Current Concepts Review

Shoulder Apprehension: a Multifactorial Approach

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Source of Founding

None

Abstract

Shoulder apprehension is related to brain alterations induced by dislocations, peripheral neuromuscular lesions, and persistent mechanical glenohumeral instability consisting in micro-motion. All the damages to the osseous and soft tissue stabilizers of the shoulder, as well as neurologic impairment persisting even after stabilization must be properly identified in order to offer the best possible treatment to the patient. There is growing evidence supporting the use of a global multimodal approach, involving on the one hand shoulder "re-afferentation", including proprioception, mirror therapy, and even cognitive behavioral approaches, and, on the other hand, surgical stabilization techniques and traditional physical therapy in order to minimize persistent micro-motion, which may help brain healing. This combined management could improve return to sport and avoid dislocation arthropathy in the long-term.

Key words: Shoulder instability; anteroinferior glenohumeral dislocation; Apprehension; Brain lesion

Introduction

The glenohumeral joint has six degrees of freedom, three translational and three rotational, with minimal bony constraints that provide a large functional range of motion, making this joint vulnerable to instability. The latter can lead to increased pain, decreased level of activities, prolonged absence from work and sport, and a general decrease in quality of life.(Headey, Brooks, & Kemp, 2007; Meller et al., 2007) Apprehension can be difficult to diagnose pre- or post-operatively, as it seems more complex than a pure mechanical problem of the shoulder. Although clinical definition seems to be well established, its underlying pathologic mechanism remains unclear. This may explain the wide reported range (3% to 51%) of patients with ongoing apprehension or who will avoid any shoulder movement after an open or arthroscopic stabilization, despite a clinically stable joint(Hovelius & Rahme, 2016; Hovelius, Vikerfors, Olofsson, Svensson, & Rahme, 2011; Lädermann et al., 2013) Failure to recognize and adequately address this issue of may result in poor outcome and lead to unnecessary surgery or even revision. Furthermore, identifying this condition may allow establishing adequately targeted rehabilitation programs.

The purpose of this article is to review the current state of knowledge about shoulder apprehension and its etiologic factors. Finally, this work presents practical guidelines and promising future perspectives.

Definition

An important aspect to incorporate in dislocation management is *apprehension*, defined as anxiety and motor resistance in patients with a history of anterior glenohumeral instability. Clinically, *apprehension* sign is defined as fear of imminent dislocation when placing the arm in abduction and external rotation, and should be distinct from mere pain which can be related to inflammation, stiffness and other shoulder pathologies.(Jobe, Kvitne, & Giangarra, 1989; Rowe & Zarins, 1981) *Proprioception*, as defined by Charles Scott Sherrington, is the sense of the relative position of neighboring parts of the body and strength of effort being employed during movement.(Sherrington, 1906) It is distinct from exteroception, by which one perceives the outside world, and interoception, by which one perceives pain, hunger, or the movement of internal organs. The brain integrates information from proprioception and from the vestibular system into its overall sense of body position, movement, and acceleration. *Kinesthesia* refers either to the brain's integration of proprioceptive or vestibular inputs.

Localization of the lesion

The pathogenesis of apprehension is not fully understood. Theoretically, apprehension could be related to (1) brain changes induced by dislocations,(Cunningham, Zanchi, et al., 2015; Haller et al., 2014; Zanchi et al., 2017a, 2017b) (2) peripheral neuromuscular lesions consecutive to dislocation affecting proprioception,(Atef, El-Tantawy, Gad, & Hefeda, 2015) or (3) persistent mechanical instability consisting in micro-motion (Figure 1).(Lädermann, Denard, et al., 2016)

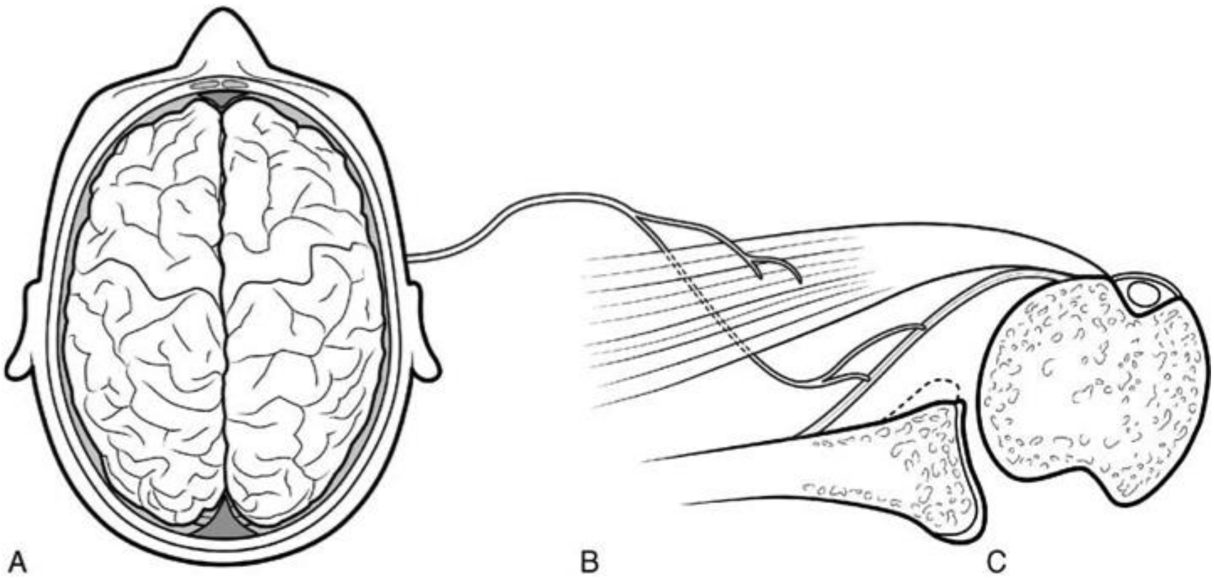

Figure 1. Apprehension may be related to (A) central nervous system sequelae, (B) peripheral neurological, muscular or capsular/ligamentous lesions consecutively to dislocation, or (C) mechanical instability as micromovements. Reproduced from Lädermann A, Denard PJ, Tirefort J, Kolo FC, Chagué S, Cunningham G, Charbonnier C. Does surgery for instability of the shoulder truly stabilize the glenohumeral joint?: A prospective comparative cohort study. Medicine (Baltimore). 2016 Aug;95(31):e4369 with permission.

Brain

Fear, anxiety and anticipation of situations that could lead to a dislocation are essential cognitive processes in shoulder apprehension. Recently, our group used functional magnetic resonance imaging (fMRI) with visual apprehension stimulation to explore neuronal connections and cerebral changes induced by shoulder dislocation.(Haller et al., 2014) Several cerebral areas were modified during those analyses, representing the different aspects of shoulder apprehension. Specific reorganization were found in apprehension-related functional connectivity of the primary sensory-motor areas (motor resistance), dorsolateral prefrontal cortex (cognitive control of motor behavior), and the dorsal anterior cingulate cortex/dorsomedial prefrontal cortex and anterior insula (anxiety and emotional regulation) (Figure 2).

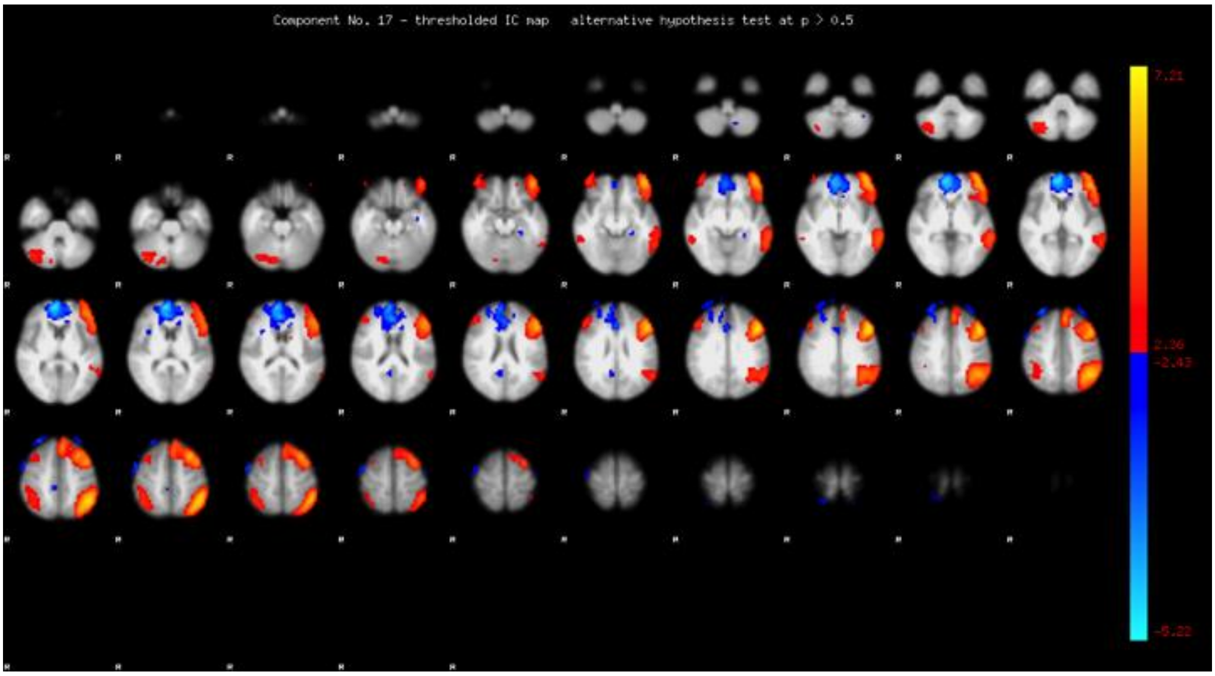

Figure 2. Patients vs control participants had a significantly (P < .05 corrected) higher task-correlated functional connectivity in two almost mirror symmetric components. Reproduced from Haller S, Cunningham G, Lädermann A, Hofmeister J, Van De Ville D, Lovblad KO, Hoffmeyer P. Shoulder apprehension impacts large-scale functional brain networks. AJNR Am J Neuroradiol. 2014;35(4):691-7 with permission.

Those regions are involved in the cognitive control of motor behavior.(Cieslik et al., 2013) Hence, there is motor control anticipation and muscular resistance (protective reflex mechanism), in order to avoid shoulder movement that could lead to dislocation.(Hovelius et al., 2011; Lädermann et al., 2013) Another recent study published by Shitara et al. analyzed cerebral changes induced by shoulder dislocation in 14 patients. Although results were similar to our study, they observed larger area of cerebral activation that can be explained by static abstract images projected that could be subject to interpretation and that did not express movement necessary for the dynamic process of apprehension.

In a subsequent study, our group extended these findings by investigating further structural alterations in patients with shoulder apprehension.(Zanchi et al., 2017b) We found that fractional anisotropy, representing white matter integrity, was increased in the left internal capsule and partially in the thalamus in patients compared to healthy controls. Fractional anisotropy correlated positively with pain visual analog scale (VAS) scores ($p < .05$) and negatively with simple shoulder test (SST) scores ($p < .05$).(Zanchi et al., 2017b)This suggests an abnormal increased axonal integrity and therefore pathological structural plasticity due to the over-connection of white matter fibers in the motor pathway. These structural alterations affect several dimensions of shoulder apprehension as pain perception and performance in daily life.

The neuronal changes previously mentioned and presented in shoulder apprehension can also be assessed in daily clinical practice. Indeed, Cunningham et al. correlated clinical scores and tests (Rowe,(Rowe & Zarins, 1981) pain VAS,(Huskisson, 1982) SST,(Lippitt, Harryman, & Matsen, 1993) SSV,(Gilbart & Gerber, 2007) WOSI(Kirkley, Griffin, & Dainty, 2003)) with functional cerebral imaging in patients with shoulder apprehension.(Cunningham, Zanchi, et al., 2015) Their hypothesis was that it might be possible to simplify shoulder instability scores as it has been previously possible with rotator cuff and SLAP lesions,(Cunningham, Lädermann, Denard, Kherad, & Burkhart, 2015) and that at least one score could encompass the spectrum of these cerebral alterations. They found that the Rowe score integrated several aspect of apprehension, notably the motor and sensory functions, as well as pain anticipation and attention. This could be explained by the fact that the Rowe score is the only tested scores integrating range of motion. This also provides the ability to evaluate motor component (stability and motion) and cognitive component (perceived pain) of shoulder apprehension. Pain VAS and WOSI seemed to correlate with less brain networks compared to the Rowe. This could be explained by the fact that their assessment is focused only on cognitive aspects (pain for pain VAS, shoulder function in everyday life activities for WOSI), and that they do not integrate pure shoulder motion. SST and SSV were not found to be associated with brain network alterations, which is corroborated by the fact that they are general shoulder scores and were not specifically validated for instability.

Recently, a similar study demonstrated that shoulder stabilization could allow the brain to partially "recover".(Zanchi et al., 2017a) Patients with shoulder apprehension underwent clinical and fMRI examination before and one year after shoulder stabilization surgery. Clinical examination showed a significant improvement in postoperative shoulder function compared with preoperative. Coherently, results showed decreased activation in the left pre-motor cortex postoperatively, demonstrating that stabilization surgery induced improvements both at the physical and at the brain level, one year postoperatively (Figure 3).(Zanchi et al., 2017a) Most interestingly, right–frontal pole and right-occipital cortex activity was associated with good outcome in shoulder performance.

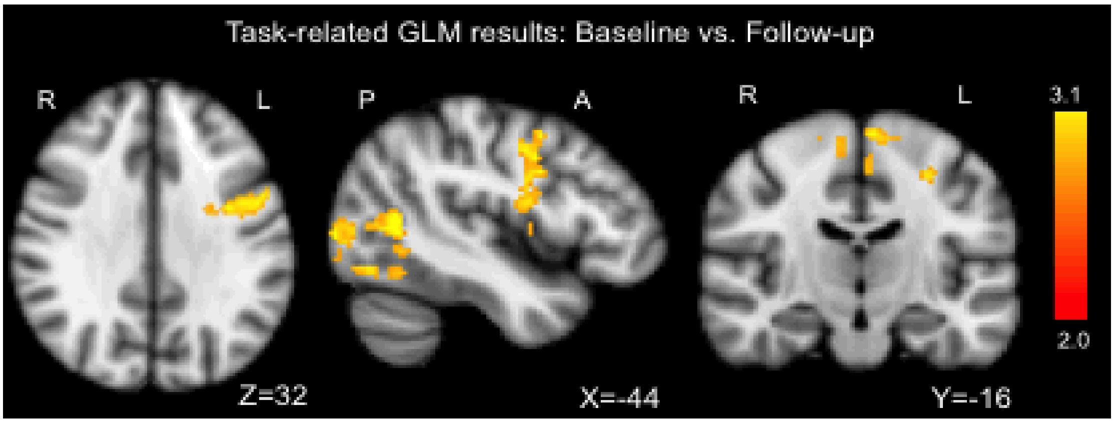

Figure 3: Task related General Linear Model (GLM) shows higher activation in baseline vs. follow-up for apprehension videos vs. control videos, representing partial brain healing. Reproduced from Zanchi D, Cunningham G, Lädermann A, Ozturk M, Hoffmeyer P, Haller S. Brain activity in the right-frontal pole and lateral occipital cortex predicts successful post-operatory outcome after surgery for anterior glenoumeral instability. Sci Rep. 2017;7(1):498 with permission.

Peripheral Neuromuscular Lesion

During a traumatic dislocation, there are a disruption of the shoulder tendinomuscular (in 10% of cases)(Robinson, Shur, Sharpe, Ray, & Murray, 2012) and peripheral nerve lesions (in 14% of cases).(Robinson et al., 2012) However, this does not account for subclinical neurologic damage that may be much more preponderant. Capsuligamentous structures surrounding the glenohumeral joint are richly innervated with proprioceptors and therefore play an important sensorimotor role in addition to their primary mechanical stabilizising function. Thus, when considering the extensive and frequent damage to these structures after shoulder dislocation (Figure 4),(Antonio et al., 2007) there is bound to be an important loss in glenohumeral proprioception,(Atef et al., 2015) which plays a significant role in stabilization of a normal healthy shoulder and after any shoulder injury by contributing to motor control.(Fyhr, Gustavsson, Wassinger, & Sole, 2015) Surgical stabilization has been shown to help proper healing of these structures and thus restoring proprioception of the glenohumeral joint.(Myers & Lephart, 2002)

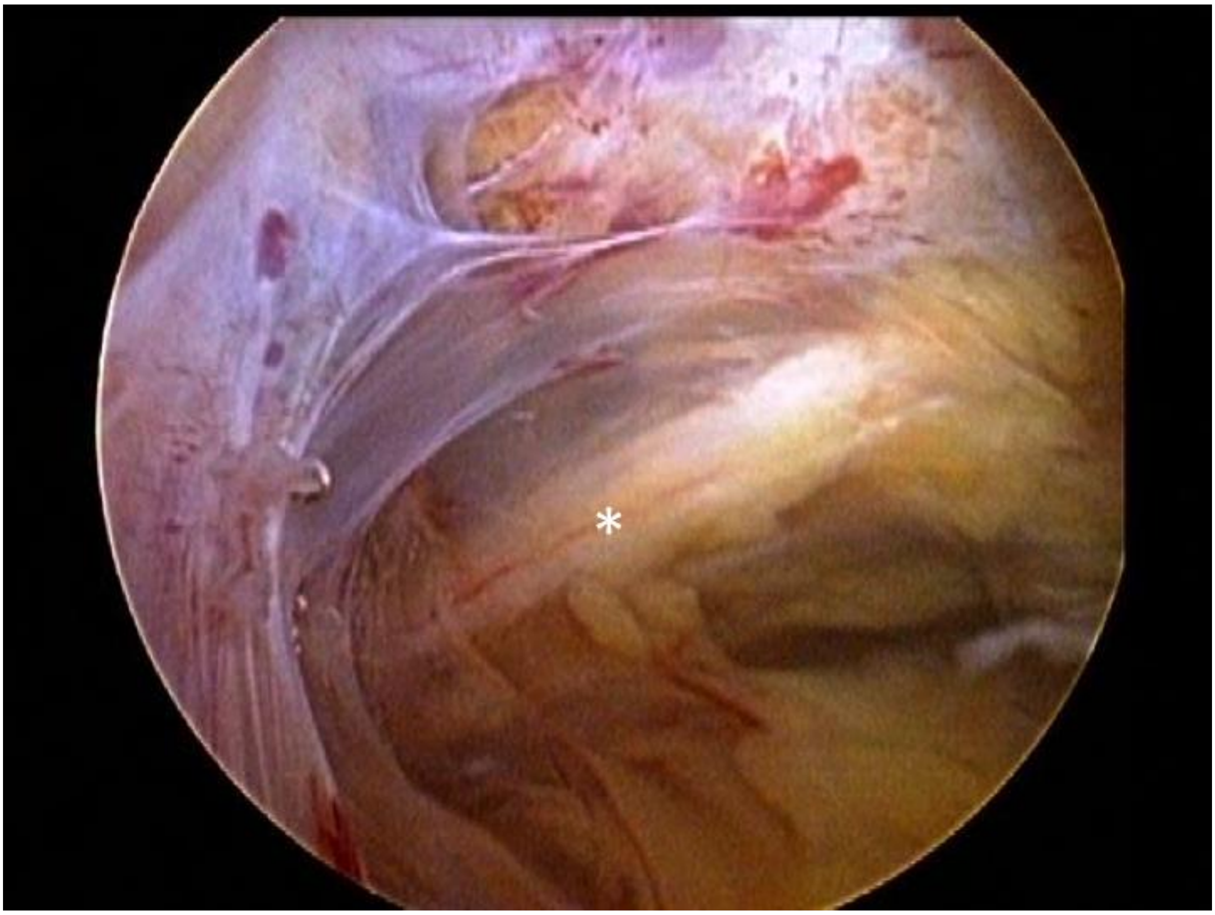

Figure 4: Arthroscopic view of a left shoulder through a posterior portal. This patient has sustained more than 50 subluxations. The axillary nerve is clearly identifiable (white asterisk). There is no more capsule or inferior glenohumeral ligament, and the subscapularis muscle is hardly recognizable. Reproduced from Lädermann A, Benchouk S, Denard PJ. Traumatic Anterior Shoulder Instability: General concepts & proper management. Edited by Park J in Sports Injuries to the Shoulder and Elbow. Springer-Verlag Berlin Heidelberg 2015 ISBN978-3-642-41794-8, with permission.

Glenohumeral Joint

The third possibility that might explain apprehension is that shoulders continue to present micro-motion despite a normal clinical exam and good radiographic results with no further episode of dislocation. As stated above, shoulder dislocation causes damage to the capsuloligamentous complex in 52% of the cases,(Liavaag et al., 2011) and the glenoid labrum in 73% of the cases.(Antonio et al., 2007) The plastic deformity of these structures becomes progressively worse with subsequent episodes.(Bigliani et al., 1992; Habermeyer, Gleyze, & Rickert, 1999; Urayama, Itoi, Sashi, Minagawa, & Sato, 2003) In addition to progressive soft tissue injury, recurrent dislocations induce bone injury,(Edwards, Boulahia, & Walch, 2003) which may include defects of the glenoid (bony Bankart) or impaction of the posterolateral humeral head (Malgaine lesion).(Malgaigne, 1855) Severity of apprehension, quantified as the moment at which it is expressed during the course of abduction and external rotation, seems to be correlated to the extent of bone loss.(Bushnell, Creighton, & Herring, 2008) Capsular redundancy has also been recognized as a risk factor for ongoing apprehension after surgical stabilization and Ropars et al. found a significantly decreased apprehension in patients with associated capsulorraphy to Latarjet procedures, compared with patients with Latarjet and no capsular reconstruction.(Ropars et al., 2016) However, these changes can be very subtle and therefore not detectable on standard clinical MRI in neutral position. This has been described by Patte et al.(Patte, Bernageau, Rodineau, & Gardes, 1980) in non-operated patients and popularized under the name of "unstable painful shoulder". This entity, defined as anteroinferior instability of the shoulder without any apparent history of dislocations or subluxations, may also be present in operated patients.(Singer, Kirkland, & Emery, 1995)

Shoulder stabilizations may thus only avoid new episodes of dislocation, rather than actually stabilizing the shoulder. Studies have been able to report translation values at the glenohumeral joint using external measurement systems such as optical motion capture combined with computer tomography (CT) or magnetic resonance imaging (MRI).(Charbonnier, Chague, Kolo, Chow, & Lädermann, 2014; Charbonnier, Chague, Kolo, & Lädermann, 2015; Lädermann, Chague, Kolo, & Charbonnier, 2016) Based on this technology, a recent study described glenohumeral translation in patients with traumatic anteroinferior instability and subsequently analyzed the effect of glenohumeral stabilization on this translation.(Lädermann, Denard, et al., 2016) For all movements, the authors recorded humeral head position of the contralateral and ipsilateral shoulders in relation to the glenoid center pre- and 1 year post-operatively. They observed an anterior translation of the humeral head (Figure 5), especially during flexion and abduction movements ($p = 2.00e-10$ and $p = 2.56e-07$, respectively).

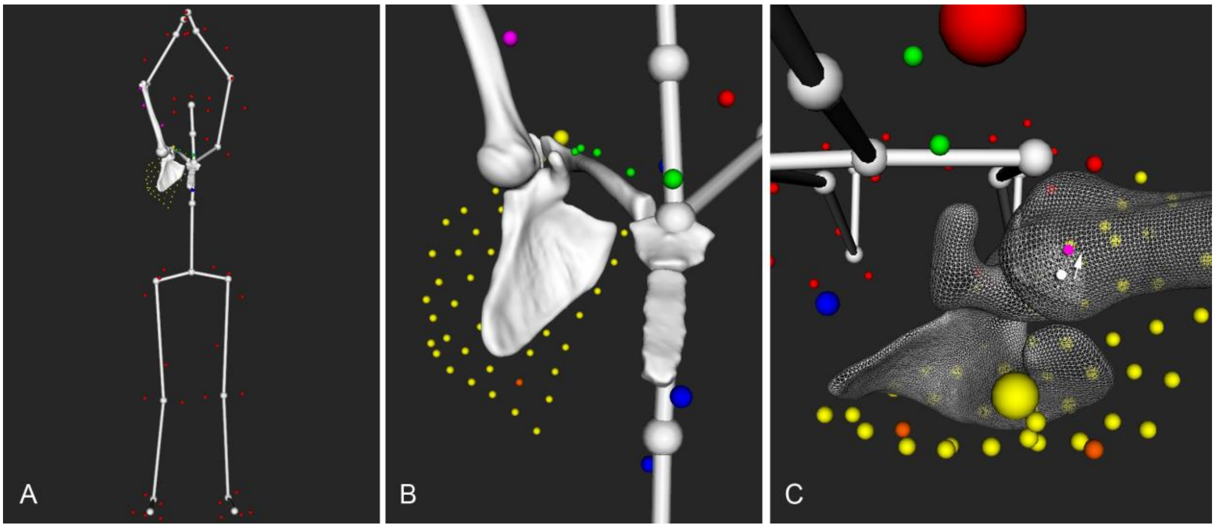

Figure 5: (A) Abduction simulation obtained from shoulder's CT reconstruction and optical motion capture, (B) and (C) show a zoom in the shoulder (front and top views). In image (C), we clearly observe an anterior translation (arrow) of the humeral head center (pink sphere) with respect to the glenoid center (white sphere). Note that the clavicle is not shown for

clarity. Reproduced from Lädermann A, Denard PJ, Tirefort J, Kolo FC, Chagué S, Cunningham G, Charbonnier C. Does surgery for instability of the shoulder truly stabilize the glenohumeral joint?: A prospective comparative cohort study. Medicine (Baltimore). 2016 Aug;95(31):e4369, modified with permission.

One year after surgery, all patients had a clinically stable shoulder and none presented with a new episode of dislocation or subluxation. However, anterior translation of the humeral head was not significantly reduced and remained close to preoperative values confirming that shoulder stabilization does not stabilize the shoulder but uniquely prevents further dislocation. These findings have several important implications. First, it may explain residual pain, apprehension, and impossibility to return to sport at the same level as reported in other studies.(Boileau, Zumstein, Balg, Penington, & Bicknell, 2011; Lädermann et al., 2013) Second, persistent abnormal motion between the glenoid and the humeral head might be the underlying cause of dislocation arthropathy that is observed with a prevalence of 36%.(Lädermann et al., 2013) Indeed, Hovelius et al. demonstrated that arthritis development was related to the instability phenomenon itself rather than to surgery, when properly carried out.(Hovelius & Saeboe, 2009) Repeated sliding of the humeral head against the glenoid associated with degenerative changes of cartilage properties and decreased biological healing potential related to aging, could lead to a vicious circle of extensive cartilage damage.

Treatments and Perspectives

The degree, nature and combination of the shoulder injuries induced by traumatic glenohumeral instability are highly variable. Damage to the osseous and soft tissue stabilizers of the shoulder, as well as neurologic impairment, must be detected and analyzed in order to provide the patient with the best treatment option. This new knowledge should be applied to rehabilitation therapy and surgical stabilization techniques. As the current stabilization techniques do not seem to prevent residual glenohumeral micro-motion, it remains to be determined which factors help to minimize this phenomenon, whether it is, the increase in the anteroposterior diameter of the glenoid with a bone graft, the sling effect provided by the conjoined tendon, the capsulorraphy, the repaired labrum or the remplissage.(Young, Maia, Berhouet, & Walch, 2011) Interestingly, less invasive approaches do not seem to improve results regarding stability compared with open ones; more recurrence have been noted after arthroscopic Latarjet(Cunningham, Benchouk, Kherad, & Lädermann, 2016) or Bankart(Chen et al., 2015) procedures. Although the latter factor could be related to technical problems linked to the development of these new procedures, the bulk effect conferred by anterior scar tissue formation, already sought since the beginning of shoulder stabilization,(Hippocrates, 1927) may also plays a important role in decreasing humeral head translation. New and mini-invasive techniques lead to less scar formation that may allow more postoperative mobility, but could on the other hand also reduce stability.(Chen et al., 2015)

Heading towards a better understanding of the origin of instability and subsequent apprehension, postoperative management may in turn also be improved, notably in challenging cases of patients with persistent apprehension, despite a clinically stable shoulder. Knowing that shoulder apprehension could be the result of ongoing cerebral abnormalities or residual micro-motion may avoid costly series of onerous investigations, useless physiotherapy sessions or even re-operations. Furthermore, this perspective offers a new angle of a therapeutic approach that differs from conventional manual rehabilitation methods centered on mechanical shoulder stability. If persistent subtle shoulder instability is suspected, growing research evidence supports the use of a multidisciplinary approach including (1) a "reafferentation" of their shoulder based on a neuromuscular and proprioceptive work,(Fyhr et al., 2015) (2) a neuro-feedback therapy where the patient directly visualizes his abnormal response to a negative stimulus on fMRI or electroencephalogram, and can thereby actively correct it,(deCharms et al., 2005) (3) a cognitive behavioral approach to decondition this pathological residual apprehension by making them realize residual micro-motion does not necessarily lead to recurrent instability with gradual exposition that has already shown successful results in the treatment of kinesiophobia,(Linton & Andersson, 2000; Monticone et al., 2014; Morley, Eccleston, & Williams, 1999) a condition based on a re-injury fear-avoidance model initially described in low-back pain,(Vlaeyen & Crombez, 1999) further popularized in sports medicine(Kvist, Ek, Sporrstedt, & Good, 2005) and various upper limb conditions,(Das De, Vranceanu, & Ring, 2013) coupled with (4) rotator cuff reinforcement to avoid further dysfunction due to muscle fatigue, notably anterosuperior migration of the humeral head and consequent impingement.(Seitz, McClure, Finucane, Boardman, & Michener, 2011) Clinicians and physiotherapist could also consider incorporating these therapies as a pre- or postoperative treatment modality. Furthermore, different techniques of stabilization with for example better reconstruction of the glenoid concavity(Steffen & Hertel, 2013) and of the ligament complex,(Cvetanovich et al., 2013) or dynamic anterior stabilization(Collin & Lädermann, Submitted) may open new horizons leading to improved management regimens for joint instability. Finally, these proposed principles could potentially be applied to other unstable joints such as wrist, knee or ankle instability.

Overview

This article provides a concise and comprehensive summary of the central and peripheral impairments observed after an anterior shoulder dislocation. Apprehension is a common problem with a complex multisystem origin that can be regrouped in three types: central neurologic, peripheral neurologic, and mechanical. Shoulder instability induces major alterations in the central nervous system, especially in the primary sensorimotor cortex, dorsolateral and dorsomedial prefrontal cortex, as well as the insula. Changes in these brain areas involve complex emotional and cognitive functions, anxiety and salience, and induce more negative anticipation and motor resistance in patients, following a cerebral conditioning process generated by dislocation episodes. Persistent peripheral neurological impairment and articular micro-motion may also explain why some patients keep an apprehension despite a clinically stable shoulder with no further episode of instability. Instability scores such as Rowe Score, integrating shoulder motion seem to evaluate apprehension changes more precisely than general shoulder scores and are good assessment tools, although no score can entirely assess the extent of cognitive changes of shoulder apprehension. The suggested range of treatments should help to streamline the clinician and physiotherapist's rehabilitation strategy, avoiding stabilizations or revision surgery in some situations, as well as preventing long-term dislocation arthropathy.

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