Understanding shoulder pseudoparalysis: Part I: Definition to diagnosis

Stefan Bauer¹, Taro Okamoto¹, Stephanie M Babic², Jonathon C Coward², Charline M P L Coron¹ and William G Blakeney²

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

Introduction

The definition of the term “shoulder pseudoparalysis” remains controversial among clinicians (1), with regards to the degree and direction of impaired active shoulder motion, chronicity, whether it is traumatic or atraumatic, and whether the loss of active motion is influenced by pain. There is further debate as to the role and indications for specific non-operative and operative treatments. The variety of definitions for pseudoparalysis found in the literature (1, 2, 3, 4) may include additional features that characterize the different syndromes with impaired force couple balance. These syndromes have implications for potential treatment options, which may include physiotherapy, cuff repair, capsular reconstruction, tendon transfers, arthroplasty, or a combination of these options to restore function. The goal of this review was to clarify the definition of pseudoparalysis and pseudoparesis based on the current literature and to delineate the clinical manifestations as well as the underlying anatomical structural lesions and biomechanical rationales for both entities. There is increasing evidence for the theory that the lower subscapularis is a key player for pseudoparalysis (5). A differentiated physical examination and thorough evaluation of imaging modalities are important to reach a clear diagnosis.

Definition

Historically, Rössler as well as Gschwend and Patte used the term ‘pseudoparalysis’ in the 1970s and 1980s to describe limited or absent active shoulder movement associated with rotator cuff tears without neurological impairment (6, 7). In recent years, the most widely used definition of shoulder pseudoparalysis has been active forward elevation (AFE) of less than 90° with preserved passive range of motion (ROM) in the setting of a massive rotator cuff tear without neurological impairment (3). However,
a frequently quoted benchmark article by Gerber’s group described reduced AFE of less than 90° more correctly as pseudoparesis, implying the maintenance of some AFE (2). Some authors therefore recommend defining pseudoparalysis as AFE of less than 45° with preserved passive ROM and chronic onset, without a recent traumatic event (4). In a consensus statement developed by Hawkins, eight international leaders in the field of shoulder surgery defined ‘real pseudoparalysis’ as no active elevation with maintained passive elevation, chronic in nature, and usually with anterior–superior escape with no improvements in active elevation after pain-relieving injections (1).

To consider appropriate management options, it is therefore important to distinguish two conditions of impaired AFE:

1. AFE pseudoparesis as already defined by Gerber’s group (1, 2) (Fig. 1A; massive rotator cuff tear; <90° of active elevation with full passive elevation and no anterior–superior escape; and pain eliminated with local anaesthetic injection).
2. AFE pseudoparalysis (1) (Fig. 1B; massive rotator cuff tear; 0° of active elevation and full passive elevation usually with anterior–superior escape; and pain eliminated with local anaesthetic injection).

For impairment of active external rotation (AER), two conditions must be separated (1):

1. AER pseudoparesis (Fig. 2A and B; tested in 20° of abduction (8); active external rotation (ER) to neutral with full passive ER lagging back to neutral; and pain eliminated with local anaesthetic injection).
2. AER pseudoparalysis (tested in 20° of abduction (8); no active ER with full passive ER lagging back to −40°; and pain eliminated with local anaesthetic injection).

The subscapularis muscle–tendon unit has been identified as a key player for shoulder function and treatment outcomes for non-arthroplasty options (3, 5, 9, 10, 11, 12, 13). There is increasing evidence that the lower half of subscapularis is an important factor for maintaining humeral head centring and force couple balance. The need for isolated grading of impairment of active internal rotation (AIR) is a logical requirement. Two entities should be distinguished:

1. AIR pseudoparesis (tested and measured with a modified belly-press test (10, 14, 15, 16) with wrist flexion of 30°–60° to keep hand contact to the abdomen).
2. AIR pseudoparalysis (Fig. 3; tested and measured with a modified belly-press test (10, 14, 15, 16) with wrist flexion of 90° to keep hand contact to the abdomen).

In patients with irreparable, chronic rotator cuff tears, Boileau (17) classified loss of ER as either isolated (ILER) or

Figure 1
Clinical photographs of patients attempting AFE. (A) Patient with left shoulder massive cuff tear with AFE <90° and (B) massive cuff tear of the right shoulder with no AFE.
Understanding shoulder pseudoparalysis

Combined with loss of AFE (CLEER). This classification was developed after early observations of poorer outcomes of reverse shoulder arthroplasty (RSA) in combined pseudoparalytic syndromes especially with additional loss of ER (18). Treatment of CLEER is currently controversial, with some surgeons suggesting it should be treated with RSA combined with a simultaneous tendon transfer (17, 19, 20) and others suggesting that using a lateralized RSA prosthesis is adequate (21, 22). It is the authors’ opinion and experience that there are patients who still suffer from loss of ER with a “hornblower” and dropping sign despite RSA lateralization (Fig. 4), so perhaps not all CLEER patients are the same. It would seem useful to distinguish CLEER patients into:

1. CLEER grade 1: AFE pseudoparesis or pseudoparalysis + AER pseudoparesis.
2. CLEER grade 2: AFE pseudoparesis or pseudoparalysis + AER pseudoparalysis.

CLEER grading has not been undertaken in any study at present and the Activities of Daily Living and External Rotation score proposed by Boileau has not been further studied, graded, or validated (23, 24). In 2018, Boileau further subclassified pseudoparalytic conditions of massive irreparable cuff tears into four groups (23): painful loss of active elevation (PLEA; group 1), isolated loss of active elevation or pseudoparalysed shoulder (ILEA, group 2),

Figure 2
Clinical photographs of a patient being examined for ER1 lag. Passive ER starting position with shoulder in 20° of abduction (A) demonstrating a lag with end position (B).

Figure 3
Clinical photograph of a belly-press test in AIR pseudoparalysis, belly-off sign: wrist flexion of 70° (A) before the elbow is brought forward by examiner passively, which would increase wrist flexion to 90°. Clinically an antero-superior escape of the humeral head is seen (A). Increased ER of the right shoulder due to complete subscapularis tear (B). Radiographic antero-superior subluxation (C). Soft tissue CT sagittal images demonstrate grade 4 fatty infiltration of subscapularis (D).
isolated loss of external rotation (ILER; group 3), and combined loss of active elevation and external rotation (CLEER; group 4). We recommend the use of painful loss of elevation or rotation (PLER), a term which has not been presented or published before being more comprehensive including reversible loss of rotational movement due to pain.

Pathobiomechanics

The hand is a crucially important sensitive organ and is the motor executive organ of the highest order in humans. Fine motor ability requires complex central nervous interactions and the hand can be considered as the extension of the human brain (25, 26). Therefore, the ability to position the hand in space, 360° around the human body, is of paramount importance for human life and to function with the highest demands on glenohumeral mobility. This is the reason the shoulder is the most unconstrained and mobile joint with a glenoid socket acting more as a platform than a cavity. Stability and shoulder function are therefore dependent on muscle balance, also called ‘force coupling’, centring the resulting force vector towards the centre of the glenoid surface. It can be broken up into horizontal (Fig. 5A) and vertical (Fig. 5B) muscle balance with specific muscles acting as horizontal and external rotators and vertical elevators and depressors (27).

It is evident that these two directions of muscle balance represent a simplification of multidirectional shoulder balance and force coupling. Since there are insufficient static restraints in any direction, 360° around the centre of the glenoid apart from the acromion and coracoacromial arch, which contribute to limiting superior migration of the humeral head as long as sufficient dynamic joint stabilization, is maintained (28). In cuff tear arthropathy (CTA), the acromion can undergo acetabularisation with maintenance of a functional shoulder in early stages. In advanced stages, dynamic stabilization is lost and this instability can lead to antero–superior escape, detensioning of the deltoid, its length is determined by the acromion, the deltoid muscle origin, and punctum fixum. These CTA stages are described by Seebauer's classification, the only biomechanical CTA classification to date which is less commonly used than morphological classifications (28). Advanced stages are often associated with pseudoparalysis.

In the normal functioning shoulder, the forces produced by the rotator cuff cause centring compression of the humeral head across the concave glenoid surface, thereby providing a stable fulcrum for the periscapular muscles and the deltoid to move the humerus relative to the glenoid and the centre of rotation of the joint (29). The rotator cuff also provides countertraction against the cranial pull of the deltoid during attempted elevation (Fig. 4B) (30). The deltoid represents the motor and powerhouse of the glenohumeral joint with a divergent force vector to the sum of the rotator cuff force vectors representing the fine biomechanics to centre the joint. Loss of force couple balance is known to lead to pathological conditions such as instability, eccentric wear, decentered osteoarthritis, and CTA. The pathomechanics of pseudoparesis and pseudoparalysis are thought to be multifactorial (31). When pain as a cause is excluded, the biomechanical basis of pseudoparesis and pseudoparalysis is thought to include insufficient centralisation of the humeral head on the glenoid by the rotator cuff and an antero-superior subluxation of the proximal humerus from the cranially directed pull of the deltoid during attempted elevation (32, 33, 34, 35). Glenohumeral balance and stability is therefore defined as the multifactorial ability to keep the humeral head centred in the glenoid fossa (29). Di Giacomo et al. (36) suggested that dynamic stabilization through muscle contraction and the resulting compression of the articular surfaces is the most important factor in ensuring shoulder stability. Favre and Gerber (37) postulated that the stability of the glenohumeral joint in all possible positions of the humerus can only be achieved by an interplay of the glenohumeral muscles, equilibrating an external force or moment, while at the same time balancing each other's
redundant actions. Superiorly directed forces from the deltoid must be stabilized by the rotator cuff musculature. The biomechanical relationship between the moment arms of these muscles is likely to be a major factor in chronic overloading of the cuff (38). Whether pseudoparesis is clinically seen or not has been shown to depend on the size and location of a rotator cuff tear as well as the degree of tendon involvement. Denard et al. (39) concluded from their series of massive rotator cuff tears that one disruption of the two rotator cuff muscle attachments, either anterior (anterior supraspinatus) or posterior (inferior infraspinatus) is a prerequisite for loss of AFE to 90°. Collin et al. (3) distinguished five rotator cuff muscle–tendon units (separate upper and lower subscapularis unit) and classified them by the involved components: type A, supraspinatus and superior subscapularis tears; type B, supraspinatus and entire subscapularis tears; type C, supraspinatus, superior subscapularis, and infraspinatus tears; type D, supraspinatus and infraspinatus tears; and type E, supraspinatus, infraspinatus, and teres minor tears (Fig. 6A).

They reported that a tear of the entire subscapularis and supraspinatus or the involvement of three tendons are associated with inability to raise the arm to 90°. Looking carefully at the data of this study should also lead to the conclusion that a massive tear either comprising:

1. the entire anterior units (lower and upper subscapularis) + the supraspinatus unit (Fig. 6A, type B),
2. the entire posterior units (teres minor and infraspinatus) + the supraspinatus unit (Fig. 6A, type E), or
3. all three superior units above the equator of the head (infracapitus to upper subscapularis) (Fig. 6A, type C)

is predictive of pseudoparesis.

One can conclude that to prevent pseudoparesis, at least one anterior unit in antero-superior tears, or one posterior unit in posterosuperior tears, or one superior unit in anterior-to-posterior tears above the horizontal equator is needed to provide a rotator cuff fulcrum for rotation powered by the deltoid force. The proximal humerus as a sphere can be separated by horizontal and oblique vertical equators into a superior cuff segment (S), anterior cuff segment (A), and posterior cuff segment (P) (Fig. 6 in blue). Each segment needs at least one functioning muscle–tendon unit to prevent loss of the force couple balance and to provide a rotator cuff fulcrum for rotation powered by the deltoid force. A theory we named ‘the shoulder equator concept’. Wieser et al. (13) and Ernstbrunner et al. (5) confirmed that loss of the inferior subscapularis is the most important predictor for AFE pseudoparesis. This underlines the importance of operative subscapularis tendon repair for prevention.

A fluoroscopic, MRI-controlled study by Wieser et al. (13) further improved the understanding of pseudoparalytic biomechanics demonstrating complete loss of glenohumeral abduction around a centre of rotation in pseudoparesis. Interestingly, patients with very similar bilateral tendon tears often have drastically different capacities for AFE unrelated to pain inhibition. The study showed that a tear involving the ‘subscapularis minor’ (infraspinatus) (40) is the most significant

---

**Figure 5**
Illustration demonstrating anterior (A) and posterior (B) views of the right shoulder with horizontal (A) and vertical (B) muscle balance vectors.
predictive factor for inability to forward flex the arm beyond 90°. A more recent study of the same group (5) refined the impact of impairment of the inferior subscapularis, which lead rather to pseudoparalysis <45° of AFE than to pseudoparesis >45°or <90° of AFE and confirmed the key role of the subscapularis in massive rotator cuff tears and the need for prevention of tear propagation highlighting the importance for repair. The important mechanical role of subscapularis has been pointed out by Gerber in the context of latissimus dorsi transfers (41), by Burkhart et al. reporting their results of rotator cuff repair (9, 10), and Kwano et al. (12) who have shown in a cadaveric study on humeral head translation that subscapularis has the important function of centring the humeral head to provide an anterior inferior check rain. Kwano et al. (12) conclude that propagation of subscapularis tears should be prevented whenever possible.

Figure 6
Illustration demonstrating schematic representation of a sagittal slice of the humeral head with rotator cuff tendons, as per Collin et al. Horizontal and oblique vertical equators in blue demonstrating the equator concept: type B (complete antero–superior (AS) cuff loss), type C (complete superior (S) cuff loss), type E (complete postero–superior (PS) cuff loss) (A), and percentage of pseudoparalysis (B). Reproduced with permission.

To better understand the varying clinical function of patients with similar size, location, and fatty infiltration of massive rotator cuff tears, Bouaicha et al. examined the contribution of the bony anatomy and the moment arms (30). They conducted a study defining the shoulder abduction moment index (SAM index) as the ratio of the radius of the humeral head to the moment arm of the deltoid. The authors concluded that the SAM index plays a determinant role for the presence or absence of pseudoparalysis. Relatively large deltoid moment arms with SAM indices <0.77 showed significantly increased risk of pseudoparalysis subject to limitations of accuracy and reproducibility of the proposed measurements.

Teres minor was for a long time an under-investigated segment of the rotator cuff (42) until the first long-term outcome study on RSA pointed out its importance (18). Although its atrophy and fatty infiltration on CT or MR imaging is rare (43), it has been reported to have an impact on rotator cuff repair and RSA outcomes (44), as well as outcomes of latissimus dorsi tendon transfers (45). As shown by Collin, high-grade fatty infiltration of teres minor in massive rotator cuff tears is associated with both AFE pseudoparalysis and ER pseudoparalysis (3). It can be concluded that teres minor is the key player providing the posterior inferior check rain of the humeral head.

In conclusion, the importance of the inferior subscapularis has been pointed out as an anterior check rain and subscapularis tear propagation should be prevented at all cost (5, 11, 12, 13) to maintain shoulder function and balance. The long-forgotten teres minor seems to have a similar role as the last posterior check rain in large posterior tears. Collin’s data teaches us further that the loss of all superior rotator cuff units inserting above the humeral head equator is predictive for loss of force couple balance.

History and examination
The history should include the duration of inability to lift up or rotate the arm, whether the onset was acute traumatic, chronic progressive, or acute on chronic, and if the loss of function is pain related. From the outset, it is important to know if symptoms are associated with injuries, chronic stiffness, pain of the cervical spine, or neurological deficit of the limb. Problems encountered during activities of daily living (unable to reach above head level, to comb, shave or apply make-up, to hold a telephone, to eat with a spoon, to pour water from a bottle in a glass, to tuck in a shirt, or reach the trousers back pocket) should be recorded. It is important to question the influence of pain eliminating injections and if physiotherapy was conducted appropriately with adequate exercises over a sufficient time. The history should be completed with the relevant
understanding shoulder pseudoparalysis

surgical, rheumatological, and neurological background of the patient.

Examination

Inspection of the anterior, posterior, and superior shoulder girdle with particular attention to the deltoid, trapezius, supraspinatus, infraspinatus, and teres minor atrophy, as well as scapular winging, is the first step of the clinical examination.

A general examination of the sensory and motor function of the affected upper limb is carried out paying attention to C5 (forearm supination and deltoid contraction) and axillary nerve motor function (deltoid contraction during attempted AFE), after passive elevation to 90° and Hertel’s (46) deltoid extension lag test (Fig. 7) since isolated impairment of the C5 nerve root described by Mareddu et al. (47) or isolated motor impairment of the axillary nerve without impairment of sensation can occur and mimic shoulder pseudoparalysis. In the authors’ experience, the sensory assessment of the ‘regiments badge area’ to evaluate the function of the axillary nerve is not reliable and cases of impaired axillary nerve motor function without complaints about loss of sensation have been seen in clinical practice.

Cervical spine

The ROM of the cervical spine is examined with attention to posture, stiffness, and pain at end ROM. A Spurling test is also carried out which is useful to confirm the absence of a cervical radiculopathy with a reported specificity of 93% (48).

Deltoid extension lag (axillary nerve)

A very useful and validated test for deltoid and axillary nerve function, which could also be affected by a C5 nerve root lesion, was described by Hertel (46) as an arm extension lag test (Fig. 7). The patient is asked to sit on a chair. Both arms with extended elbows are maximally extended by the examiner. The patient is asked to hold the position and the lag is recorded in degrees. In case of a positive test, elbow flexion and supination strength examination can be helpful to distinguish from a C5 nerve root lesion.

Active forward elevation

Examination of AFE can be conducted after elimination or reduction of pain by a subacromial local anaesthetic injection into the subacromial space in the setting of a massive cuff tear (1). The patient is asked to slowly elevate the arm maintaining full elbow extension. The degree of AFE and associated anterior–superior humeral escape are recorded (Fig. 1).

Figure 7
Clinical photograph of a patient’s right shoulder being examined demonstrating deltoid extension lag test according to Hertel (46).

Active external rotation and AER lag sign (dropping sign)

Active and passive ER are examined with the arm by the side in 20° of abduction (Fig. 2) as described by Hertel (8). The patient’s elbow is supported before positioning of the arm in maximal passive ER by the examiner. The patient is asked to maintain this position before its release. The ER lag is recorded (lag to neutral or to −40°ER and amount of absolute lag). This is the most accurate test for teres minor dysfunction if a lag of more than 40° is found (49, 50). The test needs to be interpreted with care if a subscapularis lesion with increased external rotation and no firm end point is suspected (Fig. 3).

Hornblower sign

The second test is a modification of the Hornblower sign test described by Walch (50). The arm is brought into passive flexion to 90° and passive ER with the forearm reaching a vertical position. The elbow remains supported. The patient is asked to maintain the vertical position of the forearm. Contraction of teres minor can be inspected and palpated at the posterolateral boarder of the scapula. Lagging into IR from the vertical forearm position is recorded (Fig. 4).

Belly-press, belly-off, and lift-off test

Since some patients are unable to position the arm adequately behind the back for a lift-off test (51) and lift-off lag sign (8), the belly-press test (52) has been studied and modified to assess AIR. The flexion of the wrist can
be measured with a goniometer for grading of the subscapularis deficiency. We recommend the modification by Scheibel (16). The patient is asked to place the hand flat on the abdomen with the elbow close to the body. Next, the patient is asked to bring the elbow forward and extend the wrist (Fig. 3A). The flexion angle of the wrist is measured. This modified test yields a sensitivity of 80% and a specificity of 88% (14). The lift-off test with a sensitivity of 100% for a complete subscapularis rupture (15) and the lift-off lag sign with a sensitivity of 95% and a specificity of 96% (8) should be used to confirm the diagnosis paying attention to flex the elbow to 90° to rule out compensation by elbow extension with triceps contraction (Fig. 8).

**Radiographic evaluation and classification**

Mandatory radiographs include a true anterior–posterior (AP) (5) view and supraspinatus outlet view (53). The true AP view (Fig. 9) allows assessment of the greater tuberosity, cranial decentring of the humeral head (54), acromiohumeral interval (AHI) to radiographically grade massive cuff tears according to Hamada et al. (55, 56). The supraspinatus outlet view allows the assessment of acromion morphology (57), its slope (58), and if the humeral head is horizontally centred. Valuable additional radiographs involve the axillary view (59) to further evaluate osteophytes, horizontal centring (53) and to exclude an os acromiale (60), and AP external rotation and internal rotation views which load the posterior and anterior joint space and display eccentric wear if present.

**Hamada classification**

The most commonly used and simple radiographic grading of massive cuff tears was proposed by Hamada et al. (55) in 1990 and has stood the test of time. It consists of five grades based on the AHI on true AP radiographs for grade 1–2 (AHI >6 mm; AHI <5 mm) and addition of grade 3 (acetabularisation), grade 4 (glenohumeral joint space narrowing), and grade 5 (humeral head collapse). The AHI has been considered in the literature to be a sensitive indicator for full-thickness rotator cuff tears (61).

**CT and MR imaging and classifications**

Additional investigations include CT scans with 3D modelling and MR imaging, ideally with intra-articular contrast.

**Patte classification**

The widely used coronal classification of supraspinatus retraction is only a subclassification of the comprehensive work published by Patte in 1990 (42). The grades are:

**Figure 8**

Clinical photograph of a patient’s right shoulder being examined demonstrating lift-off-lag test (A) and and lift-off test (B).
1. Proximal stump near the bony insertion.
2. Proximal stump is at the level of the humeral head.
3. Proximal stump at the level of glenoid or more proximal.

It is important to point out that coronal cuts mimicking grade 3 retraction to the glenoid level must be carefully examined whether they represent L-shaped or reverse L-shaped tears which are reducible and therefore repairable (62, 63).

Goutallier classification

Based on sagittal CT imaging, Goutallier et al. (64) published a benchmark classification on fatty degeneration also termed as ‘fatty infiltration’ in 1989 and 1994. Tears with stage 3 or 4 fatty degeneration have a poor prognosis for repair.

A more recent reliability study by Williams and Walch (65) concluded that the axial CT plane should be used for Goutallier staging of fatty infiltration, that the fish backbone sign (Fig. 10A) is the visual cue for stage 3 and that the CT-based tangent sign is valid for determining the presence of muscle atrophy correlating with stage 3/4 fatty infiltration. According to the authors, the tangent sign is acceptable for clinical decision-making.

Zanetti’s tangent sign

To facilitate the diagnostic cut-off for a poor prognosis Zanetti et al. (66) published the tangent sign, a line from the superior aspect of the coracoid to the superior aspect of the scapular spine failing to transect the supraspinatus muscle volume. This MRI evaluation is performed using the most lateral image where the scapular spine is in contact with the body of the scapula.
Impact of fatty infiltration

Fatty infiltration is irreversible and progressive if left untreated, but slight reversal of atrophy after repair has been noted (67). Poorer outcomes of repair have particularly been demonstrated with fatty infiltration of infraspinatus (68) and especially in Goutallier grade 4 fatty infiltration of more than 75% (9). Despite reports of repairability of tears with stage 3 fatty infiltration, Melis and Walch (69) concluded after follow-up of 1688 patients that the objective of early rotator cuff surgery is to prevent stages of intermediate fatty infiltration (stage 2) which is associated with irreversible functional loss. They also examined the natural history of infraspinatus fatty infiltration and recommended repair within 2.5 years of onset of symptoms prior to intermediate fatty infiltration (70) which occurs earlier than supraspinatus fatty infiltration (71).

Discussion

To make the definitive diagnosis of pseudoparesis and pseudoparalysis, the conditions of true paralysis and paresis need to be excluded. CS neurological lesions can occur in isolation or with rotator cuff tears and mimic AFE pseudoparalysis (47). Isolated suprascapular nerve impairment can also be caused by nerve compression in the suprascapular notch without sensory impairment affecting the supraspinatus and infraspinatus innervation. More distal on its course, the nerve can also be exposed to compression by a spinoglenoid notch ganglion or cyst creating a selective paresis or paralysis of the infraspinatus muscle. In isolated chronic ER pseudoparesis/pseudoparalysis, an MRI is mandatory to confirm the diagnosis and to evaluate the muscle status of the infraspinatus and teres minor muscle units.

Massive rotator cuff tears are not infrequently caused by a chronic degenerative rotator cuff tear aggravated by a traumatic shoulder dislocation after a fall which can potentially be associated with an axillary nerve or a brachial plexus lesion. Massive rotator cuff tears can present with a coexisting neurological dissociative motor lesion of the axillary nerve without sensory impairment or with a CS nerve root lesion due to trauma or degenerative disease of the cervical spine. Hertel’s deltoid extension lag sign (46) is a good clinical test to differentiate AFE pseudoparesis/pseudoparalysis from true paresis/paralysis.

To establish a detailed diagnosis as a basis for appropriate management and treatment, it is recommended to independently evaluate loss of force couple balance for AFE, AER, and AIR with grading into paresis and paralysis. Traumatic aetiology, chronicity, patient age, fatty infiltration of involved muscle–tendon units, and arthritides (Hamada classification) are important features to guide treatment.

The importance of the inferior subscapularis has been pointed out as an anterior check rain, and every effort should be made to prevent subscapularis tear propagation (5, 11, 12, 13) to maintain shoulder function and balance. The often-forgotten teres minor seems to have a similar role as the last posterior check rain in large posterior tears. Collin’s data teaches us further that the loss of all superior rotator cuff units inserting above the humeral head equator is predictive for loss of force couple balance.

Conclusions

AFE, AER, and AIR should be assessed independently, the severity of loss of force couple balance should be graded, and paresis and paralysis should be distinguished. Pain must be excluded as a cause of pseudopaes and pseudoparalysis. Loss of function of three out of five shoulder muscle–tendon units is predictive of loss of force couple balance. The vertical and horizontal shoulder equator concept derived from previous studies illustrates that above the horizontal and vertical oblique equators, at least one muscle–tendon unit is necessary to maintain a fulcrum to counter the deltoid force enabling humeral head rotation instead of the pure translation associated with humeral head escape.

ICMJE Conflict of Interest Statement

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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. Tokish JM, Alexander TC, Kissenberth MJ & Hawkins RJ. Pseudoparalysis: a systematic review of term definitions, treatment approaches, and outcomes of management techniques. Journal of Shoulder and Elbow Surgery 2017 26 e177–e187. (https://doi.org/10.1016/j.jse.2017.02.024)
2. Werner CM, Steinmann PA, Gilbart M & Gerber C. Treatment of painful pseudoparesis due to irreparable rotator cuff dysfunction with the delta III reverse-ball-and-socket total shoulder prosthesis. Journal of Bone and Joint Surgery: American Volume 2005 87 1476–1486. (https://doi.10.1016/j.jbjs.d.02342)
3. Collin P, Matsumura N, Lademann A, Denard PJ & Walch G. Relationship between massive chronic rotator cuff tear pattern and loss of active shoulder range of motion. Journal of Shoulder and Elbow Surgery 2014 23 1195–1202. (https://doi.10.1016/j.jse.2013.11.019)
4. Burks RT & Tashjian RZ. Should we have a better definition of pseudoparalysis in patients with rotator cuff tears? Arthroscopy 2017 33 2281–2283. (https://doi.org/10.1016/j.arthro.2017.07.024)
5. 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/10.1177/0363546520969838)

6. Gschwend N, Ivosevic-Radovanovic D & Patte D. Rotator cuff tear — relationship between clinical and anatomopathological findings. Archives of Orthopaedic and Traumatic Surgery 1988 107 7–15. (https://doi.org/10.1007/BF00463518)

7. Rossler H. Ruptures in the rotator aponeurosis (author’s transl). Zeitschrift für Orthopadie und Ihre Grenzgebiete 1976 114 282–294.

8. Hertel R, Ballmer FT, Lombert SM & Gerber C. Lag signs in the diagnosis of rotator cuff rupture. Journal of Shoulder and Elbow Surgery 1996 5 307–313. (https://doi.org/10.1016/s1058-2746(96)80058-9)

9. 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)

10. Burkhart SS & Tehrany AM. Arthroscopic subscapularis tendon repair: technique and preliminary results. Arthroscopy 2002 18 454–463. (https://doi.org/10.1053/jars.2002.30648)

11. Eichinger JK. Editorial commentary: the subscapularis is king, ignore it at your peril. Arthroscopy 2018 34 1785. (https://doi.org/10.1016/j.arthro.2018.02.028)

12. Kawano Y, Matsumura N, Murai A, Tada M, Matsumoto M, Nakamura M & Nagura T. Evaluation of the translation distance of the glenohumeral joint and the function of the rotator cuff on its translation: a cadaveric study. Arthroscopy 2018 34 1776–1784. (https://doi.org/10.1016/j.arthro.2018.01.011)

13. Wieser K, Rahm S, Schubert M, Fischer MA, Farshad M, Gerber C & Meyer DC. Fluoroscopic, magnetic resonance imaging, and electrophysiologic assessment of shoulders with massive tears of the rotator cuff. Journal of Shoulder and Elbow Surgery 2015 24 288–294. (https://doi.org/10.1016/j.jse.2014.05.026)

14. Bartsch M, Greiner S, Haas NP & Scheibel M. Diagnostic values of clinical tests for subscapularis lesions. Knee Surgery, Sports Traumatology, Arthroscopy 2010 18 1712–1717. (https://doi.org/10.1007/s00167-010-1109-1)

15. Scheibel M, Magosch P, Pritsch M, Lichtenberg S & Habermeyer P. The belly-off sign: a new clinical diagnostic sign for subscapularis lesions. Arthroscopy 2005 21 1229–1235. (https://doi.org/10.1016/j.arthro.2005.06.021)

16. Scheibel M, Tysnman A, Magosch P, Schroeder RJ & Habermeyer P. Postoperative subscapularis muscle insufficiency after primary and revision open shoulder stabilization. American Journal of Sports Medicine 2006 34 1586–1593. (https://doi.org/10.1177/0363546506288852)

17. 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 (2 Supplement) 20–30. (https://doi.org/10.1016/j.jse.2009.12.011)

18. Sirveaux F, Favard L, oudet D, Huquet D, Walch G & Mole D. Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive rupture of the cuff: Results of a multicentre study of 80 shoulders. Journal of Bone and Joint Surgery: British Volume 2004 86 388–395. (https://doi.org/10.1302/0301-620x.86b3.130424)

19. Popescu IA, Biheil T, Henderson D, Martin Becerra J, Agneskirchner J & Lafosse L. Functional improvements in active elevation, external rotation, and internal rotation after reverse total shoulder arthroplasty with isolated latissimus dorsi transfer: surgical technique and midterm follow-up. Journal of Shoulder and Elbow Surgery 2019 28 2356–2363. (https://doi.org/10.1016/j.jse.2019.04.039)

20. Valenti P, Zanjani LO, Schoch BS, Kazem & Werthel JD. Mid- to long-term outcomes after reverse shoulder arthroplasty with latissimus dorsi and teres major transfer for irreparable posterosuperior rotator cuff tears. International Orthopaedics 2021 45 1263–1271. (https://doi.org/10.1007/s00264-021-04948-z)

21. Berglund DD, Rosas S, Triplet JJ, Kurowicki J, Horn B & Levy JC. Restoration of external rotation following reverse shoulder arthroplasty without latissimus dorsi transfer. J8 and JS Open Access 2018 3 e0054. (https://doi.org/10.2106/JBJS.OA.17.00054)

22. 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)

23. Boileau P, Baba M, McClelland Jr WB, Thelu CÉ, Trojani C & Bransard N. Isolated loss of active external rotation: a distinct entity and results of L’Episcopo tendon transfer. Journal of Shoulder and Elbow Surgery 2018 27 499–509. (https://doi.org/10.1016/j.jsse.2017.07.008)

24. Boileau P, Chuinard C, Roussanne Y, Nepton LJ & Trojani C. Modified latissimus dorsi and teres major transfer through a single deltopectoral approach for external rotation deficit of the shoulder: an isolated procedure or with a reverse arthroplasty. Journal of Shoulder and Elbow Surgery 2007 16 671–682. (https://doi.org/10.1016/j.jse.2007.02.127)

25. Burr P & Choudhury P. Fine motor disability. StatPearls Publishing, Treasure Island (FL): 2021.

26. Young RW. Evolution of the human hand: the role of throwing and clubbing. Journal of Anatomy 2003 202 165–174. (https://doi.org/10.1046/j.1469-7580.2003.00144.x)

27. Burkhart SS. Arthroscopic treatment of massive rotator cuff tears. Clinical results and biomechanical rationale. Clinical Orthopaedics and Related Research 1991 267 45–56. (https://doi.org/10.1097/00002064-199106000-00006)

28. Visotsky JL, Basamania C, Seebauer L, Rockwood CA & Jensen KL. Cuff tear arthropathy: pathogenesis, classification, and algorithm for treatment. Journal of Bone and Joint Surgery: American Volume 2004 86-A (Supplement 2) 35–40. (https://doi.org/10.2106/JBJS.A.01455)

29. Lademann 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)

30. Bouaicha S, Ernstbrunner L, Jud L, Meyer DC, Sneedeke JG & Bachmann E. The lever arm ratio of the rotator cuff to deltoid muscle explains and predicts pseudoparalysis of the shoulder: the shoulder abduction moment index. Bone and Joint Journal 2018 100-B 1600–1608. (https://doi.org/10.1302/0301-620X.100B12.BJU-2018-0493.R1)

31. Goetti P, Denard PJ, Collin P, Ibrahim M, Hoffmeyer P & Lademann A. Shoulder biomechanics in normal and selected pathological conditions. EFORT Open Reviews 2020 5 508–518. (https://doi.org/10.1058/2058-5241.s.20006)

32. Hansen ML, Otis JC, Johnson JS, Cordasco FA, Craig EV & Warren RF. Biomechanics of massive rotator cuff tears: implications for treatment. Journal of Bone and Joint Surgery: American Volume 2008 90 316–325. (https://doi.org/10.2106/JBJS.F.00880)
33. Keener JD, Wei AS, Kim HM, Steger-May K & Yamaguchi K. Proximal humeral migration in shoulders with symptomatic and asymptomatic rotator cuff tears. Journal of Bone and Joint Surgery: American Volume 2009 91 1405–1413. (https://doi.org/10.2106/JBJS.H.00854)

34. Su WR, Budoff JE & Luo ZP. The effect of anterosuperior rotator cuff tears on glenohumeral translation. Arthroscopy 2009 25 282–289. (https://doi.org/10.1016/j.arthro.2008.10.005)

35. Yamaguchi K, Sher JS, Andersen WK, Garretson R, Uribe JW, Hechtman K & Nevisar RJ. Glenohumeral motion in patients with rotator cuff tears: a comparison of asymptomatic and symptomatic shoulders. Journal of Shoulder and Elbow Surgery 2000 9 6–11. (https://doi.org/10.1067/msj.2000.109002–8)

36. Di Giacomo G, Pouliart N, Costantini A & De Vita A. Atlas of Functional Shoulder Anatomy. Milano: Springer, 2008. (available at: https://www.springer.com/gp/book/9788847007581)

37. Favre P, Jacob HA & Gerber C. Changes in shoulder muscle function with humeral position: a graphical description. Journal of Shoulder and Elbow Surgery 2009 18 114–121. (https://doi.org/10.1016/j.jse.2008.06.010)

38. Viehofer AF, Gerber C, Favre P, Bachmann E & Sneedecker JG. A larger critical shoulder angle requires more rotator cuff activity to preserve joint stability. Journal of Orthopaedic Research 2016 34 961–968. (https://doi.org/10.1002/jor.23104)

39. Denard PJ, Koo SS, Murena L & Burkhart SS. Pseudoparalysis: the importance of rotator cable integrity. Orthopedics 2012 35 e1353–e1357. (https://doi.org/10.3928/01477447-20120822-21)

40. Collin P, Lädermann A, Le Bourg M & Walsh G. Subcapsularis minor — an analogue of the teres minor? Orthopaedics and Traumatology, Surgery and Research 2013 99 (4 Supplement) S255–S258. (https://doi.org/10.1016/j.jotsr.2013.03.003)

41. Gerber C. Latissimus dorsi transfer for the treatment of irreparable tears of the rotator cuff. Clinical Orthopaedics and Related Research 1992 275 152–160. (https://doi.org/10.1097/00003086-199202000-00022)

42. Patte D. Classification of rotator cuff lesions. Clinical Orthopaedics and Related Research 1990 254 81–86. (https://doi.org/10.1097/00003086-199005000-00012)

43. Melis B, DeFranco MJ, Lädermann A, Barthelmy R & Walsh G. The teres minor muscle in rotator cuff tendon tears. Skeletal Radiology 2011 40 1335–1344. (https://doi.org/10.1007/s00256-011-1178-3)

44. Sarkissian EJ, Xiao M & Abrams GD. Preoperative fatty infiltration of the teres minor negatively affects postoperative outcomes in patients with rotator cuff pathology. Orthopaedic Journal of Sports Medicine 2020 8 2325967120960107. (https://doi.org/10.1177/2325967120960107)

45. Costouros JG, Espinosa N, Schmid MR & Gerber C. Teres minor integrity predicts outcome of latissimus dorsi tendon transfer for irreparable rotator cuff tears. Journal of Shoulder and Elbow Surgery 2007 16 727–734. (https://doi.org/10.1016/j.jse.2007.02.128)

46. Hertel R, Lambert SM & Ballmer FT. The deltoid extension lag sign for diagnosis and grading of axillary nerve palsy. Journal of Shoulder and Elbow Surgery 1998 7 97–99. (https://doi.org/10.1016/s1058-2746(98)02117-8)

47. Maredu E, Traverso A, Laudato P & Bauer S. Bilateral isolated CS paralysis of the shoulder: atypical presentation of a transdiscal C4-C5 cervical spine fracture. BMJ Case Reports 2021 14. (https://doi.org/10.1136/bcr-2020-236323)

48. Tong HC, Haig AJ & Yamakawa K. The Spurling test and cervical radiculopathy. Spine 2002 27 156–159. (https://doi.org/10.1097/00007632-200201150-00007)

49. Collin P, Treseder T, Denard PJ, Neffcy L, Walch G & Lädermann A. What is the best clinical test for assessment of the teres minor in massive rotator cuff tears? Clinical Orthopaedics and Related Research 2015 473 2959–2966. (https://doi.org/10.1007/s11999-015-4392-9)

50. Walch G, Boulafia A, Calderone S & Robinson AH. The ‘dropping’ and ‘hornblower’s signs in evaluation of rotator-cuff tears. Journal of Bone and Joint Surgery: British Volume 1998 80 624–628. (https://doi.org/10.1302/0301-6200.80b4.8651)

51. Gerber C & Krushell RJ. Isolated rupture of the tendon of the subscapularis muscle. Clinical features in 16 cases. Journal of Bone and Joint Surgery: British Volume 1991 73 389–394. (https://doi.org/10.1302/0301-6200.73B3.1670434)

52. Gerber C, Hersche O & Farron A. Isolated rupture of the subscapularis tendon. Journal of Bone and Joint Surgery: American Volume 1996 78 1015–1023. (https://doi.org/10.2106/00003623-199607000-00005)

53. Deutsche Vereinigung für Schulter- und Ellenbogenschirurgie e. V. Bildgebung in der Schulter- und Ellenbogenschirurgie. Obere Extremität 2017 12 1–3. (https://doi.org/10.1007/s11678-017-0393-5)

54. Ahovuo J, Paavolainen P & Slatis P. The diagnostic value of arthrography and plain radiography in rotator cuff tears. Acta Orthopaedica Scandinavica 1984 55 220–223. (https://doi.org/10.3109/17453678408992341)

55. Hamada K, Fukuda H, Mikasa M & Kobayashi Y. Roentgenographic findings in massive rotator cuff tears. A long-term observation. Clinical Orthopaedics and Related Research 1990 254 92–96. (https://doi.org/10.1097/00003086-199005000-00014)

56. Moor BK, Bouaicha S, Rothenfluh DA, Sukthankar A & Gerber C. Is there an association between the individual anatomy of the scapula and the development of rotator cuff tears or osteoarthrits of the glenohumeral joint? A radiological study of the critical shoulder angle. Bone and Joint Journal 2013 95-B 935–941. (https://doi.org/10.1302/0301-620X.95B7.31028)

57. Duralde XA & Gauntt SJ. Troubleshooting the supraspinatus outlet view. Journal of Shoulder and Elbow Surgery 1999 8 314–319. (https://doi.org/10.1016/s1058-2746(99)90152-0)

58. Bialke M, Schmidt C, Dedy N, Banerjee M, Bouillon B & Liem D. Correlation of acromial morphology with impingement syndrome and rotator cuff tears. Acta Orthopaedica 2013 84 178–183. (https://doi.org/10.3109/17453674.2013.773413)

59. De Smet AA. Auxiliary projection in radiography of the nontraumatized shoulder. American Journal of Roentgenology 1980 134 511–514. (https://doi.org/10.2214/ajr.134.3.511)

60. Warner JJ, Beim GM & Higgins L. The treatment of symptomatic acromial. Journal of Bone and Joint Surgery: American Volume 1998 80 1320–1326. (https://doi.org/10.2106/00003623-199809000-00011)

61. Novo-Josserand L, Levigne C, Noel E & Walch G. The acromio–humeral interval. A study of the factors influencing its height. Revue de Chirurgie Orthopédique et Reparatrice de l’Appareil Moteur 1996 82 379–385.

62. Eichinger JK. Editorial commentary: Look more closely at those coronal magnetic resonance imaging cuts before concluding a rotator cuff tendon tear is irreparable—don’t let an L-shaped tear fool you. Arthroscopy 2020 36 2831. (https://doi.org/10.1016/j.arthro.2020.08.027)

63. Guo S, Zhu Y, Song G & Jiang C. Assessment of tendon retraction in large to massive rotator cuff tears: a modified patte classification based on 2 coronal sections on preoperative magnetic resonance imaging with higher specificity on predicting reparability. Arthroscopy 2020 36 2822–2830. (https://doi.org/10.1016/j.arthro.2020.06.023)
64. Goutallier D, Postel JM, Bernageau J, Lavau L & Voisin MC. Fatty muscle degeneration in cuff ruptures. Pre- and postoperative evaluation by CT scan. Clinical Orthopaedics and Related Research 1994 304 78–83. (https://doi.org/10.1097/00003086-199407000-00014)

65. Williams MD, Ladermann A, Melis B, Barthelemy R & Walch G. Fatty infiltration of the supraspinatus: a reliability study. Journal of Shoulder and Elbow Surgery 2009 18 581–587. (https://doi.org/10.1016/j.jse.2008.12.014)

66. Zanetti M, Gerber C & Hodler J. Quantitative assessment of the muscles of the rotator cuff with magnetic resonance imaging. Investigative Radiology 1998 33 163–170. (https://doi.org/10.1097/00004424-199803000-00006)

67. Kuzel BR, Grindel S, Papandrea R & Ziegler D. Fatty infiltration and rotator cuff atrophy. Journal of the American Academy of Orthopaedic Surgeons 2013 21 613–623. (https://doi.org/10.5435/JAAOS-21-10-613)

68. Gladstone JN, Bishop JY, Lo IK & Flatow EL. Fatty infiltration and atrophy of the rotator cuff do not improve after rotator cuff repair and correlate with poor functional outcome. American Journal of Sports Medicine 2007 35 719–728. (https://doi.org/10.1177/0363546506297539)

69. Melis B, Nemoz C & Walch G. Muscle fatty infiltration in rotator cuff tears: descriptive analysis of 1688 cases. Orthopaedics and Traumatology, Surgery and Research 2009 95 319–324. (https://doi.org/10.1016/j.otsr.2009.05.001)

70. Melis B, Wall B & Walch G. Natural history of infraspinatus fatty infiltration in rotator cuff tears. Journal of Shoulder and Elbow Surgery 2010 19 757–763. (https://doi.org/10.1016/j.jse.2009.12.002)

71. Melis B, DeFranco MJ, Chuinard C & Walch G. Natural history of fatty infiltration and atrophy of the supraspinatus muscle in rotator cuff tears. Clinical Orthopaedics and Related Research 2010 468 1498–1505. (https://doi.org/10.1007/s11999-009-1207-x)