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DEGENERATIVE ROTATOR CUFF TEAR

Results and Prognostic Factors of Arthroscopic Repair

by

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With love

To Mari, Anni and Eetu

ABSTRACT

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Degenerative rotator cuff tear – Results and prognostic factors of arthroscopic repair

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Factors affecting outcome after arthroscopic rotator cuff repair are unclear and there is still insufficient evidence of efficacy of any treatment modality for rotator cuff tears. The purpose of the current study was to determine in a prospective randomized multicenter trial whether there is a difference in clinical outcome between three different treatment modalities in the treatment of degenerative, atraumatic supraspinatus tendon tear in elderly patients. 180 shoulders were randomized into three treatment groups: 1) physiotherapy, 2) arthroscopic acromioplasty and physiotherapy, 3) arthroscopic rotator cuff reconstruction, acromioplasty and physiotherapy. The objective of this study was also to evaluate retrospectively the effect of trauma, the size of the rotator cuff tear, smoking habits and glenohumeral osteoarthritis on the clinical treatment outcome after arthroscopic rotator cuff repair in a consecutively prospectively collected series of patients. The patient data was gathered to the electronic database. The Constant score was used as a primary outcome measure. The follow-up time was one year.

The main finding was that operative treatment did not provide benefit over conservative regimen in elderly patients with atraumatic supraspinatus tear. Trauma did not affect on the clinical outcome and there was neither difference in the age of patients with traumatic vs. non-traumatic rotator cuff tears. The size of the rotator cuff tear correlated significantly with the clinical results. The outcome was significantly poorer in tears with infraspinatus involvement compared to anterosuperior tears. Operatively treated rotator cuff tear patients who smoked were significantly younger than non-smokers, and smoking was associated with poorer clinical outcome. Concomitant osteoarthritis of the glenohumeral joint was found to be a relatively common finding in supraspinatus tear patients. Osteoarthritis of the glenohumeral joint in operatively treated supraspinatus tear patients predicted poorer clinical results comparing to patients without osteoarthritis.

Keywords: shoulder, tendon degeneration, rotator cuff tear, treatment, arthroscopy, acromioplasty, rotator cuff reconstruction, physiotherapy, trauma, tear size, smoking, osteoarthritis, Constant score

TIIVISTELMÄ

Juha Kukkonen

Degeneratiivinen kiertäjäkalvosimen repeämä - Tähystysleikkauksen tulokset ja ennusteeseen vaikuttavat tekijät

Ortopedian ja traumatologian klinikka
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Tähystyksessä hoidettavan kiertäjäkalvosinjänteen repeämän ennusteeseen vaikuttavat tekijät ovat osittain epäselviä, ja näyttö minkään hoitomuodon puolesta on edelleen riittämätön. Tämän väitöskirjan tarkoituksena oli selvittää iäkkäillä potilailla toisaalta konservatiivisen ja leikkauksellisen hoidon eroa jännerappeuman pohjalta syntyneissä ylemmän lapalihasjänteen repeämissä, toisaalta kahden eri leikkausmenetelmän eroa satunnaistetussa prospektiivisessa monikeskustutkimuksessa. 180 jännerappeuman pohjalta syntynyttä ylemmän lapalihasjänteen repeämää satunnaistettiin kolmeen hoitoryhmään: 1) fysioterapia, 2) tähystyksellinen olkalisäkkeen avarrus ja fysioterapia, 3) tähystyksellinen jännerepeämän korjaus, olkalisäkkeen avarrus ja fysioterapia. Lisäksi oli tavoitteena selvittää retrospektiivisesti tapaturman, kiertäjäkalvosimen repeämän koon, tupakoinnin ja olkanivelen nivelrikon vaikutusta tähystyksessä hoidetun kiertäjäkalvosinrepeämän kliiniseen lopputulokseen prospektiivisesti kerätyssä potilasaineistossa. Potilastiedot kerättiin tätä tarkoitusta varten luotuun sähköiseen tietokantaan. Tulosmittarina käytettiin Constant-pisteytystä. Seuranta-aika oli yksi vuosi.

Tutkimuksen päälöydöksenä oli se, että iäkkäillä potilailla ilman tapaturmaa syntyneissä ylemmän lapalihasjänteen repeämissä leikkaushoidolla ei saavutettu etua fysioterapiaan verrattuna. Olkaoiretta edeltävän tapaturman ei todettu vaikuttavan leikkauksella hoidetun kiertäjäkalvosinrepeämän kliiniseen lopputulokseen. Potilaat olivat samanikäisiä riippumatta siitä, edelsikö todettua kiertäjäkalvosinrepeämää tapaturma vai ei. Kiertäjäkalvosinrepeämän koko korreloi leikkaustulokseen. Jännerepeämän ulottuminen alemman lapalihasjänteen alueelle ennusti huonompaa kliinistä lopputulosta verrattuna jännerepeämiin ylemmän lapalihaksen ja lavanaluslihaksen alueella. Tupakoivat potilaat, joilla kiertäjäkalvosinrepeämä hoidettiin leikkauksella olivat nuorempia tupakoimattomiin leikkauspotilaisiin verrattuna. Leikkauksen jälkeinen kliininen lopputulos oli tupakoivilla huonompi. Olkanivelen nivelrikko todettiin yleiseksi löydökseksi ylemmän lapalihasjänteen repeämästä kärsivillä potilailla. Olkanivelen nivelrikko jännekorjauksen yhteydessä ennusti huonompaa kliinistä lopputulosta verrattuna potilaisiin, joilla nivelrikkomuutoksia ei todettu.

Avainsanat: olkapää, jännerappeuma, kiertäjäkalvosimen repeämä, hoito, tähystyskirurgia, olkalisäkkeen avarrus, kiertäjäkalvosimen repeämän korjaus, fysioterapia, tapaturma, repeämän koko, tupakointi, nivelrikko, Constant-pisteet

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ABBREVIATIONS

AC	acromioclavicular
AP	anteroposterior
BLHT	biceps long head tendon
CT	computed tomography
IFSP	infraspinatus
K-L	Kellgren-Lawrance
MRA	magnetic resonance arthrography
MRI	magnetic resonance imaging
MTJ	musculotendinous junction
NSAID	non-steroidal anti-inflammatory drug
RC	rotator cuff
ROM	range of motion
SC	subscapularis
SSP	supraspinatus
TM	teres minor
US	ultrasonography

LIST OF ORIGINAL PUBLICATIONS

The thesis is based on the following original publications, referred to as I-V in the text:

I **Kukkonen J, Joukainen A, Itälä A, Äärimaa V.**
Operatively treated traumatic versus non-traumatic rotator cuff ruptures: a registry study. Ups J Med Sci. 2013 Mar;118(1):29-34.

II **Kukkonen J, Kauko T, Virolainen P, Äärimaa V.**
The effect of tear size on the treatment outcome of operatively treated rotator cuff tears. Knee Surg Sports Traumatol Arthrosc. 2013 Aug 31. [Epub ahead of print]

III **Kukkonen J, Kauko T, Virolainen P, Äärimaa V.**
Smoking and operative treatment of rotator cuff tear. Scand J Med Sci Sports. 2012 Dec 4. [Epub ahead of print]

IV **Kukkonen J, Joukainen A, Lehtinen J, Äärimaa V.**
The effect of glenohumeral osteoarthritis on the outcome of isolated operatively treated supraspinatus tears. J Orthop Sci. 2013 May;18(3): 405-9.

V **Kukkonen J, Joukainen A, Lehtinen J, Mattila KT, Tuominen EKJ, Kauko T, Äärimaa V.**
Treatment on non-traumatic rotator cuff tears: a randomized controlled trial with one-year clinical results. Bone Joint J. 2013 Accepted. (unedited, pre-publication version)

1. INTRODUCTION

A rotator cuff (RC) tear is one of the most common causes of pain and disability in the upper extremity. The RC may rupture as a result of direct trauma or it may be purely degenerative with no obvious relation to trauma. Most often, RC tears are a consequence of a combination of both trauma and degenerative changes, i.e., following an acute-on-chronic situation. The risk of such tear is increased by age and advancing tendon degeneration (Yamaguchi et al. 2006). RC tears in elderly patients are often asymptomatic, and no less than 50% of population aged over 60 years may have a RC tear (Milgrom et al. 1995). It is unclear which conditions convert an asymptomatic RC tear into a symptomatic tear. An increased size of the RC tear may generate symptoms (Mall et al. 2010, Yamaguchi et al. 2001). Symptomatic RC tendon tears typically cause shoulder pain and limit movement. Usually the tear is located in the supraspinatus tendon (Kim et al. 2010), and thus there is pain and impaired abduction and movement in the overhead positions.

The treatment of RC tear is generally operative since the tendon does not attach to bone spontaneously and the tear may enlarge by time. However, for patients with severe tendon degeneration it is not known whether operatively re-insertion of the tendon is compatible with healing (Boileau et al. 2005), and it is unclear whether operative treatment of these degenerative RC tears is, in fact, beneficial. Recent studies have reported good results of conservative treatment of RC tears, but only one level I trial comparing conservative and operative treatment of RC tears has been published previously. Despite traumatic event is often associated with the onset of shoulder symptoms there is only one earlier study comparing outcome between traumatic and non-traumatic rotator cuff tears (Braune et al. 2003). The RC tear size is reported to correlate with the rotator cuff re-tear rate (Cho and Rhee 2009, Cole et al. 2007, Oh et al. 2009), but it is unclear if there is a direct correlation between the tear size and clinical outcome after RC repair. In literature there are only few earlier studies with partly controversial results about the effect of smoking and concomitant osteoarthritis of the glenohumeral joint on the treatment outcome after RC repair (Klinger et al. 2005, Mallon et al. 2004, Prasad et al. 2005).

The purpose of this thesis was to address these controversial issues associated with arthroscopic repair of degenerative RC tears. It was designed a prospective, randomized trial investigating three different treatment modalities of atraumatic supraspinatus tears in elderly patients. The effect of trauma, the size of the RC tear, smoking habits and glenohumeral osteoarthritis on the clinical treatment outcome were analyzed retrospectively in a consecutively prospectively collected series of patients.

2. REVIEW OF THE LITERATURE

2.1. ROTATOR CUFF

2.1.1. Etymology

Rotator is derived from the Latin word *rotationem*, noun of action from past participle stem of *rotare* “revolve, roll”. *Rotator* “muscle which allows a part to be moved circularly” is recorded from 1670s (Online Etymology Dictionary). *Cuff* comes from Middle English *cuffe, coffe* (”glove, mitten”), of obscure origin (Wiktionary).

The RC is composed of a group of flat tendons, which fuse together and surround the front, back, and top of the shoulder joint like a cuff of a shirt sleeve. These tendons are connected individually to short, but very important, muscles that originate from the scapula. When the muscles contract, they pull on the RC tendon, causing the shoulder to rotate upward, inward, or outward, hence the name ”rotator cuff” (Southern California Orthopedic Institute site).

2.1.2. Anatomy

The RC is a complex of four muscles that forms a continuous “collar” of reinforcement around the anterior, superior and posterior surfaces of the glenohumeral joint. RC is composed of four muscle tendons: the subscapularis (SC), supraspinatus (SSP), infraspinatus (IFSP) and teres minor (TM). The tendons of these muscles blend in with the subjacent capsule as they attach to the tuberosities of the humerus (Minagawa et al. 1998). The subscapularis arises from the anterior aspect of the scapula and attaches over much of the lesser tuberosity (Ide et al. 2008). It is the largest and strongest of the RC muscles, providing 53% of the total cuff strength. The strengths of the other muscles are: SSP 14%, IFSP 22% and TM 10% (Keating et al. 1993). The supraspinatus muscle arises from the supraspinatus fossa of the posterior scapula, passes beneath the acromion and acromioclavicular (AC) joint and attaches to the superior aspect of the greater tuberosity. The infraspinatus muscle arises from the infraspinatus fossa of posterior scapula and attaches to the posterolateral aspect of the greater tuberosity. The teres minor arises from lower lateral aspect of the scapula and attaches to the lower aspect of the greater tuberosity (Curtis et al. 2006 (Fig. 1), Dugas et al. 2002). Mochizuki et al. (2008) reported that the footprint of the supraspinatus on the greater tuberosity is much smaller than previously believed, and this area of the greater tuberosity is actually occupied by a substantial amount of the infraspinatus. The tendons of RC are inseparable, except for the subscapularis, which is separate and joined to the rest of the cuff via the rotator interval. The biceps long head tendon (BLHT) may be considered a part of the RC. It originates from the supraglenoid tubercle of the scapula and from the posterior, anterior or both aspects of the superior labrum (Vangsness et al. 1994). An intra-articular portion of the BLHT passes over the humeral head before exiting the glenohumeral joint through the bicipital groove. The superior glenohumeral ligament, the coracohumeral ligament and the distal attachment of the subscapularis tendon form a pulley structure within the rotator interval (Fig. 2). This is a critical structure that keeps the BLHT in the bicipital groove (Bennett 2001, Jost et al. 2000).

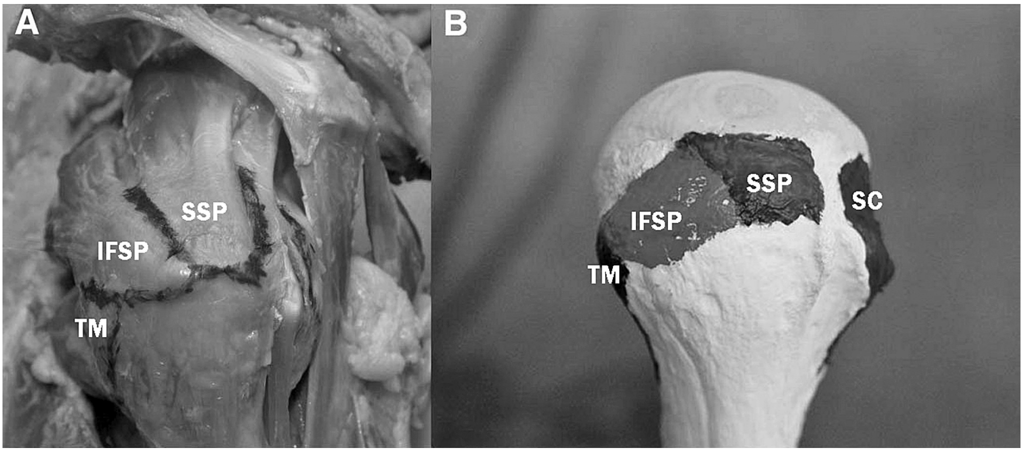

Fig. 1. Footprints of the rotator cuff tendons shown with a cadaveric (A) and a plastic bone (B) model (Figure modified from Curtis et al.)

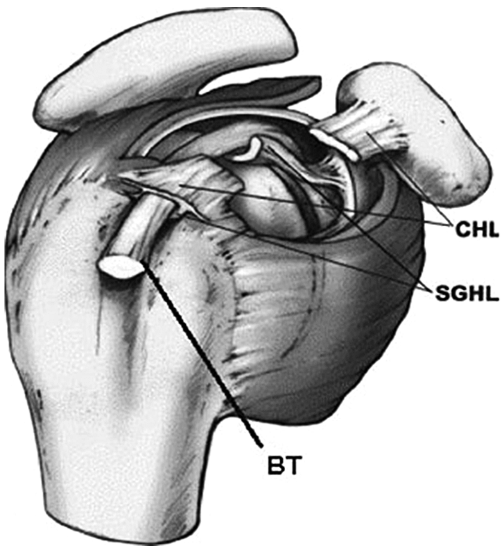

Fig. 2. Biceps pulley structure within the rotator interval (BT=biceps tendon, CHL=coracohumeral ligament, SGHL=superior glenohumeral ligament) (Reprinted with permission by Dr Jason Crane)

The RC muscles are innervated by cervical spinal nerves C5-C6. The subscapularis is innervated by the upper and lower subscapular nerves. The innervation to the supraspinatus and infraspinatus muscles originates from the suprascapular nerve after it passes through the suprascapular notch. The teres minor is innervated by a branch of the axillary nerve (Hattrup and Cofield 2010). The innervation to the biceps brachii muscle originates from the musculocutaneous nerve (Pacha Vicente et al. 2005). The BLHT is also innervated by a network of sensory sympathetic fibers (Alpantaki et al. 2005, Tosounidis et al. 2013).

The major arterial supply to the RC is derived from the ascending branch of the anterior humeral circumflex artery, the acromial branch of the thoracoacromial artery and the suprascapular and posterior humeral circumflex arteries (Chansky and Iannotti 1991, Laing 1956). Arterial supply to the BLHT comes from the muscular branches of brachial artery (Kanbayashi et al. 1993).

The RC tendons are composed primarily of water, collagen, glycosaminoglycans and cells referred to as tenocytes (Riley et al. 1994). Collagen is composed predominately of type I molecules making up 85% of the dry weight of the tendons (Brinker and O'Connor 2004). The microanatomy of the supraspinatus and infraspinatus tendons is composed of five layers (Clark and Harryman 1992). The most superficial layer is composed of the fibers of coracohumeral ligament. Layers two and three are thick tendinous structures. Layer four is composed of loose connective tissue and layer five is the joint capsule of the shoulder. The collagen fiber organization is important for normal mechanics of the tendon (Szczesny et al. 2012). There is little published data about the tensile strength of the RC tendons. In a biomechanical study it was found significant correlation between age and maximum strength of the supraspinatus tendon. A 30 years old specimen demonstrated about 1500 N tensile strength, whereas the strength for 65 old specimen was about 900 N (Rickert et al. 1998).

2.1.3. Function of the rotator cuff

The RC muscles rotate the humerus in relation to the scapula. The supraspinatus muscle acts closely with the deltoid muscle to elevate the upper extremity in flexion and abduction. The supraspinatus initiates the first 15 to 30º of arm abduction and acts throughout the range of abduction of the shoulder. The deltoid muscle, which is the most important abductor of the arm, performs its action after the humeral head has been fixed and snubbed to the glenoid cavity by the RC. The subscapularis muscle together with the teres major, latissimus dorsi and pectoralis major muscles are internal rotators of the shoulder. Compared to these four internal rotators, the infraspinatus and teres minor are the only external rotators of the shoulder. The internal rotator muscles comprise a larger muscle mass than the external rotator muscles, which leads to greater power of internal rotation (Ng and Kramer 1991). The infraspinatus acts primarily with the arm in the neutral position while the teres minor is more active in external rotation at 90 degrees of abduction (Neri et al. 2009, Walch et al. 1998). Despite the primary external rotatory function of the infraspinatus muscle, it contributes substantially also to the strength of abduction. In an experimental study Gerber et al. (2007) reported a loss of approximately 70% of external rotation strength and of approximately 45% of abduction strength in patients with complete isolated infraspinatus palsy.

The four RC muscles not only move but also stabilize the glenohumeral joint. They do this by centralizing the humeral head in the glenoid fossa (Neri et al. 2009). An important characteristic of the RC muscles is that they can function as head compressors in almost any position of the glenohumeral joint. The other shoulder muscles (deltoid, BLHT, pectoralis major, latissimus dorsi and teres major) can contribute to humeroglenoid compression only in certain glenohumeral positions. The supraspinatus muscle is the primary superior compressor of the humeral head and resists the superior force exerted by the deltoid muscle (Parsons et al. 2002). The subscapularis and the infraspinatus muscles are the primary anterior and posterior compressors, respectively. The stabilizing mechanism of the RC depends on the integrity of the entire RC, specifically, the transverse force couple formed by the anterior (SC) and posterior (IFSP/TM) RC tendons (Parsons et al. 2002) (Fig. 3).

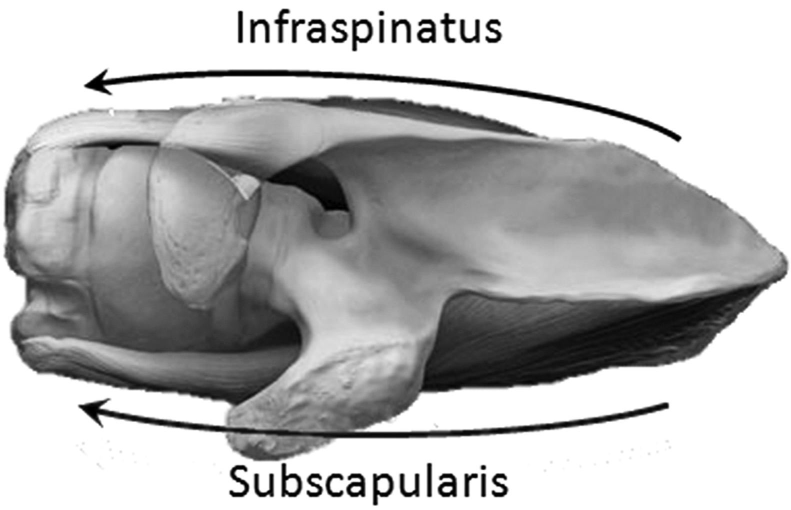

Fig. 3. SC and IFSP form a transverse force couple. (Reprinted with permission by Shoulderdoc.co.uk)

The exact function of the BLHT in shoulder is controversial. Cadaver studies suggest that the BLHT has stabilizing effect on the glenohumeral joint in all directions (Itoi et al. 1993, Kumar et al. 1989, Pagnani et al. 1996, Rodosky et al. 1994, Su et al. 2010, Warner and McMahon 1995, Youm et al. 2009). However, clinically this stabilizing effect of the BLHT appears to be insignificant (Berlemann and Bayley 1995, Klinger et al. 2005, Walch et al. 2005).

2.2. ROTATOR CUFF TEAR

RC diseases rank among the most prevalent of all musculoskeletal disorders. Neer (1983) described RC disease as a progressive degenerative disorder of the RC tendons which begins with an acute tendinitis, progresses to tendinosis with degeneration and partial thickness tears, and result in full thickness tear. Later histological and clinical studies have shown that degenerative tendon changes and partial tears occur more often on the articular side of the RC (Longo et al. 2007). This may due to greater tensile strain in articular-side tendon fibers compared to bursal-side fibers with the arm in abduction (Reilly et al. 2003). Supraspinatus tendon is most frequently involved (Kim et al. 2010). RC tear may also result suddenly from an acute trauma, fall onto an outstretched arm being the most common mechanism of injury (Mall et al. 2013). These traumatic tears are typically larger and involve more often the subscapularis and infraspinatus tendons compared to atraumatic tears (Mall et al. 2013). Torn RC muscles especially with larger tears atrophy with time and muscle is replaced by fat (Chaudhury et al. 2012).

2.2.1. Prevalence

The true prevalence of RC tears in the general population is difficult to determine because a tear can cause significant disability or it may be fully asymptomatic. The prevalence of RC tears has been estimated in many cadaveric and radiological studies. Yamanaka and Fukuda (1987) found an overall prevalence of 20% (full-thickness tear 7%, partial thickness tear 13%) of RC tears in 249 cadaveric shoulders and Lehman et al. (1995) 17% full-thickness tears in 235 cadavers (mean age 64,7 years, range 27-102). The largest cadaveric study reported an overall prevalence of 30% (full thickness tear 12%, partial thickness tear 18%) of RC tears in 2553 cadaveric shoulders (mean age 70,1 years) (Reilly et al. 2006).

In radiologic studies the prevalence of RC tears has been evaluated in asymptomatic and symptomatic shoulders. Yamamoto et al. (2010) studied 1366 shoulders (mean age 57,9 years, range 22-87) and this population-based study reported an overall prevalence of 21% of RC tears by ultrasonography. The prevalence of RC tears was 17% in asymptomatic and 36% in symptomatic shoulders. Reilly et al. (2006) reported an overall tear rate of 39% in asymptomatic and 41% in symptomatic shoulders (mean age 70,1 years) by ultrasonographs; by magnetic resonance imaging (MRI) the prevalences were 26% and 49%, respectively. Sher et al. (1995) studied asymptomatic shoulders and reported an overall prevalence in all age-groups (mean age 53 years, range 19-89) of 34% by MRI, whereas Tempelhof et al. (1999) arrived at a figure of 23% by ultrasonography in patients over 50 years.

Based on these studies RC tear is a common finding both in asymptomatic and symptomatic shoulders in individuals over 50 years of age.

2.2.2. Etiology

Several theories have been proposed as etiologic factors for rotator cuff tear. Extrinsic theory refers to the mechanical abrasion of the RC tendons by the surrounding anatomical structures whereas intrinsic theory includes the mechanisms occurring within the RC itself.

2.2.2.1. Extrinsic theory

RC tears have been related to the morphology of the acromion. Historically, mechanical compression of the RC tendons under the subacromial arch was thought to be the factor initiating RC tears. Neer (1983) introduced the concept of a continuum of the impingement syndrome. Bigliani et al. (1986) analyzed the shape of the acromion on lateral radiographs and found a higher prevalence of RC tears in patients with a hooked (type III) acromion compared to individuals with a curved (type II) or a flat (type I) acromion. Especially the type III Bigliani acromion was thought to cause mechanical abrasion of the RC (Gill et al. 2002, Toivonen et al. 1995). In a later study entesophytes were reported to be more common in type III acromion compared to other types of acromion and this condition was thus associated with subacromial impingement syndrome and RC tears (Natsis et al. 2007).

In support of the mechanical theory, Björnsson et al. (2010) reported that arthroscopic subacromial decompression seems to reduce the prevalence of RC tears in patients with impingement. The association between large lateral extension of the acromion and RC tear is controversial. Nyffeler et al. (2006) found that a large lateral extension of the acromion was combined with full-thickness RC tears. Similar finding was described later by Torrens et al. (2007). On the other hand Baechler and Kim (2006) reported in a MRI study that RC tears may be associated with low acromion coverage by allowing hinging of the humeral head on the anterolateral edge of the acromion during early abduction of the shoulder. Although there are many theories, the cause and ultimate impact of external shoulder impingement on RC tears are still controversial.

2.2.2.2. Intrinsic factors

Already 1944 Inman et al. reported that degenerative changes lead to loss of the force couples and this further leads to translation of the superior humeral head and impingement. The arterial supply to the humeral head was described by Laing (1956), but the vascular supply to the tendons remained unclear. Since then, many studies have focused on the effect of vascularity on the RC tears. Moseley and Goldie (1963) showed in a cadaveric study that the RC has a rich vascular bed and that there is little difference between the vascular patterns of newborns and adults. Nor was there evidence that the critical zone for tears is less vascularized than other parts of the tendinous cuff. Rathbun and Macnab (1970) studied the microvascular pattern of the RC in cadavers, and reported that the vascular bed of the supraspinatus tendon is radically different from the vascular bed of the other RC tendons. The avascular zone near the insertion of the supraspinatus tendon has also been described in later cadaveric and in vivo studies (Biberthaler et al. 2003, Lohr and Uhthoff 1990). However, it is unclear whether the hypoperfusion within this critical zone is, in fact, the reason for tendon degeneration and failure. Other studies have reported contradictory findings of the vascularity of the supraspinatus tendon. Fukuda et al. (1990) found that the critical zone of the tendon in partial-thickness RC tears had relative hyperfusion when compared to more proximal parts of the RC tendon. Similar results were described in a laser Doppler study; here, blood flow was significantly higher at the edges of the torn tendons compared with the intact RC (Levy et al. 2008).

Many studies have also emphasized that cellular changes in the RC, e.g. disorganization and fragmentation of the architechture of collagen or abnormal collagen synthesis, could be associated with RC tears (Goodmurphy et al. 2003, Hamada et al. 1994, Kumagai et al. 1992, Nirschl 1989, Yuan et al. 2002). The cellular synthesis of type III collagen increases and production of type I collagen reduces as the RC tendon degenerates (Kumagai et al. 1992, Yuan et al. 2002). It has been shown that these degenerative changes make the torn RC tendons mechanically weaker compared to normal tendons (Chaudhury et al. 2011). Kannus and Jozsa (1991) demonstrated that degenerative changes were evident in 865 of 891 cases (97%) in RC tendons with atraumatic tear. It has been also reported that the torn tendons have lower levels of cellular activity compared to normal tendons (Matthews et al. 2007).

2.2.2.3. Other factors

Trauma

A history of trauma has been reported to be a risk factor for RC tear both according to cadaveric and epidemiological studies (Fukuda et al. 1990, Yamamoto et al. 2010). Weiser et al. (2012) showed in a radiological study that trauma before symptoms was associated with larger RC tears involving more often the infraspinatus and subscapularis tendons than with non-traumatic RC tears. Similar effects of trauma on RC tears were reported in another study in which traumatic RC tears were typically larger and involved the subscapularis tendon (Mall et al. 2013). However, also in traumatic tears, the RC tendon is most often torn from the bone before the musculotendinous junction (MTJ) fails indicating the degenerative character of RC diseases. In normal healthy tendon the MTJ is mechanically the weakest point of bone-tendon-muscle continuity (Noonan et al. 1994, Tidball et al. 1993). The relationship between minimal trauma and degenerative RC tear is unknown.

RC tear may also be due to repetitive microtrauma, usually seen in the athlete involved in overhead sports (Blevins 1997). Akbar et al. (2010) reported a tenfold higher risk of RC tears among paraplegic patients than age-matched able-bodied volunteers.

Age

The risk of RC tears is increased by age and advancing tendon degeneration (Fehringer et al. 2008, Yamaguchi et al. 2006). Tempelhof et al. (1999) reported a prevalence of 13% of RC tears in asymptomatic patients aged 50-59 years and of 51% in patients over 80 years old. A similar age-related increase was described by Yamamoto et al. (2010). Sher et al. (1995) reported asymptomatic RC tears in more than half of patients over sixty years old. The prevalence of RC tears may be as high as 80% in individuals over 80 years of age (Milgrom et al. 1995).

Gender

In a series of 279 patients undergoing RC surgery, Ramzmjou et al. (2006) found that small (largest dimension <1cm), full-thickness RC tears are more common among young (<55 years) females than males of similar age. The difference leveled off and was not statistically significant between older females and males. There are no other studies addressing the question of gender as a predisposing factor to RC tears.

Genetic factors

Gwilym et al. (2009) investigated the genetic influences on RC tears by comparing the prevalence of RC tears in siblings and in a control population. They found that genetic factors do play a role, not only in the development but also in the progression of full-thickness RC tears. A significantly increased risk of RC tears in siblings was also reported by Harvie et al. (2004). The results of Tashjian et al. (2009) also support a heritable predisposition to RC disease.

Smoking

The reason for association between RC tear and smoking is unknown. Smoking is known to lead to microvascular disease. Nicotine is a potent vasoconstrictor and carbon monoxide diminishes oxygen transport and cellular metabolism (Leow and Maibach 1998, Silverstein 1992). It is hypothesized that these changes result in degeneration and worsening of the vascularity of the RC tendon leading to RC pathology and tendon tear. Baumgarten et al. (2010) reported a strong association between smoking and RC disease. The relationship was both dose- and time-dependent. In a recent study Carbone et al. (2012) found a correlation between cigarette smoking and RC tears. They also demonstrated an association between the dose of smoking and the severity of RC tears.

Comorbid conditions

Abboud and Kim (2010) reported a relationship between hypercholesterolemia and RC tears. RC tendon tears were associated with higher total cholesterol, triglycerides and low-density lipoprotein cholesterol and lower high-density lipoprotein cholesterol than healthy RC tendons. In a sonographic study degenerative RC tears were more common among diabetics than non-diabetics

(Abate et al. 2010). In a recent study hypertension was a significant risk factor for the occurrence and severity of RC tears (Gumina et al. 2013).

The etiology of RC tears is probably multifactorial. Several extrinsic and intrinsic factors including mechanical impingement, relative hypovascularity, age-related degenerative soft tissue changes and traumatic events are apparently involved. Tears typically involve the supraspinatus tendon (Fig. 4). Degenerative changes and partial tear occur most often on the articular side of the RC tendon and can enlarge with time to full-thickness tear.

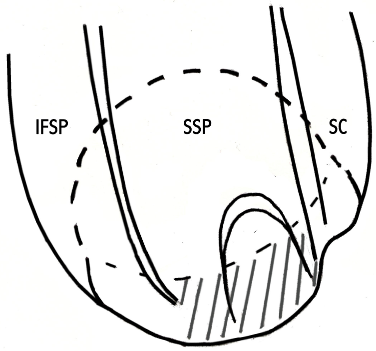

Fig. 4. Rotator cuff tear involves most often the supraspinatus tendon.

2.2.3. Pathophysiology

RC tear changes the muscle physiology, structure and the mechanics of the glenohumeral joint. The loss of tendon attachment to bone leads to decrease in tension across the muscle and sarcomer shorthening (Jamali et al. 2000). Tendon tear induces early radial and longitudinal athrophy of the muscle (Ward et al. 2010). Fatty infiltration progresses rapidly after RC tears and it correlates with the RC tear size (Kim et al. 2010). However, fatty infiltration of infraspinatus has been reported even in the absence of an infraspinatus tear if a supraspinatus tear was present (Cheung et al. 2011). It is thereby suggested that neuropathy of suprascapular nerve due to supraspinatus tear could have a role for fatty infiltration. However, according to a recent study morphological patterns of fatty infiltration due to suprascapular neuropathy are specific and different from the changes seen with chronic RC tears (Beeler et al. 2013). Isolated supraspinatus tendon tear with normal function of subscapularis and infraspinatus does not disrupt transverse force couple affecting no changes in glenohumeral reaction forces compared to intact cuff (Parsons et al. 2002). Tears enlargement to subscapularis or infraspinatus area disrupts the transverse force couple and inferior force vector will no longer counteract the pull of the deltoid muscle. This leads to superior migration of the humeral head and will often result painful shoulder with marked loss of motion and strength (Keener et al. 2009). Additional deltoid muscle force is needed to compensate for lost RC abductor forces. This further leads to compensatory adductor co-activation of the teres major muscle ensuring the stability of the glenohumeral joint (Steenbrink et al. 2010).

2.2.4. Clinical presentation and evaluation

The natural history of the RC tears is not fully known. Yamaguchi et al. (2001) evaluated the natural history of asymptomatic RC tears over a 5-year period and assessed the risk for development of symptoms and tear progression. 51% of the patients with a previously asymptomatic tear developed symptoms over an average time span of 2,8 years. 50% of the newly symptomatic tears progressed in size. Only 20% of the tears which remained asymptomatic progressed in size. In a cohort of 195 asymptomatic patients with RC tears, Mall et al. (2010) found that with pain development, the size of full-thickness RC tears increased significantly: 18% of the full-thickness tears increased >5 mm, and 40% of the partial-thickness tears progressed to full-thickness tears.

The conditions that causes the conversion of an asymptomatic RC tear into a symptomatic tear are not known. Imaging findings alone do not allow assessment of which individual RC tears will produce clinical symptoms and which will remain asymptomatic (Schibany et al. 2004). It has been suggested that the location of the tear, rather than its size, plays an important role (Burkhart 1991). Some studies imply that the symptoms might be due to altered normal kinematics of the glenohumeral joint as the tear size increases (Keener et al. 2009).

Symptoms of RC tear include pain, weakness of the affected RC muscles and limitation of movement of the glenohumeral joint (Crusher 2000). These symptoms are typical but not specific for RC tears. The differential diagnosis include the subacromial impingement syndrome, calcific tendinitis, adhesive capsulitis, osteoarthritis of the glenohumeral and AC joints, the thoracic outlet syndrome, cervical radiculopathy and proximal peripheral neuropathies (Fongemie et al. 1998, Freehill et al. 2012).

2.2.4.1. Clinical examination

A full clinical examination includes a detailed history, a physical exam and conventional radiographs of the glenohumeral joint. The following need to be carefully recorded: the main symptom (pain or functional deficit), duration of symptoms, any preceding trauma and conservative treatment given.

The physical examination includes inspection and palpation of the shoulder, assessment of the passive and active range of motion (ROM) and the strength of the scapular muscles. The patient should be properly disrobed to permit complete inspection of the upper body. Posture of the patient, swelling or asymmetry of the shoulder and atrophy of the scapular or deltoid muscles must be assessed. The following structures should be carefully palpated: the subacromial space, BLHT, AC and sternoclavicular joints. Active and passive ROM should be tested and compared to the contralateral side. The strength of each scapular muscle is tested one by one and compared to the corresponding isometric muscle strength to the unaffected side. Functional impairment due to the pain should be distinguished from true muscle weakness (Matsen et al. 2006).

The Jobe and full can tests for evaluating the supraspinatus tendon have a sensitivity of 77-95% and a specificity of 65-68% for RC disease (Itoi et al. 1999, Noel et al. 1989). Resisted external rotation to evaluate the infraspinatus tendon has a sensitivity of 76% and a specificity of 57% (Litaker et al. 2000). In a study by Hertel et al. (1996) the external rotation lag sign for detecting infraspinatus tears had a high specificity (100%) but sensitivity was lower (70%). The presence or absence of the dropping and hornblower's signs of impaired external rotation have been reported to correlate with Goutallier stage 3 or stage 4 fatty degeneration of the infraspinatus and teres minor muscles (Walch et al. 1998). The hornblower's sign is reportedly 100% sensitive and 93% specific for irreparable degeneration of the teres minor, and the dropping sign 100% sensitive and 100% specific for degeneration of the infraspinatus. The lift-off test for evaluation of the subscapularis tendon has a reported specificity of 100% but a sensitivity of only 62% (Hertel et al. 1996). The internal rotation lag sign has been reported to be both sensitive (97%) and specific (96%) for subscapularis tendon disease.

2.2.4.2. Imaging

Radiography

Conventional radiography is the basic radiological examination of patients with shoulder pain who may have RC disease. The anteroposterior (AP)-view is helpful for assessing the AC joint, spurring of the inferior surface of the acromion, lateral tilt of the acromion and the distance between the humeral head and the anterior part of the acromion. The glenohumeral joint is best evaluated by the Grashey projection, i.e., AP-view taken at an oblique angle of 30 degrees in the plane of the glenoid surface forearm in the neutral rotation. The morphology of the acromion is best assessed in images taken in the outlet projection. (Anderson et al. 2012). Narrowing of the acromiohumeral distance to less than 7 mm has been considered to be a specific indicator of full-thickness RC tears with posterior extension to the infraspinatus (Bellumore et al. 1994, Nove-Josserand et al. 1996). Hamada et al. (1990) described how the radiological changes progress as the RC tears increase and become massive.

Ultrasonography

Ultrasonography (US) has been reported to be an accurate method, in experienced hands, for assessing RC pathology (Fotiadou et al. 2008, Rutten et al. 2010). US has been reported to be highly accurate for detecting full-thickness RC tears, but less sensitive for detecting partial-thickness RC tears and ruptures of the BLHT (Teefey et al. 2000). Other studies have reported accuracy of US also in partial RC tears (Teefey et al. 2004, Vlychou et al. 2009). In a meta-analysis, US and MRI were comparable in terms of both sensitivity and specificity when comparing the accuracy for diagnosing RC tears (de Jesus et al. 2009).

Computed tomography

Goutallier et al. (1994) described the classification carrying the name of the author by examining the amount of fatty degeneration of the RC muscles on computed tomography (CT) scans. Since then CT has been largely used in the diagnostics of RC disease, especially for determining the presence of atrophy and fatty infiltration of the RC muscles (Williams et al. 2009). For evaluation of RC pathology, arthrography is needed because soft tissues are poorly assessed with conventional CT. Although CT arthrography is not used so widely as MRI, it has some advantages. MRI is often contraindicated in patients with heart pacemakers, CT arthrography is not. CT arthrography is useful for examining very large or claustrophobic patients and patients who have undergone MRI unsuccessfully (Buckwalter 2009, Fritz et al. 2012). CT arthrography is also useful for studying patients who have undergone earlier shoulder surgery, especially when adjacent metallic implants produce artifacts (Mohana-Borges et al. 2004).

Magnetic resonance imaging

MRI has been considered to be the best imaging technique for evaluating RC pathology (Guckel and Nidecker 1997). MRI can reliable detect full-thickness medium and large RC tears, but small full-thickness and partial tears of the RC are not as reliable detected (Smith et al. 2012). In a meta-analysis of 44 studies including 2751 shoulders, the pooled sensitivity and specificity values for full-thickness RC tears were 91% and 97%, respectively. For partial-thickness RC tears the values were 80% and 95%, respectively. Magnetic resonance arthrography (MRA) might nevertheless be the most sensitive and specific technique for diagnosing full- and partial-thickness RC tears (de Jesus et al. 2009). Atrophy and fatty infiltration of the RC muscles are reliably evaluated with MRI/MRA (Omoumi et al. 2012, Rulewicz et al. 2013).

2.2.4.3. Classification

Numerous systems to classify RC tears have been proposed. A good classification takes into account the extent of the tear, its topography in the sagittal and frontal planes and the trophic quality of the scapula muscles (Patte 1990). Currently, with the exception of distinguishing partial-thickness from full-thickness RC tears, classification systems have little interobserver agreement (Kuhn et al. 2007, Lippe et al. 2012, Slabaugh et al. 2012, Spencer et al. 2008).

Classification of partial tears

Ellman (1990) and Snyder (2003) independently described classification systems of partial RC tears. In these classifications partial tears are graded according to the depth of the tear. There is a high correlation between these two classification systems (Habermeyer et al. 2008).

Classification of full-thickness tears by tendon tear size

Cofield (1982) classified full-thickness tears according to tear size (small <1 cm, medium 1-3 cm, large 3-5 cm, massive >5 cm). Later, Bateman's classification was introduced and was similarly based on tear size (Bayne and Bateman 1984). Ellman classified the full-thickness RC tears according to the degree of retraction on the tendon in the frontal plane without regard to the size of the tear in the sagittal plane (Patte 1990). The classification of Ellman and Gartsman is based on the shape of the tear and it does not consider tendon retraction (Ellman and Gartsman 1993). A good intra- and interobserver agreement has been reported for this kind of geometric classification system of RC tears (van der Zwaal et al. 2012).

Classification of full-thickness tears according to tendon tear location

Topographic classifications of RC tears were proposed by Patte (1990)(Fig. 5) and Habermeyer et al. (2006). Patte divided the sagittal plane into six sectors, Habermeyer into three.

Classification of full-thickness tears according to muscle changes

Goutallier et al. (1994) graded the tears by muscular fatty degeneration of the scapular muscles into five stages on the basis of CT images (Fig. 6). Later Thomazeau et al. (1996) described a 3-staged classification based on supraspinatus muscle atrophy by MRI. Zanetti et al. (1998) demonstrated that the tangent sign is a useful method for quantification of the degree of supraspinatus muscle atrophy.

Classification of full-thickness tears according to size of tendon tear and muscle changes

Lafosse et al. (2007) used on preoperative CT/MRI and intraoperative clinical evaluation to classify subscapularis tears into five categories based on the extent of the tendon tear and fatty infiltration of the muscle.

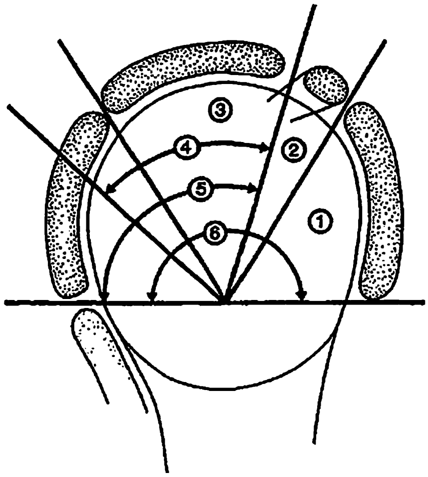

Fig. 5. Classification of tendon tears by Patte according to location of the tear.
Anterosuperior lesions (segments 1-3)
Superior lesions (segments 2-3)
Posterosuperior lesions (segments 4-5)
Total-cuff lesions (segment 6)

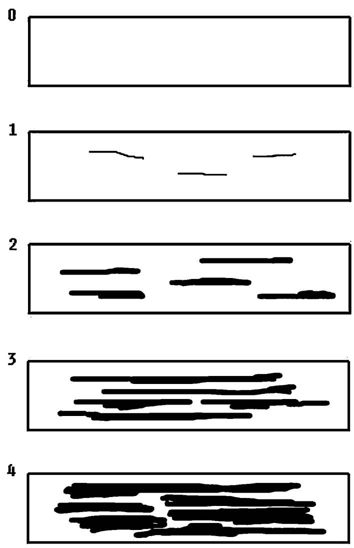

Fig. 6. CT-based classification of fatty muscle degeneration in RC tendon tears by Goutallier.

0: Normal muscle, no fatty streaks
1: Muscle with some fatty streaks
2: Marked fatty infiltration, but there is still more muscle than fat
3: There is as much fat as muscle
4: There is more fat than muscle

2.2.4.4. Scoring systems

Many scoring systems have been presented, but there is still no universally accepted scoring system of shoulder symptoms and function. Most of the scoring systems are patient-based self-assessment devices, but there are some that also include an observer-reported evaluation of ROM and muscle strengths. Purely patient-reported scoring systems in RC pathology include: The Disabilities of the Arm, Shoulder, and Hand questionnaire (DASH), the Shoulder Pain and Disability Index (SPADI), the American Shoulder and Elbow Surgeons Shoulder score (ASES), the Simple Shoulder Test (SST), the Oxford Shoulder Score (OSS), the Shoulder Disability Questionnaire (SDQ), the Shoulder Rating Questionnaire (SRQ), the Penn Shoulder Score (PSS) and the Western Ontario Rotator Cuff Index (WORC) (Angst et al. 2011, Kirkley et al. 2003, Leggin et al. 2006). The Constant Score (CS) and the University of California at Los Angeles Shoulder Rating scale (UCLA) are widely used shoulder scoring systems which include observer-reported evaluation of the shoulder (Constant and Murley 1987, Kirkley et al. 2003). The Constant score correlates strongly with RC integrity (Flurin et al. 2005) and this scoring system is reportedly suited for evaluating RC tears (Gilbart and Gerber 2007).

2.3. TREATMENT OF ROTATOR CUFF TEARS

A torn RC tendon does not attach to the bone spontaneously and a RC tear may enlarge over time, and this results in tendon retraction, irreversible muscle atrophy and fatty infiltration (Tashjian 2012). The goal of treatment is to eliminate pain and improve function with increased shoulder strength and active range of motion. Despite several studies on the effect of conservative and operative treatment of RC tears on clinical and anatomical outcomes, there is still insufficient evidence to prove efficacy of treatment modality (Downie and Miller 2012, Ejnisman et al. 2009, Seida et al. 2010).

One prospective, randomized level I trial has been published where physiotherapy and operative treatment of RC tears has been compared (Moosmayer et al. 2010). The patients underwent open or mini-open operative treatment of a RC tear and were followed up for one year. The control group was treated with physiotherapy. The result was that the surgically treated patients had a statistically significantly better outcome (Moosmayer et al. 2010).

2.3.1. Conservative treatment

Conservative treatment for RC tear includes non-steroidal anti-inflammatory drugs (NSAID), injections of glucocorticosteroids or hyaluronate, and physiotherapy. The best programme for conservative treatment is not defined by current evidence (Longo et al. 2012). The aim of conservative treatment is to decrease pain and regain shoulder function (Soslowsky et al. 1997). NSAID and subacromial injections relieve pain and inflammatory process. Furthermore, physiotherapy aims to improve range of motion. After a full, painless range of motion is achieved, training aims to improve muscle balance of the shoulder by activating the healthy part of the RC. It has been shown that if the remaining anterior and posterior RC can produce sufficient force, glenohumeral abduction without excessive superior translation is possible also in large RC tears (Hansen et al. 2008). Only few studies, most retrospective, have been published on the efficacy of conservative treatment of RC tears. Conservative treatment is associated with no spontaneous healing and can lead to tear progression, muscle fatty degeneration, tendon retraction and poor tendon mobilization if and when operative treatment is decided on (Tashjian 2012). Even though there is no current evidence supporting conservative treatment, most authors prefer non-operative management in case of degenerative RC tears (Handelberg 2001, Koubaa et al. 2006, Walch et al. 2006).

2.3.1.1. Physiotherapy

No randomized controlled trial has been published on physiotherapy in the management of RC tears. The characteristics of an exercise programme are not standardized (Longo et al. 2012). Ainsworth and Lewis (2007) published a systematic review on exercise therapy as conservative management of full thickness RC tears. Ten observational studies were included, six trials involved physiotherapy in combination with other conservative treatments, four trials involved only an exercise programme. This systematic review concluded that there is some evidence to support the use of exercise to manage full thickness RC tears. Fucentese et al. (2012) reported on 24 nonoperatively treated patients with symptomatic, isolated full-thickness supraspinatus tears. They reported high clinical patient satisfaction and no increase in the average size of the RC tears during 3,5 years of follow-up. Kijima et al. (2012) reported good subjective results of conservative treatment of RC tears followed up for 13 years. 88% of the patients had no pain or only slight pain, and 72% were not disturbed by the RC tear in their activities of daily life. In a recent prospective multicenter cohort study of 452 patients Kuhn et al. (2013) reported that physical therapy is effective treatment for atraumatic full-thickness RC tears for approximately 75% of patients who were followed up for two years. There is no evidence of the effect of electrical stimulation, laser therapy or ultrasound in the treatment of RC disease (Green et al. 2003).

2.3.1.2. Other conservative treatments

Two randomized controlled trials have been published on the effect of corticosteroid injections to treat RC tears. Shibata et al. (2001) reported that the therapeutic efficacy of sodium hyaluronate injected into the glenohumeral joint is equivalent to corticosteroid injections. Ten years later Gianella and Prometti (2011) reported that intra-articular triamcinolone improves pain relief for three months and that its action was not prolonged or potentiated by two further injections of triamcinolone at 21-day intervals. Vecchio et al. (1993) reported in a level I study that suprascapular nerve block can be used for reducing pain and improving the shoulder movement of patients with RC tears. The authors recommended this treatment because it can be carried out in outpatient settings and the risk of complications is negligible. Platelet-rich plasma does not affect the clinical or anatomical outcome after arthroscopic RC repair (Chahal et al. 2012). The role of growth factors and stem cell augmentation in RC healing is currently unclear, but under investigation (Isaac et al. 2012).

2.3.1.3. Prognostic outcome factors of conservative treatment

Itoi et al. (1993) reported that conservative treatment yields satisfactory results for patients with well-preserved motion and strength. However, function tended to deteriorate with time. Maman et al. (2009) reported that increasing age of the patient affected negatively RC tear patients treated conservatively. These patients had also an association between fatty infiltration of the RC muscles and the progression of a RC tear. Bokor et al. (1993) reported that conservatively treated patients with RC tears and with symptoms for more than six months fared significantly worse compared to patients with a shorter duration of symptoms. A similar effect of the duration of symptoms was reported in another study; here, a history of clinical symptoms of more than one year was a negative prognostic factor (Bartolozzi et al. 1994). Tanaka et al. (2010) proposed four factors related to the outcome of conservative treatment: 1) degree of integrity of the intramuscular supraspinatus tendon; 2) degree of supraspinatus muscle atrophy; 3) impingement sign and 4) external rotation angle.

2.3.2. Operative treatment

The goal of the operative treatment is to attach the tendon back to the bone footprint area where it tore off. Most of the current knowledge of the tendon healing is based on the animal studies and there is no clear evidence of the capability of the torn RC tendon to heal. In acute injuries the tendon healing occurs in three overlapping phases (inflammatory stage – remodeling stage – modeling stage) (Sharma and Maffulli 2006). However, in degenerative tendon tears the healing is disordered and inflammation is not typically seen. It has been reported that there is significant cellular changes as RC tear size increases and reparative reponse to healing in larger sized tears is diminished compared to small- and medium-sized tears (Matthews et al. 2006). In complete rotator cuff tears there is a marked increase in vascular channels derived mainly from the bursal wall indicating extrinsic healing mechanism of RC tendon (Uhthoff and Sarkar 1991).

2.3.2.1. Operative techniques

RC tears have been operated on 1911 (Codman 1911). Neer later developed the current surgical technique and was the first to use acromioplasty to repair RC tears (Yamaguchi et al. 2003). Open surgery is performed releasing the deltoid muscle from anterior acromion and the torn tendon is fixed with sutures passing through bony tunnels or with suture anchors. After repairing the tendon the deltoid muscle is reattached to the acromion. Open RC repair provides good to excellent outcomes in terms of functional improvement (75-95% of patients) and pain relief (85-100%) (Aleem and Brophy 2012).

The mini-open, arthroscopy-assisted approach to RC repair was first described by Levy et al. (1990). In this technique subacromial decompression is performed arthroscopically without deltoid takedown. In addition to subacromial debridement and acromioplasty, RC mobilization and anchor placement are performed arthroscopically. Tendon fixation is accomplished through 1-2 cm deltasplit approach. Many studies have reported good to excellent results at long-term follow-up in 80-88% of patients undergoing mini-open RC repair (Bell et al. 2013, Paulos and Kody 1994, Posada et al. 2000).

The first arthroscopic RC repair with suture anchors was performed by Wolf in 1990 (Wolf et al. 2004). Since then, improved arthroscopic techniques and implants have rapidly increased the number of RC repairs during the last decades (Colvin et al. 2012). In arthroscopic technique all the procedure is performed arthroscopically through small incisions and the deltoid muscle is not detached (Ghodadra et al. 2009). Multiple studies have shown 78–88% of patients having good to excellent outcomes at long-term follow-up (Denard et al. 2012, Denard et al. 2012, Marrero et al. 2011).

Despite good results of operative treatment, there is still debate about the indications for RC repairs, and the patient characteristics and the indications for surgery have not been clearly determined in most clinical outcome studies on RC repair (Marx et al. 2009).

Open vs. mini-open repair

A level I randomized clinical trial resulted in no outcome differences between open and mini-open procedures at one and two years after surgery (Mohtadi et al. 2008). Similar outcomes were reported in a retrospective cohort study comparing open and mini-open repair with two years of follow-up (Baker and Liu 1995). In another retrospective cohort study the open procedure was associated with more postoperative atrophy of the deltoid muscle and delayed recovering than the mini-open procedure (Hata et al. 2004). In addition to, possibly, swifter recovery after operation, mini-open procedures have the added advantages compared to open repairs that the deltoid muscle is not taken down from the acromion and that intra-articular pathologies can be identified and treated. Indeed, RC tears are often combined with intra-articular pathologies (Gartsman and Taverna 1997).

Mini-open vs. arthroscopic repair

A comprehensive review and meta-analysis of five studies found no difference in functional outcome scores or complications between patients who had undergone arthroscopic or mini-open repair of a RC tear (Morse et al. 2008). In a recent level II randomized trial study with 100 patients, functional outcome and complications did not significantly differ between patients treated with arthroscopic vs. mini-open repair. However, patients treated with arthroscopic method recovered more quickly (van der Zwaal et al. 2013). Compared to the mini-open procedure the advantages of all-arthroscopic techniques include small skin incisions and less soft-tissue dissection (Aleem and Brophy 2012).

Open vs. arthroscopic repair

A prospective cohort study of 100 shoulders found no statistically significant differences in outcomes when comparing open and arthroscopic procedures (Ide et al. 2005). Another prospective study of 72 patients found that arthroscopic and open RC repairs have similar clinical outcomes, but large tears had twice the re-tear rate after arthroscopic treatment compared to open repair (Bishop et al. 2006). Opposite results of structural healing was reported by Millar et al. (2009) who reported that re-tear occurred more often after open than after arthroscopic repair.

Single vs. double row fixation

A torn tendon can be attached with suture anchors or transosseous sutures to the lateral aspect of the footprint of the humerus (single row) or using additional medial anchors close to the articular margin of the glenohumeral joint (double row). Double row fixation has been reported to be biomechanically more robust than single row fixation (Kim et al. 2006, Waltrip et al. 2003), but clinical studies have been less convincing of advantages of double row fixation. There are six prospective, randomized high quality studies comparing the two operative methods. Burks et al. (2009) found no clinical or MRI differences at one year of follow-up between patients repaired with a single or double row technique. Four studies have shown that clinical outcome at two years' follow-up is similar after single and double row fixation of RC tears (Franceschi et al. 2007, Grasso et al. 2009, Koh et al. 2011, Lapner et al. 2012). In a recent study statistically significant differences were reported in favour of double row repair especially in larger RC tears (Carbonel et al. 2012). However, these detected differences may not be clinically significant.

2.3.2.2. Concomitant procedures

Acromioplasty

The benefits of acromioplasty are believed to be due to reduced extrinsic compression on the RC, improved arthroscopic visualization and induction of a healing response through bleeding bone tissue in the subacromial space (Shi and Edwards 2012). Packer et al. (1983) reported that operative repair of the chronically torn RC should always include adequate decompression of the subacromial space. In recent years, however, the role of acromioplasty in connection with RC reconstruction has been debated. There are three prospective, randomized level I studies on the effect of acromioplasty on treatment outcome after arthroscopic RC repair. The first study concluded that arthroscopic subacromial decompression does not appear to change the functional outcome after RC repair within 15 months follow-up (Gartsman and O'Connor D 2004). Two year follow-up studies did not find differences in clinical outcomes after RC repair with or without acromioplasty (Milano et al. 2007, MacDonald et al. 2011). On the other hand, a 13-year follow-up study of small, full-thickness RC tears showed good results after arthroscopic subacromial decompression without RC repair (Norlin and Adolfsson 2008).

Biceps- and AC-procedures

A RC tear is often associated with BLHT pathology or painful AC joint osteoarthritis (Beall et al. 2003, Boileau et al. 2007, Brown et al. 2000, Chen et al. 2005, Murthi et al. 2000, Namdari et al. 2008). These pathologies may require specific procedures when a RC tear is being operated on and such associated procedures may affect the overall treatment outcome. Although BLHT tenotomy and tenodesis have been reported as effective procedures to manage BLHT pathology in conjunction with RC reconstruction (De Carli et al. 2012), the effect of concomitant BHLT procedures on the outcome of surgical RC repair is controversial. Tenodesis has some theoretical advantages over tenotomy (Ahmad and ElAttrache 2003). Although there is a lack of high-quality evidence to advocate one BLHT procedure over the other, a review article by Frost et al. (2009) proposes BLHT tenotomy as the preferred method. A prospective cohort study of tenotomy versus tenodesis in association with RC repair reported less of the Popeye deformity in the tenodesis group than the tenotomy group, but that was the only clinical difference between the two treatment modalities (Koh et al. 2010). A similar clinical result was described by Kukkonen et al. (2013). Nho et al. (2009) evaluated the prognostic factors affecting clinical and ultrasonographic outcome after primary arthroscopic RC repair. They found that the occurrence of RC tendon defects was 11,4-fold among the patients who underwent BLHT tenotomy or tenodesis compared to the patients who had no BLHT pathology. Interestingly, however, the concomitant BLHT procedure did not affect the clinical outcome. In the same study, shoulders that were treated by concomitant AC joint coplaning or distal clavicle excision had an occurrence that was 3,9 times higher of a tendon defect compared with shoulders that had healthy AC joints. In contrast to BLHT procedures AC joint procedures affected negatively the clinical scores (Nho et al. 2009). Gulotta et al. (2011) involved 193 patients in a prospective five-year study to evaluate the prognostic factors affecting clinical and radiological outcomes. They found that concomitant procedures did not affect clinical outcome, but concomitant BLHT and AC joint procedures predicted some radiological defect of the RC.

2.3.2.3. Postoperative rehabilitation

Seven prospective randomized clinical trials have evaluated rehabilitation after RC repair. Both continuous passive motion and manual passive ROM home exercises yielded favorable results (Lastayo et al. 1998). The outcomes were equal in standardized home exercise regimen conveyed either by videotaped instructions or by personal instruction by a physical therapists (Roddey et al. 2002). There was neither difference in outcomes between individualized supervised physiotherapy and a standardized, unsupervised home exercise regimen (Hayes et al. 2004). Specific, progressive muscle activation exercises did not affect to clinical outcome (Klintberg et al. 2009). Two studies found no difference in clinical outcomes when comparing early versus delayed passive motion exercises (Cuff and Pupello 2012, Kim et al. 2012). One study reported that functional results were better in the patients with early passive motion compared to patients treated with postoperative immobilization for six weeks (Arndt et al. 2012).

2.3.2.4. Structural and functional outcome

The goal of operative treatment of RC tears is complete structural and functional healing of the attached tendon. However, re-tears after RC repair are quite common (Randelli et al. 2012). A prospective multi-institutional imaging study showed that 95% of the re-tears were diagnosed within 26 weeks after the arthroscopic repair (Iannotti et al. 2013). This probably means failed tendon healing rather than re-tear. The effect of a re-tear on the functional outcome is controversial. Many authors have reported that the clinical outcome is associated with structural healing, and others have not found any association between structural and functional healing.

Jost et al. (2000) documented that an attempt at RC repair significantly decreased pain and improved function despite a possible postoperative re-tear. The clinical outcome correlated with the size of the postoperative tear. In a study of RC tears, 210 shoulders underwent arthroscopic RC repair with double-row fixation (Huijsmans et al. 2007). The strength and active elevation of the shoulder increased significantly more if the RC was intact postoperatively than if there was a postoperative re-tear of the RC. A similar result stating that there are strength deficits among patients with re-tears after operation has been reported by many other authors, as well (Anderson et al. 2006, Boileau et al. 2005, Sugaya et al. 2007).

49 operatively treated RC tear shoulders were followed up at least for 5 years (Nich et al. 2009). This study concluded that a re-tear does not influence overall functional outcome. Neither Boughebri et al. (2012) nor Oh et al. (2009) reported any associations between functional and anatomical results after surgical fixation of supraspinatus tears.

Slabaugh et al. (2010) published a systematic review about the association between radiological healing of the RC and clinical outcome. They concluded that there are probably some important differences in clinical outcomes between patients with healed and nonhealed RC repairs. Further studies are needed to establish this difference.

2.3.2.5. Prognostic outcome factors

Trauma

The effect of trauma on the treatment outcome after arthroscopic RC tear is not clear. There is only one earlier study comparing the outcomes between traumatic and non-traumatic RC tears (Braune et al. 2003). In that study it was found that the postoperative results were significantly better when the RC tear was traumatic than non-traumatic.

Age

The age of the patient as a prognostic factor for both structural and functional outcome has been reported by many authors. In a prospective study Prasad et al. (2005) reported that older patients benefit from open RC repair, but not as much as younger patients. RC structural healing after arthroscopic repair is significantly poorer among patients over 65 years than among younger patients (Boileau et al. 2005, Lichtenberg et al. 2006). Other studies have found the negative effect of increasing age on both structural and functional healing after arthroscopic RC repair (Cole et al. 2007, DeFranco et al. 2007). In a recent study the patient's age at operation was significantly associated with re-tear free survival, but this was true only for patients aged over 70 years (Robinson et al. 2013).

Tear size

The tear size of the RC affects both structural and functional outcomes after open as well as arthroscopic RC repair (Lee et al. 2007, Oh et al. 2009, Prasad et al. 2005, Robinson et al. 2013, Sugaya et al. 2007). Extension of the supraspinatus tear to the infraspinatus tendon is associated with tear recurrence after RC repair (Cole et al. 2007). Tashjian et al. (2010) reported a significant difference in the healing rates between single-tendon (67%) and multi-tendon tears (36%). Wu et al. (2012) stated that the size of the tear before operation is the best predictor of postoperative RC integrity. They base their claim on a study with no less than 500 consecutive patients who underwent RC repair. They also found that the re-tear rate increased in linearly with the size of the tear before operation. Despite earlier studies it is still unclear if there is a direct linear correlation between the tear size and clinical outcome after RC repair.

Fatty infiltration and muscle atrophy

Fatty infiltration and atrophy of the RC muscles predict clinical and structural outcomes after open and arthroscopic rotator repair according to many studies (Bartl et al. 2012, Kim et al. 2012, Oh et al. 2009, Thomazeau et al. 1997).

Gerber et al. (2000) reported that muscle atrophy and fatty infiltration of the RC muscles are not reversible, not even in the patients with an intact repair. In support of the concept of irreversible RC muscle changes, a study reported that there was no functional improvement after open RC repair in patients with infraspinatus fatty infiltration of Goutallier stage 3 or 4 (Mellado et al. 2005). Irreversible muscle atrophy and accumulation of fat into the RC muscles was also reported by Liem et al. (2007), who also concluded that higher degrees of muscular atrophy and fatty infiltration before the operation are associated with recurrence of the tear as well as progression of the fatty infiltration and muscular atrophy, yielding ultimately an inferior clinical result. Gladstone et al. (2007) reported a similar negative effect of muscle atrophy and fatty infiltration on 1) clinical outcome, 2) progression of muscle degeneration in failed repairs and 3) irreversibility of muscle degeneration despite successful repair of the RC muscles. Nich et al. (2009) found that if the supraspinatus tendon healed, atrophy of the supraspinatus muscle never worsened. However, fatty infiltration of the supraspinatus, infraspinatus and subscapularis muscles increased after the operation, despite tendon healing.

Yamaguchi et al. (2012) recently reported opposite results of the irreversibility of muscle atrophy and fatty degeneration. The study involved in 24 patients with massive RC tear. The authors report that muscle atrophy abated in 50% and fatty degeneration in 25% of the patients, when the RC was well repaired.

Duration of symptoms

The effect of the duration of the preoperative symptoms on final treatment outcome is not fully known. According to Vastamäki (1986), an operative delay affects treatment outcome while Björkenheim et al. (1988) claimed that the duration of the symptoms before the operation have only little predictive value with regards to the final treatment outcome after open RC repair. Patel et al. (1999) reported that the duration of symptoms before surgery was the most significant predictor of outcome in partial RC tears treated arthroscopically by acromioplasty. In a recent study of 305 non-traumatic RC tears, the duration of preoperative symptoms did not correlate with the final clinical outcome (Kukkonen et al. 2012). Björsson et al. (2011) evaluated the influence of repair delay in a study involving 42 patients with posttraumatic pseudoparalysis. They reported that a delay of three months to repair had no effect on outcome. Gerber et al. (2000) found that the duration of shoulder pain and dysfunction before the operation was significantly shorter among patients with re-tears compared to patients with an intact cuff.

Gender

The effect of gender on the outcome after RC repair is not clear. Some studies have suggested that female gender may be an adverse prognostic factor (Cofield et al. 2001, Gerber et al. 2000, Piasecki et al. 2010, Romeo et al. 1999). However, most studies have not found differences between women and men with regard to outcomes (Bartolozzi et al. 1994, Hattrup 1995, Prasad et al. 2005).

Smoking

Carbon monoxide reduces cellular oxygen tension level causing tendinous degeneration and a risk for re-tearing of RC (Mosely and Finseth 1977). It has been shown in an animal model that nicotine delays tendon-to-bone healing (Galatz et al. 2006). Nicotine weakened mechanical properties of the supraspinatus tendon. Histologically there was more inflammation whereas vascular and fibroblast proliferation was lower in rats exposed to nicotine following RC repair. Furthermore, cell density, cellular proliferation and type I collagen expression were lower in rats exposed to nicotine. In a clinical study Mallon et al. (2004) found that non-smokers undergoing open RC repair had greater reduction in pain and better clinical results than smokers. Also opposite results have been published: Prasad et al. (2005) reported that smoking did not affect significantly the outcome after open RC repair.

Preoperative stiffness

Different factors have been suggested as possible causes for stiff shoulder accompanying RC tear, however the exact etiology is unknown (Seo et al. 2012). Morever, stiffness may be result of associated osteoarthritis of the glenohumeral joint (Weinstein et al. 2000). Regardless of etiology there is controversy about the effect of preoperative stiffness on the postoperative stiffness and outcome. Trenerry et al. (2005) reported that preoperative restriction of the hand-behind-the-back motion was the best predictor of shoulder stiffness after RC repair. In another study, active abduction <90 degrees of the upper extremity before the operation was associated with worse clinical outcome than if the degree of abduction was bigger (Pai and Lawson 2001). Cho and Rhee (2008) evaluated the functional outcome after arthroscopic RC repair with concomitant manipulation in RC tears with stiff shoulder preoperatively. In their study, the final outcomes concerning the degree of motion and pain of the upper extremity of patients with RC tears and preoperative stiffness were as good as the outcomes of patients with no stiffness. However, the return of the ROM took longer for the patients who underwent manipulation for shoulder stiffness. Chuang et al. (2012) compared the functional outcomes with and without capsular release in arthroscopic treatment of RC tears with stiff shoulder. They concluded that both methods produced overall satisfactory results, but more rapid recovery and improvement of the ROM was achieved by an arthroscopic repair and concomitant capsular release.

Comorbid conditions

Clement et al. (2010) reported that patients with diabetes mellitus had less pain and better function following arthroscopic RC repair in the short term, but these effects were less pronounced than among their non-diabetic counterparts. Similar results were reported in another cohort study by Dhar et al. (2013). Arthroscopic RC repair in patients with diabetes mellitus improved the postoperative ROM and function, but the postoperative ROM and clinical scores were poorer than for non-diabetics. Boissonnault et al. (2007) reported that a higher number of comorbidities had a negative effect on general health status outcomes but not on shoulder function outcomes. Bone mineral density has an effect on RC healing after surgery (Chung et al. 2011).

Worker's compensation

Pending worker's compensation claims seem to affect negatively treatment outcomes after RC repair (Balyk et al. 2008, Oh et al. 2007).

2.3.2.6. Complications

Randelli et al. (2012) published a review article including 56 level I-IV clinical studies and reported on the complications associated with arthroscopic RC repair. They found 414 complications in 2890 patients. Re-tearing of the RC (re-tear rate 11,4–94,0%) was the most frequent complication. The highest re-rupture rate occurred in a series of 18 patients with massive RC tears. The lowest tear rate was found in a group of patients with either an isolated supraspinatus tear or a combination of supraspinatus and infraspinatus tears repaired with double-row anchorage. The re-rupture rate after repaired isolated supraspinatus tendon tears varied from 24,5 to 40,0%. Stiffness was reported in 2,6% of the patients (range 1,5-11,0%). Hardware complications occurred in 0,4% of the patients, of these, anchor pull-out was the most common failure. Other complications were neurovascular (0,2%), septic (0,1%), thromboembolic (0,1%) and related to anesthesia (0,03%).

2.3.3. Treatment of massive and irreparable tears

The definition of massive RC tear is controversial. It is usually defined as a large tear with a maximum diameter of 5 cm or greater (Cofield 1985). It can also be defined as a tear involving two or more RC tendons (Zingg et al. 2007).

The characterization of a RC tear as irreparable is based not only on size, but also on tissue quality and degree of tendon retraction. The RC tear is irreparable if it is unable to mobilize the tendon to the anatomic humeral footprint and/or if the tendon is unable to heal because of bad tissue quality due to muscle fatty infiltration (Kim et al. 2012, Meyer et al. 2012).

2.3.3.1. Conservative treatment

Ainswort (2006) reported the effect of physiotherapeutic rehabilitation in a series of only 10 patiens with massive irreparable RC tears. All patients improved over the three-month period in terms of pain and function. Satisfactory shoulder function was described by Zingg et al. (2007) in patients with conservatively treated massive RC tears during four years of follow-up. Levy et al. (2008) pointed out the important role of anterior deltoid re-education in patients with massive irreparable RC tears. In a series of 17 patients the Constant scores improved at least for nine months after intervention.

2.3.3.2. Operative treatment

Debridement and subacromial decompression

Arthroscopic debridement and decompression of massive and irreparable RC tears have given good results in terms of pain relief (Burkhart 1991). Functional recovery, on the other hand, is debatable. Ellman et al. (1993) noted that although patients with massive and irreparable RC tears treated with debridement got relief for their pain, upper extremity strength and ROM were not regained. In another study there was improved function but decreased strength as compared with the situation before surgery (Gartsman 1997). Rockwood et al. (1995) reported in over 6,5 years of follow-up improvement in pain, function, ROM and strength in shoulders with irreparable RC tears undergoing open acromioplasty and debridement. In this study, results were unsatisfactory in shoulders with a weak or absent anterior part of the deltoid muscle or if an acromioplasty and attempted repair of RC had been performed previously. Mellilo et al. (1997) found that the results of debridement of massive RC tears deteriorate significantly with time.

Biceps tenotomy and tenodesis

The function and role of BLHT in the setting of irreparable RC tears is controversial. Klinger et al. (2005) compared debridement alone with a combined procedure involving biceps tenotomy in shoulders with massive irreparable RC tears. They found that BLHT tenotomy did not significantly influence the postoperative results by the time of the latest follow-up. Boileau et al. (2007) reported that both arthroscopic biceps tenotomy and tenodesis can effectively treat severe pain or dysfunction caused by an irreparable RC tear associated with a biceps lesion. A multicenter study of 210 RC tears treated by arthroscopic acromioplasty demonstrated that BLHT tenotomy was particularly effective for massive RC tears (Kempf et al. 1999). Walch et al. (2005) reported the results of 307 BLHT tenotomies performed in patients with massive irreparable RC tears or in patients who were not willing to participate in the rehabilitation required after RC repair. They found that arthroscopic biceps tenotomy yields favorable objective results and high patient satisfaction in patients with full-thickness RC tears in who repair is not possible and/or desirable.

Partial repair

The aim of the partial repair of irreparable RC tears is to restore the stable fulcrum and transverse plane force couple (SC-IFSP) of the glenohumeral joint (Burkhart 1997). In massive RC tears involvement of subscapularis tendon is less common than infraspinatus tendon lesions. Therefore, the crucial point is often isolated repair of the infraspinatus tendon which can significantly improve shoulder function (Oh et al. 2012). Duralde and Bair (2005) reported good or excellent results in 67% of the patients and 92% were satisfied with the result at

43 months of follow-up. Similar outcomes after partial repair of massive RC tears were described earlier by Burkhart al. (1994, 1996, 2001).

Tendon transfers

Tendon transfers have been described as salvage procedures for young patients with irreparable RC tears where the main symptom is weakness (Warner 2001). The most commonly used donor tendons are the latissimus dorsi and teres major in posterosuperior tears (Donaldson et al. 2011, Gerber et al. 2006) and the pectoralis major in anterosuperior tears (Lederer et al. 2011). In a systematic review of ten studies, Namdari et al. (2012) reported significant improvement in the Constant score during a mean follow-up time of 46 months after latissimus dorsi transfer. Subscapularis muscle insufficiency, advanced teres minor muscle atrophy and a need for revision surgery were associated with poor functional outcomes in some of the ten studies. Satisfactory results have been reported after pectoralis major transfer in patients with isolated irreparable tears of the subscapularis (Jost et al. 2003, Resch et al. 2000, Wirth and Rockwood 1997). There is a lack of outcome data on pectoralis major transfers for massive anterosuperior RC tears (Neri et al. 2009).

Reverse shoulder arthroplasty

A reverse shoulder arthroplasty can provide predictable pain relief and return of function for patients with RC arthropathy and/or painful pseudoparalysis. However, reverse shoulder arthroplasty is associated with a substantial risk of complications (Bedi et al. 2010). Werner et al. (2005) reported significant improvement in Constant scores in 58 patients treated with reverse shoulder arthroplasty for RC arthropathy. However, the complication rate was 50%, and 33% of the patients required a revision procedure. Mulieri et al. (2010) reported that reverse shoulder arthroplasty provides reliable pain relief and return of shoulder function in patients without osteoarthritis in the glenohumeral joint but with massive irreparable RC tears. Naveed et al. (2011) reported the short to medium term results of the Delta III reverse arthroplasty in a consecutive series of patients with a total of 50 shoulders with painful pseudoparalysis due to irreparable RC tears and osteoarthritis. They found that patient satisfaction, freedom from pain, improvement in activities of daily living and functional independence improved significantly. The clinical results of reverse shoulder arthroplasty are apparently inferior if there is dysfunction of the posterior aspect of the RC, specifically the teres minor (Boileau et al. 2007, Guery et al. 2006).

3. AIMS OF THE STUDY

The purpose of the present study was to assess the results and prognostic outcome factors of arthroscopic repair of rotator cuff tears. The following specific points were addressed:

1. To study the differences in demographics, preoperative findings and outcome after operative treatment of traumatic vs. non-traumatic rotator cuff tears (I).

2. To study the effect of tear size on treatment outcome of operatively treated rotator cuff tears (II).

3. To assess the effect of smoking on the treatment outcome of operatively treated rotator cuff tears (III).

4. To study the effect of pre- and peroperatively detected glenohumeral osteoarthritis on the treatment outcome of operatively treated supraspinatus tears (IV).

5. To investigate the effect of three treatment modalities on the outcome of degenerative supraspinatus tears in elderly patients in a randomized controlled study design (V).

4. PATIENTS AND METHODS

4.1. PATIENTS

Studies I-IV

Studies I-IV are retrospective studies of prospectively collected cohorts of consecutively operated RC tear patients in the Turku University Hospital. All patients were treated because of a symptomatic RC tear. The indication for operative treatment of the RC tear was a clinical suspicion of a RC tear with typical symptoms of pain and functional weakness assessed clinically. Contraindications included cuff tear arthropathy, severe osteoarthritis (Kellgren-Lawrance (K-L) grade III or above) with clearly visible osteophytes, drug abuse, severe internal disease contraindicating general anesthesia and patient refusal. Study I included patients with partial or full-thickness RC tears. Studies II-III included full-thickness RC tears. Male patients with an intraoperatively detected full-thickness, 5–25 mm (AP dimension) supraspinatus tendon tear were included in study IV. Institutional approval was obtained for all studies. Patient data before, during and after the operation was collected and saved in a structured electronic patient register (ArtuX, BCB Medical, Turku, Finland).

Study V

Study V is a prospective, randomized level I multicenter study with patients treated in the Turku University Hospital, Kuopio University Hospital and the Hatanpää Hospital in Tampere. The inclusion criteria were a patient age over 55 years, atraumatic symptomatic supraspinatus tendon tear comprising less than ¾ of the tendon insertion by MRI, full range of motion of the shoulder and written informed consent. The exclusion criteria were stiffness and/or osteoarthritis (K-L grade II or above) of the glenohumeral joint, severe internal, rheumatoid or malignant diseases, cytostatic or corticosteroid medication, alcoholism, drug abuse, severe psychiatric illness and previous surgery on the same shoulder. All eligible patients were invited to participate in the trial. The patients were sequentially recruited from the referrals from the three participating hospitals. The interventions were explained to patients and it was stated that the treatments are, as far as known, of similar effect and no known differences in outcome. Patients were informed that they could consider crossing over to RC repair, if adequate relief of symptoms was not achieved by six months after the allocated intervention. After informed consent the patients (180 shoulders) were randomized into one of the three treatment groups (physiotherapy (Group 1), acromioplasty + physiotherapy (Group 2) and RC repair + acromioplasty + physiotherapy (Group 3)) using opaque, sealed envelopes. The patient was openly informed of the allocated intervention. After enrollment, treatment commenced within one month. The study protocol was approved by the Ethics Committee of the Hospital District of Southwest Finland and it was registered at www.clinicaltrials.gov. Patient data before, during and after the operation was collected and saved in a structured electronic patient register (ArtuX, BCB Medical, Turku, Finland). The patients in the study V were partly included in the studies I-IV.

The study consisted of the following groups of patients in studies I-V (Table 1).

Table 1. Summary of the number of the shoulders, the mean age of the patients and timing of the operations in studies I-V.

STUDY	TOTAL NUMBER OF SHOULDERS	DROP-OUT	NUMBER OF SHOULDERS AT FINAL FOLLOW-UP (females/males)	MEAN AGE OF PATIENTS AT INTERVENTION (years)	TIMING OF OPERATIONS (years)
I	306	8,8%	279 (118/161)	58 (range 26-80)	2007-2008
II	576	1,2%	569 (225/344)	60 (range 22-83)	2007-2010
III	576	2,1%	564 (223/341)	60 (range 22-83)	2007-2010
IV	85	3,5%	82 (-/82)	58 (range 27-79)	2007-2009
V	180	7,2%	167 (85/82)	65 (range 55-81)	2007-2011

4.2. METHODS

Definition of traumatic and non-traumatic rotator cuff tears (Study I)

The classification of the etiology of RC ruptures (traumatic vs. non-traumatic) was based entirely on the patient history and mechanism of injury. In case of an obvious trauma at the onset of symptoms, the rupture was regarded as traumatic and the mechanism was recorded. If the patient could not recall any traumatic event relating to the onset of symptoms, the RC rupture was regarded as non-traumatic.

Smoking habits (Study III)

Patients were interviewed for their smoking habits before and after the operation. Daily tobacco consumption and duration of consumption were recorded as pack-years (1 pack-year = 1 pack of cigarettes per day for 1 year). All smokers were actively encouraged to quit smoking in order to enhance postoperative healing and convalescence. Patients were grouped according to their smoking status into non-smokers and smokers. Patients who had quit smoking altogether as instructed after the operation were also recorded as separate subgroup.

Evaluation of the glenohumeral osteoarthritis (Study IV)

The grade of osteoarthritis was estimated from preoperative, standardized shoulder radiographs taken from the anteroposterior position and 30 degrees obliquely (in the plane of the glenoid surface forearm in neutral rotation). A modified K-L classification was used. The patients were grouped according to the K-L classification into two groups: 1) no glenohumeral osteoarthritis (K-L grade 0) and 2) glenohumeral osteoarthritis (K-L grade I or above). The joint surfaces were evaluated peroperatively and classified by the surgeon according to the Outerbridge classification (Outerbridge and Dunlop 1975).

Physical examination

A clinical physical examination was made in the outpatient clinic by orthopaedic surgeons. The Constant score was measured by an independent physiotherapist.

Imaging procedures

In studies I-IV radiography was performed in all patients and MRI/MRA only when clinically indicated. In study V, MRI was performed on all patients.

Operative treatment

All operations were performed in a similar fashion, arthroscopically in general anesthesia with the patient in the lateral decubitus (Turku University Hospital) or beach chair (Kuopio University Hospital and Hatanpää Hospital) position. RC tendon involvement and other pathological findings of the shoulder joint and subacromial space were structurally recorded. The sagittal size of the supraspinatus tear (in millimeters) was measured with a probe. The joint surfaces were evaluated and classified intraoperatively by the surgeon according to the Outerbridge classification. RC tears were re-inserted anatomically, if possible, and fixed with non-absorbable titanium anchors. In study V only group 3 patients were treated by repairing the RC. In studies I-IV an acromioplasty (straightening of the inferior surface of the acromion from back to front) was performed if the inferior surface of the acromion was frayed. In study V an acromioplasty was performed in all operatively treated patients. In addition, the AC joint was resected by 6 mm if the joint was preoperatively painful and if there were severe degenerative changes in the AC joint by radiography or MRI. In studies I-IV BLHT tenotomy or tenodesis was performed if the BLHT provocation tests were positive preoperatively or if the tendon was frayed and/or unstable during the operation. In study V the BLHT procedure, if any, was always tenotomy.

Conservative treatment (Study V)

The physiotherapist (trained in shoulder rehabilitation) gave the patient written information and thorough guidance for exercises at home. The exercise protocol was standardized and included exercises for free glenohumeral motion and active scapular retraction for the first 6 weeks, then gradually increasing static and dynamic exercises of the scapular and glenohumeral musculature from 6 weeks to 12 weeks, and thereafter increasing resistance and strength training until 6 months. In addition to the written protocol, the patient got a referral for

10 physiotherapy sessions in an outpatient health care facility for monitoring of the progress.

Postoperative rehabilitation

In studies I-IV a supporting sling was used for two weeks postoperatively. At two weeks postoperatively patients were called in for physiotherapist guidance of passive movement exercises, and at six weeks active overhead motion exercises were begun. Strength exercises were begun at 10 weeks after the operation. In study V, after the acromioplasty procedure (Group 2), the physiotherapist gave the patient guidance for free glenohumeral motion and active scapular retraction exercises. At three weeks the physiotherapist assessed the progress of the rehabilitation and gave the patient written information on movement and gradual resistance exercises to be conducted at home as for Group 1. After the acromioplasty + RC repair procedure (Group 3) the arm was immobilized in a sling for three weeks and thereafter the physiotherapist gave the patient guidance for free glenohumeral motion and active scapular retraction exercises. At six weeks the physiotherapist assessed the progress of rehabilitation and gave the patient written information on movement and gradual resistance exercises to be conducted at home as for Group 1. In addition, all operatively treated patients got a referral for 10 physiotherapy sessions in an outpatient health care facility for monitoring the progress of therapy.

Follow-up and clinical evaluation

In studies I-IV the patients were followed up at the Turku University Hospital at three months and one year. The Constant score was used as an outcome measure and was measured by an independent physiotherapist at the follow-up visits. Additional follow-ups were scheduled as necessary. In study V the patients were followed up at the Turku University Hospital, Kuopio University Hospital and Hatanpää Hospital in Tampere at three, six and twelve months after the intervention. The Constant score was used as the primary outcome measure, and it was measured by an independent study nurse at the follow-up visits. Patients were also asked to subjectively evaluate whether the shoulder was better or worse compared to the pre-treatment state and if they were satisfied with the treatment outcome. Additional follow-ups were scheduled as necessary.

Cost analysis (V)

The management of all patients was systematically analyzed for cost of treatment. The total health care cost was retrieved from structured questionnaire forms, including direct cost for the patient (expenses for transportation, hospital, doctor, physiotherapist, medication and lost income), and indirect societal costs (operation, supplies, patient care). This cumulative data was collected from all patients during the follow-up visits at six and twelve months.

Statistical methods

The differences in categorical variables between groups were tested with χ^2-test or Fisher's exact test. In the case of dichotomous factors, normally distributed continuous variables were analysed using two-sample t-test or Wilcoxon signed-rank test and the factors with more than two levels were analysed with ANOVA or Kruskal-Wallis test respectively. In cases of multiple independent variables or multiple measurements generalized linear mixed models were fitted. Analyses were performed adjusting for essential confounding factors prior to the phenomenon that was investigated. Post-hoc multiple comparisons were adjusted with Tukey-Kramer method. Power calculations were based on ANOVA design. P-values less than 0.05 were considered statistically significant. The statistical analyses were performed using SAS System for Windows, versions 9.2 and 9.3 (SAS Institute Inc., Cary, NC, USA).

5. RESULTS

Study I

There was no difference in the age of traumatic vs. non-traumatic RC tear patients (58 vs. 57 years, p=0.63) and both traumatic and non-traumatic patients improved similarly in terms of the Constant score and subjective satisfaction after operative treatment of the RC rupture. The traumatic tears were significantly larger in size (p=0.0002), involved more often the whole insertion of supraspinatus tendon (p<0.0001) and the subscapularis tendon tear was more prevalent in conjunction with traumatic supraspinatus ruptures than non-traumatic ruptures (p=0.049). There were more biceps pathologies and biceps procedures associated with traumatic tears than non-traumatic tears (p=0.02). The mean preoperative Constant scores were lower in the trauma group (46 vs. 52, p=0.01). Despite a longer delay between symptom onset and the operation for the non-traumatic patients than the traumatic ones (p<0.0001), there was no statistically significant difference in terms of an absolute increase of the Constant scores between traumatic and non-traumatic patients (p=0.64). At final follow-up there was a statistically significant difference between traumatic and non-traumatic tears in Constant scores (73 vs. 77, p=0.03), but after adjustment for the preoperative Constant score, gender and size of rupture, the difference in the Constant score between traumatic and non-traumatic group at one year was not significant (adjusted means 74 and 75, p=0.46). 91% of the patients in the traumatic and 93% in the non-traumatic group were satisfied with the treatment result and felt that they had benefited subjectively from the operative treatment (p=0.45).

Study II

Intraoperatively detected tear size correlated significantly with the pre- and one-year postoperative Constant score (r=-0.20, p<0.0001; r=-0.36, p<0.0001, respectively). The overall correlation was similar for the genders, but the Constant scores were significantly lower in women (p<0.0001). The strongest correlation between tear size and the final postoperative Constant score was recorded for subscapularis tears (r=-0.47) and the correlation weakened slightly if the tear involved more posteriorly the supraspinatus (r=-0.36) and infraspinatus (r=-0.26). The total tear size of tears with infraspinatus involvement was significantly larger and involved more often the whole supraspinatus tendon insertion than tears with subscapularis involvement (p<0.0001). Accordingly, the associated supraspinatus tear was significantly larger in conjunction with infraspinatus tears than in conjunction with subscapularis tears (p<0.0001). The associated procedures, i.e., biceps tenotomy (p=0.63), tenodesis (p=0.76) or AC joint resection (p=0.59), did not affect the final postoperative Constant score. The mean final postoperative Constant score was 75.5 for tears with supraspinatus involvement and 76.2 for tears with subscapularis involvement (p=0.0697). The Constant score was significantly lower for tears with infraspinatus involvement 64.3 (p=0.0018).

Study III

The RC tear patients who smoke were younger than non-smokers with RC tears (p<0.001). There was no statistically significant difference in the age adjusted preoperative Constant scores (50 vs. 53, p=0.075) or the intraoperative age adjusted tendon tear size (p=0.500) between smokers and non-smokers. However, at one year of follow-up the age adjusted Constant score was better in non-smokers (75 vs. 71, p=0.017). At the final follow-up there was no statistically significant difference in the age adjusted Constant scores between patients who quit smoking postoperatively compared to smokers (p=0.997). The number of pack-years did not correlate significantly with the Constant score (p=0.226) nor with the size of the tear (p=0.786).

Study IV

Pre- and peroperatively detected osteoarthritis of the glenohumeral joint predicted lower pre- and postoperative Constant scores. There was no statistically significant difference between the mean ages of patients with vs. without radiographic osteoarthritic changes (p=0.149). 22/82 patients (26.8%) had osteoarthritis according to preoperative radiographs. All patients with osteoarthritic changes in preoperative radiographs had also ostoarthritic changes of the glenohumeral joint diagnosed peroperatively. 16/60 patients (26.7%) with no osteoarthritic changes in preoperative radiographs had, nevertheless, intraoperatively arthroscopically diagnosed osteoarthritic changes. Any pre- and intraoperatively detected osteoarthritis was associated with lower Constant scores both preoperatively (60.1 vs. 49.9, p=0.0185 and 60.9 vs. 53.2, p=0.0445, respectively) and at follow-up (82.8 vs. 73.9, p=0.0074 and 83.5 vs. 76.8 SD, p=0.0223, respectively).

Study V

Operative treatment did not provide benefit over conservative treatment of atraumatic supraspinatus tears at one year of follow-up. The mean sagittal size of the supraspinatus tear was similar in different treatment groups by pre-treatment MRI (p=0.48). The mean pre-treatment Constant score in three different treatment groups were 57.1 (Group 1), 59.6 (Group 2) and 58.1 (Group 3), p=0.65. Intraoperatively, there was no difference in the mean sagittal size of the tear between Group 2 and Group 3 (p=0.18). Nor were there differences in the number of AC joint or biceps procedures between Group 2 and Group 3 (p=0.40 and p=0.50, respectively). The change of the Constant score from pre-treatment to one-year follow-up values was similar in all treatment groups (p=0.34), and there was no statistically significant difference in the mean Constant score between the groups at one-year follow-up (74.1 (Group 1), 77.2 (Group 2), 77.9 (Group 3), p= 0.34). The patients' subjective satisfaction at one-year follow-up was 87% in Group 1, 96% in Group 2, and 95% in Group 3, (p=0.14). There were 4 patients (7.3%) in Group 1 and one patient (1.8%) in Group 2 who chose to cross over to cuff repair after a mean of 0,7 years. The mean cost of treatment was 2417 euros (SD 1443) in group 1, 4765 euros (SD 896) in group 2 and 5709 euros in group 3, (p<0.0001). The mean direct cost for the patient was 427 euros, 486 euros and 456 euros, respectively (p=0.96).

6. DISCUSSION

The main finding was that in elderly patients with non-traumatic supraspinatus tears, there was no significant difference in outcome between the three studied interventions at one-year follow-up. Traumatic and non-traumatic groups improved similarly after operative treatment of RC tear. It was found a strong linear negative correlation of RC tear size and Constant score both pre- and postoperatively. Smoking had a negative effect on the clinical outcome after RC repair. Osteoarthritis of the glenohumeral joint in operatively treated supraspinatus tendon tear patients predicted poorer clinical results compared to patients without osteoarthritic changes.

A comparison of outcomes after traumatic and nontraumatic RC repair has been previously reported in only one study (Braune et al. 2003). Based on these results we hypothesized that traumatic RC tear patients are younger and benefit more from operative treatment than non-traumatic tear patients. In our study the mean age and also age range were similar for patients with traumatic and non-traumatic RC tear and a preceding trauma before symptoms did not affect the clinical outcome, although the traumatic tears were larger in size. Our results underscore that traumatic and non-traumatic RC tears have a similar degenerative nature. It is generally accepted that RC tears with acute functional weakness after a traumatic event is an indication for operative treatment. However, in elderly patients it is clinically difficult to assess which component of the RC tear is acute, and are the acute symptoms after a traumatic event an indication for operative treatment. Or can the pre-traumatic asymptomatic state be regained with conservative treatment only. A diagnosis of RC tear can generally be made clinically, but in elderly patients who may have earlier asymptomatic RC tears, MRI may be useful in showing the quality of the tendons and RC muscles.

The operative management of RC tears aims at anatomical healing of the re-inserted tendon. Optimal functional treatment outcome is often associated with restoration of normal anatomy after tendon repair (Huijsmans et al. 2007). The tear size is associated with the RC re-tear rate (Wu et al. 2012). Good functional results have been reported also after treatment of RC re-tears (Nich et al. 2009). Earlier studies have not answered the question if there is a direct association between size of the tear and clinical outcome. In our study there was a strong linear negative correlation between the tear size and the Constant score both pre- and postoperatively. Although the strongest correlation between tear size and the final postoperative Constant score was recorded for anterosuperior tears with subscapularis involvement, the final postoperative Constant score was significantly lower for posterosuperior tears with infraspinatus involvement. This finding suggests that transverse force couple is important to normal kinematics and function of the glenohumeral joint (Keener et al. 2009, Parsons et al. 2002). Retracted total tears of the subscapularis are rare (Garavaglia et al.

2011). The subscapularis is often torn in the upper part of the tendon without breaking the continuity and function of the tendon, whereas infrapinatus tears are often large and cause imbalance to the transverse force couple. Although we have not carried out systematic postoperative MRI investigations, we assume that the poorer functional outcomes with larger tears are due to lower tendon healing rates, since these affect imbalance to the transverse force couple.

Tobacco smoking damages many organs in the body, including the heart, blood vessels, lungs, eyes, mouth, reproductive organs, bones, bladder and digestive organs (Ambrose and Barua 2004, Archontogeorgis et al. 2012, Chen et al. 2011, Cleary et al. 2010, Freedman et al. 2011, Rad et al. 2010, Solberg et al. 1998, Talbot and Riveles 2005). However, there are only few articles focusing on the association between smoking and RC disease. A strong dose- and time-dependent association between smoking and RC tears has been reported by Baumgarten et al. (2010). It has also been shown that smokers tend to get larger RC tears than non-smokers (Carbone et al. 2012). Still, the effect of smoking on treatment outcome after RC repair has been controversial. Mallon et al. (2004) reported that clinical results were better for non-smokers than smokers after open RC repair, whereas Prasad et al. (2005) found no significant effect of smoking on treatment outcome after open RC repair. In our study smoking had a negative effect on the clinical outcome. The final postoperative Constant score was significantly lower among smokers than non-smokers. There was no difference in tear sizes between smokers and non-smokers, but smokers were significantly younger. This is in concordance with previous studies, which reported smoking as a prognostic factor for RC tears (Baumgarten et al. 2010, Carbone et al. 2012). In our study quitting smoking at the time of surgery did not affect the final results. This may due to the small number of patients who quit smoking. The amount of smoking did not correlate with clinical outcome in our study. This may imply that smoking, even in the small amount, affects RC healing.

Although the RC tear is the most common shoulder disorder of elderly patients, also incipient osteoarthritis of the glenohumeral joint is quite common in this patient population. An association between glenohumeral osteoarthritic changes and RC tears has been described (Kernwein 1965, Miller and Savoie 1994) but only few studies have reported a negative effect of concomitant glenohumeral osteoarthritis on the clinical outcome after RC repair (Klinger et al. 2005, Post et al. 1983). In order to homogenize the cohort and minimize the confounding factors of this study, we included only male patients with similar sized RC tears. Our results are in accordance with these previous results: they show significantly lower Constant scores both pre- and postoperatively in patients with glenohumeral osteoarthritic changes in radiographs or intraoperative evaluation. The prevalence of RC tears and of osteoarthritis increases with age. In our study osteoarthritic changes in conventional radiographs were found in 26.8% of the patients and arthroscopic intraoperative osteoarthritic changes in no less than 46.3% of RC tear patients who had a mean age 58 years. The symptoms of incipient glenohumeral osteoarthritis and degenerative RC tears can be quite similar. In patients with both conditions it is sometimes difficult to assess the reason for pain and the optimal treatment method. It is not known if a RC tear and glenohumeral osteoarthritis, when manifested together, are two different diseases or if there is a cause and effect relation between osteoarthritis and RC tears. Different theories have been suggested to explain this relation (Braune et al. 2000, Hsu et al. 2003, Petersson 1983, Ruckstuhl et al. 2008, Sekiya et al. 2012). However, based on our results, concomitant glenohumeral osteoarthritis should be considered as a negative prognostic factor with regard to clinical outcome after RC repair.

Contrary to our hypothesis and an earlier prospective randomized study by Moosmayer et al. (2010) we found no statistically significant difference in clinical outcome between the three studied interventions for supraspinatus tears. Arthroscopic repair of the supraspinatus tear did not result in a significantly better Constant score compared to acromioplasty or conservative treatment. We included only non-traumatic supraspinatus tears to our trial, whereas in the Moosmayer trial over 50% of patients had a traumatic onset of symptoms. This large amount of traumatic patients may be the reason for lower pre-treatment Constant scores in the Moosmayer study compared to our study. In the Moosmayer study the final one-year Constant scores were similar to ours. We had similar results for the three treatment modalities at one year of follow-up and this raises the question if similarly instructed physiotherapy is the main effector for a similar improvement in all groups in our study. However, there is no hard evidence for an effect of physiotherapy on the clinical treatment outcome. Maybe in patients with symptomatic degenerative non-traumatic RC tears the symptoms disappear spontaneously in due time. It was not able to setup a placebo controlled trial because one group was treated conservatively. Therefore, we were not able to see any possibly superior placebo effect in the operatively treated patients. It is also noteworthy that in the outcome analysis performed in an intention to treat fashion, the four crossover patients after six-month follow-up lowered the one-year Constant scores in Group 1 due to early postoperative phase after RC repair. Despite these factors, there was no difference in clinical outcomes between the groups at the final follow-up. Our results support the use of conservative treatment as the primary modality to treat elderly patients with symptomatic non-traumatic supraspinatus tears. Further studies are needed to investigate the longterm-outcome in these non-traumatic RC tear patients.

Study limitations

The current study has several limitations. Studies I-IV are retrospective register studies of prospectively collected cohorts partly at the same time period and there is overlapping of the patients in these studies. The reliability of register information depends on the accuracy of the inputted data. There is possibility to source of errors, on the other hand register enables to gather and analyse data of large number of patients. It is possible that the register does not represent true epidemiologic data because also private hospitals operate on RC tear patients. In study V the population was selected and strict inclusion criteria limit the applicability of the results only to isolated, non-traumatic supraspinatus tears in elderly. The follow-up time in all studies was only one year. Although it has been reported that after arthroscopic RC repair the Constant score improves for up to one year after which it will stabilize (Charousset et al. 2008), it is possible that the final clinical outcome is gained later.

The Constant score as an outcome measure has some known limitations. Kirkley et al. (2003) observed that no formal validity testing data nor responsiveness of the Constant score has been published. Further, Constant et al. (2008) noted that there may be too much room for interpretation of terminology, which may affect interobserver reliability. Accordingly, a level I systematic review by Roy et al. (2010) underscores the need for standardization of the Constant score. A later level I study by Blonna et al. (2012) showed that the standardization significantly improved both the intra- and interobserver reliability of the Constant score.

The lack of pre- and postoperative MRI study made systematically in studies I-IV and the lack of a postoperative MRI study in study V are obvious weaknesses of the study. MRI can detect intra-articular lesions (Miller and Savoie 1994), establish the size of the RC tear and assess the quality of the tendon and RC muscles (Melis et al. 2010, Rulewicz et al. 2013). Especially muscle atrophy and fatty infiltration into the RC muscles are associated with treatment outcome (Chung et al. 2011, Gladstone et al. 2007). Re-tearing after RC repair is quite common (Randelli et al. 2012) and because of a lack of postoperative MRI studies, we are not aware of the re-tear rate. However, structural and clinical outcomes are not always associated (Oh et al. 2009). We are especially interested in clinical results and the subjective satisfaction of the patients. In study V we did not evaluate Quality Adjusted Life Year. It would have been better instrument for cost efficiency than direct costs.

Study strengths

The randomized, prospective setup in study V and the prospectively collected data with a large series of consecutive patients in studies I-IV are strengths of the study. The results of the study are highly applicable to clinical practice. Electronic patient database allows continuous collection of all data of consecutive patients. The follow-up of this consecutive cohort provides a platform for quality control of our own clinical activities.

Future studies

Future study is needed to define the structural healing of the re-inserted supraspinatus tendon. What is re-tear rate and is there an increase in tear size in patients treated with acromioplasty or physiotherapy only? Do the groups differ in terms of muscle atrophy and fatty infiltration in follow-up? Based on this study conservative treatment can be suggested as primary treatment for only elderly RC tear patients. Randomized controlled trial comparing different treatment modalities in younger RC tear patients is needed. It is unknown if there are some differences in tendon degenerative changes in younger individuals. Are symptoms different in younger patients because of higher physical activity? The effect of physiotherapy on the outcome in RC patients is unclear. The effect of standardized exercise training should be studied in a placebo-controlled setup.

7. CONCLUSIONS

The results of the present study lead to the following conclusions:

1. In our patient population the age of patients with traumatic and non-traumatic RC tears was similar. Both traumatic and non-traumatic patients improved similarly in terms of the Constant score and subjective satisfaction after operative treatment of RC rupture. The traumatic tears were significantly larger in size.

2. The intraoperatively assessed RC tear size correlated significantly with the pre- and postoperative Constant score. The strongest correlation between the tear size and the final postoperative Constant score was recorded for anterosuperior tears. However, the total tear size was significantly larger with infraspinatus involvement. The clinical outcome was poorer for patients with posterosuperior RC tears than for patients with anterosuperior or superior tears.

3. Operatively treated patients with RC tears who smoked were significantly younger than non-smokers. Smoking was associated with a lower postoperative Constant score.

4. Osteoarthritis of the glenohumeral joint was common among patients treated operatively for supraspinatus tears. Osteoarthritis of the glenohumeral joint, if present pre- or intraoperatively during RC reconstruction, predicted lower pre- and postoperative Constant score.

5. Operative treatment of isolated atraumatic full-thickness supraspinatus tears did not provide benefit over conservative treatment in elderly patients.

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9. REFERENCES

Abate M, Schiavone C, Salini V. Sonographic evaluation of the shoulder in asymptomatic elderly subjects with diabetes. BMC Musculoskelet Disord 2010; 11: 278, 7pages.

Abboud JA, Kim JS. The effect of hypercholesterolemia on rotator cuff disease. Clin Orthop Relat Res 2010; 468: 1493-7.

Ahmad CS, ElAttrache NS. Arthroscopic biceps tenodesis. Orthop Clin North Am 2003; 34: 499-506.

Ainsworth R. Physiotherapy rehabilitation in patients with massive, irreparable rotator cuff tears. Musculoskeletal Care 2006; 4: 140-51.

Ainsworth R, Lewis JS. Exercise therapy for the conservative management of full thickness tears of the rotator cuff: a systematic review. Br J Sports Med 2007; 41: 200-10.

Akbar M, Balean G, Brunner M, Seyler TM, Bruckner T, Munzinger J, Grieser T, Gerner HJ, Loew M. Prevalence of rotator cuff tear in paraplegic patients compared with controls. J Bone Joint Surg Am 2010; 92: 23-30.

Aleem AW, Brophy RH. Outcomes of rotator cuff surgery: what does the evidence tell us? Clin Sports Med 2012; 31: 665-74.

Alpantaki K, McLaughlin D, Karagogeos D, Hadjipavlou A, Kontakis G. Sympathetic and sensory neural elements in the tendon of the long head of the biceps. J Bone Joint Surg Am 2005; 87: 1580-3.

Ambrose JA, Barua RS. The pathophysiology of cigarette smoking and cardiovascular disease: an update. J Am Coll Cardiol 2004; 43: 1731-7.

Anderson K, Boothby M, Aschenbrener D, van Holsbeeck M. Outcome and structural integrity after arthroscopic rotator cuff repair using 2 rows of fixation: minimum 2-year follow-up. Am J Sports Med 2006; 34: 1899-905.

Anderson MW, Brennan C, Mittal A. Imaging evaluation of the rotator cuff. Clin Sports Med 2012; 31: 605-31.

Angst F, Schwyzer HK, Aeschlimann A, Simmen BR, Goldhahn J. Measures of adult shoulder function: Disabilities of the Arm, Shoulder, and Hand Questionnaire (DASH) and its short version (QuickDASH), Shoulder Pain and Disability Index (SPADI), American Shoulder and Elbow Surgeons (ASES) Society standardized shoulder assessment form, Constant (Murley) Score (CS), Simple Shoulder Test (SST), Oxford Shoulder Score (OSS), Shoulder Disability Questionnaire (SDQ), and Western Ontario Shoulder Instability Index (WOSI). Arthritis Care Res (Hoboken) 2011; 63 Suppl 11: S174-88.

Archontogeorgis K, Steiropoulos P, Tzouvelekis A, Nena E, Bouros D. Lung cancer and interstitial lung diseases: a systematic review. Pulm Med 2012; 2012: 315918.

Arndt J, Clavert P, Mielcarek P, Bouchaib J, Meyer N, Kempf JF. Immediate passive motion versus immobilization after endoscopic supraspinatus tendon repair: a prospective randomized study. Orthop Traumatol Surg Res 2012; 98: S131-8.

Baechler MF, Kim DH. "Uncoverage" of the humeral head by the anterolateral acromion and its relationship to full-thickness rotator cuff tears. Mil Med 2006; 171: 1035-8.

Baker CL, Liu SH. Comparison of open and arthroscopically assisted rotator cuff repairs. Am J Sports Med 1995; 23: 99-104.

Balyk R, Luciak-Corea C, Otto D, Baysal D, Beaupre L. Do outcomes differ after rotator cuff repair for patients receiving workers' compensation? Clin Orthop Relat Res 2008; 466: 3025-33.

Bartl C, Kouloumentas P, Holzapfel K, Eichhorn S, Wortler K, Imhoff A, Salzmann GM. Long-term outcome and structural integrity following open repair of massive rotator cuff tears. Int J Shoulder Surg 2012; 6: 1-8.

Bartolozzi A, Andreychik D, Ahmad S. Determinants of outcome in the treatment of rotator cuff disease. Clin Orthop Relat Res 1994; 308: 90-7.

Baumgarten KM, Gerlach D, Galatz LM, Teefey SA, Middleton WD, Ditsios K, Yamaguchi K. Cigarette smoking increases the risk for rotator cuff tears. Clin Orthop Relat Res 2010; 468: 1534-41.

Beall DP, Williamson EE, Ly JQ, Adkins MC, Emery RL, Jones TP, Rowland CM. Association of biceps tendon tears with rotator cuff abnormalities: degree of correlation with tears of the anterior and superior portions of the rotator cuff. AJR Am J Roentgenol 2003; 180: 633-9.

Bedi A, Dines J, Warren RF, Dines DM. Massive tears of the rotator cuff. J Bone Joint Surg Am 2010; 92: 1894-908.

Beeler S, Ek ET, Gerber C. A comparative analysis of fatty infiltration and muscle atrophy in patients with chronic rotator cuff tears and suprascapular neuropathy. J Shoulder Elbow Surg 2013; [Epub ahead of print].

Bell S, Lim YJ, Coghlan J. Long-term longitudinal follow-up of mini-open rotator cuff repair. J Bone Joint Surg Am 2013; 95: 151-7.

Bellumore Y, Mansat M, Assoun J. [Results of the surgical repair of the rotator cuff. Radio-clinical correlation]. Rev Chir Orthop Reparatrice Appar Mot 1994; 80: 582-94.

Bennett WF. Visualization of the anatomy of the rotator interval and bicipital sheath. Arthroscopy 2001; 17: 107-11.

Berlemann U, Bayley I. Tenodesis of the long head of biceps brachii in the painful shoulder: improving results in the long term. J Shoulder Elbow Surg 1995; 4: 429-35.

Biberthaler P, Wiedemann E, Nerlich A, Kettler M, Mussack T, Deckelmann S, Mutschler W. Microcirculation associated with degenerative rotator cuff lesions. In vivo assessment with orthogonal polarization spectral imaging during arthroscopy of the shoulder. J Bone Joint Surg Am 2003; 85-A: 475-80.

Bigliani LU, Morrison DS, April EW. The morphology of the acromion and its relationship to rotator cuff tears. Orthop Trans 1986; 10: 228.

Bishop J, Klepps S, Lo IK, Bird J, Gladstone JN, Flatow EL. Cuff integrity after arthroscopic versus open rotator cuff repair: a prospective study. J Shoulder Elbow Surg 2006; 15: 290-9.

Bjorkenheim JM, Paavolainen P, Ahovuo J, Slatis P. Surgical repair of the rotator cuff and surrounding tissues. Factors influencing the results. Clin Orthop Relat Res 1988; 236: 148-53.

Bjornsson H, Norlin R, Knutsson A, Adolfsson L. Fewer rotator cuff tears fifteen years after arthroscopic subacromial decompression. J Shoulder Elbow Surg 2010; 19: 111-5.

Bjornsson HC, Norlin R, Johansson K, Adolfsson LE. The influence of age, delay of repair, and tendon involvement in acute rotator cuff tears: structural and clinical outcomes after repair of 42 shoulders. Acta Orthop 2011; 82: 187-92.

Blevins FT. Rotator cuff pathology in athletes. Sports Med 1997; 24: 205-20.

Blonna D, Scelsi M, Marini E, Bellato E, Tellini A, Rossi R, Bonasia DE, Castoldi F. Can we improve the reliability of the Constant-Murley score? J Shoulder Elbow Surg 2012; 21: 4-12.

Boileau P, Baque F, Valerio L, Ahrens P, Chuinard C, Trojani C. Isolated arthroscopic biceps tenotomy or tenodesis improves symptoms in patients with massive irreparable rotator cuff tears. J Bone Joint Surg Am 2007; 89: 747-57.

Boileau P, Brassart N, Watkinson DJ, Carles M, Hatzidakis AM, Krishnan SG. Arthroscopic repair of full-thickness tears of the supraspinatus: does the tendon really heal? J Bone Joint Surg Am 2005; 87: 1229-40.

Boileau P, Chuinard C, Roussanne Y, Neyton L, Trojani C. Modified latissimus dorsi and teres major transfer through a single delto-pectoral approach for external rotation deficit of the shoulder: as an isolated procedure or with a reverse arthroplasty. J Shoulder Elbow Surg 2007; 16: 671-82.

Boileau P, Maynou C, Balestro JC, Brassart N, Clavert P, Cotten A, Gosselin O, Lespagnol F, Jacquot N, Walch G. [Long head of the biceps pathology]. Rev Chir Orthop Reparatrice Appar Mot 2007; 93: 5S19-53.

Boissonnault WG, Badke MB, Wooden MJ, Ekedahl S, Fly K. Patient outcome following rehabilitation for rotator cuff repair surgery: the impact of selected medical comorbidities. J Orthop Sports Phys Ther 2007; 37: 312-9.

Bokor DJ, Hawkins RJ, Huckell GH, Angelo RL, Schickendantz MS. Results of nonoperative management of full-thickness tears of the rotator cuff. Clin Orthop Relat Res 1993; 294: 103-10.

Boughebri O, Roussignol X, Delattre O, Kany J, Valenti P. Small supraspinatus tears repaired by arthroscopy: are clinical results influenced by the integrity of the cuff after two years? Functional and anatomic results of forty-six consecutive cases. J Shoulder Elbow Surg 2012; 21: 699-706.

Braune C, Gramlich H, Habermeyer P. [The macroscopic aspect of rotator cuff tears in traumatic and nontraumatic rupture cases]. Unfallchirurg 2000; 103: 462-7.

Braune C, von Eisenhart-Rothe R, Welsch F, Teufel M, Jaeger A. Mid-term results and quantitative comparison of postoperative shoulder function in traumatic and non-traumatic rotator cuff tears. Arch Orthop Trauma Surg 2003; 123: 419-24.

Brown JN, Roberts SN, Hayes MG, Sales AD. Shoulder pathology associated with symptomatic acromioclavicular joint degeneration. J Shoulder Elbow Surg 2000; 9: 173-6.

Buckwalter KA. Current concepts and advances: computerized tomography in sports medicine. Sports Med Arthrosc 2009; 17: 13-20.

Burkhart SS. Arthroscopic treatment of massive rotator cuff tears. Clinical results and biomechanical rationale. Clin Orthop Relat Res 1991; 267: 45-56.

Burkhart SS. Partial repair of massive rotator cuff tears: the evolution of a concept. Orthop Clin North Am 1997; 28: 125-32.

Burkhart SS, Athanasiou KA, Wirth MA. Margin convergence: a method of reducing strain in massive rotator cuff tears. Arthroscopy 1996; 12: 335-8.

Burkhart SS, Danaceau SM, Pearce CE, Jr. Arthroscopic rotator cuff repair: Analysis of results by tear size and by repair technique-margin convergence versus direct tendon-to-bone repair. Arthroscopy 2001; 17: 905-12.

Burkhart SS, Nottage WM, Ogilvie-Harris DJ, Kohn HS, Pachelli A. Partial repair of irreparable rotator cuff tears. Arthroscopy 1994; 10: 363-70.

Burks RT, Crim J, Brown N, Fink B, Greis PE. A prospective randomized clinical trial comparing arthroscopic single- and double-row rotator cuff repair: magnetic resonance imaging and early clinical evaluation. Am J Sports Med 2009; 37: 674-82.

Carbone S, Gumina S, Arceri V, Campagna V, Fagnani C, Postacchini F. The impact of preoperative smoking habit on rotator cuff tear: cigarette smoking influences rotator cuff tear sizes. J Shoulder Elbow Surg 2012; 21: 56-60.

Carbonel I, Martinez AA, Calvo A, Ripalda J, Herrera A. Single-row versus double-row arthroscopic repair in the treatment of rotator cuff tears: a prospective randomized clinical study. Int Orthop 2012; 36: 1877-83.

Chahal J, Van Thiel GS, Mall N, Heard W, Bach BR, Cole BJ, Nicholson GP, Verma NN, Whelan DB, Romeo AA. The role of platelet-rich plasma in arthroscopic rotator cuff repair: a systematic review with quantitative synthesis. Arthroscopy 2012; 28: 1718-27.

Chansky HA, Iannotti JP. The vascularity of the rotator cuff. Clin Sports Med 1991; 10: 807-22.

Charousset C, Grimberg J, Duranthon LD, Bellaiche L, Petrover D, Kalra K. The time for functional recovery after arthroscopic rotator cuff repair: correlation with tendon healing controlled by computed tomography arthrography. Arthroscopy 2008; 24: 25-33.

Chaudhury S, Dines JS, Delos D, Warren RF, Voigt C, Rodeo SA. Role of fatty infiltration in the pathophysiology and outcomes of rotator cuff tears. Arthritis Care Res (Hoboken) 2012; 64: 76-82.

Chaudhury S, Holland C, Vollrath F, Carr AJ. Comparing normal and torn rotator cuff tendons using dynamic shear analysis. J Bone Joint Surg Br 2011; 93: 942-8.

Chen CH, Hsu KY, Chen WJ, Shih CH. Incidence and severity of biceps long head tendon lesion in patients with complete rotator cuff tears. J Trauma 2005; 58: 1189-93.

Chen Y, Guo Q, Pan X, Qin L, Zhang P. Smoking and impaired bone healing: will activation of cholinergic anti-inflammatory pathway be the bridge? Int Orthop 2011; 35: 1267-70.

Cheung S, Dillon E, Tham SC, Feeley BT, Link TM, Steinbach L, Ma CB. The presence of fatty infiltration in the infraspinatus: its relation with the condition of the supraspinatus tendon. Arthroscopy 2011; 27: 463-70.

Cho NS, Rhee YG. The factors affecting the clinical outcome and integrity of arthroscopically repaired rotator cuff tears of the shoulder. Clin Orthop Surg 2009; 1: 96-104.

Cho NS, Rhee YG. Functional outcome of arthroscopic repair with concomitant manipulation in rotator cuff tears with stiff shoulder. Am J Sports Med 2008; 36: 1323-9.

Chuang TY, Ho WP, Chen CH, Lee CH, Liau JJ, Huang CH. Arthroscopic treatment of rotator cuff tears with shoulder stiffness: a comparison of functional outcomes with and without capsular release. Am J Sports Med 2012; 40: 2121-7.

Chung SW, Oh JH, Gong HS, Kim JY, Kim SH. Factors affecting rotator cuff healing after arthroscopic repair: osteoporosis as one of the independent risk factors. Am J Sports Med 2011; 39: 2099-107.

Clark JM, Harryman DT, 2nd. Tendons, ligaments, and capsule of the rotator cuff. Gross and microscopic anatomy. J Bone Joint Surg Am 1992; 74: 713-25.

Cleary SP, Cotterchio M, Shi E, Gallinger S, Harper P. Cigarette smoking, genetic variants in carcinogenmetabolizing enzymes, and colorectal cancer risk. Am J Epidemiol 2010; 172: 1000-14.

Clement ND, Hallett A, MacDonald D, Howie C, McBirnie J. Does diabetes affect outcome after arthroscopic repair of the rotator cuff? J Bone Joint Surg Br 2010; 92: 1112-7.

Codman EA. Complete rupture of the supraspinatus tendon. Operative treatment with report of two successful cases. Boston Med Surg J 1911; 164: 708-10.

Cofield RH. Rotator cuff disease of the shoulder. J Bone Joint Surg Am 1985; 67: 974-9.

Cofield RH. Subscapular muscle transposition for repair of chronic rotator cuff tears. Surg Gynecol Obstet 1982; 154: 667-72.

Cofield RH, Parvizi J, Hoffmeyer PJ, Lanzer WL, Ilstrup DM, Rowland CM. Surgical repair of chronic rotator cuff tears. A prospective long-term study. J Bone Joint Surg Am 2001; 83-A: 71-7.

Cole BJ, McCarty LP, 3rd, Kang RW, Alford W, Lewis PB, Hayden JK. Arthroscopic rotator cuff repair: prospective functional outcome and repair integrity at minimum 2-year follow-up. J Shoulder Elbow Surg 2007; 16: 579-85.

Colvin AC, Egorova N, Harrison AK, Moskowitz A, Flatow EL. National trends in rotator cuff repair. J Bone Joint Surg Am 2012; 94: 227-33.

Constant CR, Gerber C, Emery RJ, Sojbjerg JO, Gohlke F, Boileau P. A review of the Constant score: modifications and guidelines for its use. J Shoulder Elbow Surg 2008; 17: 355-61.

Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. Clin Orthop Relat Res 1987; 214: 160-4.

Crusher RH. Rotator cuff injuries. Accid Emerg Nurs 2000; 8: 129-33.

Cuff DJ, Pupello DR. Prospective randomized study of arthroscopic rotator cuff repair using an early versus delayed postoperative physical therapy protocol. J Shoulder Elbow Surg 2012; 21: 1450-5.

Curtis AS, Burbank KM, Tierney JJ, Scheller AD, Curran AR. The insertional footprint of the rotator cuff: an anatomic study. Arthroscopy 2006; 22: 609.e1.

De Carli A, Vadala A, Zanzotto E, Zampar G, Vetrano M, Iorio R, Ferretti A. Reparable rotator cuff tears with concomitant long-head biceps lesions: tenotomy or tenotomy/tenodesis? Knee Surg Sports Traumatol Arthrosc 2012; 20: 2553-8.

de Jesus JO, Parker L, Frangos AJ, Nazarian LN. Accuracy of MRI, MR arthrography, and ultrasound in the diagnosis of rotator cuff tears: a meta-analysis. AJR Am J Roentgenol 2009; 192: 1701-7.

DeFranco MJ, Bershadsky B, Ciccone J, Yum JK, Iannotti JP. Functional outcome of arthroscopic rotator cuff repairs: a correlation of anatomic and clinical results. J Shoulder Elbow Surg 2007; 16: 759-65.

Denard PJ, Jiwani AZ, Ladermann A, Burkhart SS. Long-term outcome of a consecutive series of subscapularis tendon tears repaired arthroscopically. Arthroscopy 2012; 28: 1587-91.

Denard PJ, Jiwani AZ, Ladermann A, Burkhart SS. Long-term outcome of arthroscopic massive rotator cuff repair: the importance of double-row fixation. Arthroscopy 2012; 28: 909-15.

Dhar Y, Anakwenze OA, Steele B, Lozano S, Abboud JA. Arthroscopic rotator cuff repair: impact of diabetes mellitus on patient outcomes. Phys Sportsmed 2013; 41: 22-9.

Donaldson J, Pandit A, Noorani A, Douglas T, Falworth M, Lambert S. Latissimus dorsi tendon transfers for rotator cuff deficiency. Int J Shoulder Surg 2011; 5: 95-100.

Downie BK, Miller BS. Treatment of rotator cuff tears in older individuals: a systematic review. J Shoulder Elbow Surg 2012; 21: 1255-61.

Dugas JR, Campbell DA, Warren RF, Robie BH, Millett PJ. Anatomy and dimensions of rotator cuff insertions. J Shoulder Elbow Surg 2002; 11: 498-503.

Duralde XA, Bair B. Massive rotator cuff tears: the result of partial rotator cuff repair. J Shoulder Elbow Surg 2005; 14: 121-7.

Ejnisman B, Andreoli CV, Soares B, Peccin MS, Abdalla RJ, Faloppa F, Cohen M. WITHDRAWN: Interventions for tears of the rotator cuff in adults. Cochrane Database Syst Rev 2009; CD002758.

Ellman H. Diagnosis and treatment of incomplete rotator cuff tears. Clin Orthop Relat Res 1990; 254: 64-74.

Ellman H, Kay SP, Wirth M. Arthroscopic treatment of full-thickness rotator cuff tears: 2- to 7-year follow-up study. Arthroscopy 1993; 9: 195-200.

Fehringer EV, Sun J, VanOeveren LS, Keller BK, Matsen FA, 3rd. Full-thickness rotator cuff tear prevalence and correlation with function and comorbidities in patients sixty-five years and older. J Shoulder Elbow Surg 2008; 17: 881-5.

Flurin PH, Landreau P, Gregory T, Boileau P, Brassart N, Courage O, Dagher E, Graveleau N, Guillo S, Kempf JF, Lafosse L, Laprelle E, Toussaint B. [Arthroscopic repair of full-thickness cuff tears: a multicentric retrospective study of 576 cases with anatomical assessment.]. Rev Chir Orthop Reparatrice Appar Mot 2005; 91: 31-42.

Fongemie AE, Buss DD, Rolnick SJ. Management of shoulder impingement syndrome and rotator cuff tears. Am Fam Physician 1998; 57: 667-74, 680-2.

Fotiadou AN, Vlychou M, Papadopoulos P, Karataglis DS, Palladas P, Fezoulidis IV. Ultrasonography of symptomatic rotator cuff tears compared with MR imaging and surgery. Eur J Radiol 2008; 68: 174-9.

Franceschi F, Ruzzini L, Longo UG, Martina FM, Zobel BB, Maffulli N, Denaro V. Equivalent clinical results of arthroscopic single-row and double-row suture anchor repair for rotator cuff tears: a randomized controlled trial. Am J Sports Med 2007; 35: 1254-60.

Freedman ND, Silverman DT, Hollenbeck AR, Schatzkin A, Abnet CC. Association between smoking and risk of bladder cancer among men and women. JAMA 2011; 306: 737-45.

Freehill MT, Shi LL, Tompson JD, Warner JJ. Suprascapular neuropathy: diagnosis and management. Phys Sportsmed 2012; 40: 72-83.

Fritz J, Fishman EK, Small KM, Winalski CS, Horger MS, Corl F, McFarland E, Carrino JA, Fayad LM. MDCT arthrography of the shoulder with datasets of isotropic resolution: indications, technique, and applications. AJR Am J Roentgenol 2012; 198: 635-46.

Frost A, Zafar MS, Maffulli N. Tenotomy versus tenodesis in the management of pathologic lesions of the tendon of the long head of the biceps brachii. Am J Sports Med 2009; 37: 828-33.

Fucentese SF, von Roll AL, Pfirrmann CW, Gerber C, Jost B. Evolution of nonoperatively treated symptomatic isolated full-thickness supraspinatus tears. J Bone Joint Surg Am 2012; 94: 801-8.

Fukuda H, Hamada K, Yamanaka K. Pathology and pathogenesis of bursal-side rotator cuff tears viewed from en bloc histologic sections. Clin Orthop Relat Res 1990; 254: 75-80.

Galatz LM, Silva MJ, Rothermich SY, Zaegel MA, Havlioglu N, Thomopoulos S. Nicotine delays tendon-to-bone healing in a rat shoulder model. J Bone Joint Surg Am 2006; 88: 2027-34.

Garavaglia G, Ufenast H, Taverna E. The frequency of subscapularis tears in arthroscopic rotator cuff repairs: A retrospective study comparing magnetic resonance imaging and arthroscopic findings. Int J Shoulder Surg 2011; 5: 90-4.

Gartsman GM. Massive, irreparable tears of the rotator cuff. Results of operative debridement and subacromial decompression. J Bone Joint Surg Am 1997; 79: 715-21.

Gartsman GM, O'Connor D P. Arthroscopic rotator cuff repair with and without arthroscopic subacromial decompression: a prospective, randomized study of one-year outcomes. J Shoulder Elbow Surg 2004; 13: 424-6.

Gartsman GM, Taverna E. The incidence of glenohumeral joint abnormalities associated with full-thickness, reparable rotator cuff tears. Arthroscopy 1997; 13: 450-5.

Gerber C, Blumenthal S, Curt A, Werner CM. Effect of selective experimental suprascapular nerve block on abduction and external rotation strength of the shoulder. J Shoulder Elbow Surg 2007; 16: 815-20.

Gerber C, Fuchs B, Hodler J. The results of repair of massive tears of the rotator cuff. J Bone Joint Surg Am 2000; 82: 505-15.

Gerber C, Maquieira G, Espinosa N. Latissimus dorsi transfer for the treatment of irreparable rotator cuff tears. J Bone Joint Surg Am 2006; 88: 113-20.

Ghodadra NS, Provencher MT, Verma NN, Wilk KE, Romeo AA. Open, mini-open, and all-arthroscopic rotator cuff repair surgery: indications and implications for rehabilitation. J Orthop Sports Phys Ther 2009; 39: 81-9.

Gialanella B, Prometti P. Effects of corticosteroids injection in rotator cuff tears. Pain Med 2011; 12: 1559-65.

Gilbart MK, Gerber C. Comparison of the subjective shoulder value and the Constant score. J Shoulder Elbow Surg 2007; 16: 717-21.

Gill TJ, McIrvin E, Kocher MS, Homa K, Mair SD, Hawkins RJ. The relative importance of acromial morphology and age with respect to rotator cuff pathology. J Shoulder Elbow Surg 2002; 11: 327-30.

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. Am J Sports Med 2007; 35: 719-28.

Goodmurphy CW, Osborn J, Akesson EJ, Johnson S, Stanescu V, Regan WD. An immunocytochemical analysis of torn rotator cuff tendon taken at the time of repair. J Shoulder Elbow Surg 2003; 12: 368-74.

Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures. Pre- and postoperative evaluation by CT scan. Clin Orthop Relat Res 1994; 304: 78-83.

Grasso A, Milano G, Salvatore M, Falcone G, Deriu L, Fabbriciani C. Single-row versus double-row arthroscopic rotator cuff repair: a prospective randomized clinical study. Arthroscopy 2009; 25: 4-12.

Green S, Buchbinder R, Hetrick S. Physiotherapy interventions for shoulder pain. Cochrane Database Syst Rev 2003; CD004258.

Guckel C, Nidecker A. Diagnosis of tears in rotator-cuff-injuries. Eur J Radiol 1997; 25: 168-76.

Guery J, Favard L, Sirveaux F, Oudet D, Mole D, Walch G. Reverse total shoulder arthroplasty. Survivorship analysis of eighty replacements followed for five to ten years. J Bone Joint Surg Am 2006; 88: 1742-7.

Gulotta LV, Nho SJ, Dodson CC, Adler RS, Altchek DW, MacGillivray JD. Prospective evaluation of arthroscopic rotator cuff repairs at 5 years: part II--prognostic factors for clinical and radiographic outcomes. J Shoulder Elbow Surg 2011; 20: 941-6.

Gumina S, Arceri V, Carbone S, Albino P, Passaretti D, Campagna V, Fagnani C, Postacchini F. The association between arterial hypertension and rotator cuff tear: the influence on rotator cuff tear sizes. J Shoulder Elbow Surg 2013; 22: 229-32.

Gwilym SE, Watkins B, Cooper CD, Harvie P, Auplish S, Pollard TC, Rees JL, Carr AJ. Genetic influences in the progression of tears of the rotator cuff. J Bone Joint Surg Br 2009; 91: 915-7.

Habermeyer P, Krieter C, Tang KL, Lichtenberg S, Magosch P. A new arthroscopic classification of articular-sided supraspinatus footprint lesions: a prospective comparison with Snyder's and Ellman's classification. J Shoulder Elbow Surg 2008; 17: 909-13.

Hamada K, Fukuda H, Mikasa M, Kobayashi Y. Roentgenographic findings in massive rotator cuff tears. A long-term observation. Clin Orthop Relat Res 1990; 254: 92-6.

Hamada K, Okawara Y, Fryer JN, Tomonaga A, Fukuda H. Localization of mRNA of procollagen alpha 1 type I in torn supraspinatus tendons. In situ hybridization using digoxigenin labeled oligonucleotide probe. Clin Orthop Relat Res 1994; 304: 18-21.

Handelberg FW. Treatment options in full thickness rotator cuff tears. Acta Orthop Belg 2001; 67: 110-5.

Hansen ML, Otis JC, Johnson JS, Cordasco FA, Craig EV, Warren RF. Biomechanics of massive rotator cuff tears: implications for treatment. J Bone Joint Surg Am 2008; 90: 316-25.

Harvie P, Ostlere SJ, Teh J, McNally EG, Clipsham K, Burston BJ, Pollard TC, Carr AJ. Genetic influences in the aetiology of tears of the rotator cuff. Sibling risk of a full-thickness tear. J Bone Joint Surg Br 2004; 86: 696-700.

Hata Y, Saitoh S, Murakami N, Kobayashi H, Takaoka K. Atrophy of the deltoid muscle following rotator cuff surgery. J Bone Joint Surg Am 2004; 86-A: 1414-9.

Hattrup SJ. Rotator cuff repair: relevance of patient age. J Shoulder Elbow Surg 1995; 4: 95-100.

Hattrup SJ, Cofield RH. Rotator cuff tears with cervical radiculopathy. J Shoulder Elbow Surg 2010; 19: 937-43.

Hayes K, Ginn KA, Walton JR, Szomor ZL, Murrell GA. A randomised clinical trial evaluating the efficacy of physiotherapy after rotator cuff repair. Aust J Physiother 2004; 50: 77-83.

Hertel R, Ballmer FT, Lombert SM, Gerber C. Lag signs in the diagnosis of rotator cuff rupture. J Shoulder Elbow Surg 1996; 5: 307-13.

Hsu HC, Luo ZP, Stone JJ, Huang TH, An KN. Correlation between rotator cuff tear and glenohumeral degeneration. Acta Orthop Scand 2003; 74: 89-94.

Huijsmans PE, Pritchard MP, Berghs BM, van Rooyen KS, Wallace AL, de Beer JF. Arthroscopic rotator cuff repair with double-row fixation. J Bone Joint Surg Am 2007; 89: 1248-57.

Iannotti JP, Deutsch A, Green A, Rudicel S, Christensen J, Marraffino S, Rodeo S. Time to failure after rotator cuff repair: a prospective imaging study. J Bone Joint Surg Am 2013; 95: 965-71.

Ide J, Maeda S, Takagi K. A comparison of arthroscopic and open rotator cuff repair. Arthroscopy 2005; 21: 1090-8.

Ide J, Tokiyoshi A, Hirose J, Mizuta H. An anatomic study of the subscapularis insertion to the humerus: the subscapularis footprint. Arthroscopy 2008; 24: 749-53.

Inman VT, Saunders JB, Abbott LC. Observations on the function of the shoulder joint. JBJS 1944; 26: 1-30.

Isaac C, Gharaibeh B, Witt M, Wright VJ, Huard J. Biologic approaches to enhance rotator cuff healing after injury. J Shoulder Elbow Surg 2012; 21: 181-90.

Itoi E, Kido T, Sano A, Urayama M, Sato K. Which is more useful, the "full can test" or the "empty can test," in detecting the torn supraspinatus tendon? Am J Sports Med 1999; 27: 65-8.

Itoi E, Kuechle DK, Newman SR, Morrey BF, An KN. Stabilising function of the biceps in stable and unstable shoulders. J Bone Joint Surg Br 1993; 75: 546-50.

Jamali AA, Afshar P, Abrams RA, Lieber RL. Skeletal muscle response to tenotomy. Muscle Nerve 2000; 23: 851-62.

Jost B, Koch PP, Gerber C. Anatomy and functional aspects of the rotator interval. J Shoulder Elbow Surg 2000; 9: 336-41.

Jost B, Pfirrmann CW, Gerber C, Switzerland Z. Clinical outcome after structural failure of rotator cuff repairs. J Bone Joint Surg Am 2000; 82: 304-14.

Jost B, Puskas GJ, Lustenberger A, Gerber C. Outcome of pectoralis major transfer for the treatment of irreparable subscapularis tears. J Bone Joint Surg Am 2003; 85-A: 1944-51.

Kanbayashi T, Takafuji T, Sato Y. On the arterial supply in the human biceps brachii muscle. Okajimas Folia Anat Jpn 1993; 69: 289-310.

Kannus P, Jozsa L. Histopathological changes preceding spontaneous rupture of a tendon. A controlled study of 891 patients. J Bone Joint Surg Am 1991; 73: 1507-25.

Keating JF, Waterworth P, Shaw-Dunn J, Crossan J. The relative strengths of the rotator cuff muscles. A cadaver study. J Bone Joint Surg Br 1993; 75: 137-40.

Keener JD, Wei AS, Kim HM, Steger-May K, Yamaguchi K. Proximal humeral migration in shoulders with symptomatic and asymptomatic rotator cuff tears. J Bone Joint Surg Am 2009; 91: 1405-13.

Kempf JF, Gleyze P, Bonnomet F, Walch G, Mole D, Frank A, Beaufils P, Levigne C, Rio B, Jaffe A. A multicenter study of 210 rotator cuff tears treated by arthroscopic acromioplasty. Arthroscopy 1999; 15: 56-66.

Kernwein GA. Roentgenographic diagnosis of shoulder dysfunction. JAMA 1965; 194: 1081-5.

Kijima H, Minagawa H, Nishi T, Kikuchi K, Shimada Y. Long-term follow-up of cases of rotator cuff tear treated conservatively. J Shoulder Elbow Surg 2012; 21: 491-4.

Kim DH, Elattrache NS, Tibone JE, Jun BJ, DeLaMora SN, Kvitne RS, Lee TQ. Biomechanical comparison of a single-row versus double-row suture anchor technique for rotator cuff repair. Am J Sports Med 2006; 34: 407-14.

Kim HM, Dahiya N, Teefey SA, Keener JD, Galatz LM, Yamaguchi K. Relationship of tear size and location to fatty degeneration of the rotator cuff. J Bone Joint Surg Am 2010; 92: 829-39.

Kim HM, Dahiya N, Teefey SA, Middleton WD, Stobbs G, Steger-May K, Yamaguchi K, Keener JD. Location and initiation of degenerative rotator cuff tears: an analysis of three hundred and sixty shoulders. J Bone Joint Surg Am 2010; 92: 1088-96.

Kim JR, Cho YS, Ryu KJ, Kim JH. Clinical and radiographic outcomes after arthroscopic repair of massive rotator cuff tears using a suture bridge technique: assessment of repair integrity on magnetic resonance imaging. Am J Sports Med 2012; 40: 786-93.

Kim SJ, Lee IS, Kim SH, Lee WY, Chun YM. Arthroscopic partial repair of irreparable large to massive rotator cuff tears. Arthroscopy 2012; 28: 761-8.

Kim YS, Chung SW, Kim JY, Ok JH, Park I, Oh JH. Is early passive motion exercise necessary after arthroscopic rotator cuff repair? Am J Sports Med 2012; 40: 815-21.

Kirkley A, Griffin S, Dainty K. Scoring systems for the functional assessment of the shoulder. Arthroscopy 2003; 19: 1109-20.

Klinger HM, Spahn G, Baums MH, Steckel H. Arthroscopic debridement of irreparable massive rotator cuff tears--a comparison of debridement alone and combined procedure with biceps tenotomy. Acta Chir Belg 2005; 105: 297-301.

Klinger HM, Steckel H, Ernstberger T, Baums MH. Arthroscopic debridement of massive rotator cuff tears: negative prognostic factors. Arch Orthop Trauma Surg 2005; 125: 261-6.

Klintberg IH, Gunnarsson AC, Svantesson U, Styf J, Karlsson J. Early loading in physiotherapy treatment after full-thickness rotator cuff repair: a prospective randomized pilot-study with a two-year follow-up. Clin Rehabil 2009; 23: 622-38.

Koh KH, Ahn JH, Kim SM, Yoo JC. Treatment of biceps tendon lesions in the setting of rotator cuff tears: prospective cohort study of tenotomy versus tenodesis. Am J Sports Med 2010; 38: 1584-90.

Koh KH, Kang KC, Lim TK, Shon MS, Yoo JC. Prospective randomized clinical trial of single- versus double-row suture anchor repair in 2- to 4-cm rotator cuff tears: clinical and magnetic resonance imaging results. Arthroscopy 2011; 27: 453-62.

Koubaa S, Ben Salah FZ, Lebib S, Miri I, Ghorbel S, Dziri C. [Conservative management of full-thickness rotator cuff tears. A prospective study of 24 patients]. Ann Readapt Med Phys 2006; 49: 62-7.

Kuhn JE, Dunn WR, Ma B, Wright RW, Jones G, Spencer EE, Wolf B, Safran M, Spindler KP, McCarty E, Kelly B, Holloway B. Interobserver agreement in the classification of rotator cuff tears. Am J Sports Med 2007; 35: 437-41.

Kuhn JE, Dunn WR, Sanders R, An Q, Baumgarten KM, Bishop JY, Brophy RH, Carey JL, Holloway BG, Jones GL, Ma CB, Marx RG, McCarty EC, Poddar SK, Smith MV, Spencer EE, Vidal AF, Wolf BR, Wright RW. Effectiveness of physical therapy in treating atraumatic full-thickness rotator cuff tears: a multicenter prospective cohort study. J Shoulder Elbow Surg 2013; [Epub ahead of print].

Kukkonen J, Kauko T, Joukainen A, Isotalo K, Virolainen P, Äärimaa V. The effect of waiting time on operatively treated non-traumatic rotator cuff tears. Eur Orthop Traumatol 2013; 4: 147-52.

Kukkonen J, Rantakokko J, Virolainen P, Äärimaa V. The Effect of Biceps Procedure on the Outcome of Rotator Cuff Reconstruction. ISRN Orthopedics 2013; Article ID 840965, 5 pages.

Kumagai J, Uhthoff HK, Sarkar K, Murnaghan JP. Collagen type III in rotator cuff tears: An immunohistochemical study. J Shoulder Elbow Surg 1992; 1: 187-92.

Kumar VP, Satku K, Balasubramaniam P. The role of the long head of biceps brachii in the stabilization of the head of the humerus. Clin Orthop Relat Res 1989; 244: 172-5.

Lafosse L, Jost B, Reiland Y, Audebert S, Toussaint B, Gobezie R. Structural integrity and clinical outcomes after arthroscopic repair of isolated subscapularis tears. J Bone Joint Surg Am 2007; 89: 1184-93.

Laing PG. The arterial supply of the adult humerus. J Bone Joint Surg Am 1956; 38-A: 1105-16.

Lapner PL, Sabri E, Rakhra K, McRae S, Leiter J, Bell K, Macdonald P. A multicenter randomized controlled trial comparing single-row with double-row fixation in arthroscopic rotator cuff repair. J Bone Joint Surg Am 2012; 94: 1249-57.

Lastayo PC, Wright T, Jaffe R, Hartzel J. Continuous passive motion after repair of the rotator cuff. A prospective outcome study. J Bone Joint Surg Am 1998; 80: 1002-11.

Lederer S, Auffarth A, Bogner R, Tauber M, Mayer M, Karpik S, Matis N, Resch H. Magnetic resonance imaging-controlled results of the pectoralis major tendon transfer for irreparable anterosuperior rotator cuff tears performed with standard and modified fixation techniques. J Shoulder Elbow Surg 2011; 20: 1155-62.

Lee E, Bishop JY, Braman JP, Langford J, Gelber J, Flatow EL. Outcomes after arthroscopic rotator cuff repairs. J Shoulder Elbow Surg 2007; 16: 1-5.

Leggin BG, Michener LA, Shaffer MA, Brenneman SK, Iannotti JP, Williams GR, Jr. The Penn shoulder score: reliability and validity. J Orthop Sports Phys Ther 2006; 36: 138-51.

Lehman C, Cuomo F, Kummer FJ, Zuckerman JD. The incidence of full thickness rotator cuff tears in a large cadaveric population. Bull Hosp Jt Dis 1995; 54: 30-1.

Leow YH, Maibach HI. Cigarette smoking, cutaneous vasculature, and tissue oxygen. Clin Dermatol 1998; 16: 579-84.

Levy HJ, Uribe JW, Delaney LG. Arthroscopic assisted rotator cuff repair: preliminary results. Arthroscopy 1990; 6: 55-60.

Levy O, Mullett H, Roberts S, Copeland S. The role of anterior deltoid reeducation in patients with massive irreparable degenerative rotator cuff tears. J Shoulder Elbow Surg 2008; 17: 863-70.

Levy O, Relwani J, Zaman T, Even T, Venkateswaran B, Copeland S. Measurement of blood flow in the rotator cuff using laser Doppler flowmetry. J Bone Joint Surg Br 2008; 90: 893-8.

Lichtenberg S, Liem D, Magosch P, Habermeyer P. Influence of tendon healing after arthroscopic rotator cuff repair on clinical outcome using single-row Mason-Allen suture technique: a prospective, MRI controlled study. Knee Surg Sports Traumatol Arthrosc 2006; 14: 1200-6.

Liem D, Lichtenberg S, Magosch P, Habermeyer P. Magnetic resonance imaging of arthroscopic supraspinatus tendon repair. J Bone Joint Surg Am 2007; 89: 1770-6.

Lippe J, Spang JT, Leger RR, Arciero RA, Mazzocca AD, Shea KP. Inter-rater agreement of the Goutallier, Patte, and Warner classification scores using preoperative magnetic resonance imaging in patients with rotator cuff tears. Arthroscopy 2012; 28: 154-9.

Litaker D, Pioro M, El Bilbeisi H, Brems J. Returning to the bedside: using the history and physical examination to identify rotator cuff tears. J Am Geriatr Soc 2000; 48: 1633-7.

Lohr JF, Uhthoff HK. The microvascular pattern of the supraspinatus tendon. Clin Orthop Relat Res 1990; 254: 35-8.

Longo UG, Franceschi F, Berton A, Maffulli N, Droena V. Conservative treatment and rotator cuff tear progression. Med Sport Sci 2012; 57: 90-9.

Longo UG, Franceschi F, Ruzzini L, Rabitti C, Morini S, Maffulli N, Forriol F, Denaro V. Light microscopic histology of supraspinatus tendon ruptures. Knee Surg Sports Traumatol Arthrosc 2007; 15: 1390-4.

MacDonald P, McRae S, Leiter J, Mascarenhas R, Lapner P. Arthroscopic rotator cuff repair with and without acromioplasty in the treatment of full-thickness rotator cuff tears: a multicenter, randomized controlled trial. J Bone Joint Surg Am 2011; 93: 1953-60.

Mall NA, Kim HM, Keener JD, Steger-May K, Teefey SA, Middleton WD, Stobbs G, Yamaguchi K. Symptomatic progression of asymptomatic rotator cuff tears: a prospective study of clinical and sonographic variables. J Bone Joint Surg Am 2010; 92: 2623-33.

Mall NA, Lee AS, Chahal J, Sherman SL, Romeo AA, Verma NN, Cole BJ. An evidenced-based examination of the epidemiology and outcomes of traumatic rotator cuff tears. Arthroscopy 2013; 29: 366-76.

Mallon WJ, Misamore G, Snead DS, Denton P. The impact of preoperative smoking habits on the results of rotator cuff repair. J Shoulder Elbow Surg 2004; 13: 129-32.

Maman E, Harris C, White L, Tomlinson G, Shashank M, Boynton E. Outcome of nonoperative treatment of symptomatic rotator cuff tears monitored by magnetic resonance imaging. J Bone Joint Surg Am 2009; 91: 1898-906.

Marrero LG, Nelman KR, Nottage WM. Long-term follow-up of arthroscopic rotator cuff repair. Arthroscopy 2011; 27: 885-8.

Marx RG, Koulouvaris P, Chu SK, Levy BA. Indications for surgery in clinical outcome studies of rotator cuff repair. Clin Orthop Relat Res 2009; 467: 450-6.

Matsen FA, 3rd, Chebli C, Lippitt S. Principles for the evaluation and management of shoulder instability. J Bone Joint Surg Am 2006; 88: 648-59.

Matthews TJ, Hand GC, Rees JL, Athanasou NA, Carr AJ. Pathology of the torn rotator cuff tendon. Reduction in potential for repair as tear size increases. J Bone Joint Surg Br 2006; 88: 489-95.

Matthews TJ, Smith SR, Peach CA, Rees JL, Urban JP, Carr AJ. In vivo measurement of tissue metabolism in tendons of the rotator cuff: implications for surgical management. J Bone Joint Surg Br 2007; 89: 633-8.

Melillo AS, Savoie FH, 3rd, Field LD. Massive rotator cuff tears: debridement versus repair. Orthop Clin North Am 1997; 28: 117-24.

Melis B, DeFranco MJ, Chuinard C, Walch G. Natural history of fatty infiltration and atrophy of the supraspinatus muscle in rotator cuff tears. Clin Orthop Relat Res 2010; 468: 1498-505.

Mellado JM, Calmet J, Olona M, Esteve C, Camins A, Perez Del Palomar L, Gine J, Sauri A. Surgically repaired massive rotator cuff tears: MRI of tendon integrity, muscle fatty degeneration, and muscle atrophy correlated with intraoperative and clinical findings. AJR Am J Roentgenol 2005; 184: 1456-63.

Meyer DC, Wieser K, Farshad M, Gerber C. Retraction of supraspinatus muscle and tendon as predictors of success of rotator cuff repair. Am J Sports Med 2012; 40: 2242-7.

Milano G, Grasso A, Salvatore M, Zarelli D, Deriu L, Fabbriciani C. Arthroscopic rotator cuff repair with and without subacromial decompression: a prospective randomized study. Arthroscopy 2007; 23: 81-8.

Milgrom C, Schaffler M, Gilbert S, van Holsbeeck M. Rotator-cuff changes in asymptomatic adults. The effect of age, hand dominance and gender. J Bone Joint Surg Br 1995; 77: 296-8.

Millar NL, Wu X, Tantau R, Silverstone E, Murrell GA. Open versus two forms of arthroscopic rotator cuff repair. Clin Orthop Relat Res 2009; 467: 966-78.

Miller C, Savoie FH. Glenohumeral abnormalities associated with full-thickness tears of the rotator cuff. Orthop Rev 1994; 23: 159-62.

Minagawa H, Itoi E, Konno N, Kido T, Sano A, Urayama M, Sato K. Humeral attachment of the supraspinatus and infraspinatus tendons: an anatomic study. Arthroscopy 1998; 14: 302-6.

Mochizuki T, Sugaya H, Uomizu M, Maeda K, Matsuki K, Sekiya I, Muneta T, Akita K. Humeral insertion of the supraspinatus and infraspinatus. New anatomical findings regarding the footprint of the rotator cuff. J Bone Joint Surg Am 2008; 90: 962-9.

Mohana-Borges AV, Chung CB, Resnick D. MR imaging and MR arthrography of the postoperative shoulder: spectrum of normal and abnormal findings. Radiographics 2004; 24: 69-85.

Mohtadi NG, Hollinshead RM, Sasyniuk TM, Fletcher JA, Chan DS, Li FX. A randomized clinical trial comparing open to arthroscopic acromioplasty with mini-open rotator cuff repair for full-thickness rotator cuff tears: disease-specific quality of life outcome at an average 2-year follow-up. Am J Sports Med 2008; 36: 1043-51.

Moosmayer S, Lund G, Seljom U, Svege I, Hennig T, Tariq R, Smith HJ. Comparison between surgery and physiotherapy in the treatment of small and medium-sized tears of the rotator cuff: A randomised controlled study of 103 patients with one-year follow-up. J Bone Joint Surg Br 2010; 92: 83-91.

Morse K, Davis AD, Afra R, Kaye EK, Schepsis A, Voloshin I. Arthroscopic versus mini-open rotator cuff repair: a comprehensive review and meta-analysis. Am J Sports Med 2008; 36: 1824-8.

Moseley HF, Goldie I. The Arterial Pattern of the Rotator Cuff of the Shoulder. J Bone Joint Surg Br 1963; 45: 780-9.

Mosely LH, Finseth F. Cigarette smoking: impairment of digital blood flow and wound healing in the hand. Hand 1977; 9: 97-101.

Mulieri P, Dunning P, Klein S, Pupello D, Frankle M. Reverse shoulder arthroplasty for the treatment of irreparable rotator cuff tear without glenohumeral arthritis. J Bone Joint Surg Am 2010; 92: 2544-56.

Murthi AM, Vosburgh CL, Neviaser TJ. The incidence of pathologic changes of the long head of the biceps tendon. J Shoulder Elbow Surg 2000; 9: 382-5.

Namdari S, Henn RF, 3rd, Green A. Traumatic anterosuperior rotator cuff tears: the outcome of open surgical repair. J Bone Joint Surg Am 2008; 90: 1906-13.

Namdari S, Voleti P, Baldwin K, Glaser D, Huffman GR. Latissimus dorsi tendon transfer for irreparable rotator cuff tears: a systematic review. J Bone Joint Surg Am 2012; 94: 891-8.

Natsis K, Tsikaras P, Totlis T, Gigis I, Skandalakis P, Appell HJ, Koebke J. Correlation between the four types of acromion and the existence of enthesophytes: a study on 423 dried scapulas and review of the literature. Clin Anat 2007; 20: 267-72.

Naveed MA, Kitson J, Bunker TD. The Delta III reverse shoulder replacement for cuff tear arthropathy: a single-centre study of 50 consecutive procedures. J Bone Joint Surg Br 2011; 93: 57-61.

Neer CS, 2nd. Impingement lesions. Clin Orthop Relat Res 1983; 173: 70-7.

Neri BR, Chan KW, Kwon YW. Management of massive and irreparable rotator cuff tears. J Shoulder Elbow Surg 2009; 18: 808-18.

Ng LR, Kramer JS. Shoulder rotator torques in female tennis and nontennis players. J Orthop Sports Phys Ther 1991; 13: 40-6.

Nho SJ, Brown BS, Lyman S, Adler RS, Altchek DW, MacGillivray JD. Prospective analysis of arthroscopic rotator cuff repair: prognostic factors affecting clinical and ultrasound outcome. J Shoulder Elbow Surg 2009; 18: 13-20.

Nich C, Mutschler C, Vandenbussche E, Augereau B. Long-term clinical and MRI results of open repair of the supraspinatus tendon. Clin Orthop Relat Res 2009; 467: 2613-22.

Nirschl RP. Rotator cuff tendinitis: basic concepts of pathoetiology. Instr Course Lect 1989; 38: 439-45.

Noel E, Walch G, Bochu M. [Jobe's maneuver. Apropos of 227 cases]. Rev Rhum Mal Osteoartic 1989; 56: 803-4.

Noonan TJ, Best TM, Seaber AV, Garrett WE, Jr. Identification of a threshold for skeletal muscle injury. Am J Sports Med 1994; 22: 257-61.

Norlin R, Adolfsson L. Small full-thickness tears do well ten to thirteen years after arthroscopic subacromial decompression. J Shoulder Elbow Surg 2008; 17: 12S-16S.

Nove-Josserand L, Levigne C, Noel E, Walch G. [The acromio-humeral interval. A study of the factors influencing its height]. Rev Chir Orthop Reparatrice Appar Mot 1996; 82: 379-85.

Nyffeler RW, Werner CM, Sukthankar A, Schmid MR, Gerber C. Association of a large lateral extension of the acromion with rotator cuff tears. J Bone Joint Surg Am 2006; 88: 800-5.

Oh JH, Kim SH, Ji HM, Jo KH, Bin SW, Gong HS. Prognostic factors affecting anatomic outcome of rotator cuff repair and correlation with functional outcome. Arthroscopy 2009; 25: 30-9.

Oh JH, McGarry MH, Jun BJ, Gupta A, Chung KC, Hwang J, Lee TQ. Restoration of shoulder biomechanics according to degree of repair completion in a cadaveric model of massive rotator cuff tear: importance of margin convergence and posterior cuff fixation. Am J Sports Med 2012; 40: 2448-53.

Oh LS, Wolf BR, Hall MP, Levy BA, Marx RG. Indications for rotator cuff repair: a systematic review. Clin Orthop Relat Res 2007; 455: 52-63.

Omoumi P, Bafort AC, Dubuc JE, Malghem J, Vande Berg BC, Lecouvet FE. Evaluation of rotator cuff tendon tears: comparison of multidetector CT arthrography and 1.5-T MR arthrography. Radiology 2012; 264: 812-22.

Outerbridge RE, Dunlop JA. The problem of chondromalacia patellae. Clin Orthop Relat Res 1975; 110: 177-96.

Pacha Vicente D, Forcada Calvet P, Carrera Burgaya A, Llusa Perez M. Innervation of biceps brachii and brachialis: Anatomical and surgical approach. Clin Anat 2005; 18: 186-94.

Packer NP, Calvert PT, Bayley JI, Kessel L. Operative treatment of chronic ruptures of the rotator cuff of the shoulder. J Bone Joint Surg Br 1983; 65: 171-5.

Pagnani MJ, Deng XH, Warren RF, Torzilli PA, O'Brien SJ. Role of the long head of the biceps brachii in glenohumeral stability: a biomechanical study in cadavera. J Shoulder Elbow Surg 1996; 5: 255-62.

Pai VS, Lawson DA. Rotator cuff repair in a district hospital setting: outcomes and analysis of prognostic factors. J Shoulder Elbow Surg 2001; 10: 236-41.

Parsons IM, Apreleva M, Fu FH, Woo SL. The effect of rotator cuff tears on reaction forces at the glenohumeral joint. J Orthop Res 2002; 20: 439-46.

Patel VR, Singh D, Calvert PT, Bayley JI. Arthroscopic subacromial decompression: results and factors affecting outcome. J Shoulder Elbow Surg 1999; 8: 231-7.

Patte D. Classification of rotator cuff lesions. Clin Orthop Relat Res 1990; 254: 81-6.

Paulos LE, Kody MH. Arthroscopically enhanced "miniapproach" to rotator cuff repair. Am J Sports Med 1994; 22: 19-25.

Petersson CJ. Degeneration of the gleno-humeral joint. An anatomical study. Acta Orthop Scand 1983; 54: 277-83.

Piasecki DP, Verma NN, Nho SJ, Bhatia S, Boniquit N, Cole BJ, Nicholson GP, Romeo AA. Outcomes after arthroscopic revision rotator cuff repair. Am J Sports Med 2010; 38: 40-6.

Posada A, Uribe JW, Hechtman KS, Tjin ATEW, Zvijac JE. Mini-deltoid splitting rotator cuff repair: do results deteriorate with time? Arthroscopy 2000; 16: 137-41.

Post M, Silver R, Singh M. Rotator cuff tear. Diagnosis and treatment. Clin Orthop Relat Res 1983; 173: 78-91.

Prasad N, Odumala A, Elias F, Jenkins T. Outcome of open rotator cuff repair. An analysis of risk factors. Acta Orthop Belg 2005; 71: 662-6.

Rad M, Kakoie S, Niliye Brojeni F, Pourdamghan N. Effect of Long-term Smoking on Whole-mouth Salivary Flow Rate and Oral Health. J Dent Res Dent Clin Dent Prospects 2010; 4: 110-4.

Randelli P, Spennacchio P, Ragone V, Arrigoni P, Casella A, Cabitza P. Complications associated with arthroscopic rotator cuff repair: a literature review. Musculoskelet Surg 2012; 96: 9-16.

Rathbun JB, Macnab I. The microvascular pattern of the rotator cuff. J Bone Joint Surg Br 1970; 52: 540-53.

Razmjou H, Holtby R, Myhr T. Gender differences in quality of life and extent of rotator cuff pathology. Arthroscopy 2006; 22: 57-62.

Reilly P, Amis AA, Wallace AL, Emery RJ. Mechanical factors in the initiation and propagation of tears of the rotator cuff. Quantification of strains of the supraspinatus tendon in vitro. J Bone Joint Surg Br 2003; 85: 594-9.

Reilly P, Macleod I, Macfarlane R, Windley J, Emery RJ. Dead men and radiologists don't lie: a review of cadaveric and radiological studies of rotator cuff tear prevalence. Ann R Coll Surg Engl 2006; 88: 116-21.

Resch H, Povacz P, Ritter E, Matschi W. Transfer of the pectoralis major muscle for the treatment of irreparable rupture of the subscapularis tendon. J Bone Joint Surg Am 2000; 82: 372-82.

Rickert M, Georgousis H, Witzel U. [Tensile strength of the tendon of the supraspinatus muscle in the human. A biomechanical study]. Unfallchirurg 1998; 101: 265-70.

Riley GP, Harrall RL, Constant CR, Chard MD, Cawston TE, Hazleman BL. Glycosaminoglycans of human rotator cuff tendons: changes with age and in chronic rotator cuff tendinitis. Ann Rheum Dis 1994; 53: 367-76.

Robinson PM, Wilson J, Dalal S, Parker RA, Norburn P, Roy BR. Rotator cuff repair in patients over 70 years of age: early outcomes and risk factors associated with re-tear. Bone Joint J 2013; 95-B: 199-205.

Rockwood CA, Jr., Williams GR, Jr., Burkhead WZ, Jr. Debridement of degenerative, irreparable lesions of the rotator cuff. J Bone Joint Surg Am 1995; 77: 857-66.

Roddey TS, Olson SL, Gartsman GM, Hanten WP, Cook KF. A randomized controlled trial comparing 2 instructional approaches to home exercise instruction following arthroscopic full-thickness rotator cuff repair surgery. J Orthop Sports Phys Ther 2002; 32: 548-59.

Rodosky MW, Harner CD, Fu FH. The role of the long head of the biceps muscle and superior glenoid labrum in anterior stability of the shoulder. Am J Sports Med 1994; 22: 121-30.

Romeo AA, Hang DW, Bach BR, Jr., Shott S. Repair of full thickness rotator cuff tears. Gender, age, and other factors affecting outcome. Clin Orthop Relat Res 1999; 367: 243-55.

Roy JS, MacDermid JC, Woodhouse LJ. A systematic review of the psychometric properties of the Constant-Murley score. J Shoulder Elbow Surg 2010; 19: 157-64.

Ruckstuhl H, de Bruin ED, Stussi E, Vanwanseele B. Post-traumatic glenohumeral cartilage lesions: a systematic review. BMC Musculoskelet Disord 2008; 9: 107.

Rulewicz GJ, Beaty S, Hawkins RJ, Kissenberth MJ. Supraspinatus atrophy as a predictor of rotator cuff tear size: an MRI study utilizing the tangent sign. J Shoulder Elbow Surg 2013; 22: e6-10.

Rutten MJ, Spaargaren GJ, van Loon T, de Waal Malefijt MC, Kiemeney LA, Jager GJ. Detection of rotator cuff tears: the value of MRI following ultrasound. Eur Radiol 2010; 20: 450-7.

Schibany N, Zehetgruber H, Kainberger F, Wurnig C, Ba-Ssalamah A, Herneth AM, Lang T, Gruber D, Breitenseher MJ. Rotator cuff tears in asymptomatic individuals: a clinical and ultrasonographic screening study. Eur J Radiol 2004; 51: 263-8.

Seida JC, LeBlanc C, Schouten JR, Mousavi SS, Hartling L, Vandermeer B, Tjosvold L, Sheps DM. Systematic review: nonoperative and operative treatments for rotator cuff tears. Ann Intern Med 2010; 153: 246-55.

Sekiya JK, Jolly J, Debski RE. The effect of a Hill-Sachs defect on glenohumeral translations, in situ capsular forces, and bony contact forces. Am J Sports Med 2012; 40: 388-94.

Seo SS, Choi JS, An KC, Kim JH, Kim SB. The factors affecting stiffness occurring with rotator cuff tear. J Shoulder Elbow Surg 2012; 21: 304-9.

Sharma P, Maffulli N. Biology of tendon injury: healing, modeling and remodeling. J Musculoskelet Neuronal Interact 2006; 6: 181-90.

Sher JS, Uribe JW, Posada A, Murphy BJ, Zlatkin MB. Abnormal findings on magnetic resonance images of asymptomatic shoulders. J Bone Joint Surg Am 1995; 77: 10-5.

Shi LL, Edwards TB. The role of acromioplasty for management of rotator cuff problems: where is the evidence? Adv Orthop 2012; 2012: 467571.

Shibata Y, Midorikawa K, Emoto G, Naito M. Clinical evaluation of sodium hyaluronate for the treatment of patients with rotator cuff tear. J Shoulder Elbow Surg 2001; 10: 209-16.

Silverstein P. Smoking and wound healing. Am J Med 1992; 93: 22S-24S.

Slabaugh MA, Friel NA, Karas V, Romeo AA, Verma NN, Cole BJ. Interobserver and intraobserver reliability of the Goutallier classification using magnetic resonance imaging: proposal of a simplified classification system to increase reliability. Am J Sports Med 2012; 40: 1728-34.

Slabaugh MA, Nho SJ, Grumet RC, Wilson JB, Seroyer ST, Frank RM, Romeo AA, Provencher MT, Verma NN. Does the literature confirm superior clinical results in radiographically healed rotator cuffs after rotator cuff repair? Arthroscopy 2010; 26: 393-403.

Smith TO, Daniell H, Geere JA, Toms AP, Hing CB. The diagnostic accuracy of MRI for the detection of partial- and full-thickness rotator cuff tears in adults. Magn Reson Imaging 2012; 30: 336-46.

Solberg Y, Rosner M, Belkin M. The association between cigarette smoking and ocular diseases. Surv Ophthalmol 1998; 42: 535-47.

Southern California Orthopedic Institute site: www.scoi.com.

Soslowsky LJ, Carpenter JE, Bucchieri JS, Flatow EL. Biomechanics of the rotator cuff. Orthop Clin North Am 1997; 28: 17-30.

Spencer EE, Jr., Dunn WR, Wright RW, Wolf BR, Spindler KP, McCarty E, Ma CB, Jones G, Safran M, Holloway GB, Kuhn JE. Interobserver agreement in the classification of rotator cuff tears using magnetic resonance imaging. Am J Sports Med 2008; 36: 99-103.

Steenbrink F, Meskers CG, Nelissen RG, de Groot JH. The relation between increased deltoid activation and adductor muscle activation due to glenohumeral cuff tears. J Biomech 2010; 43: 2049-54.

Su WR, Budoff JE, Luo ZP. The effect of posterosuperior rotator cuff tears and biceps loading on glenohumeral translation. Arthroscopy 2010; 26: 578-86.

Sugaya H, Maeda K, Matsuki K, Moriishi J. Repair integrity and functional outcome after arthroscopic double-row rotator cuff repair. A prospective outcome study. J Bone Joint Surg Am 2007; 89: 953-60.

Szczesny SE, Peloquin JM, Cortes DH, Kadlowec JA, Soslowsky LJ, Elliott DM. Biaxial tensile testing and constitutive modeling of human supraspinatus tendon. J Biomech Eng 2012; 134: 021004.

Talbot P, Riveles K. Smoking and reproduction: the oviduct as a target of cigarette smoke. Reprod Biol Endocrinol 2005; 3: 52.

Tanaka M, Itoi E, Sato K, Hamada J, Hitachi S, Tojo Y, Honda M, Tabata S. Factors related to successful outcome of conservative treatment for rotator cuff tears. Ups J Med Sci 2010; 115: 193-200.

Tashjian RZ. Epidemiology, natural history, and indications for treatment of rotator cuff tears. Clin Sports Med 2012; 31: 589-604.

Tashjian RZ, Farnham JM, Albright FS, Teerlink CC, Cannon-Albright LA. Evidence for an inherited predisposition contributing to the risk for rotator cuff disease. J Bone Joint Surg Am 2009; 91: 1136-42.

Tashjian RZ, Hollins AM, Kim HM, Teefey SA, Middleton WD, Steger-May K, Galatz LM, Yamaguchi K. Factors affecting healing rates after arthroscopic double-row rotator cuff repair. Am J Sports Med 2010; 38: 2435-42.

Teefey SA, Hasan SA, Middleton WD, Patel M, Wright RW, Yamaguchi K. Ultrasonography of the rotator cuff. A comparison of ultrasonographic and arthroscopic findings in one hundred consecutive cases. J Bone Joint Surg Am 2000; 82: 498-504.

Teefey SA, Rubin DA, Middleton WD, Hildebolt CF, Leibold RA, Yamaguchi K. Detection and quantification of rotator cuff tears. Comparison of ultrasonographic, magnetic resonance imaging, and arthroscopic findings in seventy-one consecutive cases. J Bone Joint Surg Am 2004; 86-A: 708-16.

Tempelhof S, Rupp S, Seil R. Age-related prevalence of rotator cuff tears in asymptomatic shoulders. J Shoulder Elbow Surg 1999; 8: 296-9.

Thomazeau H, Boukobza E, Morcet N, Chaperon J, Langlais F. Prediction of rotator cuff repair results by magnetic resonance imaging. Clin Orthop Relat Res 1997; 344: 275-83.

Thomazeau H, Rolland Y, Lucas C, Duval JM, Langlais F. Atrophy of the supraspinatus belly. Assessment by MRI in 55 patients with rotator cuff pathology. Acta Orthop Scand 1996; 67: 264-8.

Tidball JG, Salem G, Zernicke R. Site and mechanical conditions for failure of skeletal muscle in experimental strain injuries. J Appl Physiol 1993; 74: 1280-6.

Toivonen DA, Tuite MJ, Orwin JF. Acromial structure and tears of the rotator cuff. J Shoulder Elbow Surg 1995; 4: 376-83.

Torrens C, Lopez JM, Puente I, Caceres E. The influence of the acromial coverage index in rotator cuff tears. J Shoulder Elbow Surg 2007; 16: 347-51.

Tosounidis T, Hadjileontis C, Triantafyllou C, Sidiropoulou V, Kafanas A, Kontakis G. Evidence of sympathetic innervation and alpha1-adrenergic receptors of the long head of the biceps brachii tendon. J Orthop Sci 2013; 18: 238-44.

Trenerry K, Walton JR, Murrell GA. Prevention of shoulder stiffness after rotator cuff repair. Clin Orthop Relat Res 2005; 430: 94-9.

Uhthoff HK, Sarkar K. Surgical repair of rotator cuff ruptures. The importance of the subacromial bursa. J Bone Joint Surg Br 1991; 73: 399-401.

van der Zwaal P, Thomassen BJ, Nieuwenhuijse MJ, Lindenburg R, Swen JW, van Arkel ER. Clinical outcome in all-arthroscopic versus mini-open rotator cuff repair in small to medium-sized tears: a randomized controlled trial in 100 patients with 1-year follow-up. Arthroscopy 2013; 29: 266-73.

van der Zwaal P, Thomassen BJ, Urlings TA, de Rooy TP, Swen JW, van Arkel ER. Preoperative agreement on the geometric classification and 2-dimensional measurement of rotator cuff tears based on magnetic resonance arthrography. Arthroscopy 2012; 28: 1329-36.

Vangsness CT, Jr., Jorgenson SS, Watson T, Johnson DL. The origin of the long head of the biceps from the scapula and glenoid labrum. An anatomical study of 100 shoulders. J Bone Joint Surg Br 1994; 76: 951-4.

Vastamaki M. Factors influencing the operative results of rotator cuff rupture. Int Orthop 1986; 10: 177-81.

Vecchio PC, Adebajo AO, Hazleman BL. Suprascapular nerve block for persistent rotator cuff lesions. J Rheumatol 1993; 20: 453-5.

Vlychou M, Dailiana Z, Fotiadou A, Papanagiotou M, Fezoulidis IV, Malizos K. Symptomatic partial rotator cuff tears: diagnostic performance of ultrasound and magnetic resonance imaging with surgical correlation. Acta Radiol 2009; 50: 101-5.

Walch G, Boulahia A, Calderone S, Robinson AH. The 'dropping' and 'hornblower's' signs in evaluation of rotator-cuff tears. J Bone Joint Surg Br 1998; 80: 624-8.

Walch G, Edwards TB, Boulahia A, Nove-Josserand L, Neyton L, Szabo I. Arthroscopic tenotomy of the long head of the biceps in the treatment of rotator cuff tears: clinical and radiographic results of 307 cases. J Shoulder Elbow Surg 2005; 14: 238-46.

Walch G, Liotard JP, Nove-Josserand L, Godeneche A. [Non traumatic pathology of the shoulder: when to perform surgery?]. Rev Prat 2006; 56: 1556-63.

Waltrip RL, Zheng N, Dugas JR, Andrews JR. Rotator cuff repair. A biomechanical comparison of three techniques. Am J Sports Med 2003; 31: 493-7.

Ward SR, Sarver JJ, Eng CM, Kwan A, Wurgler-Hauri CC, Perry SM, Williams GR, Soslowsky LJ, Lieber RL. Plasticity of muscle architecture after supraspinatus tears. J Orthop Sports Phys Ther 2010; 40: 729-35.

Warner JJ. Management of massive irreparable rotator cuff tears: the role of tendon transfer. Instr Course Lect 2001; 50: 63-71.

Warner JJ, McMahon PJ. The role of the long head of the biceps brachii in superior stability of the glenohumeral joint. J Bone Joint Surg Am 1995; 77: 366-72.

Weinstein DM, Bucchieri JS, Pollock RG, Flatow EL, Bigliani LU. Arthroscopic debridement of the shoulder for osteoarthritis. Arthroscopy 2000; 16: 471-6.

Weiser L, Assheuer J, Schulitz KP, Castro WH. [Magnetic resonance imaging criteria for the differentiation of traumatic and non-traumatic rotator cuff tears]. Versicherungsmedizin 2012; 64: 122-6.

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. J Bone Joint Surg Am 2005; 87: 1476-86.

Williams MD, Ladermann A, Melis B, Barthelemy R, Walch G. Fatty infiltration of the supraspinatus: a reliability study. J Shoulder Elbow Surg 2009; 18: 581-7.

Wirth MA, Rockwood CA, Jr. Operative treatment of irreparable rupture of the subscapularis. J Bone Joint Surg Am 1997; 79: 722-31.

Wolf EM, Pennington WT, Agrawal V. Arthroscopic rotator cuff repair: 4- to 10-year results. Arthroscopy 2004; 20: 5-12.

Wu XL, Briggs L, Murrell GA. Intraoperative determinants of rotator cuff repair integrity: an analysis of 500 consecutive repairs. Am J Sports Med 2012; 40: 2771-6.

Yamaguchi K, Ditsios K, Middleton WD, Hildebolt CF, Galatz LM, Teefey SA. The demographic and morphological features of rotator cuff disease. A comparison of asymptomatic and symptomatic shoulders. J Bone Joint Surg Am 2006; 88: 1699-704.

Yamaguchi K, Levine WN, Marra G, Galatz LM, Klepps S, Flatow EL. Transitioning to arthroscopic rotator cuff repair: the pros and cons. Instr Course Lect 2003; 52: 81-92.

Yamaguchi K, Tetro AM, Blam O, Evanoff BA, Teefey SA, Middleton WD. Natural history of asymptomatic rotator cuff tears: a longitudinal analysis of asymptomatic tears detected sonographically. J Shoulder Elbow Surg 2001; 10: 199-203.

Yamamoto A, Takagishi K, Osawa T, Yanagawa T, Nakajima D, Shitara H, Kobayashi T. Prevalence and risk factors of a rotator cuff tear in the general population. J Shoulder Elbow Surg 2010; 19: 116-20.

Youm T, ElAttrache NS, Tibone JE, McGarry MH, Lee TQ. The effect of the long head of the biceps on glenohumeral kinematics. J Shoulder Elbow Surg 2009; 18: 122-9.

Yuan J, Murrell GA, Wei AQ, Wang MX. Apoptosis in rotator cuff tendonopathy. J Orthop Res 2002; 20: 1372-9.

Zanetti M, Gerber C, Hodler J. Quantitative assessment of the muscles of the rotator cuff with magnetic resonance imaging. Invest Radiol 1998; 33: 163-70.

Zingg PO, Jost B, Sukthankar A, Buhler M, Pfirrmann CW, Gerber C. Clinical and structural outcomes of nonoperative management of massive rotator cuff tears. J Bone Joint Surg Am 2007; 89: 1928-34.

10. APPENDICES

Appendix 1. Constant score questionnaire

OUT-PATIENT CLINIC **SHOULDER UNIT**

CONSTANT SCORE

Patient's Details

Operation/Diagnosis: **Date:**__________

Side: R L

Examination: Pre-op
3 months 6months
1 year 2 years ___ years

A.- Pain (/15): Average (1 + 2) ☐ **A**

1. Do you have pain in your shoulder (normal activities)?
No =15 pts, Mild pain = 10 pts, Moderate = 5 pts, Severe or permanent = 0. ____

2. Linear scale:
If "0" means no pain and "15" is the maximum pain you can experience, please circle where is the level of pain of your shoulder. (Points given are inverse to the scale. E.g. level 5 in the scale means 10 points)

Level of pain:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Points:	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

____

B.- Activities of daily living (/20) **Total (1 + 2 + 3 + 4)** ☐ **B**

1. Is your occupation or daily living limited by your shoulder?
No = 4, Moderate limitation = 2, Severe limitation = 0 ____
2. Are your leisure and recreational activities limited by your shoulder?
No = 4, Moderate limitation = 2, Severe limitation = 0 ____
3. Is your night sleep disturbed by your shoulder?
No = 2, Sometimes = 1, Yes = 0 ____
4. State to what level you can use your arm for painless, reasonably activities.
Waist = 2, Xiphoid (sternum) = 4, Neck = 6, Head = 8, Above head = 10 ____

C.- Range of movement (leave this for the doctor or physiotherapist) **(/40):** **Total (1 + 2 + 3 + 4)** ☐ **C**

1.- FWD Flexion: ____
0 - 30 0 pts
31 -60 2 pts
61 - 90 4 pts
91 - 120 6 pts
121- 150 8 pts
> 150 10 pts

2.- Abduction: ____
0 - 30
31 - 60
61 - 90
91 - 120
121 - 150
> 150

3.- External Rotation: ____
Hand behind head & elbow forward 2
Hand behind head & elbow back 4
Hand above head & elbow forward 6
Hand above head & elbow back 8
Full elevation of arm 10

4.- Internal Rotation: (Dorsum hand to) ____
Thigh 0
Buttock 2
SI joint 4
Waist 6
T12 8
Between shoulder blades 10

D.- Power (/25): Points: average (kg) x 2 = ☐ **D**

First pull: Second pull: Third pull: Fourth pull: Fifth pull:
Average pulls:

TOTAL (/100): A + B + C+ D ☐

Appendix 2. Data inputted to the shoulder patient database by operating surgeon and physiotherapist

Outpatient clinic Therapeutic decision

Shoulder surgeon

Clinical provocation tests
1) Jobe, Yokum
2) External rotation in neutral and abducted positions
3) Lift-off, bellypress
4) Hawkins, Neer
5) Biceps palpation, lateral speed
6) AC-palpation, crossarm

Preoperative examination

Physiotherapist

Constant score

Questions
1) Onset of symptoms
 -atraumatic
 -traumatic (type of trauma)
2) Duration of symptoms (in months)
3) Previous treatment
4) Arm dominance
5) Comorbidities
6) Smoking
7) Employment status
8) Education

Surgery

Shoulder surgeon

Operator and assistant

Type of anesthesia

Used implants

Operation time

Intraoperative status and procedures
1) Synovial cavity
2) Humeral articular surface
3) Glenoidal articular surface
4) Anterior labrum
5) Superior labrum
6) Posterior labrum
7) Glenohumeral ligaments
8) Biceps tendon
9) Subscapularis tendon
10) Supraspinatus tendon
11) Infraspinatus tendon
12) Subacromial bursa
13) Acromial morphology
14) AC-joint

Postoperative examination (3 months)

Physiotherapist

Constant score

Questions
1) Problems during convalescence
2) Treatment satisfaction
3) Employment status

Postoperative examination (6 months) (only in study V)

Physiotherapist

Constant score

Questions
1) Problems during convalescence
2) Treatment satisfaction
3) Employment status

Postoperative examination (12 months)

Physiotherapist

Constant score

Questions
1) Problems during convalescence
2) Treatment satisfaction
3) Employment status