable. Factors that impact this decision include the degree of retraction, fatty infiltration and corresponding muscle body atrophy (9). Traditionally, tears with Goutallier grade 3 or higher (i.e. 50% or more of fatty infiltration) were considered irreparable. There is evidence, including the study discussed below by Burkart, that repair may be a reasonable option in patients with up to 75% fatty infiltration (10). The chronicity and location are also factors, with those at the musculotendinous junction less likely to be repairable and older tears tending to have a higher degree of fatty infiltration. Tear extension into the lower subscapularis and/or teres minor has a poor prognosis for repair (11). Fixed superior subluxation of the humeral head, reduced subacromial space and acromial acetabularisation (Hamada 3) give a much higher chance of failure post-repair (11, 12). Patient-related factors should also be considered. Factors such as increasing age, comorbidities (smoking, diabetes or hypercholesterolaemia), prior treatments (prior surgery or multiple corticosteroid injections), compliance, expectations and secondary gains (workers compensation) all lead to a higher chance of failure post-tendon repair (12).

Arthroscopic rotator cuff repair

Denard *et al.* retrospectively reviewed the data from 39 patients who had massive rotator cuff tears and loss of AFE, managed with arthroscopic rotator cuff repair (13). Participants had a mean age of 62 years and were followed up for 75 months on average. The authors defined pseudoparalysis as AFE $\leq$ 90° with full passive forward flexion and loss of a stable glenohumeral fulcrum (corresponding to our definition of AFE pseudoparesis). A double-row repair was performed when there was sufficient tendon mobility. AFE pseudoparesis significantly improved from 49° preoperatively to 155° postoperatively ($P < 0.001$), and pseudoparesis was reversed in 90% of patients (10). The mean University of California at Los Angeles Shoulder Score (UCLA score) for patients improved from 12.7 preoperatively to 29.4 postoperatively ($P < 0.001$) and the mean American Shoulder and Elbow Surgeons Shoulder (ASES) Score improved from 37.5 preoperatively to 84.0 postoperatively ($P < 0.001$). The main strengths of the study were the large cohort and the length of follow-up. The main limitation of the study was a lack of control group. It should be noted that their rehabilitation protocol included immobilisation in a sling for 6 weeks. Passive forward flexion and passive external rotation were only allowed from 6 weeks. At 4 months postoperatively, strengthening was initiated and passive internal rotation was allowed. Return to full activity was allowed at 12 months.

Oh *et al.* published the results of a retrospective comparison study in which they matched 29 patients with massive rotator cuff tears and resultant AFE pseudoparesis against 29 patients with massive rotator cuff tears without pseudoparesis (14). There was no identification and differentiation of patients matching our definition of true AFE pseudoparalysis from those with pseudoparesis. Patients were matched for age, gender, hand dominance, onset period, aggravation period, number of tendons involved, retraction, operation method (arthroscopic or mini-open), rows of repair (single or double), number of anchors and fatty degeneration. The only significant difference between the matching variables of the two groups was the number of tendons involved. The average follow-up period was 30.5 months (range: 12–72 months). The authors performed arthroscopically assisted mini-open repair on 23 patients (11 of which had pseudoparesis) and all-arthroscopic repair on 35 patients (18 of which had pseudoparesis). All patients also underwent a standardised rehabilitation programme with 6 weeks of immobilisation in an abduction brace and passive range of motion exercises followed by active range of motion exercises with weaning of the brace. The range of motion improved in both groups postoperatively.

In patients with AFE pseudoparesis, AFE improved from 64° preoperatively to 135° postoperatively ($P < 0.001$) and the CMS, ASES and UCLA scores all showed significant improvements postoperatively ($P < 0.001$ for all three scoring systems). The preoperative functional scores (including the CMS, ASES and UCLA scores) for the pseudoparesis and non-pseudoparesis groups were significantly different in favour of the non-pseudoparesis group. At the final post-operative follow-up, both groups had significantly improved in all three functional outcome scores, but there was no longer a significant difference between the two groups. Importantly, the authors did not differentiate outcomes between patients who underwent a mini-open repair from those who had purely arthroscopic procedures. Another limitation of this study is the highly variable follow-up period, with many patients lost to follow-up.

Burkhart *et al.* studied the outcomes of arthroscopic repair of Goutallier grade 3 and 4 massive rotator cuffs (10). Although not isolated to patients with pseudoparesis or pseudoparalysis (mean AFE 103°), they investigated 22 patients with massive cuff tears defined as involving two or three tendons with a greater than 5 cm diameter and grade 3 or 4 (≥50% fatty infiltration) changes of infraspinatus. They further sub-divided the patients into groups for 50–75% fatty infiltration and >75% depending on MRI findings. These patients underwent arthroscopic repair based on the tear pattern. U-shaped and L-shaped tears were repaired with a combination of side-to-side sutures and tendon-to-bone repair with suture anchors, whereas crescent-shaped tears were repaired directly to the bone with suture anchors. In all repairs, a single row of suture anchors was used. The authors also pointed out that they made a careful assessment of the subscapularis insertion footprint and would repair this in both complete and partial tears. They had 17 patients in the 50–75% group, all of whom had clinical improvement. AFE improved from 103.5° preoperatively to 165.9° postoperatively and the UCLA score improved from 12.4 to 31.5. There were only five patients with >75% fatty degeneration, and clinical improvement was only observed in two of five cases. There was some functional improvement with AFE improving from 102° preoperatively to 126°. This suggests that even in patients with Goutallier grade 3 or 4 changes, there may be a role for arthroscopic repair. As previously mentioned, this study did not differentiate between patients with and without pseudoparesis. Therefore, further investigation into this direct question is required, but this study may provide a valuable basis for this as some of the patients involved would fit into our definition of AFE pseudoparesis.

In conclusion, the use of arthroscopic or open rotator cuff repair is recommended in the treatment of pseudoparesis, in certain circumstances. Careful patient selection is paramount based on the presence of arthritis, degree of fatty infiltration/atrophy, location and size of tear/tendon involvement, age of patient and ability to rehabilitate. There are no studies looking at the specific use of rotator cuff repair in patients who fit our definition of true AFE pseudoparalysis. Therefore, the use of arthroscopic or open rotator cuff repair patients with 0° of AFE cannot be recommended.

Partial rotator cuff repair with or without superior capsular reconstruction (SCR)

Patients with irreparable rotator cuff tears have a discontinuity in the superior capsule. This defect causes a change in forces across the joint with disruption of the rotator cuff–deltoid force couple, resulting in compensatory deltoid forces and superior migration of the humeral head. This causes significantly decreased glenohumeral compression force and increased subacromial contact pressure (15). Patients also have instability in the remaining capsule. Ishihara *et al.* described in a cadaveric study that massive cuff tears result in not only superior instability but also anterior–posterior capsular instability (16). A recent cadaveric study by Rybalko *et al.* found that superior capsular reconstruction (SCR) significantly decreased superior migration by 72 and 64% at 0° and 30° of abduction, respectively, compared with a full-thickness tear, largely re-centring the humeral head (17). The graft effectively functions as a spacer by shifting the humerus inferiorly and decreasing subacromial pressure. This is also thought to be associated with the reduction in shoulder pain post-SCR.

Multiple studies have supported the use of superior capsular reconstruction in the treatment of rotator cuff tears; however, only two were identified that assessed its use in true pseudoparalysis (15, 18, 19, 20). Mihata *et al.* assessed 88 patients with rotator cuff tears, all of whom were treated with arthroscopic SCR using fascia lata autografts (21). The patients were allocated to three groups: (a) no AFE pseudoparesis (45 patients), (b) moderate AFE pseudoparesis (28 patients) and (c) severe AFE pseudoparesis (15 patients). The authors used the term 'pseudoparalysis' which they defined as AFE <90° and classified as severe if patients were unable to maintain forward elevation >90° after passive elevation. The mean time to final follow-up was 60 months (range: 35–110 months). Around 95% of patients with pseudoparesis significantly improved their range of AFE from 54.3° preoperatively to 146.8° postoperatively in the moderate group ($P < 0.001$) and from 36.7° preoperatively to 150° postoperatively in the severe group ($P < 0.001$). ASES scores also improved significantly from 29.2 preoperatively to 92.2 postoperatively in the moderate group ($P < 0.001$) and from 20.3 preoperatively to 91.8 postoperatively in the severe group ($P < 0.001$). The two patients who failed to improve both had graft tears. This study provides the

best evidence for the use of SCR in pseudoparesis. This study uses fascia lata autografts, but as the technique has become popularised, there has been a shift towards using dermal allografts for which the evidence is lacking.

Burkhart *et al.* performed a retrospective study on ten patients who underwent SCR with human dermal allograft for massive rotator cuff tears with profound pseudoparesis (Fig. 1) (19). Massive rotator cuff tear was defined as two tendons fully torn or tear dimension >5 cm and profound pseudoparesis was defined as AFE <45°, which is closer to our definition of true pseudoparalysis than other studies discussed in this section. The mean age of patients was 69 years and the average follow-up period was 12.9 months. AFE significantly improved from 27° preoperatively to 159° postoperatively ($P < 0.0001$). ASES scores also improved significantly from 52 preoperatively to 89 postoperatively ($P < 0.0002$). The main limitations of this study were the small cohort size and short follow-up period.

A study by Pennington *et al.* (22) in 2018 investigated the use of SCR in massive irreparable cuff tears. Their retrospective case review of 86 patients, with an average age of 59 years and massive rotator cuff tears (defined as greater than 5 cm), suggested that arthroscopic SCR with acellular dermal allograft has been successful in decreasing pain and improving function in these patients, with an overall 90% patient satisfaction rate. There were significant improvements in the range of motion for AFE and abduction of 120° and 103° preoperatively to 160° and 159°, respectively, at 1 year. Shoulder strength also significantly improved (forward flexion: 4.8–9.8 pounds; abduction: 4.1–9.2 pounds and external rotation: 7.7–12.3 pounds) ($P = 0.0005$, $P = 0.01$ and $P = 0.02$, respectively), with no significant difference found between the operative and non-operative limbs. Although this study did not isolate the outcomes for patients with pseudoparesis or pseudoparalysis, they did include patients with AFE as low as 10°. The results for the treatment of massive cuff tears, especially the improvements in the range of motion, are promising and warrant further investigation in patients with pseudoparesis.

A prospective study by Greiner *et al.* conducted in 2021 compared patients undergoing partial infraspinatus repair of the residual cuff with those undergoing SCR for massive irreparable rotator cuff tears (23). There was no significant difference in CMS score between the partial repair and SCR groups, concluding that both are viable options. However, none of the included patients demonstrated pseudoparesis or pseudoparalysis and, in fact, pseudoparesis was listed as a contraindication for partial repair and SCR.

Techniques have been proposed that incorporate the long head of biceps in arthroscopic superior capsular reconstruction to avoid autograft harvest site concerns or the use of expensive allograft (Fig. 2). The intact long head of biceps tendon is released from the bicipital groove by releasing the transverse humeral ligament and anchored onto the superior aspect of the humeral head. The transposed biceps tendon adds live supplemental tissue to rotator cuff repair constructs. It is also suggested that it provides additional structural support and serves a stabilising role for the superior capsule because the biceps tendon is securely fixed both to the superior glenoid, owing to its native attachment, and to the superior humeral head. In two cadaveric biomechanical studies comparing superior capsular reconstruction with traditional tensor fascia lata (TFL) graft, they found statistically insignificant differences in stability between the two groups, suggesting that SCR using the long head of biceps technique is biomechanically equivalent to using a TFL autograft (24, 25). However, these were only small volume cadaveric studies and there are limited studies reporting on patient outcomes or use in pseudoparalysis.

These studies suggest that SCR may be effective at reversing pseudoparesis, and perhaps even pseudoparalysis, in patients with massive rotator cuff tears without glenohumeral arthritis. However, there is little evidence on the long-term outcomes of these patients, particularly with the newer graft types and techniques. Further evidence with large well-powered studies is required to support these early promising results.

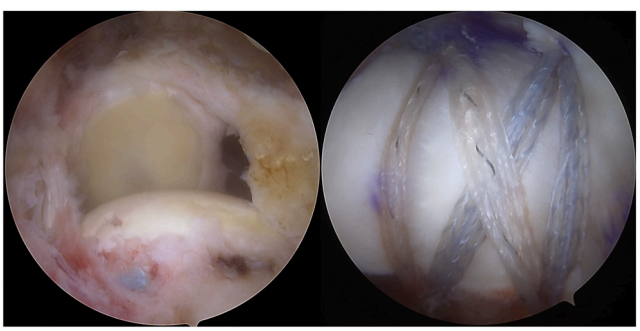

Figure 1
Massive superior cuff tear treated with dermal allograft SCR.

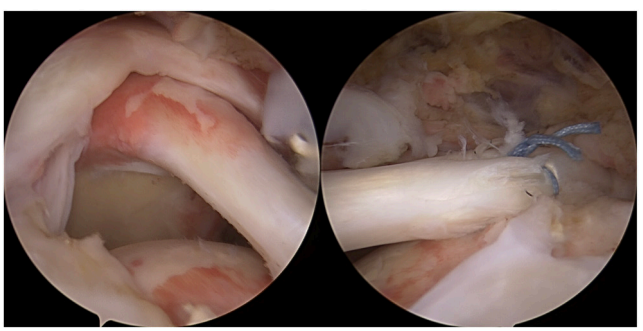

Figure 2
Biceps tenodesed to greater tuberosity to act as SCR.

Isolated biceps tenotomy or tenodesis

Walch *et al.* (26) and Boileau *et al.* (27) have both investigated the use of isolated biceps tenotomy or tenodesis in those with rotator cuff tears. However, only Boileau *et al.* assessed patients with AFE pseudoparesis and neither looked at patients matching our definition of AFE pseudoparalysis.

In the study by Boileau *et al.*, they investigated 68 patients with a total of 72 irreparable cuff tears; 39 of whom were managed with biceps tenotomies and 33 with tenodesis (27). They found that it was a valuable option for the treatment of irreparable and degenerative rotator cuff tears in elderly patients in terms of pain reduction and patient satisfaction, with a mean CMS score improvement from 46.3 to 66.5 ($P < 0.001$). They highlighted three patients preoperatively who matched our definition of pseudoparesis, all of whom had CMS scores <65 postoperatively (considered failure of surgery) and had no improvement in the range of motion. This led the authors to conclude that isolated tenotomy or tenodesis is contraindicated in the setting of true pseudoparesis.

Given the results of this study, isolated biceps tenotomy is likely of little benefit in the setting of either true pseudoparesis or pseudoparalysis (i.e. not caused by pain), but further evidence is needed on this point.

Tendon transfer

The use of tendon transfers can be considered in younger patients to improve rotation if the rotator cuff tear is irreparable (28). There is limited evidence for using tendon transfers in AFE pseudoparesis or pseudoparalysis due to their limited effect on abduction and elevation. The primary transfer used is the latissimus dorsi (LD) tendon to the greater tuberosity, thereby allowing the muscle's internal rotator force to convert to an external rotator force and providing a better balance between these opposing forces (Fig. 3). There have been several publications outlining its use and potential benefits in the restoration of external rotation for patients.

Iannotti *et al.* published findings investigating factors affecting the outcomes of patients who underwent LD tendon transfer for irreparable posterior–superior rotator cuff tears (29). The authors performed 20 LD tendon transfers between 1992 and 1999. They did not specifically look for AFE pseudoparesis but found that five of the seven patients who were dissatisfied with their outcome had AFE <90° prior to surgery. Two of the five patients were even recorded to have a decrease in AFE. However, there were improvements in mean active external rotation (AER), from 23° preoperatively to 32° postoperatively ($P < 0.05$) with the arm by the patient's side. AER was also improved when tested at 90° and in the scapular plane (mean 24° preoperatively to 50° postoperatively, $P < 0.05$). It is difficult to determine if these patients would fall into our definitions of either AER pseudoparesis or pseudoparalysis and the assessment method used was different from our own. Overall, the authors inferred the tendon transfer does not provide enough strength to overcome preoperative AFE pseudoparesis. Therefore, they advised against its use in these patients, warning that there is a risk of making weak muscle function worse.

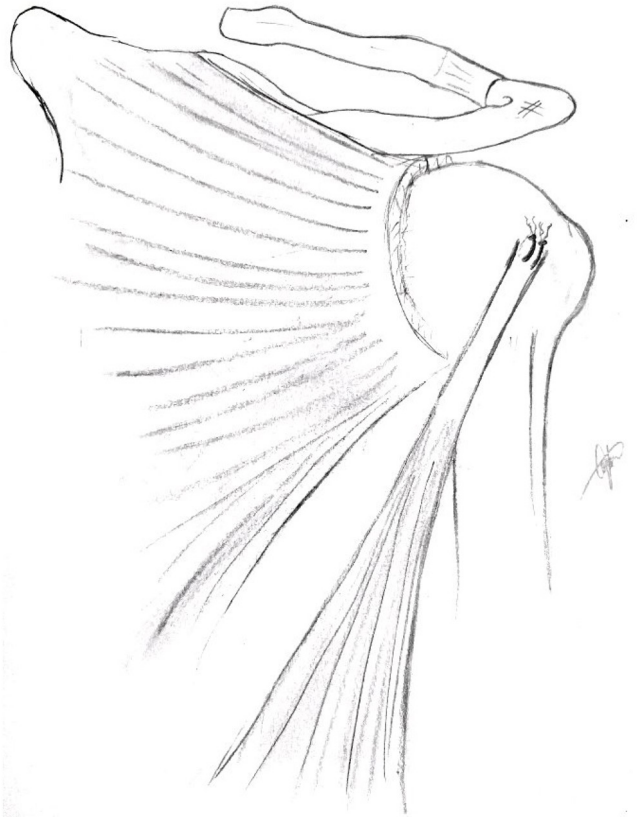

Figure 3
Posterior latissimus dorsi tendon transfer to greater tuberosity for restoration of AER.

This point is refuted by Valenti *et al.* who published results of a retrospective review of 25 consecutive patients who underwent an isolated latissimus dorsi tendon transfer for the treatment of massive irreparable rotator cuff tears with a minimum follow-up of 1 year (30). Twelve of the 25 patients had AFE <80° (mean 67°, range: 30°–80°), thereby meeting our definition of AFE pseudoparesis. Patients with AFE pseudoparesis associated with anterosuperior instability were excluded. Both primary and revision surgeries were included. The 12 patients with AFE <80° recorded an average improvement of 82.5° (mean 149°, range: 80°–180°) at 1 year. This suggests that the prognosis was even better when preoperative AFE was diminished. Limitations of this study were low patient numbers, its retrospective nature and

the poor identification of the exact tendons involved for the pseudoparesis patients.

Interestingly, Gerber who first popularised the LD transfer for the treatment of massive cuff tears (31) has pseudoparesis of anterior elevation or inability to stabilise the arm at 90° of abduction as exclusion criteria for the procedure (32).

Elhassan *et al.* (33) recently published the outcomes of arthroscopically assisted lower trapezius tendon transfer to reconstruct massive irreparable posterior-superior rotator cuff tears (Fig. 4). The theory for using the lower trapezius tendon is that it has a closer synergistic function to the infraspinatus (scapular retraction and external rotation) and a parallel line of pull (34). This theoretically reduces the extent of re-training required. The study included 41 patients with massive rotator cuff tears, of which 19 were deemed to have AFE pseudoparesis. Pseudoparesis in this study was defined as AFE <60° and active abduction <60°. The mean age of patients was 55 years, and all wished to return to being able to complete overhead activities. The average follow-up period was 14 months. AFE significantly improved from 67° preoperatively to 133° postoperatively ($P < 0.001$). However, the authors did not differentiate results for patients with and without pseudoparesis which may pose a limitation to recommendations made by this study. With regards to AER, 75% (31 patients) had external rotation lag signs. Mean lag was −22° but the position and method in which this was recorded were not clearly defined. They did find significant improvements in AER from a mean of 25° (range: −50° to 45°) preoperatively to 47° (10°–70°) postoperatively. This suggests that a proportion of these patients would have fitted into our definition of either AER pseudoparesis or pseudoparalysis and some into the combined loss of elevation and external rotation (CLEER) grade 1 or 2. This study also suggests that lower trapezius transfer may be able to reverse these to a degree, but further investigation is required.

The preponderance of evidence would suggest that LD transfer is not a good option for the treatment of AFE pseudoparalysis. Given the relatively small body of evidence, it is hard to draw strong conclusions regarding the use of lower trapezius transfer. There may be some benefit, but further evaluation is needed with careful patient selection.

In tears involving the anterosuperior cuff, some studies have investigated the use of pectoralis major or minor transfers in the repair of subscapularis (Fig. 5). This is aimed predominantly at restoring internal rotation rather than forward elevation. Wirth *et al.* were the first to describe both the pectoralis minor and major transfers (35). Their study included 13 patients with an average age of 49 (range: 27–86), all of whom had an irreparable injury of the subscapularis muscle. This group of patients was undergoing surgery for recurrent instability; the subscapularis injury was believed to be a contributing factor to the ongoing instability. They reported the outcomes of muscle transfer using the pectoralis major in seven shoulders, the pectoralis minor in five and both in one. Using the grading system of Neer and Foster, the

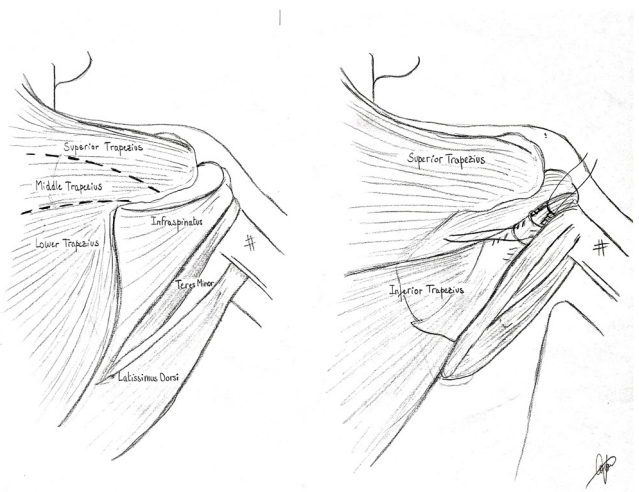

Figure 4
Lower trapezius tendon transfer as per technique by Elhassan *et al.* (33) for restoration of AER. Achilles allograft is attached to the greater tuberosity with suture anchors and then weaved into the lower trapezius tendon using the Pulvertaft technique.

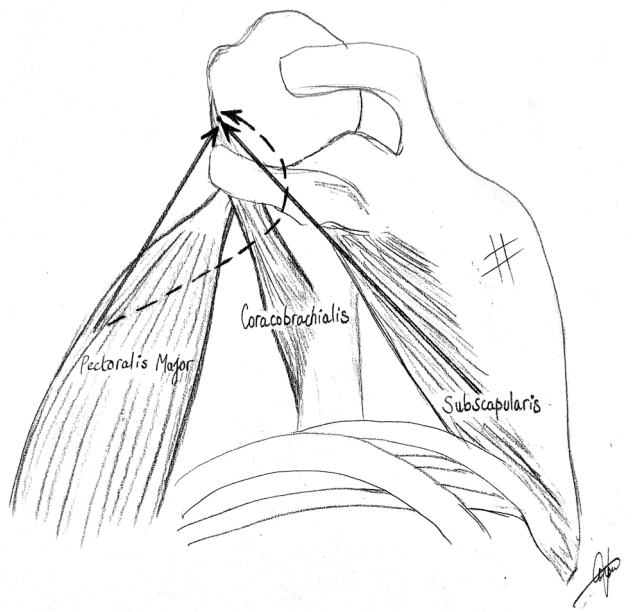

Figure 5
Pectoralis major tendon transfer for restoration of AIR. The pectoralis major can be transferred directly to the footprint of subscapularis (full arrow). It may be re-routed around the conjoint tendon (dotted arrow), to restore a line of traction closer to that of the subscapularis.

result was satisfactory for ten patients and unsatisfactory for three, at a mean of 5 years after the operation.

This technique of repair of subscapularis tendon with pectoralis major was further enhanced by Resch (36). The long-term outcomes were investigated over a 10-year period in a paper by Moroder *et al.* (37). They looked at 27 patients (average age of 62 years; range: 42–74) with irreparable anterosuperior rotator cuff tears, without osteoarthritis or cuff arthropathy treated with partial subcoracoid pectoralis major tendon transfer. They reported significant improvements in CMS scores both at 18 months and at 10 years. The authors reported improvements in the range of motion initially at 18 months follow-up, but interestingly it then decreased slightly at long-term follow-up. They do not give values on the range of motion initially or at 18 months which makes it difficult to assess the degree of improvement. The authors conclude though that range of motion in all planes remained improved from preoperative levels.

Paladini *et al.* described the results of pectoralis minor transfer in 27 patients with irreparable tears of the upper two-thirds of the subscapularis tendon, grade III fatty degeneration and irreparable supraspinatus tears (38). The technique consisted of harvesting the pectoralis minor tendon with a bone block on the medial edge of the coracoid apophysis, re-routing it behind the conjoint tendon and fixing it onto the superior two-thirds of the lesser tubercle of the humerus. They reported significant improvements in functional outcomes, including CMS score (by 41 points, $P < 0.001$) and visual analogue pain scale. Interestingly, AFE improved by 50° from an average of 127°–177° ($P > 0.001$). There was a reduction in AER from a mean of 56° to 45° ($P > 0.001$) postoperatively. An improvement in active internal rotation (AIR) was measured through the CMS score (2 preoperative to 6 post-operative; $P < 0.001$).

The use of LD transfers for irreparable subscapularis tears (Fig. 6) was investigated by Mun *et al.* (39). They looked at 24 patients under the age of 65 years (mean age 58 years) who underwent this procedure using a similar technique to that described by Elhassan *et al.* (33), with the proximal part of the pectoralis major tendon detached from its insertion and the LD tendon separated from teres major and mobilised from its insertion. This was then repaired down to the prepared footprint of subscapularis tendon on the lesser tuberosity of the humerus. Patient recorded outcome measures (CMS, ASES, and pain scores) showed significant improvement. The mean range of motion for AFE increased from 135° to 166° ($P = 0.016$) and AIR improved from L5 to L1 ($P = 0.010$). They recorded no axillary or radial nerve complications postoperatively.

Although these trials do not use the term 'AIR pseudoparalysis' (which is not currently in common usage in the literature), it is likely that given the extent of subscapularis injury, they would come under this definition. Although there is limited evidence due to the small numbers, these studies all present favourable results for the use of tendon transfers in patients with irreparable anterior cuff tears.

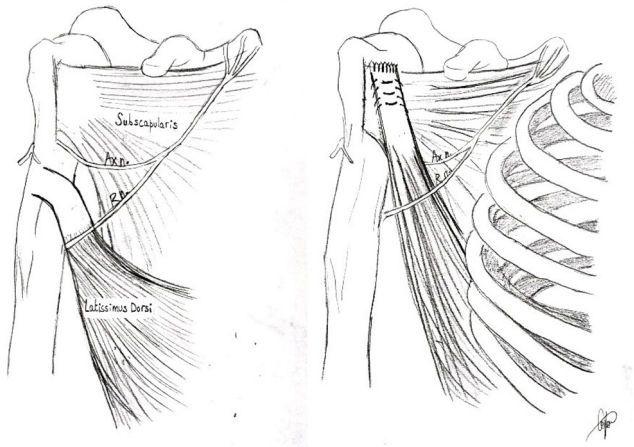

Figure 6
Anterior latissimus dorsi tendon transfer. Before and after diagrams of latissimus dorsi transfer to the footprint of subscapularis tendon for restoration of AIR.

Hemiarthroplasty

Goldberg *et al.* published the results of a 40-patient case series on the use of hemiarthroplasty in massive rotator cuff tears with resultant cuff arthropathy with the aim of investigating long-term outcomes (40). Eighteen out of 40 patients had preoperative AFE <90°. The average follow-up period was 10 years. In patients with AFE <90°, the mean AFE improved to 100° postoperatively and the mean AER improved from 9° preoperatively to 36° postoperatively. Interestingly, only 12 of the 18 patients had satisfactory outcomes when measured against Neer's limited goals criteria.

A study by Leung *et al.* was published in 2012 comparing the use of hemiarthroplasty and reverse shoulder arthroplasty (RSA) in the setting of rotator cuff arthropathy (41). The average preoperative range of AFE was 70° in the hemiarthroplasty group vs 66° in the RSA group (which would meet our criteria for pseudoparesis). However, it is uncertain whether patients who had an AFE >90° were excluded, thereby limiting the study conclusions in the setting of AFE pseudoparesis. Interestingly, their findings were that mean AFE was 58° for the hemiarthroplasty patients and 113° for the RSA patients ($P < 0.001$) at 2 years, suggesting not only that RSA is more effective at improving AFE but that on average the hemiarthroplasty patients had reduced range over this time period. Outcome scores were also significantly worse in the hemiarthroplasty group. This study did have several

limitations, including failing to define pseudoparesis or pseudoparalysis, using a different time period for surgery (RSA group more recent – with likely improvements in general medical care and rehabilitation) and being retrospective in nature.

Given the poor results of patients with pseudoparesis or pseudoparalysis treated with hemiarthroplasty compared to RSA, most surgeons have moved towards using RSA when arthroplasty is indicated in the setting of pseudoparalysis.

Reverse total shoulder arthroplasty without tendon transfer

The main factors leading to a decision to perform an RSA in the setting of pseudoparesis or pseudoparalysis are the presence of glenohumeral arthritis, shoulder instability and that the tear is irreparable (42). This treatment was generally reserved for more elderly patients, but is being increasingly used in younger patients.

Mulieri *et al.* conducted a retrospective study on 69 patients (72 shoulders) that underwent RSA for a massive irreparable rotator cuff tear involving at least two tendons and without glenohumeral arthritis (43). The indications for surgery included persistent shoulder pain and shoulder dysfunction despite a minimum of 6 months of non-operative management. All patients included in the end-analysis were followed up for a minimum of 24 months and the average follow-up period was 52 months. AFE significantly improved from 53° preoperatively to 134° postoperatively ($P < 0.0001$) suggesting a good reversal of AFE pseudoparesis in these patients. The mean ASES score improved from 33.3 preoperatively to 75.4 postoperatively ($P < 0.0001$). AIR improved from S1 spinal level to L2 ($P < 0.0001$) and AER from 27° to 51° ($P = 0.001$); however, AER measurement only began part way through the study meaning the previous result was from just 31 patients. The complication rate was 20%, with the most common complication being a failed baseplate (occurring in four patients). One limitation of this study was that implant design and surgical technique changed during the course of the series.

Boileau *et al.* conducted a retrospective multicentre study of RSA in failed rotator cuff repairs (44). There were 42 patients in total, 30 of whom met our definition of AFE pseudoparesis. The study included patients with and without glenohumeral arthritis. The average follow-up period was 50 months. In the patient cohort with AFE pseudoparesis, AFE significantly improved from 56° preoperatively to 123° postoperatively ($P < 0.0001$). The mean CMS score also significantly improved in this cohort from 18.7 preoperatively to 55.8 postoperatively ($P = 0.002$). It is interesting to note that the patient cohort without pseudoparesis had a significant reduction in AFE postoperatively. There was no significant difference between both AER and AIR pre- or postoperatively across the whole patient cohort.

Ernstbrunner *et al.* (45) conducted a systematic review to evaluate the long-term outcomes of RSA for massive irreparable rotator cuff tears. The absence of glenohumeral arthritis was not an inclusion requirement and indeed 40% of patients had glenohumeral arthritis which would have impacted outcomes. The review evaluated eight studies and covered 365 shoulders. The minimum and average follow-up periods were 5 years and 9.5 years, respectively. Overall, AFE improved from 66° preoperatively to 127° postoperatively ($P < 0.004$) at the latest follow-up. The mean CMS score improved from 24 preoperatively to 59 postoperatively ($P < 0.004$) at the latest follow-up. Importantly, there was no significant reduction in the range of motion of functional assessment scores over the follow-up period, even in the studies extending to 20 years of follow-up. This review again supports the use of RSA to reverse AFE pseudoparesis.

Sevivas *et al.* (46) also performed a systematic review of RSA in massive irreparable rotator cuff tears but with a shorter follow-up period and a requirement that patients should not have glenohumeral arthritis. The review evaluated six studies and covered 266 shoulders. The minimum and average follow-up periods were 34 and 47.4 months, respectively. The review noted that there was significant heterogeneity between studies but did detect an overall improvement in AFE, shoulder pain and shoulder function.

All these studies support the use of RSA for patients with pseudoparesis and pseudoparalysis. Concerns about the longevity of the prosthesis have traditionally reserved this option for older patients or those with no other surgical options.

Reverse total shoulder arthroplasty with tendon transfer

Patients who present with CLEER present a more challenging problem than simple AFE pseudoparesis.

Boileau *et al.* posited that patients with massive irreparable rotator cuff tears can be separated into three groups: isolated loss of AFE (muscular imbalance in the vertical plane), isolated loss of AER (muscular imbalance in the horizontal plane) and CLEER (muscular imbalance in both planes) (47). They studied 17 patients with CLEER to assess whether an LD and teres major transfer (L'Episcopo) with a simultaneous RSA would improve AFE pseudoparesis and AER pseudoparesis by correcting shoulder balance in the vertical and horizontal planes, respectively (Fig. 7). AFE significantly improved from 74° preoperatively to 149° postoperatively ($P < 0.005$) and AER improved from −21° preoperatively to 13° postoperatively ($P < 0.005$). However, there was a negative impact on AIR which decreased from 6° preoperatively to 2° postoperatively

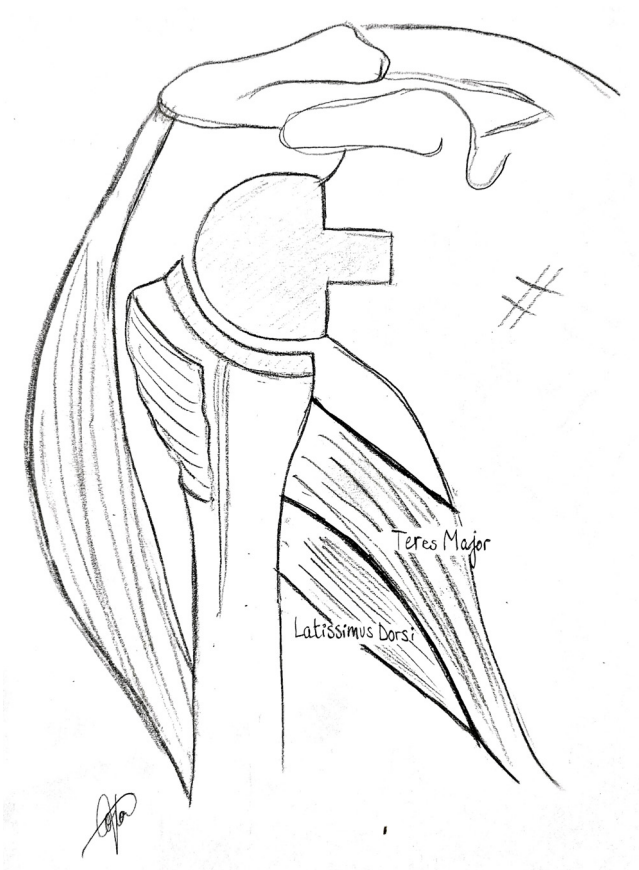

Figure 7
L'Episcopo with RSA for patients with CLEER.

($P < 0.005$). The mean CMS score improved from 27 preoperatively to 62 postoperatively, with the most impact on the mobility component of the score. A clear limitation of this study is the small patient cohort.

Berglund *et al.*, however, questioned whether a tendon transfer was necessary (48). They defined patients with CLEER as a combined loss of AFE with AER, specifying AER as <0° (however, not specifying whether AER was tested in 20° of abduction as per our part I definition of AER pseudoparesis). They demonstrated that RSA alone using a lateralised glenoid could restore AER pseudoparesis from −21° to 27° ($P < 0.001$) in a series of 24 patients with CLEER. This was further supported by evidence from Boutsiadis *et al.* who retrospectively investigated 46 patients who underwent RSA for cuff tear arthropathy comparing radiographic and functional outcomes of patients that had bony increased offset reverse shoulder arthroplasty (BIO-RSA) glenoid augmentation against those that did not, and also comparing the outcomes from the design of stem inclination of either 145 or 155° (49). They found that those with a lateralised centre of rotation had better functional outcomes with improved AER and AFE pseudoparesis.

Young *et al.* conducted a prospective study randomising 28 patients with CLEER to a RSA either with or without latissimus dorsi and teres minor tendon transfer (50). Sixteen patients were randomised to the treatment group and 12 patients were randomised to the control group. CLEER was defined as AFE <110° (AFE pseudoparesis), a positive hornblower sign on physical examination and teres minor fatty infiltration of grade 2 or higher on MRI using a combined Goutallier, Patte and Warner classification. The follow-up period ranged from 2 to 3.25 years. The authors found no significant difference in AFE or AER between the groups. Similarly, there was no significant difference in the functional outcome scores used, including American Shoulder and Elbow Score (ASES) and Disabilities of Arm, Shoulder and Hand (DASH) scores, at any of the post-operative check-points. A hornblower sign could be reversed in 73% of cases in the RSA with transfer group and in 58% in the RSA alone group. The authors drew the conclusion that RSA with or without transfer improved the Activities of Daily Living requiring External Rotation (ADLER) score significantly. Looking at the mean preoperative ADLER score for both groups, it is remarkable that the preoperative mean ADLER score measured 17 points for both groups compared to the patients in Boileau's study with a mean ADLER score of 7. It seems that Boileau's patients had a more severe form of CLEER preoperatively, perhaps in keeping with our definition of CLEER-2 in part 1, with AER pseudoparalysis rather than pseudoparesis.

It is also possible to do a staged tendon transfer after RSA, if it is not performing well. Puskas *et al.* (51) published their findings of staged LD transfer in ten patients who were dissatisfied following primary RSA due to poor range of motion. The study focused predominantly on the improvement of AER but did also record outcomes for AFE and abduction. Four patients had LD transfer by the technique described by Gerber *et al.* (19) using dual incisions through the deltopectoral approach from the previous RSA and an additional posterior axillary approach. The other six subsequently had tendon transfers via the single deltopectoral approach using the L'Episcopo technique. They found that AFE and abduction that had already increased after RSA increased further after LD transfer from 86° (range: 10°–140˚) to 109° (range: 70°–140°) for flexion ($P = 0.017$) and from 80° (range: 40°–130°) to 92° (range: 50°–130°) for abduction ($P = 0.039$). AER with the arm at the side decreased in this selected patient collective from 0° (range: −80 to 50°) to −18° (range: −50 to 10°) after RSA and significantly increased to 2° (−40° to 40°) after LD transfer ($P = 0.024$). They also recorded improvements in CMS score, but non-significant, between performing the RSA and the tendon transfer. This suggests the tendon transfer may have a role in improving the range of motion for patients with persisting AFE

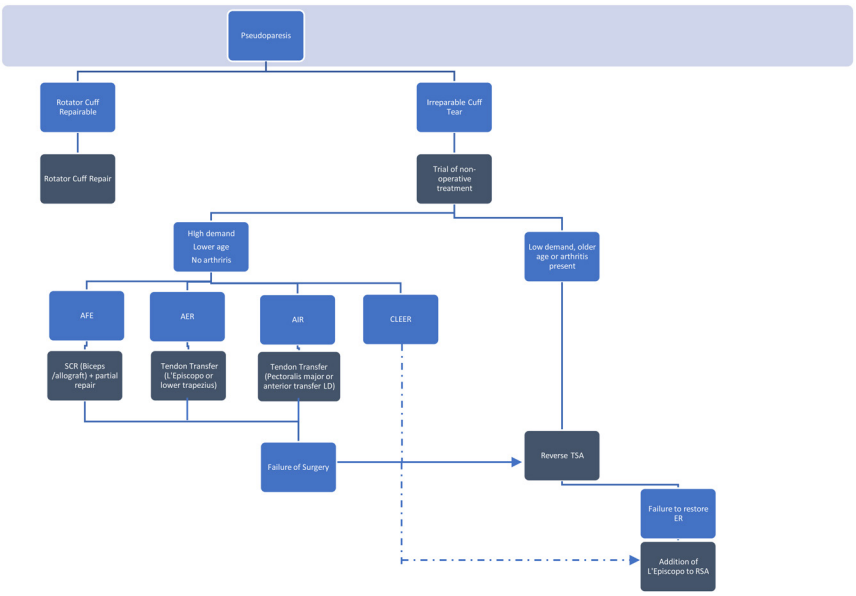

Figure 8
Management flow chart.

pseudoparesis or indeed worsening AER pseudoparesis or reduced range of motion (ROM) following RSA. However, this study was significantly limited by very small study numbers and the change in technique mid-way through the study.

Given the findings of these trials, we recommend performing RSA with a lateralised glenoid for patients presenting with CLEER-1 and with the addition of latissimus dorsi ± teres major transfer in patients with CLEER-2. In patients in whom a tendon transfer is not performed and who are not satisfied with post-operative AER, it is reasonable to do a staged tendon transfer.

Conclusion

The management of pseudoparesis and pseudoparalysis is complex with multifactorial considerations. The bulk of evidence is surrounding AFE pseudoparesis, with far fewer studies investigating true AFE pseudoparalysis or limitations in AER or AIR. History and examination findings with careful assessment of functional deficits are key to diagnosis and guiding radiological investigations. Part 1 of this review discussed in detail the diagnosis, pathology and biomechanics of pseudoparalysis. In particular, the surgeon needs to exclude pain as a cause of the functional deficit, for it to be true pseudoparalysis or pseudoparesis. Using the evidence synthesised in this review, the authors have devised a broad treatment algorithm to help guide management options based on defined circumstances (Fig. 8). As there is very limited evidence for the treatment of true pseudoparalysis, the algorithm should be used in the treatment of pseudoparesis. We would advise a high degree of caution when undertaking joint-preserving procedures in patients with pseudoparalysis as they are likely to have poorer outcomes. In patients with pseudoparalysis, the surgeon should have a lower threshold to proceed to RSA. In patients with CLEER-2, we would recommend the addition of a L'Episcopo transfer.

The first branch in the algorithm is based on the characteristics of the cuff tear, to determine whether it can be repaired. Whether a tear is repairable is based on the location, chronicity, degree of retraction (preferably Patte <3) and the presence of fatty atrophy (preferably Goutallier <3). It may also be surgeon-dependent, with experienced surgeons reporting good results with even 50–75% fatty infiltration (12).

Patient-specific factors and goals of treatment are paramount when deciding on the appropriate management strategy. The use of this flow chart is designed to aid the clinician with the management options available and their indications, but as with any treatment algorithm, it should not supplant rigorous clinical assessment and individualised decision-making.

ICMJE Conflict of Interest Statement
The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of this study.

Funding Statement
This work did not receive any specific grant from any funding agency in the public, commercial, or not-for-profit sector.

References

1. Bauer S, Okamoto T, Babic SM, Coward JC, Coron CMPL & Blakeney WG Understanding shoulder pseudoparalysis. Part I: Definition to diagnosis. EFORT Open Reviews 7. (https://doi.org/10.1530/EOR-21-0069)

2. Collin PG, Gain S, Huu FN & Lädermann A. Is rehabilitation effective in massive rotator cuff tears? *Orthopaedics and Traumatology, Surgery and Research* 2015 **101** (Supplement 4) S203–S205. (https://doi.org/10.1016/j.otsr.2015.03.001)

3. Levy O, Mullett H, Roberts S & Copeland S. The role of anterior deltoid reeducation in patients with massive irreparable degenerative rotator cuff tears. *Journal of Shoulder and Elbow Surgery* 2008 **17** 863–870. (https://doi.org/10.1016/j.jse.2008.04.005)

4. Agout C, Berhouet J, Spiry C, Bonnevialle N, Joudet T, Favard L & French Arthroscopic Society. Functional outcomes after non-operative treatment of irreparable massive rotator cuff tears: prospective multicenter study in 68 patients. *Orthopaedics and Traumatology, Surgery and Research* 2018 **104** S189–S192.

5. Gutiérrez-Espinoza H, Arriagada-Núñez V, Araya-Quintanilla F, Zavala-González J, Rubio-Oyarzún D, Sfeir-Castro R & Gana-Hervias G. Physical therapy in patients over 60 years of age with a massive and irreparable rotator cuff tear: a case series. *Journal of Physical Therapy Science* 2018 **30** 1126–1130. (https://doi.org/10.1589/jpts.30.1126)

6. Ainsworth R. Physiotherapy rehabilitation in patients with massive, irreparable rotator cuff tears. *Musculoskeletal Care* 2006 **4** 140–151. (https://doi.org/10.1002/msc.85)

7. Christensen BH, Andersen KS, Rasmussen S, Andreasen EL, Nielsen LM & Jensen SL. Enhanced function and quality of life following 5 months of exercise therapy for patients with irreparable rotator cuff tears – an intervention study. *BMC Musculoskeletal Disorders* 2016 **17** 1–8.

8. Shepet KH, Liechti DJ & Kuhn JE. Nonoperative treatment of chronic, massive irreparable rotator cuff tears: a systematic review with synthesis of a standardized rehabilitation protocol. *Journal of Shoulder and Elbow Surgery* 2021 **30** 1431–1444. (https://doi.org/10.1016/j.jse.2020.11.002)

9. Novi M, Kumar A, Paladini P, Porcellini G & Merolla G. Irreparable rotator cuff tears: challenges and solutions. *Orthopedic Research and Reviews* 2018 **10** 93–103. (https://doi.org/10.2147/ORR.S151259)

10. Burkhart SS, Barth JR, Richards DP, Zlatkin MB & Larsen M. Arthroscopic repair of massive rotator cuff tears with stage 3 and 4 fatty degeneration. *Arthroscopy* 2007 **23** 347–354. (https://doi.org/10.1016/j.arthro.2006.12.012)

11. Kany J. Tendon transfers in rotator-cuff surgery. *Orthopaedics and Traumatology, Surgery and Research* 2020 **106** (Supplement 1) S43–S51. (https://doi.org/10.1016/j.otsr.2019.05.023)

12. Burnier M, Elhassan BT & Sanchez-Sotelo J. Surgical management of irreparable rotator cuff tears: what works, what does not, and what is coming. *Journal of Bone and Joint Surgery: American Volume* 2019 **101** 1603–1612. (https://doi.org/10.2106/JBJS.18.01392)

13. Denard PJ, Lädermann A, Jiwani AZ & Burkhart SS. Functional outcome after arthroscopic repair of massive rotator cuff tears in individuals with pseudoparalysis. *Arthroscopy* 2012 **28** 1214–1219. (https://doi.org/10.1016/j.arthro.2012.02.026)

14. Oh JH, Kim SH, Shin SH, Chung SW, Kim JY, Kim SH & Kim SJ. Outcome of rotator cuff repair in large-to-massive tear with pseudoparalysis: a comparative study with propensity score matching. *American Journal of Sports Medicine* 2011 **39** 1413–1420. (https://doi.org/10.1177/0363546511399865)

15. Mihata T, McGarry MH, Pirolo JM, Kinoshita M & Lee TQ. Superior capsule reconstruction to restore superior stability in irreparable rotator cuff tears: a biomechanical cadaveric study. *American Journal of Sports Medicine* 2012 **40** 2248–2255. (https://doi.org/10.1177/0363546512456195)

16. Ishihara Y, Mihata T, Tamboli M, Nguyen L, Park KJ, McGarry MH, Takai S & Lee TQ. Role of the superior shoulder capsule in passive stability of the glenohumeral joint. *Journal of Shoulder and Elbow Surgery* 2014 **23** 642–648. (https://doi.org/10.1016/j.jse.2013.09.025)

17. Rybalko D, Bobko A, Amirouche F, Peresada D, Hussain A, Patetta M, Sood A, Koh J & Goldberg B. Biomechanical effects of superior capsular reconstruction in a rotator cuff–deficient shoulder: a cadaveric study. *Journal of Shoulder and Elbow Surgery* 2020 **29** 1959–1966. (https://doi.org/10.1016/j.jse.2020.03.007)

18. Altintas B, Scheidt M, Kremser V, Boykin R, Bhatia S, Sajadi KR, Mair S & Millett PJ. Superior capsule reconstruction for irreparable massive rotator cuff tears: does it make sense? A systematic review of early clinical evidence. *American Journal of Sports Medicine* 2020 **48** 3365–3375. (https://doi.org/10.1177/0363546520904378)

19. Burkhart SS & Hartzler RU. Superior capsular reconstruction reverses profound pseudoparalysis in patients with irreparable rotator cuff tears and minimal or no glenohumeral arthritis. *Arthroscopy* 2019 **35** 22–28. (https://doi.org/10.1016/j.arthro.2018.07.023)

20. Cvetanovich GL, Waterman BR, Verma NN & Romeo AA. Management of the irreparable rotator cuff tear. *Journal of the American Academy of Orthopaedic Surgeons* 2019 **27** 909–917.

21. Mihata T, Lee TQ, Hasegawa A, Kawakami T, Fukunishi K, Fujisawa Y, Itami Y, Ohue M & Neo M. Arthroscopic superior capsule reconstruction can eliminate pseudoparalysis in patients with irreparable rotator cuff tears. *American Journal of Sports Medicine* 2018 **46** 2707–2716. (https://doi.org/10.1177/0363546518786489)

22. Pennington WT, Bartz BA, Pauli JM, Walker CE & Schmidt W. Arthroscopic superior capsular reconstruction with acellular dermal allograft for the treatment of massive irreparable rotator cuff tears: short-term clinical outcomes and the radiographic parameter of superior capsular distance. *Arthroscopy* 2018 **34** 1764–1773. (https://doi.org/10.1016/j.arthro.2018.01.009)

23. Greiner S, Kaeaeb M, Voss A, Lawton R, Bhide P & Achenbach L. Comparison of superior capsular reconstruction and partial infraspinatus repair: a matched-pair analysis of irreparable rotator cuff tears. *Orthopaedic Journal of Sports Medicine* 2021 **9** 2325967120984264. (https://doi.org/10.1177/2325967120984264)

24. El-Shaar R, Soin S, Nicandri G, Maloney M & Voloshin I. Superior capsular reconstruction with a long head of the biceps tendon autograft: a cadaveric study. *Orthopaedic Journal of Sports Medicine* 2018 **6** 2325967118785365. (https://doi.org/10.1177/2325967118785365)

25. Han F, Kong CH, Hasan MY, Ramruttun AK & Kumar VP. Superior capsular reconstruction for irreparable supraspinatus tendon tears using the long head of biceps: a biomechanical study on cadavers. *Orthopaedics and Traumatology: Surgery and Research* 2019 **105** 257–263. (https://doi.org/10.1016/j.otsr.2018.10.023)

26. Walch G, Edwards TB, Boulahia A, Nové-Josserand L, Neyton L & Szabo I. Arthroscopic tenotomy of the long head of the biceps in the treatment of rotator cuff tears: clinical and radiographic results of 307 cases. *Journal of Shoulder and Elbow Surgery* 2005 **14** 238–246. (https://doi.org/10.1016/j.jse.2004.07.008)

27. Boileau P, Baqué F, Valerio L, Ahrens P, Chuinard C & Trojani C. Isolated arthroscopic biceps tenotomy or tenodesis improves symptoms in patients with massive irreparable rotator cuff tears. *Journal of Bone and Joint Surgery: American Volume* 2007 **89** 747–757. (https://doi.org/10.2106/JBJS.E.01097)

28. Lädermann A, Denard PJ & Collin P. Massive rotator cuff tears: definition and treatment. *International Orthopaedics* 2015 **39** 2403–2414. (https://doi.org/10.1007/s00264-015-2796-5)

29. Iannotti JP, Hennigan S, Herzog R, Kella S, Kelley M, Leggin B & Williams GR. Latissimus dorsi tendon transfer for irreparable posterosuperior rotator cuff tears: factors affecting outcome. *Journal of Bone and Joint Surgery: American Volume* 2006 **88** 342–348. (https://doi.org/10.2106/JBJS.D.02996)

30. Valenti P, Kalouche I, Diaz LC, Kaouar A & Kilinc A. Results of latissimus dorsi tendon transfer in primary or salvage reconstruction of irreparable rotator cuff tears. *Orthopaedics and Traumatology, Surgery and Research* 2010 **96** 133–138. (https://doi.org/10.1016/j.rcot.2010.02.018)

31. Gerber C, Vinh TS, Hertel R & Hess CW. Latissimus dorsi transfer for the treatment of massive tears of the rotator cuff. A preliminary report. *Clinical Orthopaedics and Related Research* 1988 **232** 51–61. (https://doi.org/10.1097/00003086-198807000-00008)

32. Gerber C, Rahm SA, Catanzaro S, Farshad M & Moor BK. Latissimus dorsi tendon transfer for treatment of irreparable posterosuperior rotator cuff tears: long-term results at a minimum follow-up of ten years. *Journal of Bone and Joint Surgery: American Volume* 2013 **95** 1920–1926. (https://doi.org/10.2106/JBJS.M.00122)

33. Elhassan BT, Sanchez-Sotelo J & Wagner ER. Outcome of arthroscopically assisted lower trapezius transfer to reconstruct massive irreparable posterior-superior rotator cuff tears. *Journal of Shoulder and Elbow Surgery* 2020 **29** 2135–2142. (https://doi.org/10.1016/j.jse.2020.02.018)

34. Clouette J, Leroux T, Shanmugaraj A, Khan M, Gohal C, Veillette C, Henry P & Paul RA. The lower trapezius transfer: a systematic review of biomechanical data, techniques, and clinical outcomes. *Journal of Shoulder and Elbow Surgery* 2020 **29** 1505–1512. (https://doi.org/10.1016/j.jse.2019.12.019)

35. Wirth MA & Rockwood Jr CA. Operative treatment of irreparable rupture of the subscapularis. *Journal of Bone and Joint Surgery: American Volume* 1997 **79** 722–731. (https://doi.org/10.2106/00004623-199705000-00012)

36. Resch H, Povacz P, Ritter E & Matschi W. Transfer of the pectoralis major muscle for the treatment of irreparable rupture of the subscapularis tendon. *Journal of Bone and Joint Surgery: American Volume* 2000 **82** 372–382. (https://doi.org/10.2106/00004623-200003000-00008)

37. Moroder P, Schulz E, Mitterer M, Plachel F, Resch H & Lederer S. Long-term outcome after pectoralis major transfer for irreparable anterosuperior rotator cuff tears. *Journal of Bone and Joint Surgery: American Volume* 2017 **99** 239–245. (https://doi.org/10.2106/JBJS.16.00485)

38. Paladini P, Campi F, Merolla G, Pellegrini A & Porcellini G. Pectoralis minor tendon transfer for irreparable anterosuperior cuff tears. *Journal of Shoulder and Elbow Surgery* 2013 **22** e1–e5. (https://doi.org/10.1016/j.jse.2012.12.030)

39. Mun SW, Kim JY, Yi SH & Baek CH. Latissimus dorsi transfer for irreparable subscapularis tendon tears. *Journal of Shoulder and Elbow Surgery* 2018 **27** 1057–1064. (https://doi.org/10.1016/j.jse.2017.11.022)

40. Goldberg SS, Bell JE, Kim HJ, Bak SF, Levine WN & Bigliani LU. Hemiarthroplasty for the rotator cuff-deficient shoulder. *Journal of Bone and Joint Surgery: American Volume* 2008 **90** 554–559. (https://doi.org/10.2106/JBJS.F.01029)

41. Leung B, Horodyski M, Struk AM & Wright TW. Functional outcome of hemiarthroplasty compared with reverse total shoulder arthroplasty in the treatment of rotator cuff tear arthropathy. *Journal of Shoulder and Elbow Surgery* 2012 **21** 319–323. (https://doi.org/10.1016/j.jse.2011.05.023)

42. Harreld KL, Puskas BL & Frankle M. Massive rotator cuff tears without arthropathy: when to consider reverse shoulder arthroplasty. *Journal of Bone and Joint Surgery: American Volume* 2011 **93** 973–984.

43. Mulieri P, Dunning P, Klein S, Pupello D & Frankle M. Reverse shoulder arthroplasty for the treatment of irreparable rotator cuff tear without glenohumeral arthritis. *Journal of Bone and Joint Surgery: American Volume* 2010 **92** 2544–2556. (https://doi.org/10.2106/JBJS.I.00912)

44. Boileau P, Gonzalez JF, Chuinard C, Bicknell R & Walch G. Reverse total shoulder arthroplasty after failed rotator cuff surgery. *Journal of Shoulder and Elbow Surgery* 2009 **18** 600–606. (https://doi.org/10.1016/j.jse.2009.03.011)

45. Ernstbrunner L, El Nashar R, Favre P, Bouaicha S, Wieser K & Gerber C. Chronic Pseudoparalysis needs to be distinguished from Pseudoparesis: a structural and biomechanical analysis. *American Journal of Sports Medicine* 2021 **49** 291–297. (https://doi.org/10.1177/0363546520969858)

46. Sevivas N, Ferreira N, Andrade R, Moreira P, Portugal R, Alves D, da Silva MV, Sousa N, Salgado AJ & Espregueira-Mendes J. Reverse shoulder arthroplasty for irreparable massive rotator cuff tears: a systematic review with meta-analysis and meta-regression. *Journal of Shoulder and Elbow Surgery* 2017 **26** e265–e277. (https://doi.org/10.1016/j.jse.2017.03.039)

47. Boileau P, Rumian AP & Zumstein MA. Reversed shoulder arthroplasty with modified L'Episcopo for combined loss of active elevation and external rotation. *Journal of Shoulder and Elbow Surgery* 2010 **19** (Supplement 2) 20–30. (https://doi.org/10.1016/j.jse.2009.12.011)

48. Berglund DD, Rosas S, Triplet JJ, Kurowicki J, Horn B & Levy JC. Restoration of external rotation following reverse shoulder arthroplasty without latissimus dorsi transfer. *JB and JS Open Access* 2018 **3** e0054. (https://doi.org/10.2106/JBJS.OA.17.00054)

49. Boutsiadis A, Lenoir H, Denard PJ, Panisset JC, Brossard P, Delsol P, Guichard F & Barth J. The lateralization and distalization shoulder angles are important determinants of clinical outcomes in reverse shoulder arthroplasty. *Journal of Shoulder and Elbow Surgery* 2018 **27** 1226–1234. (https://doi.org/10.1016/j.jse.2018.02.036)

50. Young BL, Connor PM, Schiffern SC, Roberts KM & Hamid N. Reverse shoulder arthroplasty with and without latissimus and teres major transfer for patients with combined loss of elevation and external rotation: a prospective, randomized investigation. *Journal of Shoulder and Elbow Surgery* 2020 **29** 874–881. (https://doi.org/10.1016/j.jse.2019.12.024)

51. Puskas GJ, Germann M, Catanzaro S & Gerber C. Secondary latissimus dorsi transfer after failed reverse total shoulder arthroplasty. *Journal of Shoulder and Elbow Surgery* 2015 **24** e337–e344. (https://doi.org/10.1016/j.jse.2015.05.033)