Management of (traumatic) anterior shoulder instability: current treatment and future perspectives The open Bankart procedure still state of the art in 2020

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Chapter 1

General introduction and aim of this thesis

1. Epidemiology

Traumatic anterior shoulder dislocations are the most common dislocations of the shoulder.[1] Based on an annual incidence of 30 shoulder dislocations per 100,000 inhabitants, with approximately 17 million inhabitants, the Netherlands can count on about 5100 shoulder dislocations per year.[2–5] Shoulder dislocations occur mainly during private or sports accidents. Age at first dislocation is the most important factor in predicting recurrence, being up to 95% for persons younger than 20 years and up to 80% under 30 years of age.[6] In general, more men than women are treated for a shoulder dislocation.[7] Most of the patients treated surgically for persistent shoulder instability are young and active, especially males aged between 15 and 35 years and women in the older age groups.

2. Diagnosis shoulder instability including etiopathology

Age and impact of the instability complaints are two important considerations for the type of intervention in patients with shoulder instability. Typically, patients present with a history of trauma. Symptoms may be vague, varying from pain, weakness and shoulder dysfunction. Discomfort in the overhead, abducted and externally rotated position of the shoulder is associated with anterior instability. Symptoms in the forward elevated and internally rotated position (i.e. when pushing open heavy doors) is more associated with posterior instability. Pain and paresthesias (because of traction on the brachial plexus) is often reported in patients with inferior instability (i.e. when carrying heavy objects). Physical examination should focus on both diagnosis and identification of associated injuries. For anterior instability, the apprehension-relocation test (or Fowler test) is the most sensitive (specificity: 87%, sensitivity: 40% for any labral lesion including SLAP).[8] Other tests associated with shoulder instability are the (modified) load-and-shift test with an optimal reliability of this test, when tested in 0° abduction for the posterior and inferior directions (intraclass correlation coefficient (ICC), for interrater reliability and test-retest reliability was 0.68 and 0.79, respectively) with a good reliability for the anterior direction when tested in 90° abduction (ICC: 0.72) and sulcus sign (Kappa value: < 0.5, ICC: 0.60), the latter reflecting inferior laxity of the capsule.[9] The two most reliable tests associated with posterior instability are the posterior stress test and the jerk test.[10]

Multiple **definitions of shoulder instability** are in circulation, creating imprecision and ambiguity surrounding this topic. Examples are: "glenohumeral instability is the inability to maintain the humeral head centered in the glenoid fossa" or "shoulder instability describes the susceptibility of a shoulder to subluxation or dislocation". "**Traumatic** instability" arises from an injury of sufficient magnitude to tear the glenohumeral capsule, ligaments, or rotator cuff or to produce a fracture of the humerus or glenoid (rim). Since shoulder instability as such ranges from asymptomatic instabilities, due to extrinsic shoulder problems (neuro-motor systems) to intrinsic, anatomical pathologies, a simple

validated **classification system** covering all instabilities does not exist. Nevertheless several classification systems have been suggested, but due to low validity of these classifications, clinical management decisions based on these classifications are multi interpretable.[11] The most commonly used and simple classification system, divides instability into two distinct groups based on the presence or absence of trauma, resulting in instability, direction of (partial) dislocation, and whether it involves one or both shoulders.[12] Later on, a more extensive classification is proposed including three types of shoulder instability recognizing both structural and non-structural components of shoulder instability. Even more, stressing a continuum between pathologies as cause for shoulder instability, with probably multifactorial origin after years, involving the brain-musculoskeletal system.[13]

The glenohumeral joint is a complex, mobile, multiaxial, ball-and-socket articulation that allows coordinated motion in the frontal, transverse, and sagittal planes. The latter allows for 360 degrees of circumduction. **Pathologies causing instability** can be categorized in ***structural*** (internal: rotator cuff, surface area of contact, capsulolabral complex) and ***non-structural*** (external, central and peripheral nervous system) elements.[13–15] The structural elements include abnormal morphology (either genetic or intrauterine), abnormal collagen, acquired (micro-)traumatic lesions over time or traumatic morphologic abnormalities.[13]

As for these ***structural causes***, a subclassification in soft tissue (shoulder capsule, glenoid labral rim, glenohumeral ligaments) and bony structures (glenoid cavity and humeral head) can be made. For that matter, an intact labrum deepens the shallow glenoid fossa up to 50%, thus improving its articulation and contact area with the humeral head up to 75%. It probably also serves as a chock block preventing excessive humeral head rollback.[16] The shoulder labrum is attached to the joint capsule, which is the layer of soft tissue encapsulating the joint. The shoulder joint capsule is lax and thin and by itself, offers little resistance or stability. Focal thickening of the anterior capsule present the capsuloligamentous structures, the three glenohumeral ligaments. These ligaments act as restraints, and thus stabilizers at the end-range of motion of the shoulder joint.[15,17,18] Typical labral lesions are associated with acute or chronic anterior shoulder instability, especially anterior and antero-inferior tears.[19] Bankart described the "essential lesion" of anterior shoulder instability to be an anteroinferior labral tear. That is why it bears the eponymous term *Bankart lesion*. However, different types of labral lesions can be encountered, such as: the Perthes lesion (traumatic) or Buford complex (non-traumatic); GLAD lesion (Gleno-Labral Articular Disruption); Broca-Hartmann pouch; ALPSA lesion and the **Bankart** lesion. Posterior labral tears or Polpsa lesions are much less frequent than anterior tears.[20] Whether all these conditions are physiologic ageing phenomena or only related to (multiple) (micro) traumatic injury(ies) is to be seen. Labral tears can occur in stable or in unstable shoulders, so when a labral tear is present not always operative treatment is necessary.[19] Controversy still exists as to which management strategy is best in each situation.[21] Glenoid bone loss, or bone loss at the humeral head, is also a commonly encountered

problem in (anterior) shoulder instability.[22,23] When an effective glenoid cavity is present, concavity-compression is a contributing mechanism for stabilizing the glenohumeral joint.[24–27] Following an initial shoulder dislocation, osseous defects are probably present in up to 22% of patients, and up to 88% of patients with recurrent instability.[22,28,29] The (critical) amount of (glenoid or bipolar) bone loss and its assessment of optimal treatment is currently a subject of debate.[23,30,31]

As for ***non-structural causes*** of instability (central and peripheral nervous system), the importance of intact rotator cuff musculature, with active muscular contraction has been highlighted for glenohumeral stability.[25,32,33] The mechanical restraints about the shoulder (glenoid-humeral head) contribute also to the feedback loop for stability by neural feedback (proprioception) to the central nervous system. The latter is integrated with other somatosensory, vestibular, and visual input, and ultimately results in the generation of efferent control over the dynamic restraints about the shoulder joint (neuromuscular control).[34] So, when mechanical restraints of the shoulder are disrupted, the instability problem becomes aggravated by means of pathologic changes in the neural feedback system.[34]

3. History of stabilizing surgical procedures, including Bankart repair

Historically, stabilizing surgical procedures for shoulder instability are either focused on passive stability constraints at the level of the joint capsule, dynamic augmentations and osseous procedures at the glenoid, humerus or both. An overview with a time-line when the procedure was introduced is given in Table 1. The procedures are stratified in open soft tissue, open osseous surgical procedures and arthroscopic procedures.[35–37]

The ***open Bankart procedure*** was first described in the *British Medical Journal* in 1923.[38,39] Originally, this stabilizing procedure was done for the patient with habitual anterior shoulder dislocation. Initially, Bankart described a lesion where the labrum was separated from both the glenoid and the capsule. For this, he developed a technique, abrading the glenoid to facilitate natural ingrowth of the reattached labrum, he also sutured the capsule to the detached labrum. During this procedure the subscapularis tendon was not shortened, preserving its function. Later on, he described the technique, reattaching the detached labrum including the joint capsule to the glenoid bone. Since then numerous modifications have been made, such as the Bankart procedure in association with a capsular shift.[40] Some of the surgical methods, such as the Magnusson-Stack procedure, Putti-Platt procedure, arthroscopic stapling, and transosseous suture fixation have been almost completely abandoned.[37,41,42] Other strategies, such as the Bankart repair, capsular shift, and remplissage (being a combined arthroscopic posterior capsulodesis and infraspinatus tenodesis using sutures and suture anchors that fills (Remplissage: French: to fill) the Hill-Sachs lesion have persisted for decades and nowadays have been adapted for arthroscopic use.[37,43]

Table 1: Historic overview of surgical procedures for shoulder instability problems

Soft tissue procedures	*Capsular procedures*	- *Injections with iodine tincture/blood*: Genzmer 1882; Mandel/ Kepler 1937 - *Shortening of shoulder capsule*: Ricard 1894, Gerster 1883, Bardenheuer 1896, Mikulicz 1896, Putti-Platt 1923, inferior capsular shift: Neer, Foster 1980 - *Shoulder capsule reinforcements, making use of fascia, tendon, periost or other material*: Gallie-le Mesurier 1948, Henderson 1943, Nicola 1929 - *Open Hill-Sachs "remplissage"*: Connolly 1972 - *Capsuloligamentary "retensioning" procedures*: Caspari 1987 - *Closing of rotator interval*: Rowe 1987 - "*Suture-only" labrum refixation*: Harryman 1994
	Rotator cuff muscle/ tendon procedures	- *Shortening of subscapularis*: Quervain 1910, Röbke 1912, Putti 1923, Platt 1925, Matti 1936, Boicev 1938, Magnuson & Stack 1943, Boicev & Osmond-Clarke 1948 - *Transposition of (part of) deltoid muscle*: Clairmont-Ehrlich 19 09 - *Open Hill-Sachs remplissage*: Connolly 1972
	Arthroscopic procedures	- *Capsular shift by means of "stapling technique"*: Johnson 1980 - *Labrum refixation*: Morgan 1987 - *Labrum refixation with "suture anchors"*: Snyder, Wolf 1990-1991 - *Capsular shift*: Duncan 1993 - "*Laser assisted/thermal capsular shrinkage"*: Thabit 1994 - *Closing of rotator interval*: Field, Treacy 1995-1997 - *Revision of Bankart procedure*: Kim 2002 - *Hill-Sachs remplissage*: Wolf 2004, Purchase 2008
Bone procedures	*Glenoid procedures*	- *Deepening of cavum glenoidalis*: Hildebrand 1902 - *Procedures focused on the edge of cavum glenoidalis*: Perthes 1906, **Bankart** 1923 - *Bone augmentation procedures on glenoid defect*: Eden 1918, Hybbinette 1917&1932, Noordenbos 1938, Leguit 1942 - *Coracoid (augmentation) procedures*: Oudard 1924, Noesske 1924, Latarjet 1954, Bristow 1958, Trillat 1954 - *Mini-open Bristow-Latarjet procedure*: Nourissat 2006
	Humeral procedures	- *Humeral head resection*: Cramer 1882 - *Glenohumeral arthrodesis*: Albert 1888 - *Rotational osteotomy of humerus*: Weber 1969
	Arthroscopic procedures	- *Latarjet procedure*: Lafosse 2007 - *Eden procedure*: Taverna, Scheibel 2008 - *Augmentation procedure by means of autograft of distal part of clavicle*: Tokish 2014 - *Latarjet procedure with "guided surgical approach and suture endobutton" fixation*: Boileau 2015 - *Dynamic anterior stabilisation with long biceps tendon and Bankart procedure*: Mehl 2019

The open (modified) Bankart repair, with good clinical outcome and a **low recurrence rate** is historically considered to be the gold standard of care and the benchmark for all current arthroscopic techniques for anterior shoulder instability.[44] However, for potential advantages (e.g. faster rehabilitation, smaller incisions etc.), the majority of Bankart repairs are being performed arthroscopically nowadays.[45–53] Both open and arthroscopic repairs have shown to decrease the recurrence rate of shoulder dislocation and are considered to be safe and reliable surgical treatment options[54–58] Nevertheless, a majority of studies report on the higher rate of recurrent instability using arthroscopic procedures compared to the traditional open procedures.[44,59–61] Therefore, recent studies have challenged this arthroscopic trend to treat shoulder instability, reviving the interest in open repair procedures.[45,54] Results of a recent meta-analysis of open versus arthroscopic shoulder stabilisation during the last two decennia demonstrated there were no significant improvements for clinical outcome or external rotation deficits in both groups.[62] But, although the recurrence rate of dislocation for open surgery remained comparable in this 20 year time period (10.7% and 10.8%), the recurrence rate after arthroscopic stabilisation was higher, although it decreased little 16.8% to 14.2%.

The (open) Latarjet procedure (transfer of coracoid including attached muscles to the deficient glenolabral area at the anterior glenoid) is like the Bankart repair also a viable surgical option for recurrent traumatic anterior instability of the shoulder joint and is by some the preferred treatment in cases of glenoid deficiency and in revision anterior stabilization.[63–68] The open Latarjet procedure yields the most reliable outcome of stabilization. However this bone block procedure has also the highest complication rate, especially when being performed arthroscopically by non-experienced surgeons.[69] In the meantime, a few modifications of the original technique described by Latarjet have been developed, such as the congruent arc technique (developed by DeBeer), which increases the joint surface contact area of the glenoid. Another modification is the technique described by Walch & Boileau.[70]

4. Evidence and evaluation of recurrence

Until today, the optimal approach and technique to address anterior shoulder instability remains controversial. How many instabilities will resolve "spontaneously" or after conservative treatment, with or without proprioceptive training, is unknown. In 2017, Galvin et al. outlined the natural history and best clinical practices for nonoperative management of anterior shoulder instability, including an algorithm to guide management of first-time dislocators (Figure 1).[71] They concluded that, despite the continues refinement of surgical techniques for anterior glenohumeral instability, there remains a significant role for nonoperative treatment. Many different surgical stabilizing shoulder procedures have been applied, of which almost all have been subject to discussion, because of varying

results at long-term follow-up.[72] The latter and the lack of full knowledge on epidemiology of the natural cause of (traumatic) shoulder dislocations and on the definition of shoulder instability as such, underscores why there is no consensus or best treatment guideline.[73]

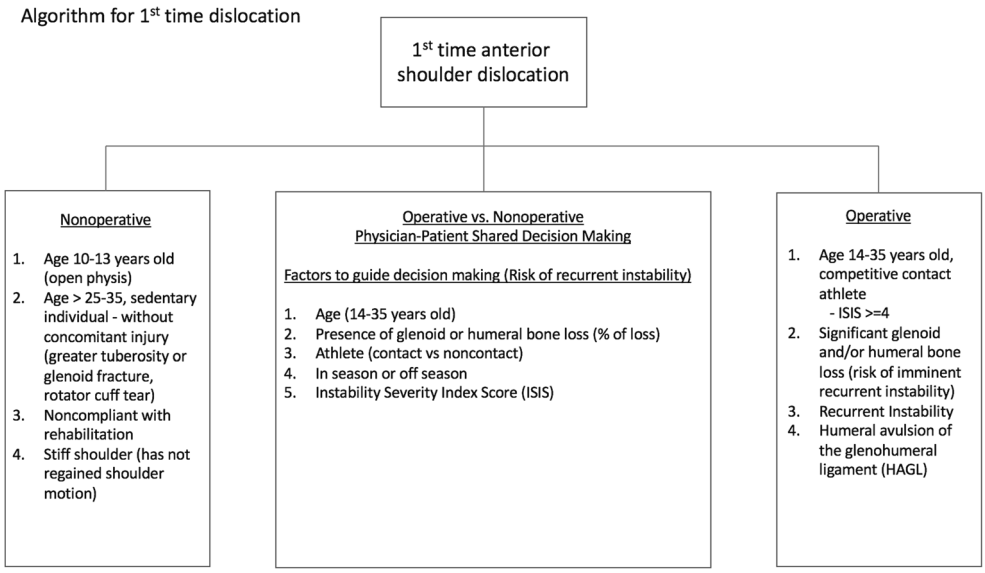

Fig. 1: Algorithm for first time dislocation.[71]

Factors predisposing to recurrent instability and revision stabilization procedures for anterior glenohumeral instability remains uncertain. There are publications of population based cohortstudies assessing risk factors of failure after stabilizing shoulder surgery, combining the results for open and arthroscopic procedures.[74,75] Common reasons for failure following previous anterior stabilizing surgery are: diagnostic errors missing associated pathology such as bony lesions; new trauma, for instance in contact or forced overhead sport; technical errors; younger age; capsular laxity or voluntary dislocations.[76–80] Underestimation of glenoid bone loss or bone loss at the humeral head is often related to redislocation before and after a stabilizing shoulder procedure.[81–84] Glenoid bone loss is a commonly encountered problem in anterior shoulder instability and should be identified to facilitate a better understanding of management of the patients in this group.[22,28,29] Following an initial shoulder dislocation, an osseous defect is probably present in up to 20% of patients, and up to 90% of patients with recurrent instability.[64,85] When recurrent symptomatic shoulder instability is present, several revision techniques are available, including open Bankart repair, bony augmentation procedures, and management of Hill Sachs defects.[86] Identifying, the patient`s primary pathology is a must. The latter includes knowledge on detailed understanding of the patient's shoulder anatomy and its static and dynamic restraints after the failed index procedure.

5. Patient perception on shoulder instability (PROM's)

An increasing number of outcome measurement tools have been designed to report on the effectiveness of treatment for shoulder pathologies. Patient's perceptions on the effect of an intervention have become more important to evaluate outcome. Using the *appropriate instrument* for evaluation of patient outcome data is essential if outcome measures are to be valid and clinically meaningful. Failure to account for patient reported outcome factors has been a major limitation in previous shoulder scoring systems.[87,88] Known scoring systems that address shoulder instability, in random order, include the Rowe/modified Rowe score (also known as rating sheet for Bankart repair);[89,90] the American Shoulder and Elbow Surgeons (ASES) score;[91,92] the L'Ìnsalata shoulder rating system / Shoulder Rating Questionnaire (SRQ);[93,94] the Melbourne Instability Shoulder Score (MISS);[95] the Disabilities of the Arm, Shoulder and Hand (DASH) score;[96,97] the Western Ontario Shoulder Instability Index (WOSI);[98] the Oxford Instability Score (OIS);[99,100] the Constant-Murley (CM) score;[101] the Athletic Shoulder Outcome Rating Scale (ASORS);[102] the University of California, Los Angeles (UCLA) score;[103] and the Simple Shoulder Test (SST).[87,104,105]

The **Oxford Shoulder Score** (OIS) was developed by Dawson et al.[99,106] Two different questionnaires exist; one was constructed in 1999 for instability patients, now called the OIS, and the other was constructed for shoulder operations other than instability (OSS), a few years earlier, in 1996. The shoulder questionnaires for instability problems that have already been translated and validated in Dutch are: the L'Ìnsalata shoulder rating system/Shoulder Rating Questionnaire (SRQ);[93,94] the Disabilities of the Arm, Shoulder and Hand (DASH) score;[96,97] and the Simple Shoulder Test (SST).[87,104,105] The Oxford Instability Score (OIS) has been translated and validated in Dutch five years after our Dutch validation of the OSS.[99,100,106,107]

Aims of thesis

1. Anatomical evaluation of one of the major passive constraints for shoulder instability, the labrum, and its phylogenetic counterpart at the hip joint (chapter 2)
2. Patient evaluation of outcome including discussion on Oxford Shoulder Score and Oxford Shoulder Instability Score ((addendum) chapter 3)
3. Evaluation of management of acute first-time anterior shoulder dislocations in the Netherlands by means of a shoulder questionnaire (including treatment of recurrent shoulder instability) (chapter 4)
4. Clinical evaluation of the mid- and long term results after a labrum joint capsule (open Bankart) repair (chapter 5 & 6)
5. Evaluation of a novel technique addressing bony defects of the glenoid (chapter 7)

Outline of the thesis

Anatomical evaluation of the shoulder labrum, with its well-known Bankart lesion, being highly associated with shoulder instability is presented in **chapter 2**. Labral pathology with special focus on the role in shoulder instability and matching treatment options are being described. We also regard evolutional differences for the labrum of the shoulder, originating from the fact that humans evolved to assume an upright position. A comparison with the labrum of the hip joint is made, since both hip and shoulder are both essentially ball and socket joints.

Chapter 3 presents the validation study of the Dutch version of the Oxford Shoulder Score, including a discussion on the relation between the Oxford Shoulder Score and the Oxford Shoulder Instability Score. The Oxford Shoulder Score (OSS) is an internationally-used patient-based outcome score. Up to now, it was not validated in Dutch.

Chapter 4 presents the results of a nationwide survey on the management of traumatic anterior shoulder dislocation amongst Dutch public hospitals. We questioned how orthopaedic surgeons at that time would manage patients with this issue, ten years after the introduction of the Dutch national guideline: "acute primary shoulder dislocation, diagnostics and treatment" in 2005. Furthermore, we evaluated how these surgeons would treat recurrent instability after one or more (traumatic) anterior shoulder dislocation.

In **chapter 5 and 6**, the outcome of the conventional open Bankart repair is evaluated in two successive studies including mid- and long term follow-up. In chapter five, the outcome of open Bankart repair using suture anchors in 31 patients (31 shoulders) with a mean follow-up of 11 years (10 to 15) for patients with instability after one or more (traumatic) anterior shoulder dislocation is being reported. In chapter six, the outcome of the open Bankart repair using suture anchors in 39 patients (39 shoulders) is reported with a mean follow-up of 21 years (16 to 26).

A potential alternative treatment option for structural bony deficits is a 3D printing technique to augment the bony glenoid defect. To this end a biomechanical cadaver study is done (**chapter 7**). Ten fresh-frozen cadaveric shoulders were tested for stability under five different conditions, being: (1) in the anatomic situation, (2) after the creation of an anterior glenoid bone defect, (3) after implantation of a 3D patient specific titanium implant, (4) after a Latarjet procedure with (4) and without (5) 10N of load attached to the conjoined tendon.

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