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Author's contribution:

I. The author conducted gross anatomical and histological experiments and participated in writing the manuscript.

II. The author conducted gross anatomical, histological, and immunohistochemical, experiments, analysed the data, and was the main person responsible for writing the manuscript.

III. The author took part in all the stages of the gross anatomical research, drafted the paper, and revised it critically until the final version of the manuscript.

IV. The author took part in all stages of the gross anatomic research and was the main person for analysing the data and writing the manuscript.

ABBREVIATIONS

A.	arteria
ABC	Avidin-Biotin Complex
CC	chondrocytes
DAB	3,3 diaminobenzidine
E	formalin embalmed
F	female
FC	fibrocytes
HRP	Haptolobin-related protein
Lig.	ligamentum
Ligg.	ligamenta
M	male
M.	musculus
MRI	magnetic resonance image
SD	standard deviation
SEM	standard error of mean
SGHL	superior glenohumeral ligament
TBS	Tris buffered saline
UE	fresh unembalmed

1. INTRODUCTION

The percentage of patients with symptoms of shoulder girdle and the glenohumeral joint pathologies increases with age. More than 30% of people older than 40 years have pathological alterations of the glenohumeral joint (Kolts et al., 1994; Lewis et al., 2009; Gumina et al., 2013). The diverse pathologies that can affect the glenohumeral joint often cause acute or chronic pain, which can significantly decrease patients' abilities to work and engage in sport as well as their overall quality of life (Resch and Breitfluss, 1995; Hyvonen et al., 2003; Tsai et al., 2006; Silva et al., 2008; Bhatia et al., 2009; Corpus et al., 2016).

The glenohumeral joint is a multiaxial synovial ball and socket joint between the glenoid cavity of the scapulae and the head of the humerus. This type of joint allows the widest range of motion, but with minimal stability due to the different sizes of the articular surfaces of the joint. The anatomical construction has an inherent high risk of dislocation and development of chronic instability. In addition, the shoulder joint has a very loose joint capsule, with the coracohumeral and glenohumeral ligaments and rotator cuff muscles reinforcing this (Turkel et al., 1981; Burkart and Debski, 2002; Millett et al., 2012; Ogul et al., 2014).

The rotator interval is an area between the supraspinatus and subscapularis tendons in the anterosuperior part of the shoulder joint. The coracohumeral and superior glenohumeral ligaments, the tendon of the long head of the biceps brachii, and the anterior joint capsule are the structures of the rotator interval (Kolts et al., 2002; Lee et al., 2007; Zappia et al., 2013; Itoigawa and Itoi, 2015). The rotator interval is a surgically important landmark when repairing glenohumeral joint laxity and rotator cuff tears (Burkhart, 2000; Hunt et al., 2007; Gaskill et al., 2011; Millett et al., 2012; Frank et al., 2015). However, articular-side partial rotator cuff tears, which are located at the supraspinatus/infraspinatus interval on the posterosuperior part of the joint capsule, are one of the most common pathological injuries of the shoulders of throwing (Nakagawa et al., 2001; Braun et al., 2009; Adams et al., 2016). According to Fessa et al. (2015) and Adams et al. (2016) the mechanisms and etiology in throwing athletes' injuries are still insufficiently studied.

Generally, the vascularity of the tendons and ligaments within the shoulder joint are reduced at areas of friction and compression. In the literature, hypovascularity of the tendons has been suggested to be a key factor in degenerative pathologies of the rotator cuff (Radke et al., 2001; Rudzki et al., 2008; Seitz et al., 2011). Already in 1934, Codman had described the „hypovascular zone" of the supraspinatus tendon as being located at the insertion of the supraspinatus to the greater tuberosity. According to Moseley (1963), the rotator cuff has a well-vascularised structure throughout life. However, many authors have since demonstrated a „hypovascular zone" located mainly in the supraspinatus tendon (Rathbun and Macnab, 1970; Fukuda et al., 1990; Ling et al., 1990; Tillmann et al., 1992; Katzer et al., 1997). Andary and Petersen (2002) found a „hypovascular zone" located near the humeral insertion of the shoulder joint capsule. However, the focus of these previous studies tended to be on the blood supply of the rotator tendons rather than the separate joint capsule structures.

Over the past 30 years, the increasing number of arthroscopic shoulder surgeries and the use of magnetic resonance imaging data analysis have led to more accurate evaluations of the pathologically affected structures and overall condition of the joint. Both methods of determining the extent of injury require detailed anatomical knowledge of the shoulder joint's structure.

2. LITERATURE REVIEW

2.1. The superior part of the shoulder joint capsule

According to Golke et al. (1994), the superior part of the shoulder joint capsule is composed of the insertion of the infraspinatus and supraspinatus muscles, the coracohumeral ligament, the superior glenohumeral ligament, and the long head of the biceps tendon. Llopis et al. (2015) state that the glenohumeral joint capsule is composed of three layers: the synovial lining on the articular surface, a subsynovial layer with loosely packed collagen, and a thicker bursal surface layer consisting of dense collagen. The superior and middle glenohumeral, coracohumeral, coracoglenoidal, and semicircular humeral ligaments reinforce the thin capsular tissue of the anterosuperior part of the joint capsule (Kolts et al., 2002; Nakata et al., 2011; Ogul et al., 2014). According to Miller (2003) and Woertler et al. (2015), the rotator cuff has two tendinous gaps covered by capsular tissue: one, between the supraspinatus and subscapularis tendons, termed the anterior rotator interval, and another, between the supra- and infraspinatus tendons, termed the posterior rotator interval. Ishihara et al. (2014) and Adams et al. (2016) have found that the superior shoulder capsule plays a significant role in stability of the glenohumeral joint. Injuries in the superior capsule, including massive rotator cuff tears, increased glenohumeral translation in all directions.

2.1.1. Anterosuperior part of the shoulder joint capsule

2.1.1.1. The rotator interval

The rotator interval, comprising the triangular capsular space in the anterosuperior part of the shoulder, was first defined by Neer (1970). The rotator interval is located in the anterosuperior portion of the glenohumeral joint between the tendons insertions of the supraspinatus superiorly and subscapularis inferiorly, and the coracoid process forms its medial base (Hunt et al., 2007; Petchprapa et al., 2010; Gaskill et al., 2011; Itoigawa and Itoi, 2015). According to Kolts et al. (2002) the rotator interval can be divided into lateral, medio-superior, and medio-inferior parts. The lateral part of the capsule is strengthened by the semicircular humeral ligament and anterior fibres of the supraspinatus tendon. The coracohumeral and coracoglenoidal ligaments are the macroscopical elements of the medio-superior part. The medio-inferior part of the rotator interval is reinforced by the superior and medium glenohumeral ligaments. According to several authors, the rotator interval contains the intra-articular portion of the long head of the biceps tendon and the anterosuperior joint capsule (Kolts et al., 2002; Lee et al., 2007; Arai et al., 2010; Gaskill et al., 2011; Zappia et al., 2013; Frank et al., 2015). However, Woertler (2015) notes the rotator interval is an anatomically complex region of the shoulder joint capsule that is difficult to evaluate trough clinical examination and imaging.

Harryman et al. (1992) showed that the capsule in the rotator interval is important in terms role of glenohumeral motion and stability. According to Habermeyer et al. (1992), stabilisation of the long head of the biceps tendon is the most important function of the superior glenohumeral ligament. Numerous clinical studies have found that the structures of the whole rotator interval are important stabilisers of the glenohumeral joint (Habermeyer et al., 2000; Burkart and Debski, 2002; Hunt et al., 2007; Arai et al., 2010; Petchprapa et al., 2010; Tischer et al., 2011). Interest in the detailed anatomy and functioning of the rotator interval has grown in terms of the diagnosis and treatment of pathologic conditions. Radiologists and orthopaedic surgeons have described several different pathologies of the rotator interval, including rotator interval laxity, Pulley and SLAP lesions, and adhesive capsulitis (Le Huec et al., 1996; Habermeyer et al., 2004; Lyons et al., 2005; Lee et al., 2007; Petchprapa et al., 2010; Gaskill et al., 2011; Woertler, 2015). According to Woertler et al. (2015), lesions of the biceps pulley and its adjacent structures can develop due to acute trauma, repetitive microtrauma, impingement, degenerative changes, and extension of rotator cuff tears in the rotator interval. These and several others authors (Nakata et al., 2011; Schaeffeler et al., 2012; Ogul et al., 2014) have described isolated superior glenohumeral ligament tears, sometimes combined with subscapularis and supraspinatus tears in the rotator interval. Therefore, the rotator interval is a surgically important area for the repair these tears.

2.1.1.2. The superior glenohumeral ligament

The glenohumeral ligaments were first described in 1829 by Flood. Many anatomy textbooks and atlases describe the superior, middle, and inferior glenohumeral ligaments as thickenings of the anterior shoulder joint capsule, but without describing their origin and insertion areas (Tillmann and Töndury, 1987; Frick 1992; Schumacher 1994; Netter 2000; Platzer 2005; Schuenke et al., 2006). Agur and Dalley (2009) argued that the glenohumeral ligaments are visible from within the joint cavity but are not easily seen externally. Thus, in the official Terminologia Anatomica (1998), which has not been updated, these ligaments are classified together as *ligg. glenohumeralia*.

Controversially, clinical orthopaedic textbooks (Gartsman, 2003; O'Brien 2004) and earlier publications (Ferrari, 1990; Clark et al., 1990; Clark and Harryman, 1992; Kolts et al., 2001; Pradhan et al., 2001; Burkart and Debski, 2002; Kolts et al., 2002; Ide et al., 2004;) describe the glenohumeral ligaments as constant macroscopic structures which are visible from the intra- and extra-articular sides of the shoulder joint capsule.

The superior glenohumeral ligament is the most important structure in the anterosuperior part of the glenohumeral joint capsule (Cooper et al., 1992). The ligament plays essential roles in anterosuperior impingement syndrome and stabilisation of the long head of the biceps tendon (Habermeyer et al., 1995; Werner et al., 2000).

In the literature, the superior glenohumeral ligament varies in its origin and insertion. One group of scientists describes that the superior glenohumeral ligament as arising from the supraglenoid tubercle or from the upper pole of the glenoid cavity (Ferrari et al., 1990; Kolts et al., 2001; Kolts et al., 2002; Burkart and Debski, 2002). Another group states that the ligament originates from the superior part of the glenoid labrum (Palmer et al., 1994; Steinbeck et al., 1998; Pradhan et al., 2001; Ide et al., 2004). According to Hunt et al. (2007), the superior glenohumeral ligament originates from the glenoid labrum and supraglenoid tubercle. Several previous studies have reported that the superior and middle glenohumeral ligaments have the common origin of the glenoid labrum (Palmer et al., 1994; Steinbeck et al., 1998; Ide et al., 2004).

Werner et al. (2000) described the existence of a „*fasciculus obliquus*", a transverse band of the rotator cuff that functions as a stabiliser of the intraarticular part of the long head of the biceps tendon. Kolts et al. (2002) described direct and oblique fibres of the superior glenohumeral ligament. According to these authors, the direct fibres bordered the long head of the biceps tendon anteriorly and inserted into lesser tubercle. The oblique fibres coursed over the intraarticular portion of the long head of the biceps tendon and inserted into the semicircular humeral ligament.

2.1.1.3. The coracohumeral and coracoglenoidal ligaments

According to Weinstabl et al. (1986), a strong band of dense connective tissue called the coracoglenoidal ligament, an anatomical variation of the pectoralis minor tendon, begins at approximately the middle of the upper or posterior surface of the coracoid process and inserts into the supraglenoid tubercle. Kolts et al. (2000) found the coracoglenoidal ligament to be a stable structure and divided the coracohumeral ligament into two separate parts. The origin of the main portion of the coracohumeral ligament was found to be the coracoglenoidal ligament, not the base of the coracoid process. The inferior portion of the coracohumeral ligament was found to fuse tightly with the superior glenohumeral ligament at the middle of the rotator interval, coursing under the supraspinatus tendon and inserting into the semicircular humeral ligament, not to the greater and lesser tubercles of the humerus as described previously. The superior part courses over the coracoglenoidal ligament parallel to the anterior margin of the supraspinatus muscle and then inserts into the semicircular humeral ligament. This new insight into the coracoglenoidal-coracohumeral complex increased interest into this clinically important region and led to intensive investigation (Yang et al., 2009; Petchprapa et al., 2010; Gaskill et al., 2011; Arai et al., 2014).

2.1.1.4. The semicircular humeral ligament (rotator cable)

Clark and Harryman (1992) demonstrated through gross anatomical examination that the capsule beneath the supraspinatus and infraspinatus tendons is thickened by a strip of fibrous tissue that runs posteriorly and perpendicular to the fibres of the tendons. In 1993, Burkhart et al. conducted arthroscopic research that led them to describe a thick bundle of fibres running perpendicular to the axis of the supraspinatus tendon; they termed this anatomical structure the „rotator cable". The structural anatomy of the „rotator cable" was studied in detail by Kolts et al. (2002), who found that it is a constant anatomical structure running semicircularly posteriorly from the lesser and greater tubercles and named it the „semicircular humeral ligament". Kask et al. (2008) provide radiological description of this ligament. Morag et al. (2006) demonstrated the existence of a rotator cable using ultrasonography. According to Gyftopoulus et al. (2013), the rotator cable is a structure that can be consistently seen using gross anatomic and histologic analysis, arthroscopy, and MRI on intact rotator cuffs. Rahu et al. (2016) state that the connection between the rotator cable and rotator cuff tendons is tight, confirming the suspension bridge theory of Burkhart et al. (1993). In its posterior insertion area, the rotator cable is a connecting structure between the teres minor and the infraspinatus and supraspinatus tendons.

2.1.2. Posterosuperior part of the shoulder joint capsule

The posterosuperior shoulder joint area is a clinically important part of the body that is susceptible to injuries, especially among throwing athletes (Barber et al., 1999; Nakagawa et al., 2006; Fessa et al., 2015). In an arthroscopic study, Walch et al. (1992) demonstrated impingement between the posterosuperior border of the glenoid and the undersurface of the tendinous insertion of the supraspinatus and infraspinatus on the greater tubercle of the humerus in athletes. Some authors have reported that this condition typically affects young to middle-aged throwing athletes who perform repetitive shoulder abduction and external rotation movements when throwing (Sonney-Cottet et al., 2002; Kirchhoff and Imhoff, 2010; Fessa et al., 2015). According to Burkhart et al. (2003), internal impingement is not a pathologic condition; it is a natural phenomenon that protects one from excess external rotation of the shoulder. Without the presence of internal impingement, a pathologic hyper external rotation with a „hypertwist" is possible and could cause fatigue and failure of the rotator cuff fibres (Burkhart, 2006).

Rotator cuff tears are one of the most common pathologies among throwing athletes, but the cause and mechanism of these lesions remains largely unknown. In an arthroscopic study, Nakagawa et al. (2001) reported that rotator cuff tears among throwing athletes are mostly articular-sided. These tears are located around the supraspinatus/infraspinatus interval and can involve both the supra- and infraspinatus tendons (Fessa et al., 2015). According to Braun et al. (2009), as the mechanism and etiology of throwing injuries remains unclear, new anatomical knowledge of the capsuloligamentous complex of the postero-superior shoulder part is important to prevent and treat injuries.

2.2. The subacromial bursa

Previous studies have reported that the subacromial bursa communicates with the subdeltoid bursa, forming the so-called subacromial-subdeltoid bursa (Tillmann and Gehrke, 1995; Radke et al. 2001; Millett et al., 2012). Tillmann and Gehrke (1995) described the structural anatomy of the subacromial space, the cranial border consists of the acromion, coracoacromial ligament, coracoid process, acromioclavicular joint, and the undersurface of the deltoid muscle. The caudal border of the subacromial space consists of the rotator cuff tendons and rotator interval. The function of the subacromial space is to ensure unrestricted movement of the acromion and rotator cuff tendons (Uhthoff and Sakar, 1991; Tillmann and Gehrke, 1995). One function of the subacromial bursa is to supply blood to the rotator cuff tendons (Uhthoff and Sakar, 1991; Uhthoff et al., 2003; Löhr and Uhthoff, 2007). Uhthoff and Sakar (1991) and Gumina et al. (2006) showed histologically that the caudal bursa and rotator cuff tendons are connected to the musculotendinous junction. This junction, located between the synovial lining of the bursa and the collagenous fascicles of the tendon, contains a small number of blood vessels.

Many studies have suggested that shoulder pain might be caused by different subacromial bursa pathologies, including impingement syndrome, subacromial bursitis, and rotator cuff tendinitis and tears (Schmelzeisen, 1990; Randolph et al., 1998; Hyvönen et al., 2003; Machida et al., 2004; Tsai et al., 2006; Witte et al., 2011; Meyer et al., 2013; Takase et al., 2014; Petri et al., 2016).

2.3. Blood supply of the shoulder joint

2.3.1. Blood supply to the rotator cuff tendons and glenohumeral joint capsule

Often, the vasculature of the tendon or ligament is reduced in areas of friction, compression, and excessive wear (Kolts et al., 1994; Cheng et al., 2010). Karthikeyan et al. (2015) found total blood flow in the supraspinatus tendon to be significantly lower in pathologic than in normal tendons. The lowest blood flow values within the tendon were from patients with impingement syndrome. These results support Levy et al. (2008), who indicated that impingement results in a significant reduction in blood flow through pathologic rotator cuffs. According to Kolts et al. (1994) and Cheng et al. (2010) the vascularisation of the variously loaded parts (pressure and tension) of the long head biceps tendon influences the formation of the different structural and vascular architecture, which indicates functional adaption to the stress of a gliding tendon. Therefore, changes to vascular supply are the main factors affecting tendon condition (Chansky and Iannotti 1991; Lazaro, 2005; Löhr and Uhthoff, 2007; Cheng et al., 2010; Pandey et al., 2015). Several studies have reported that a zone of hypovascularity is located laterally in the supraspinatus and infraspinatus tendons of neonates and adults (Rathbun and Macnab, 1970; Löhr and Uhthoff, 1990; Ling et al., 1990; Determe et al., 1996; Katzer et al., 1997; Biberthaler et.al., 2003; Levy et al., 2008). According to Löhr and Uhthoff (1990) and Rudzki et al. (2008), hypovascularity of the rotator cuff is limited to the articular side and not the bursal side of the rotator cuff tendons.

Cooper et al. (1992) found that the glenohumeral joint capsule is supplied with blood via the suprascapular, circumflex scapular, and posterior circumflex humeral arteries. A more detailed description of the blood supply to the glenohumeral capsule was provided by Andary and Petersen (2002). However, these authors tended to focus on the blood supply to the shoulder joint capsule in general rather than the ligaments separately.

Despite numerous publications, there is ongoing debate about the vascularity of the rotator cuff tendons and the underlying joint capsule (Table 1).

Table 1. Summary of previous studies of the blood supply to the structures bordering or within the rotator interval

Study	N	Method	Hypovascularity zone	Suggested clinical problems
Löhr and Uhthoff (1990)	26 UE	Histology	Close to SSP tendon	Degenerative rotator cuff tears
Ling et al. (1990)	20 UE	Observation	Articular side of SSP tendon	SSP rupture
Determe et al. (1996)	25 UE	Dissection Histology	SSP tendon	Rotator cuff disease
Katzer et al. (1997)	8 adult 6 neonate	Histology	SSP and ISP tendon Neonate = adult	Rotator cuff rupture
Andary and Petersen (2002)	24 UE	Dissection	Anterior joint capsule	Surgery may reduce or stop blood supply
Biberthaler et al. (2003)	11 patients	Arthroscopy Histology	SSP near insertion	Rotator cuff lesions
Cheng et al. (2010)	20 E 8 UE	Dissection Histology	Long head biceps brachii	Weakness and tendon rupture

E − formalin embalmed, UE − fresh unembalmed, ISP − infraspinatus, SSP − supraspinatus

2.3.2. Blood supply of the subacromial bursa and rotator cuff tendons

The blood supply to the subacromial bursa was studied by Yepes et al. (2007). These authors divided the subacromial bursa into six walls (medial/lateral, anterior/posterior, and superior/inferior) and described the vascular anatomy of these structures. Blood supply to the rotator cuff tendons on the bursal side has been described in several publications (Garza et al., 1992; Katzer et al., 1997; Levy et al., 2008; Notarnicola et al., 2012). Some researchers have described the supraspinatus tendon as less vascularised than the infraspinatus tendon on the bursal side (Determe et al., 1996; Katzer et al., 1997; Yepes et al., 2007); however, Brooks et al. (1992) found no significant difference between the blood supply to these tendons at their humeral insertions. Vascularity of the subacromial bursa and rotator cuff tendons is the key factor in the pathogenesis of subacromial bursitis, impingement syndrome, and rotator cuff tendinitis and tears (Fukuda et al., 1990; Fukuda, 2003; Machida et al., 2004; Gumina et al., 2006; Löhr and Uhthoff, 2007; Levy et al., 2008; Ko and Wang, 2011). Despite this intensive research, the vascularity of the rotator cuff tendons on the bursal side remains partly unclear.

2.4. Histology of the shoulder ligaments and tendons

Histology textbooks define the joint capsule as a dense connective tissue with an irregular arrangement of collagen fibres, with ligaments consisting of parallel-orientated collagen fibres (Lüllmann-Rauch, 2009; Ross and Pawlina, 2016). Steiner and Hermann (1989) found that the shoulder joint capsule is a regular collagen structure of densely packed fibres which are regular and cross-linked. The ligaments consist of parallel-orientated collagen fibres with fibroblasts. The fibrocytes are arranged between the collagen fibres individually, in pairs, or in rows (Kolts et al., 1994; Merila et al., 2008; Cheng et al., 2010; Ross and Pawlina, 2016). According to Lüllmann-Rauch (2009), fibrocartilaginous tissue is a combination of dense connective and cartilage tissues. Between the collagen fibres, chondrocytes are located singularly, in rows, or groups. This fibrocartilaginous tissue is in gliding areas and the origin and insertion areas of the tendons and ligaments. The fibrocartilaginous parts are populated by oval-chondrocyte-like cells (Tillmann and Kolts, 1993; Kolts et al., 1994; Lüllmann-Rauch, 2009).

2.5. Summary of the literature

The shoulder joint allows the widest range of motion, but with minimal stability, due to the different sizes of the articular surfaces of the joint. In addition, the shoulder joint has a very loose joint capsule. The anatomical construction results in a higher risk of dislocation and leads to development of chronic instability. Therefore, the joint capsule-reinforcing structures play a key role in the normal and pathological movement.

The rotator interval, located in the anterosuperior part of the shoulder joint, is a surgically important region for the repair of subscapularis laxity and supraspinatus tendons tears. According to literature, the coracohumeral and superior glenohumeral ligaments as well as the long head of the biceps brachii comprise the rotator interval. The structural morphology of the rotator interval has been studied by Kolts et al. (2002), but no articles describing the blood supply to the superior glenohumeral ligament were found. Several papers have suggested that one of the causes of shoulder pain is connected with the subacromial bursa pathologies. The function of the subacromial space is to ensure gliding between the acromion and rotator cuff tendons, and another is to supply blood to the rotator cuff tendons. The blood supply to the subacromial bursa was described by Yepes et al. (2007), who divided the bursa into six walls. Blood supply to the rotator cuff tendons on the bursal side has been studied in many publications. Despite this intensive research, the vascularity of the rotator cuff tendons on the bursal side remains partly unclear. The posterosuperior shoulder joint area is susceptible to injuries, especially among throwing athletes. Rotator cuff tears are one of the most common injuries in throwing athletes, and the full cause and mechanism of these lesions remains largely unknown.

3. AIMS OF THE STUDY

General aim:
To provide a detailed description of the blood supply of the subacromial bursa and reinforcing ligaments of the superior shoulder joint capsule in older adults.

Specific aims:
1. To describe and report the detailed structural anatomy of the superior glenohumeral ligament.
2. To investigate the blood supply to the superior glenohumeral ligament.
3. To investigate the blood supply to the cranial and caudal parts of the subacromial bursa and the vascularity of the rotator cuff tendons on the bursal side.
4. To investigate the structure and blood supply to the glenocapsular ligament of the posterosuperior shoulder joint capsule.

4. MATERIALS AND METHODS

4.1. Materials

Twenty-nine embalmed and 72 unembalmed fresh cadaveric shoulder specimens from 40 female and 61 male persons aged 60–84 years were used in four separate papers (Table 2). All anatomical shoulder specimens were collected from voluntarily donated bodies. Ethical permission for the studies was given by „Gesetz über das Leichen, Bestattungs- und Friedhoffwesen des Lands Schleswig-Holstein vom 04.02.2003, Abschnitt II, §9 (Leichenöffnung, anatomisch)".

Table 2. Cadaveric shoulder samples and methods used in papers I–IV

Paper	**Mean range ± SD/ Age (years)**	**Gender/N**	**Shoulder condition**	**Methods**
I*	74.6 ± 6.7 60−82	12F/15M =27	15 UE (5F/10M) 12 E (7F/5M)	Histology Dissection without arterial injection
II**	75.7 ± 8.2 60−84	12F/20M =32	15 UE (6F/9M) 1 E (1M) 16 UE (6F/10M)	Histology and immunohistochemistry Dissection without arterial injection Dissection with arterial injection
III***	71.7 ±10.8 61−82	6F/8M =14	14 UE (6F/8M)	Dissection with arterial injection
IV****	73.4 ±6.4 67−80	10F/18M =28	16 E (6F/10M) 12 UE (4F/8M)	Dissection without arterial injection Dissection with arterial injection

F − female, M − male, E − formalin embalmed, UE − fresh unembalmed

I* Anatomy of the superior glenohumeral ligament.
II** Blood supply of the superior glenohumeral ligament: A gross anatomical and histological study.
III*** Blood supply of the subacromial bursa and rotator cuff tendons on the bursal side.
IV**** The glenocapsular ligament and the posterosuperior part of the joint capsule of the shoulder are well vascularized.

4.2. Gross anatomical dissection without and with arterial injection generally

The rotator cuff muscles, long head of the biceps tendon, and major pectoral muscle tendons were dissected. The acromion was cut from the spine of the scapulae and removed with the coracoacromial ligament. The tendons of the rotator cuff muscles were removed from the remains of the subacromial bursa and separated from the joint capsule.

Before dissection, an arterial injection of a 10% aqueous latex solution, stabilised with ammonia (0.7% concentration), was administered to the fresh specimens. Each specimen was simultaneously injected with 200 ml of the latex solution via the subclavian and brachial arteries simultaneously. After the injection, the shoulders were fixed using an alcohol-formalin-glycerol solution and meticulously dissected under a dissection microscope.

To expose the blood vessels, the supraspinatus, infraspinatus, and teres minor were exposed posteriorly and the pectoralis minor anteriorly by removing the skin and any superficial muscles and tissues. The tendon of the pectoralis minor muscle was carefully reflected laterally, thus revealing the neurovascular structures of the axillary sheath. The blood vessels were isolated and the arterial and venous vessels separated by removing axillary fat as needed. The veins, nerves, and remaining axillary fat were removed to provide clear visibility of the subclavian and axillary arteries and their branches as well as subscapularis muscle and tendon.

4.2.1. The superior glenohumeral ligament

From the 12 fixed shoulders (7F/5M), the joint capsule, coracohumeral, coracoglenoidal, and superior, middle, and spiral glenohumeral ligaments were dissected in fine detail. The coracoid process was cut at its base and moved posteriorly with the coracohumeral and coracoglenoidal ligaments. The fibres arising from the supraglenoid tubercle region were finely dissected. The coracohumeral was separated from the underlying fibres of the superior glenohumeral ligament, and the fibres of the humeral semicircular ligament were removed from the remains of the soft connective tissue. The rotator interval was opened, and the intraarticular portion of the tendon of the long head of the biceps muscle was cut and raised to be able to see the fibres running from the glenoid labrum.

From the 16 shoulders (6F/10M), the arteries were traced to the coracohumeral ligament and the surface of the rotator cuff muscles. Arterial supply to the coracohumeral ligament was documented. Next, the coracoid process, coracohumeral ligament, and acromion were excised to increase exposure of the rotator cuff muscles and rotator interval. Each of the four rotator cuff muscles was reflected laterally, with care taken not to disrupt the vessels coursing towards the joint capsule. Next, the oblique and direct parts of the superior glenohumeral ligament were identified where they merged attached medially to the supraglenoid tubercle and glenoid labrum. The oblique part of the superior glenohumeral ligament was superficially traced laterally to the intra-articular portion of the tendon of the long head biceps to where it blended with the semicircular humeral ligament. The direct part of the superior glenohumeral ligament was followed to its attachment to the lesser tubercle and the lips of the bicipital groove, where it became continuous with the superior margin of the transverse humeral ligament. All arterial vessels were traced to their termination until no longer visible under the dissection microscope.

4.2.2. The glenocapsular ligament

From the 16 fixed shoulders (6F/10M), the rotator cuff tendons were separated from the joint capsule and from each other. The bony insertion areas of the supraspinatus, infraspinatus, and teres minor muscles were left intact. The superior joint capsule ligaments, coracohumerale, coracoglenoidale, glenocapsulare, and semicircular humeral were finely dissected.

From the 12 shoulders (4F/8M), the arteries were traced to the coracohumeral ligament and the surface of the rotator cuff muscles and their tendons. Next, the coracoid process and acromion were excised to increase exposure of the rotator cuff muscles. Each of the rotator cuff muscles was reflected laterally, with care taken not to disrupt the vessels coursing towards the joint capsule. Then the rotator cuff muscles were separated from each other and the glenohumeral joint capsule. The coracohumeral, glenocapsular, coracoglenoidal, and semicircular humeral (rotator cable) ligaments were dissected in detail. The bony insertion areas of the rotator cuff were left intact. All arteries were finely dissected and traced to the rotator cuff tendons and muscles bellies as well as the glenohumeral joint capsule.

4.2.3. The subacromial bursa

In eight shoulders (4F/4M), the deltoid muscle was released from the the clavicle, acromion, and spina scapulae. The deltoid muscles were separated from the underlying subacromial space and moved laterally. The pectoralis minor muscle was carefully reflected cranially to increase visibility of the coracohumeral ligament. Then the coracohumeral ligament was delicately dissected from the superior glenohumeral ligament to expose the subcoracoid artery. In six shoulders (2F/4M), the deltoid muscle was released from the deltoid tuberosity, separating it from the underlying subacromial space and allowing it to be moved craniomedially. The blood vessels were isolated and the arterial and venous vessels separated. The veins and remaining axillary fat were removed to make the subclavian and axillary arteries and their branches more clearly visible.

The subacromial/subdeltoid space was divided into cranial and caudal parts. The cranial part consisted of the inferior surface of the deltoid muscle and the caudal part of the rotator cuff tendons, rotator interval structures, and humerus until the humeral tuberosity. The regions of the caudal part were supplied by different arteries; thus, the caudal part was divided into anterior, medial, and posterior thirds. All arteries were finely dissected and traced to the level of the subacromial bursa, deltoid muscle, rotator cuff tendons, and rotator interval structures.

Photographs were taken throughout the dissection process and the course and termination of the arterial vessels documented.

4.3. Histology and immunohistochemistry

Material for a light-microscope investigation was taken after the fine dissection of the direct and oblique parts of the superior glenohumeral ligament, and macroscopic visualisation was accomplished. The direct and oblique parts were divided into three pieces corresponding to the origin, middle, and insertion parts. The material was fixed in 4% formalin and embedded in paraffin. Histologic sections 7 μm thick were stained using Trichrome Masson-Goldner with resorcin-fuchsin.

One fixed specimen was finely dissected to illustrate the glenohumeral joint's ligamentous structures, of which the blood supply was to be investigated. The superior glenohumeral ligament was excised at its attachment sites and removed from the specimen. Each ligament was biopsied at three locations: A) the lateral third, close to the attachment sites of the oblique and direct parts; B) the middle third, through both the oblique and direct parts, and C) the medial third, at the common attachment of the oblique and direct parts (Fig. 1). Each biopsy was fixed in 4% formalin and then embedded in paraffin. Fourteen consecutive sections, each 5 μm thick, were cut from the centre of the each tblock using a Microm Type STS microtome (Germany).

Four sections from each block were stained using the Trichrome Masson-Goldner with resorcin-fuchsin method and viewed through a Carl Zeiss Axioplan 2 microscope per the histological assessment of the superior glenohumeral ligament. The orientation of the collagen fibre bundles and the proportion of fibrocytes and chondrocytes were assessed to determine the structural characteristics of the superior glenohumeral ligament at each biopsied site. The number of chondrocytes and fibrocytes was counted manually from a microscopic field of view.

Ten sections from each block were analysed using immunohistochemistry, processed with the Avidin-Biotin technique, to determine if Type IV collagen occurs in the basement membranes of the blood vessels. Two of the ten sections were used as negative controls. Immunohistochemical staining was performed on the deparaffinised sections, which were treated with 0.6% H_2O_2 to inactivate endogenous peroxidase and then incubated in 5% goat serum for 20 minutes to block non-specific binding. Next, the sections were incubated overnight at room temperature in a moist chamber with the primary Mouse Anti-Human Collagen IV antibodies (Dako-Clone CIV 22, Code No M0785, diluted 1:50). A Strept ABComplex/HRP Duet Mouse/Rabbit System (Dako Cytomation, Glostrup, Denmark) and DAB+ Chromogen kit (Dako Cytomation) was used to visualise the primary antibody. The dehydrated slides were coverslipped with Entellan (Merck, Germany). The intervening washing steps were performed in Tris buffered saline (TBS-pH 7.4). The adjacent sections served as negative controls and were processed using the same protocol but without incubation of the primary antibody.

All slides of the histological and immunohistochemical analyses were viewed using a Carl Zeiss Axioplan 2 microscope and photographed with a Sony DXC-950P 3CCD Colour photo/video camera.

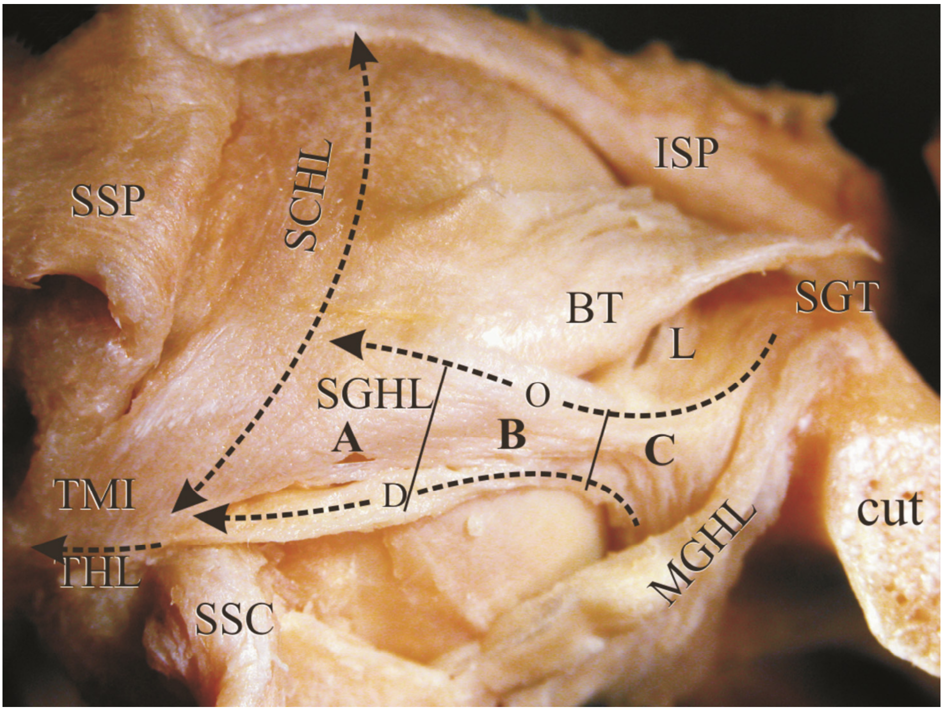

Figure 1. An anterosuperior view of a dissected right shoulder joint specimen. The superior glenohumeral ligament (SGHL) consists of oblique (O) and direct (D) parts. The lateral (A), middle (B), medial (C) parts of the SGHL, correspond to the regions, where the samples for microscopy and immunohistochemistry were taken. The coracoid process was cut at its base (cut). The supraspinatus (SSP) and subscapularis muscles (SSC) were separated from the shoulder joint capsule and placed laterally. Other structures include the infraspinatus muscle (ISP); middle glenohumeral ligament (MGHL); lesser tubercle (TMI); supraglenoidal tubercle (SGT); labrum (L); tendon of long head of biceps brachii (BT); transverse humeral ligament (THL); and semicircular humeral ligament (SCHL).

4.4. Evaluation of samples and statistical analysis

Data of the counting cells ratio (chondrocytes/fibrocytes) of the SGHL are presented as mean ± standard deviation (SD).

Processed samples of the SGHL were photographed by Sony DXC-950P 3CCD Colour video camera under the microscope Carl Zeiss Axioplan 2 with magnification objective x40 and transferred to the personal computer, where the mean grey values were measured from the regions of interest.

Data are presented ± standard error of the mean (SEM). Optical densities of the antibody labelling Type IV collagen in the three regions of the superior glenohumeral ligament were compared against the matching unlabelled controls through a Student's T-test. Pairwise comparisons for independent samples were made using the R statistical software package (Universal R 2.6.1 for Mac OS X released on 2007/11/26, Kurt Hornik, cran.r-project.org, USA). The criterion for significance was $p < 0.05$.

5. RESULTS

5.1. Gross anatomical results without and with arterial injection

5.1.1. Per the superior glenohumeral ligament

The superior glenohumeral ligament was found in all 27 shoulder joint specimens. It was always connected to the middle part of the coracohumeral ligament. The fibres of the superior glenohumeral ligament were divided into two groups: direct and oblique fibres. In 25 of 27 cases, the oblique fibres of the superior glenohumeral ligament originated from the supraglenoid tubercle with the middle glenohumeral ligament (Figs 1, 2). In two cases, when the middle glenohumeral ligament was absent, the oblique fibres arose together with the direct fibres from the antero-superior labrum (Fig. 3AB).

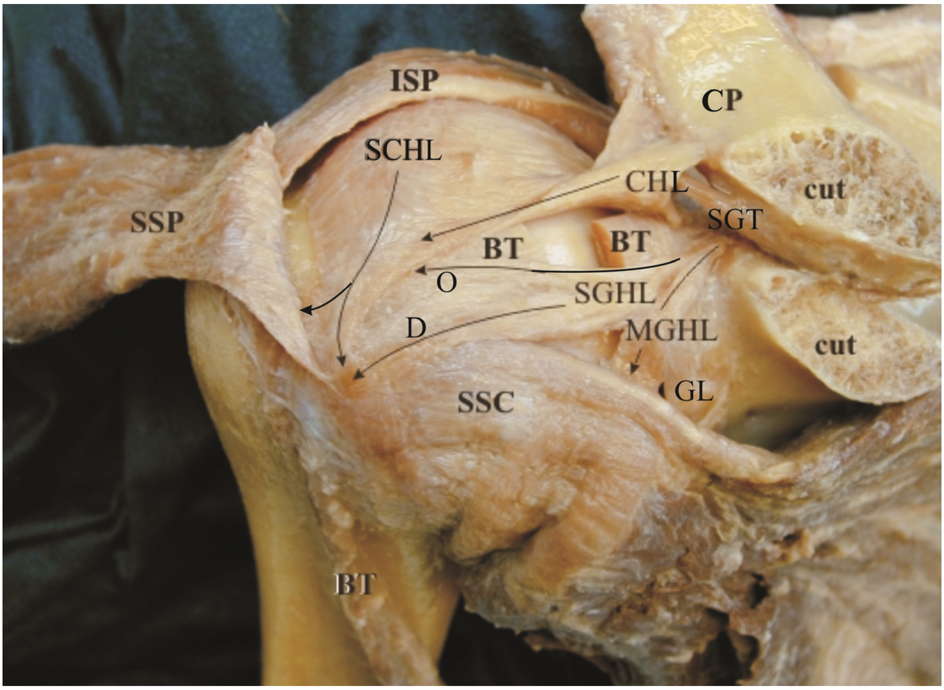

Figure 2. An anterior view of a dissected fixed right shoulder joint specimen. The coracoid process (CP) was cut its base (cut), and the coracohumeral ligament (CHL) was separated from the superior glenohumeral ligament (SGHL) and moved with the CP posteriorly. The supraspinatus (SSP), infraspinatus (ISP), and subscapularis (SSC) muscles were separated from the shoulder joint capsule, and the SSP muscle placed laterally. The SGHL originates from the antero-superior glenoid labrum (GL) and is loosely connected to the middle glenohumeral ligament (MGHL) at the origin region on the supraglenoid tubercle (SGT). The oblique fibres (O) of the SGHL arise together with the MGHL from the SGT, run over the articular part of the tendon of the long head of the biceps brachii (BT), and insert into the semicircular humeral ligament (SCHL). The direct fibres (D) of the SGHL, arise beneath the oblique fibres (O) of the Gl and run parallel with the tendon of the BT towards the lesser tubercle.

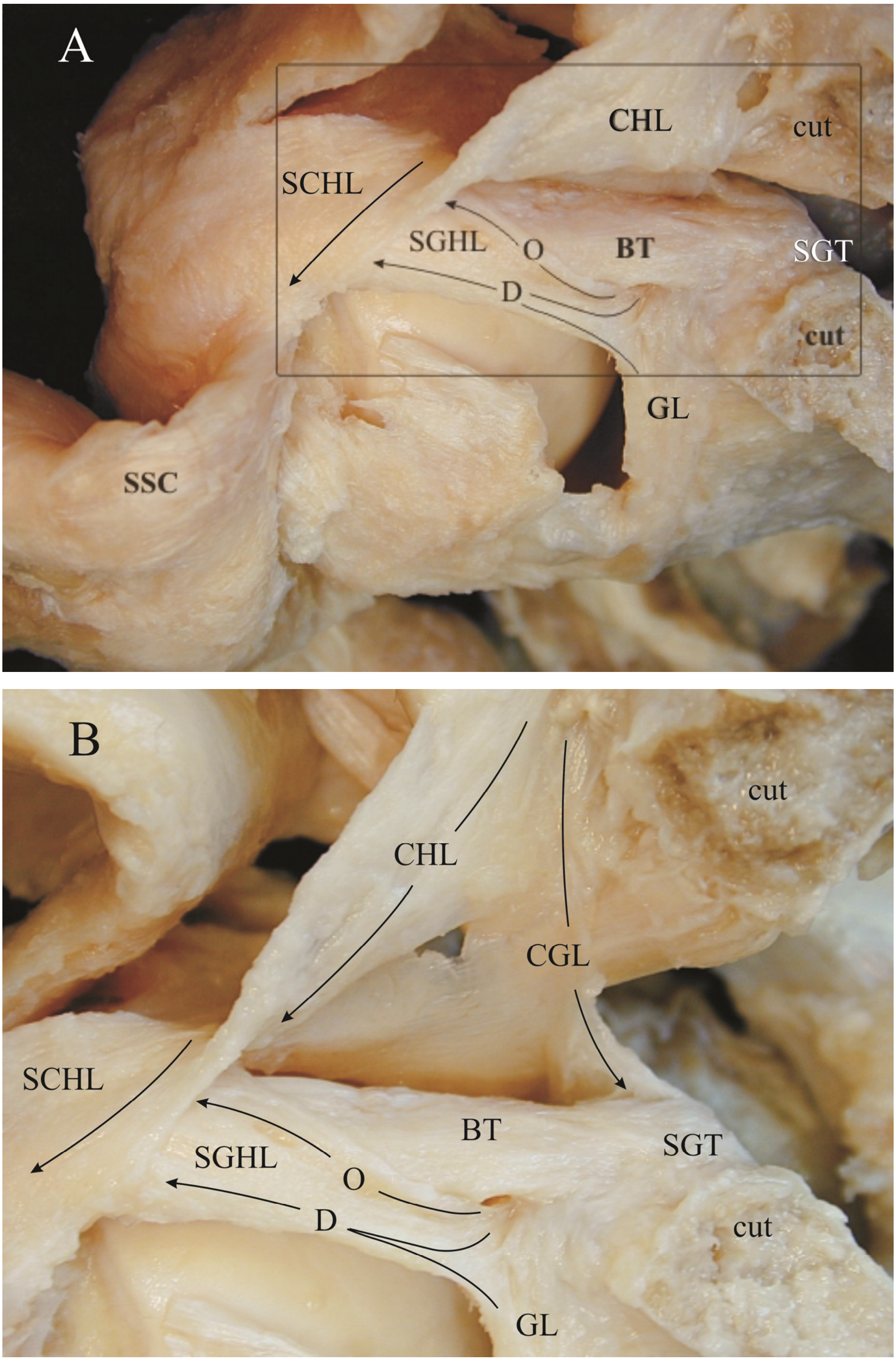

Figure 3. A, An anterior view of a fixed right shoulder joint specimen without the middle glenohumeral ligament. The coracoid process (CP) was cut at its base (cut) and moved together with the coracohumeral ligament (CHL) and coracoglenoidal ligament (CGL) backwards. The subscapularis muscle (SSC) was placed laterally. In case of the absence of the middle glenohumeral ligament the oblique (O) and direct (D) fibres of the superior glenohumeral ligament (SGHL) arise from the glenoid labrum (GL). BT – tendon of the long head of the biceps brachii; SCHL – semicircular humeral ligament; SGT – supraglenoid tubercle. **B,** Magnified view of the SGHL origin and arrangement of fibres. The CHL and CGL were placed under tension to achieve a better visualisation of their relationships with the underlying structures. Other structures include the tendon of the long head of the biceps brachii (BT); semicircular humeral ligament (SCHL); and supraglenoid tubercle (SGT).

The direct fibres originated from the antero-superior and anterior labrum. The direct fibres ran parallel with the tendon of the biceps muscle lying between the tendons of the long head of the biceps and subscapularis muscles (Fig. 2). They coursed with the overlying fibres of the coracohumeral ligament towards the lesser tubercle, partly inserted into it, then continued to the humeral semicircular ligament, did not attach but ran under it the bottom of the bicipital groove, which they partly bridged over, forming the superior part of the transverse humeral ligament (Fig. 1). The oblique fibres packed loosely with the overlying fibres of the coracohumeral ligament, coursed over the intraarticular portion of the tendon of the long head of the biceps muscle, and inserted into the semicircular humeral ligament (Figs 1, 2, 3AB).

5.1.2. Per the glenocapsular ligament

The glenocapsular ligament was found in all 28 specimens and consisted of one or two parallel-running bundles of connective tissue fibres forming the capsular-ligamentous structure in the posterosuperior part of the glenohumeral joint capsule.

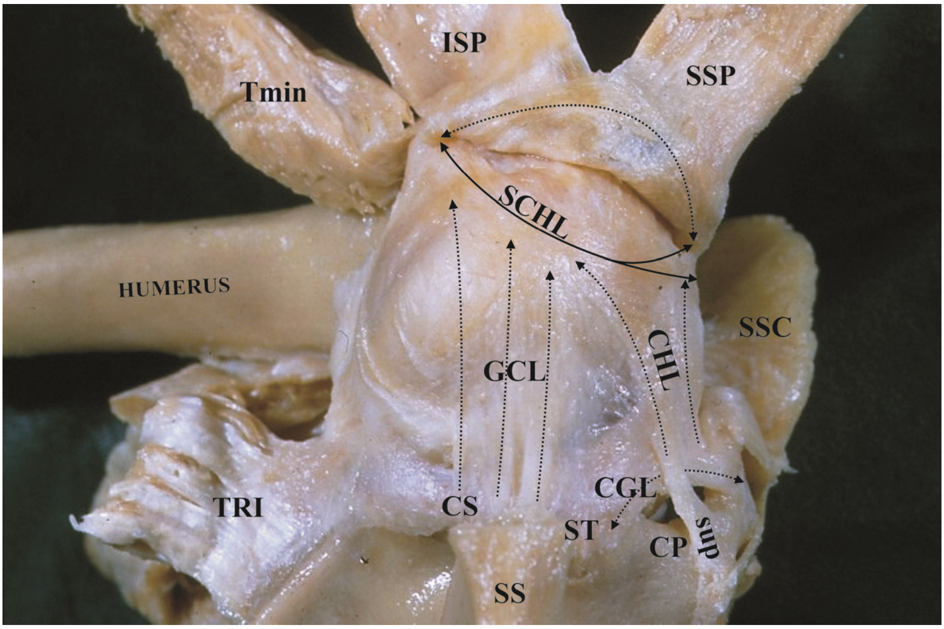

Figure 4. A posterosuperior view of a dissect specimen of the left glenohumeral joint. The glenocapsular ligament (GCL) with its two parts – the posterosuperior part *(black upward paired arrow)* and the mediosuperior part *(one black upward arrow)* – arising from the collum scapulae (CS) and supraglenoid tubercle (ST), and inserting into the semicircular humeral ligament (SCHL), one part of the semicircular ligament *(mirrow arrow)* is indicated on the under surface of the supraspinatus (SSP) and infraspinatus (ISP) tendons. Other structures displayed are the separate superior (sup) part of the coracohumeral ligament (CHL), coracoglenoidal ligament (CGL), coracoid process (CP), subscapularis muscle (SSC), teres minor muscle (Tmin), triceps brachii muscle (TRI) and spina scapulae (SS).

The glenocapsular ligament arose from the posterior part of the supraglenoid tubercle and collum scapulae, and inserted into the semicircular humeral ligament of the posterosuperior shoulder joint capsule. The glenocapsular ligament consisted of two parts, posterosuperior and mediosuperior. The mediosuperior part varied in shape and was absent in 12 of 28 cases. Both parts of the glenocapsular ligament inserted together into the humeral semicircular ligament (rotator cable) in the area between the middle and inferior facets of the greater tubercle of the humerus (Figs 4, 5).

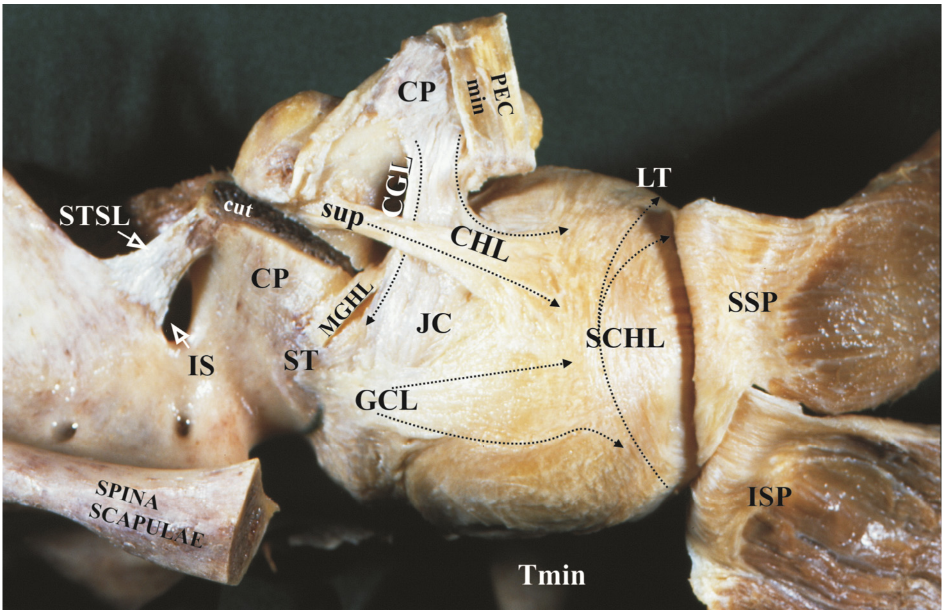

Figure 5. A superior view of a dissect specimen of the right glenohumeral joint in anteversion.The glenocapsular ligament (GCL) consisting of only the posterosuperior part *(black west east paired arrow)* and inserting into the semicircular humeral ligament (SCHL). A separate superior (sup) part of the coracohumeral ligament (CHL) was found in this specimen. The middle glenohumeral ligament (MGHL) arises from supraglenoid tubercle (ST). The deep layer of the joint capsule is indicated as JC. The coracoid process (CP) was *cut* in this specimen. Other structures include the coracoglenoidal ligament (CGL), pectoralis minor muscle (PECmin), lesser tubercle (LT), supraspinatus muscle (SSP), infraspinatus muscle (ISP), teres minor muscle (Tmin), incisura scapulae (IS) and superior transverse scapular ligament (STSL).

5.1.3. Blood supply per the superior glenohumeral ligament

A single direct branch of the axillary („subcoracoid artery"), about 1 cm distal to the origin of the suprascapular artery, coursed towards the coracohumeral ligament and bifurcated into smaller branches running between the collagen fibre bundles. These branches supplied the middle third of the superior glenohumeral ligament, with the anterior branch entering the direct part and the posterior branch the oblique part (Fig. 6AB).

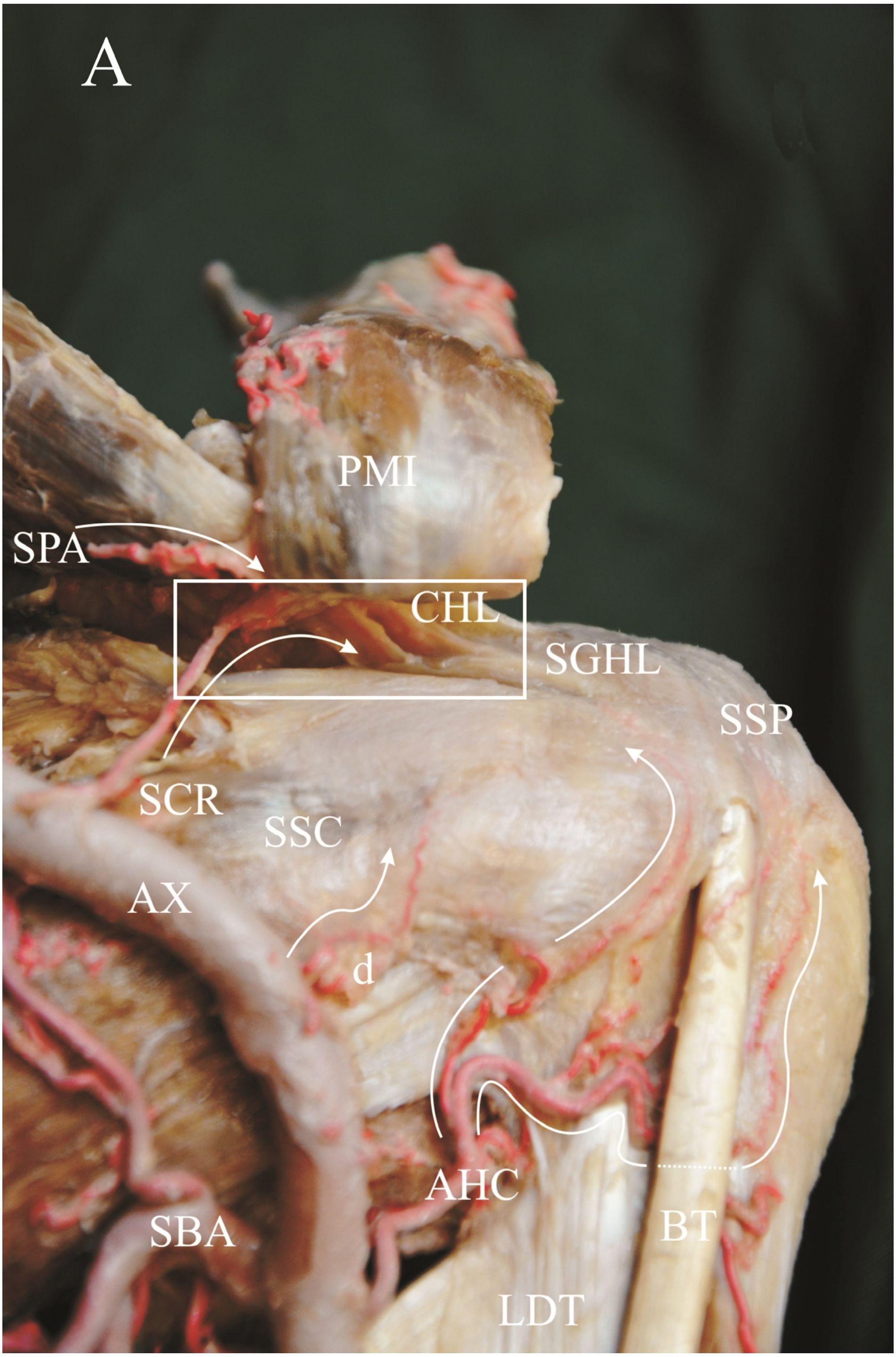

Figure 6.

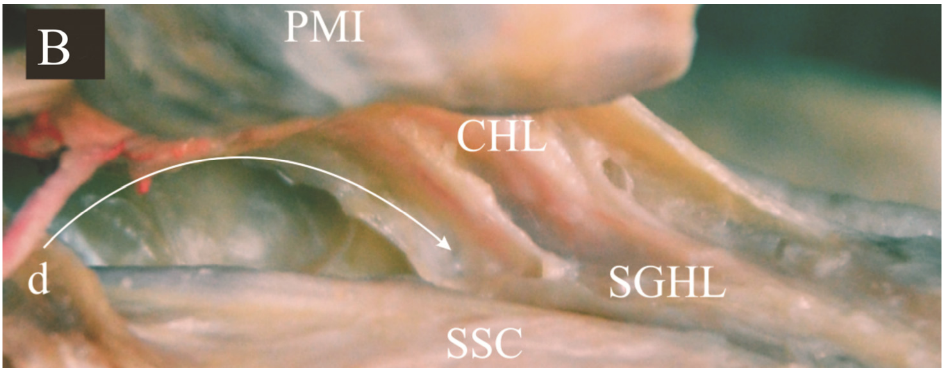

Figure 6. A, An anterior view of a left shoulder specimen. The pectoral minor muscle (PMI) was released from the coracohumeral (CHL) and superior glenohumeral ligaments (SGHL), and ascended cranially. The subcoracoid artery (SCR) ascends from the axillary artery (AX) and courses into the CHL. A branch of the suprascapular artery (SPA) courses to the superior surface of the CHL. A direct branch (d) ascends from the axillary artery to the subscapularis (SSC) tendon. The anterior circumflex humeral artery (AHC) provides medial (*upward arrow*) and lateral (*upward arrow*) ascending branches. Other structures include subscapular artery (SBA); tendon of the long head of biceps brachii (BT); and tendon of the latissimus dorsi (LDT). **B,** A quadrangular cut out from Figure 6. Blood supply of the coracohumeral (CHL) and superior glenohumeral ligaments (SGHL) by a direct branch (d) of the axillary artery („subcoracoid artery"). SSC – subscapularis muscle; PMI – pectoralis minor muscle.

The branch from the suprascapular artery gives way to the superior transverse scapular ligament. This branch coursed in the supraspinatus from below for approximately 3mm before bifurcating into two smaller branches that entered the superior glenohumeral ligament at the medial third and the coracohumeral ligament via the upper surface (Fig. 7).

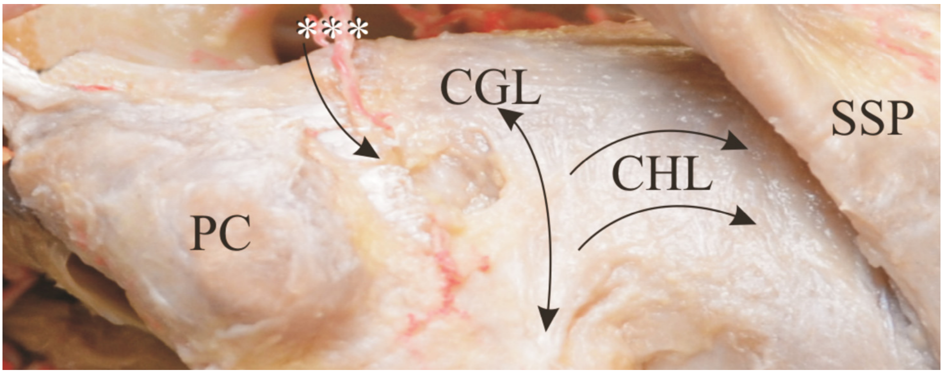

Figure 7. An anterosuperior view of the suprascapular artery branches (***) at the origin of the coracohumeral ligament (CHL). Other structures include the coracoid process (CP); coracoglenoid ligament (CGL); and supraspinatus muscle (SSP).

The anterior circumflex humeral artery had two smaller medial and lateral ascending branches. The ascending branches supplied the subscapularis tendon, the lateral third of the superior glenohumeral ligament, and the rotator interval (Figs 6A, 8).

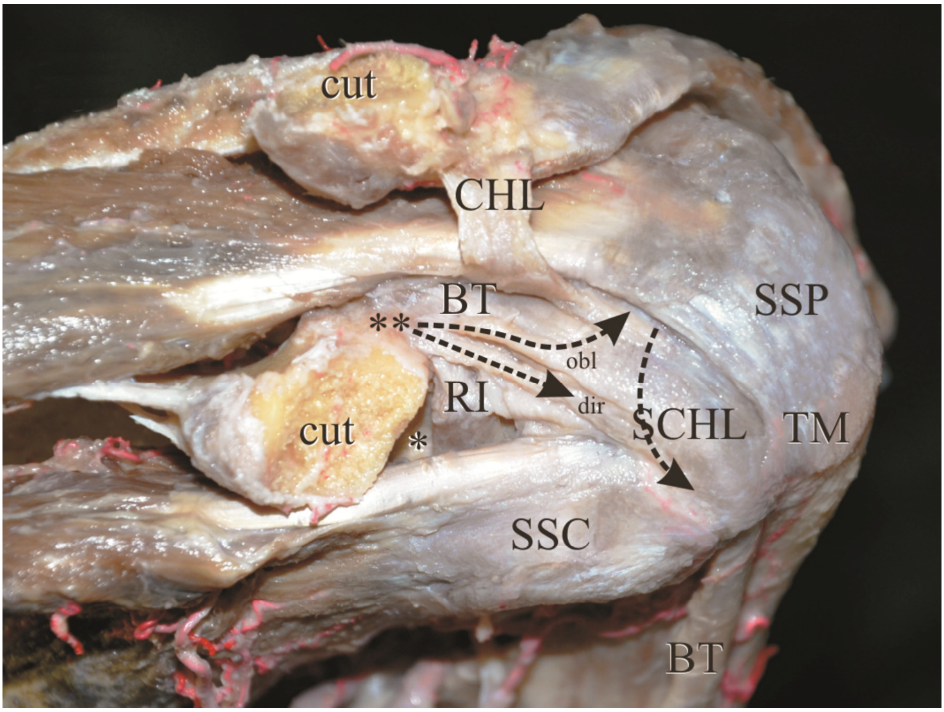

Figure 8. Latex-injected left shoulder specimen. The rotator interval (RI) between the tendons of the supraspinatus (SSP) and subscapularis (SSC) muscles was visualised with the coracohumeral ligament (CHL) and the superior glenohumeral ligament (SCHL) in terms of their oblique (obl) and direct (dir) parts. BT – tendon of the long head of the biceps brachii; TM – major tubercle of the humerus; cut – the coracoid process was cut and moved posterioly; *– middle glenohumeral ligament; **– supraglenoidal tubercle.

5.1.4. Blood supply per the glenocapsular ligament

The small branches of the circumflex scapular artery were located parallel to the connective tissue fibres of the glenocapsular ligament. The dominant ascending posterior branch of the circumflex scapular artery arose vertically in relation to the scapular neck (Figs 9–11).

The circumflex scapular artery split near the inferior part of the collum scapulae into posteriorly ascending and descending branches. The posterior ascending branch coursed towards the collum scapulae and supplied the supraspinatus muscle belly from below. This posterior ascending branch was also directly connected to small branches running laterally and medially to the posterior and posterosuperior parts of the joint capsule, and these small branches also supplied the glenocapsular ligament and the deep layer of the joint capsule (Figs 10, 11).

The posterior descending branches of the circumflex scapular artery supplied the infraspinatus, teres major, and minor muscle bellies on the articular side (Fig. 11).

The suprascapular artery supplied the infraspinatus tendon on the articular side (Fig. 11).

The posterior circumflex humeral artery supplied two-thirds of the posterior inferior surface of the deltoid muscle (Fig. 11).

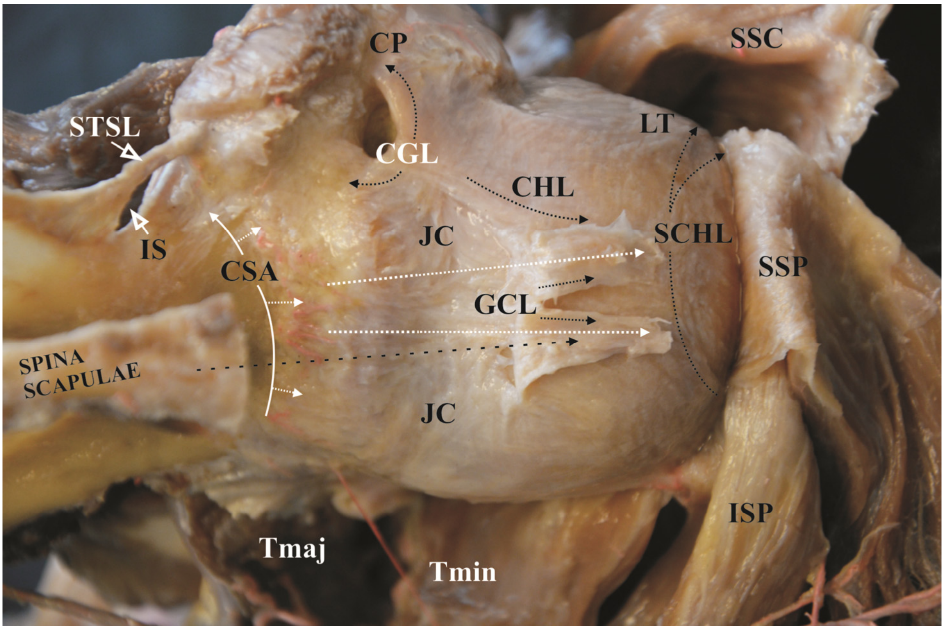

Figure 9. A superior view of a dissect specimen of the right glenohumeral joint with blood vessels. In this specimen, the glenocapsular ligament (GCL) consisted of two separate parts (*black paired arrow*), was separate from the collum scapulae and supraglenoid tubercle and located laterally from the collum scapulae (*two small black paired arrow*). Two parts of the glenocapsular ligament inserted into the semicircular humeral ligament (SCHL). The posterosuperior part is located in the gap between supraspinatus (SSP) and infraspinatus (ISP) tendons on the prolongation line of the spina scapulae (*black long west east arrow*). The posterior circumflex scapular artery (CSA) was cut from the small branches (*white three arrows*) that supply blood to the glenocapsular ligament (*white paired arrow*) and joint capsule (JC). Other structures include the lesser tubercle (LT), subscapularis muscle (SSC), teres minor (Tmin) and teres major muscles (Tmaj), coracoglenoidal ligament (CGL), coracohumeral ligament (CHL), coracoid process (CP), incisura scapulae (IS) and superior transverse scapular ligament (STSL).

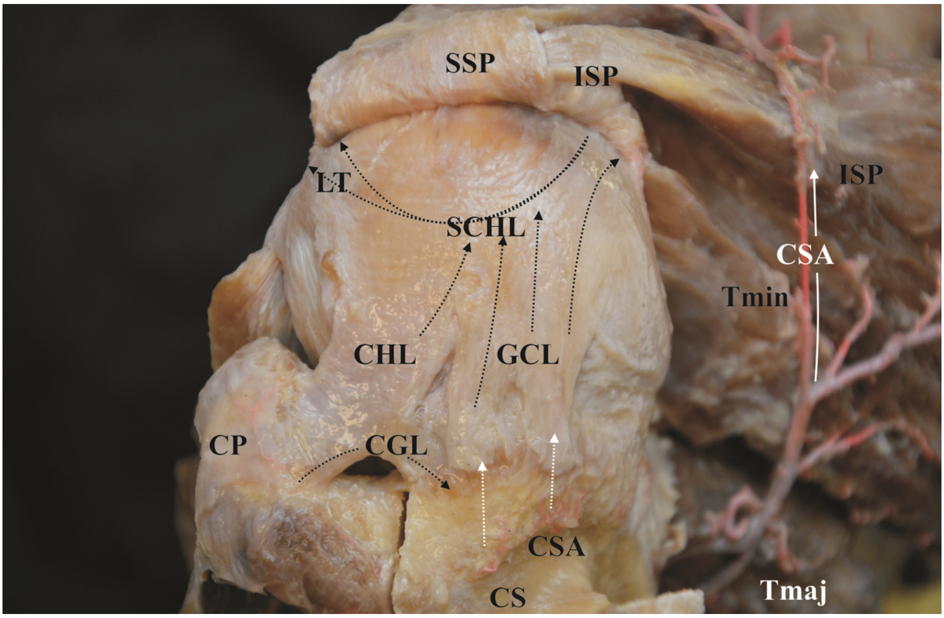

Figure 10. A superior view of a dissect specimen of the right glenohumeral joint with blood vessels. The posterior circumflex scapular artery (CSA) was cut from the small branches (*white paired arrows*) and placed laterally from the joint capsule (*white upward arrow*). These small branches supply blood to the mediosuperior (*black upward bold* arrow) and posterosuperior (*black upward paired arrows*) parts of the glenocapsular ligament (GCL). Other structures include the collum scapulae (CS), coracoglenoidal ligament (CGL), coracoid process (CP), coracohumeral ligament (CHL), semicircular humeral ligament (SCHL), lesser tubercle (LT), supraspinatus (SSP), infraspinatus (ISP), teres minor (Tmin) and teres major (Tmaj).

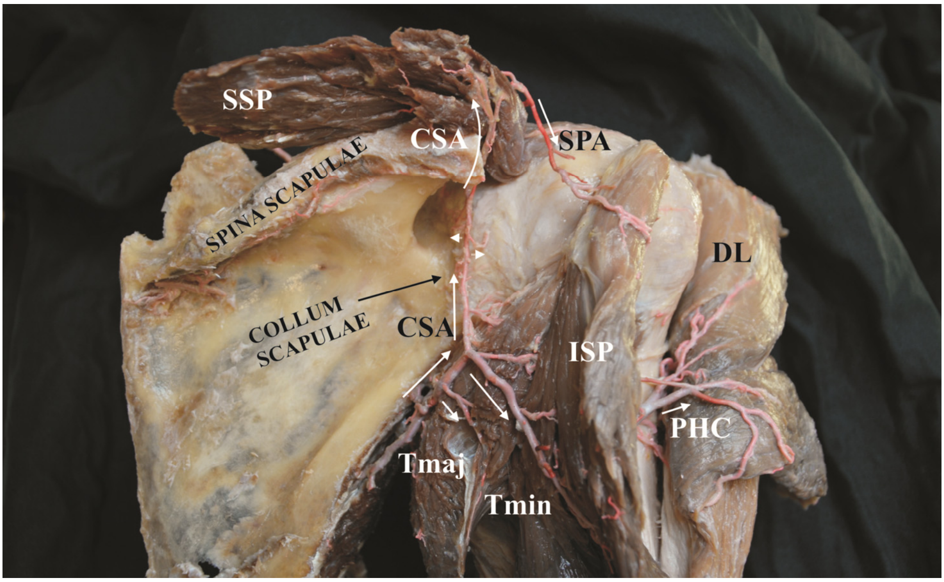

Figure 11. A posterior view of a dissect specimen of the right glenohumeral joint with its arterial network. The circumflex scapular artery (CSA) splits near the inferior part of the collum scapulae into the posterior ascending (*white upward arrow*) and descending (*white downward arrow*) branches. The posterior ascending branch supplies blood to the supraspinatus (SSP) muscle belly from below. Prior to reaching the SSP, small branches (*two small white arrow horizontally*) run laterally and medially from the CSA to supply the posterior and posterosuperior parts of the joint capsule. The posterior descending branches (*white downward paired arrow*) supply the infraspinatus (ISP) and teres major (Tmaj) and minor (Tmin) muscles bellies. The suprascapular artery (SPA) supplies the infraspinatus tendon on the articular-side. The posterior circumflex humeral artery (PHC) supplies blood to the deltoid muscle (DL).

5.1.5. Blood supply per the subacromial bursa and rotator cuff tendons on the bursal side

The subcoracoid artery ascended directly from the axillary artery, coursed cranially under the coracoid process, and entered the caudal bursa with the coracohumeral and superior glenohumeral ligaments (Figs 6AB).

The suprascapular artery provided small branches to the cranial part of the subacromial space via the rete acromiale and supraspinatus tendon on the caudal bursa (Figs 6A, 7).

The anterior humeral circumflex artery split into medial and lateral ascending branches. The medial branches supplied the subscapularis tendon and the anterior third of the caudal bursa under the coracoid process. The lateral branches supplied the long head of the biceps tendon and coursed under it laterally to form ascending and descending branches. The descending branches coursed towards the deltoid tuberosity. The ascending branches supplied the anterior third of the caudal subacromial bursa (Figs 6A, 12, 14).

The thoracoacromial artery supplied the subacromial space from the cranial part of the anterior third via branches to approximately the anterior third of the inferior surface of the belly of the deltoid muscle. The thoracoacromial artery also had small branches connected to the rete acromiale (Figs 12–14).

The posterior circumflex humeral artery and axillary nerve penetrated the quadrilateral space and then split into three groups of branches: deltoid branches to the cranial bursa, branches to the caudal bursa, and direct branches to the long head of the triceps. The deltoid cranial bursa branches covered approximately two-thirds of the posterior inferior surface of the deltoid muscle. The caudal bursa branches supplied the teres minor, infraspinatus tendons, and posterior and medial thirds of the caudal bursa (Figs 13, 14).

The direct branch from the axillary artery supplied the subscapularis tendon (Fig. 6A).

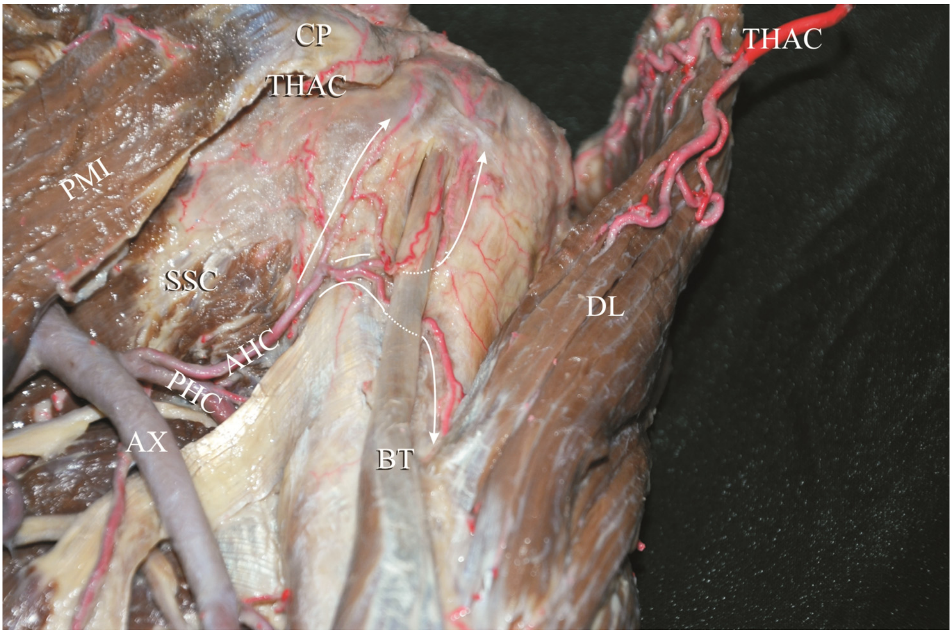

Figure 12. An anterior view of the main arteries and how they supply blood to the subacromial bursa. The thoracoacromial artery (THAC) supplies blood to the cranial part of the subacromial space, and the anterior circumflex humeral artery (AHC) with its medially and laterally ascending (*upward paired arrow*), and laterally descending branches (*downward arrow*), which supply blood to the caudal part. The anterior (AHC) and posterior (PHC) circumflex humeral arteries arise with a common trunk from the axillary artery (AX); BT, tendon of the long head of biceps brachii; SSC, subscapularis muscle; PMI, pectoralis minor muscle; CP, coracoid process; DL, deltoid muscle.

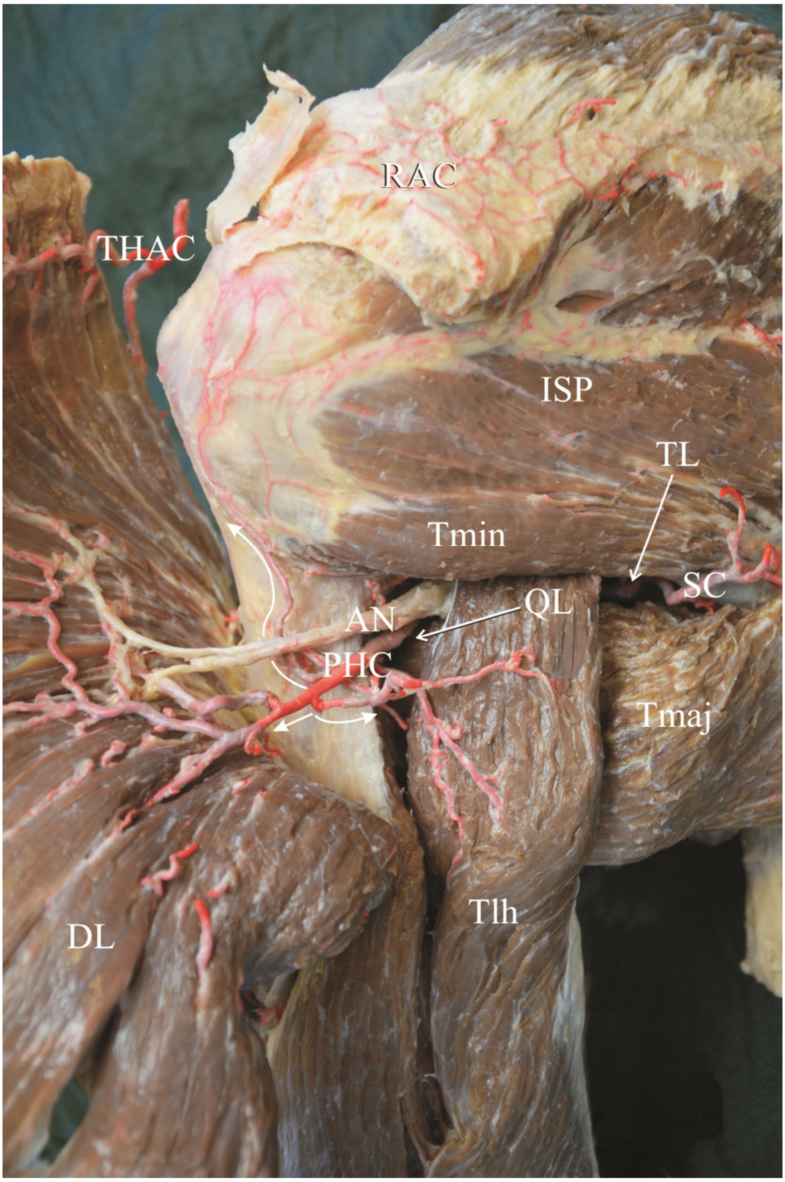

Figure 13. A posterior view of the main arteries and how they supply blood to the subacromial bursa and to other shoulder regions. The quadrilateral space (QL) with axillary nerve (AN) and with posterior circumflex humeral artery (PHC), and trilateral space (TL) with scapular circumflex artery (SC). The posterior circumflex humeral artery branches to the deltoid (DL) (*south west arrow*), to the triceps brachii of the long head muscles (Tlh) (*rightward arrow*), infraspinatus (ISP) (*upward arrow*), and teres minor (Tmin) (*upward arrow*) tendons. *THAC* thoracoacromial artery, *RAC* acromial rete, *Tmaj* teres major.

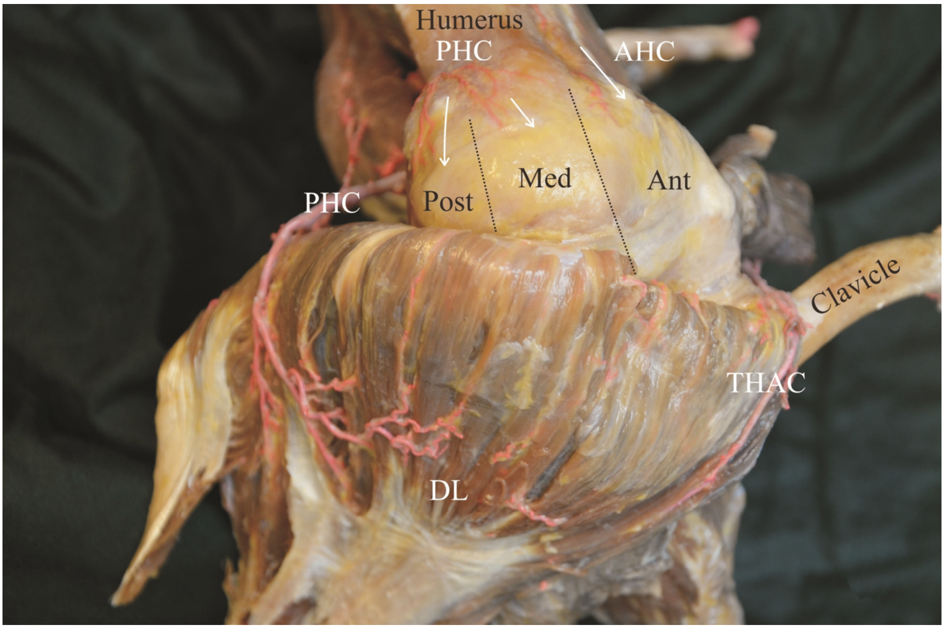

Figure 14. A superior view of a deltoid muscle released from the deltoid attachment of the humerus. A large branch of the posterior circumflex humeral artery (PHC) supplies the two-thirds of the posterior part of the deltoid muscle (DL), and the thoracoacromial artery (THAC) supplies the one-thirds of the anterior part of the deltoid muscle. The posterior circumflex humeral artery via its ascending branches, supplied the posterior (Post) and medial (Med) thirds of the caudal bursa. The anterior circumflex humeral artery (AHC), via its ascending branches, supplies the anterior (Ant) third of the caudal bursa.

5.2. Histology per the superior glenohumeral ligament

The direct and oblique parts of the superior glenohumeral ligament showed the typical features of dense connective tissue, with bundles of collagen fibres of parallel orientation in the middle part of the ligament. Between the parallel-orientated collagen fibres, typical fibrocytes lay individually, in pairs, or in rows (Fig. 15A). The origin and insertion showed typical characteristics of fibrocatilaginous tissue, with chondrocyte-like cells lying separately, in pairs, or in groups (Fig. 15B).

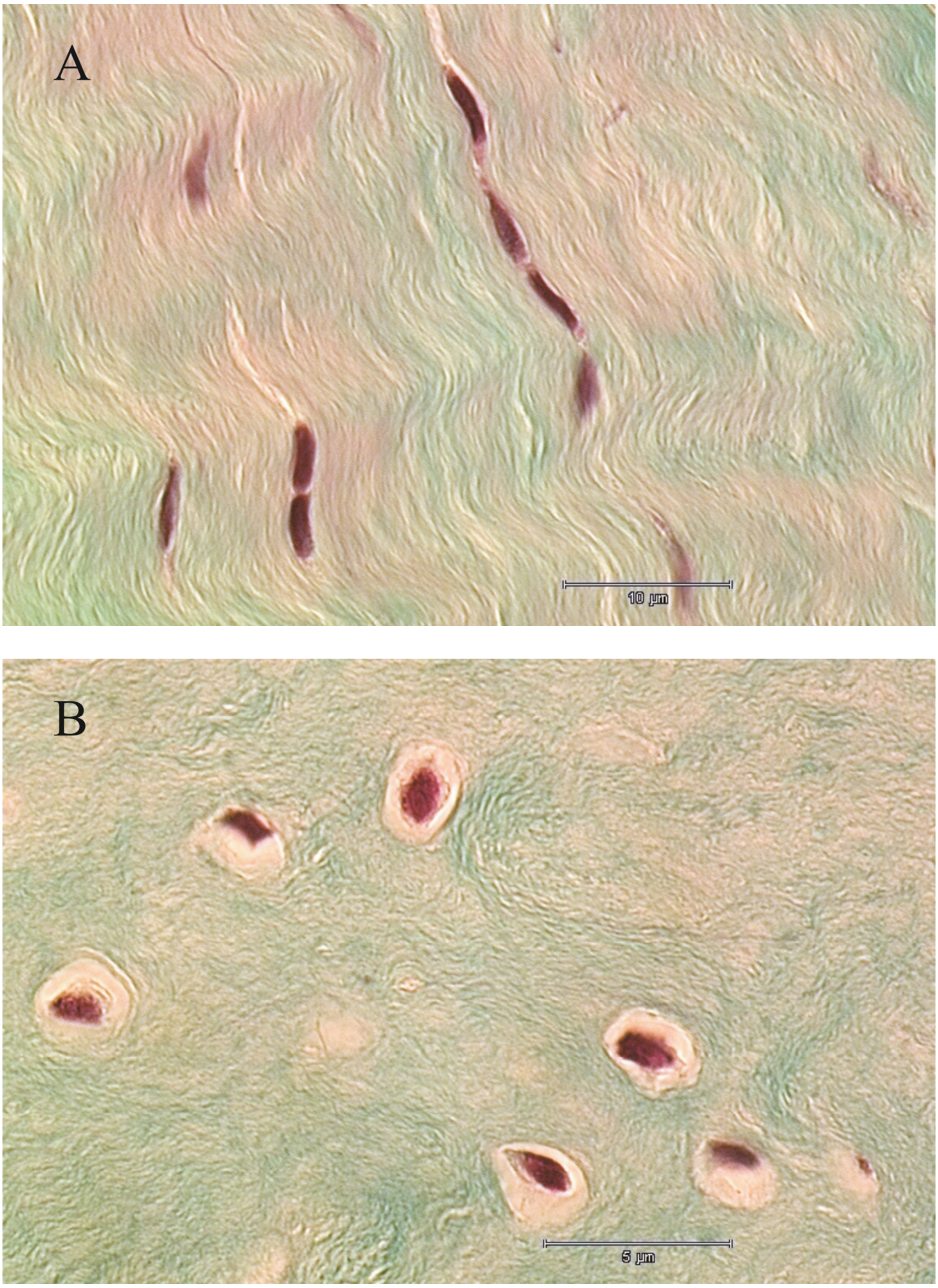

Figure 15. A, Overview of the middle part of the superior glenohumeral ligament (SGHL) at high magnification. The cells surrounded by the collagen fibres are typical fibrocytes, lying between the parallel – orientated collagen fibers individually, in pairs, or in rows. **B,** Overview of the cells of the superior glenohumeral ligament (SGHL) at the origin region. The fibrocartilaginous parts of the SGHL are populated with oval, chondrocyte-like cells.

The medial and lateral thirds of the superior glenohumeral ligament showed histologically typical characteristics of fibrocartilaginous tissue with masked collagen fibres and chondrocyte-like cells lying separately, in pairs, or in groups and fibrocytes lying individually, in pairs, or in rows. The mean ratio of Chondrocytes to Fibrocytes (CC/FC) was similar to the medial and lateral thirds: 1.13 ± 0.28 and 0.8 ± 0.12, respectively (Figs 16AC). The middle third of the ligament showed the typical features of a dense connective tissue with parallel-orientated bundles of collagen fibres and typical fibrocytes. Chondrocytes appeared occasionally in the middle third (Fig. 16B).

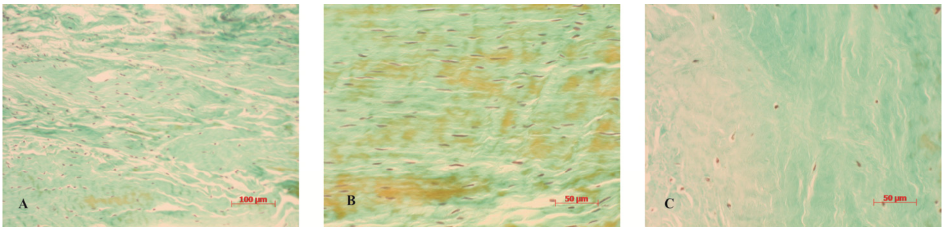

Figure 16. Light microscopic sections of the lateral (**A**), middle (**B**) and medial (**C**) thirds of the superior glenohumeral ligament (SGHL) after Trichrome Masson-Goldner staining. The middle third (**B**) of the superior SGHL showed parallel-oriented bundles of collagen fibres and typical fibrocytes; both are typical features of the parallel-orientated dense connective tissue. The lateral (**A**) and medial (**C**) third of the SGHL showed typical characteristics of the fibrocartilaginous tissue, with masked collagen fibres, chondrocytes lying individually and fibrocytes lying individually, in pairs, or in rows.

5.3. Immunohistochemical aspects of the blood supply per the superior glenohumeral ligament

The middle third of the superior glenohumeral ligament (SGHL) was highly vascularised, whereas the blood supply of the lateral and medial thirds was less dense (Fig. 17A–C). Figure 18A shows significant difference in means of SGHL and control. However, the mean difference of SGHL and control did not differ significantly among regions (Fig. 18B).

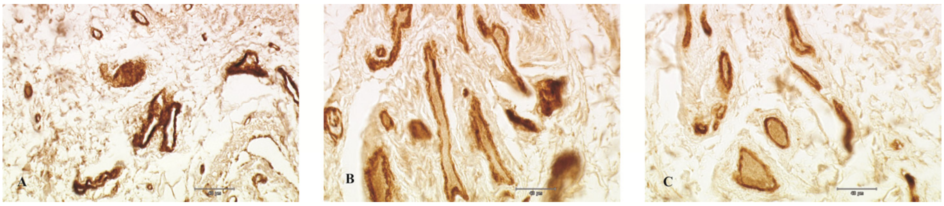

Figure 17. Light microscopic sections of the lateral (**A**), middle (**B**), and medial (**C**) thirds of the superior glenohumeral ligament (SGHL) after immunohistochemical stain for collagen type IV. The middle third (B) of the SGHL was more vascularised than the medial and lateral parts of the ligament

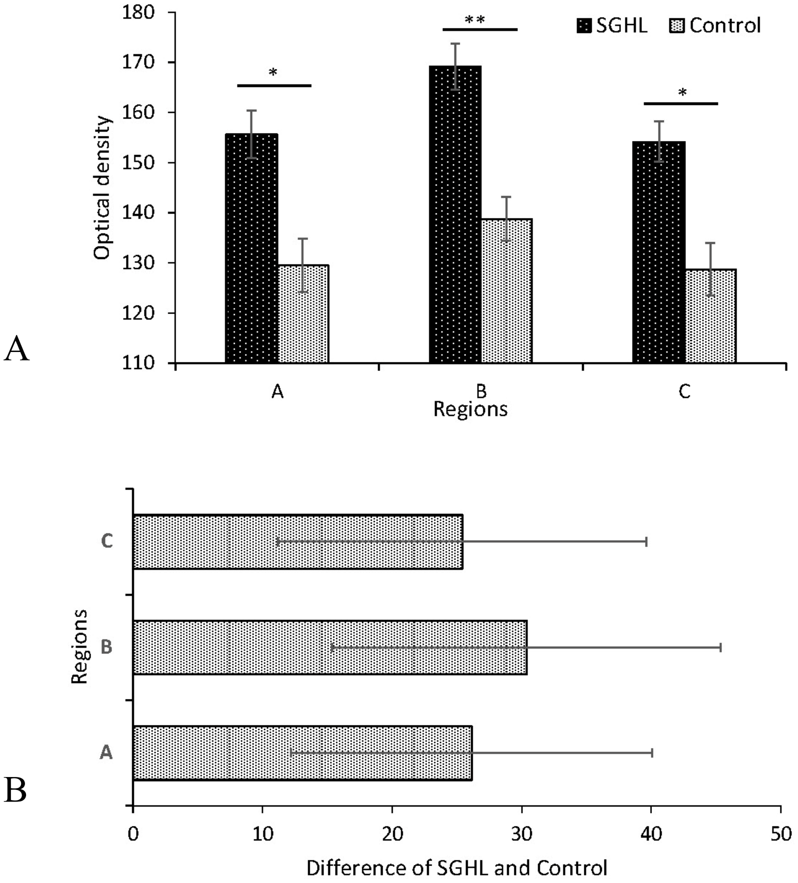

Figure 18. A, Antibody collagen type IV optical density in the lateral (A), middle (B), and medial (C) regions of the SGHL. All three regions with antibody collagen type IV have shown significant statistical differences compared to the control samples. The data are mean ± SEM; * $p < 0.01$; **$p < 0.001$ as compared to control. **B**, Mean of the difference of SGHL and control, ± SD.

6. DISCUSSION

The most important aspect of this study was the description of the blood supply to the superior part of the shoulder joint capsule.

6.1. The subacromial bursa and rotator cuff tendons on the bursal side

Investigation of the blood supply of the superior capsule is impossible without a description of the blood supply of the subacromial bursa and rotator cuff tendons on the bursal side. Due to its common involvement in different pathologies of the shoulder, blood supply to the subacromial bursa is a topic of continuing interest. Attempts to describe in detail this clinically important and anatomically complicated region have resulted in different classifications of the walls of the bursa and their blood supply (Yepes et al., 2007). To avoid misunderstandings concerning the investigated regions, the present study followed the classification of Tillmann and Gehrke (1995).

Yepes et al. (2007), who described the blood supply of six different subacromial space walls, reported, similarly to Löhr and Uhthoff (2007), that the subacromial space is highly vascularised. They claimed that the main arteries that supply the bursa are the suprascapular and thoracoacromial arteries. Only in the „posterior wall" did Yepes et al. (2007) find branches of the scapular circumflex and posterior circumflex humeral arteries. The results of the present study are generally not comparable to those of Yepes et al. (2007) because of their different anatomical division of the bursa and investigation method. The present study found no evidence to support any direct involvement of the scapular circumflex artery in the blood supply of the subacromial space.

The present study shows that the suprascapular, anterior, and posterior humeral circumflex arteries supply the rotator cuff tendons on the subacromial bursal side. According to Ling et al. (1990), Garza et al. (1992), and Notarnicola et al. (2012), the rotator cuff tendons are supplied by the suprascapular, thoracoacromial, scapular circumflex, and anterior and posterior humeral circumflex arteries. With respect to the other arteries supplying the articular side the results of the present study are partly in accordance with these authors in terms of the bursal side of the rotator cuff tendon. Determe et al. (1996) indicated that the supraspinatus tendon is also supplied by the posterior humeral circumflex artery. According to the data of the present study, the posterior circumflex artery does not supply the supraspinatus tendon, but the bursal side of the infraspinatus and teres minor tendons.

Most researchers have not focused on the blood supply of the whole bursa itself, but the supply to the rotator cuff (Brooks et al., 1992; Determe et al., 1996; Katzer et al., 1997). Similarly to previous studies, the present study described the blood supply to the caudal and cranial border of the subacromial bursa. The vascular supply of the caudal part of the subacromial bursa has been of greater interest than the cranial part because the former is connected to rotator cuff tendons. According to the literature, the rotator interval, which is in the caudal bursa, is a surgically important landmark for repair of supraspinatus tendon tears (Uhthoff et al., 2003; Millett et al., 2012; Moen et al., 2014). The present study has shown that the subcoracoid artery branches to the superior glenohumeral ligament and to the inferior surface of the coracohumeral ligament, which has not previously been described.

The results of the present study show that the suprascapular, anterior, and posterior circumflex humeral arteries supply the subacromial bursa in the caudal part and rotator cuff tendons on the bursal side. These findings support the results of Gumina et al. (2006) and Löhr and Uhthoff (2007), who showed histologically that the caudal bursa and rotator cuff tendons are linked to the musculotendinous junction. According to Uhthoff and Sakar (1991), the vascularised connective tissue covering the area of a rupture mainly consists of fibrovascular tissue from the wall of the subacromial bursa. Therefore, Uhthoff and Sakar (1991) recommended performing an extensive bursectomy during surgical repair of a rotator cuff rupture.

6.2. The anterosuperior part of the shoulder joint capsule

The results of the present study indicate that the superior glenohumeral ligament is a constant anatomical structure consisting of direct and oblique parts, which supports the findings of Kolts et al. (2002), who described the direct and oblique fibres of the superior glenohumeral ligament. According to Werner et al. (2000), the „*fasciculus obliquus*" is the transverse band of the rotator cuff, not a part of the superior glenohumeral ligament. Instead, the „*fasciculus obliquus*" represents the semicircular humeral ligament. The present study has found that the oblique fibres of the superior glenohumeral ligament orginates from the supraglenoid tubercle and the direct fibres from the glenoid labrum. These findings partly correlate with previous research indicating that the superior glenohumeral ligament originated from the supraglenoid tubercle (Ferrari et al., 1990; Burkart and Debski, 2002; Dunham et al., 2012) or the glenoid labrum (Palmer et al., 1994; Steinbeck et al., 1998; Pradhan et al., 2001; Ide et al., 2004). However, these studies described the superior glenohumeral ligament as consisting of only one part of fibre. Hunt et al. (2007) described two origin areas, but not two separate parts to the superior glenohumeral ligament. Several authors have recently described various places of origin, e.g. the supraglenoid tubercle, glenoid labrum, glenoid cavity, long head of the biceps tendon, middle glenohumeral ligament, and some combinations of these, but did not find the two parts of the superior glenohumeral ligament (Lee et al., 2007; Petchprapa et al., 2010; Llopis et al., 2015). The present study has described the superior glenohumeral ligament in fine detail, supporting the previous findings of Kolts et al. (2002).

Chloros et al. (2013) and Itoigawa and Itoi (2015) also described direct and oblique parts of the superior glenohumeral ligament, but only in review articles. The present study has shown that direct fibres of the superior glenohumeral ligament insert partly into the lesser tubercle. Some direct fibres bridge over the intertubercular groove and form the upper part of the transverse humeral ligament. The oblique fibres insert into the semicircular humeral ligament (rotator cable), wich is in agreement with the studies of Kolts et al. (2002) and Kask et al. (2008). The findings of the present study do not support the previous claim that the insertion region is only at the lesser tubercle of the humerus (Steinbeck et al., 1998; Burkart and Debski, 2002; Ogul et al., 2014; Woertler, 2015).

The histological results of the present study indicate that the origin and insertion area of the superior glenohumeral ligament showed typical characteristics of fibrocartlaginous tissue, with chondrocyte-like cells lying separately, in pairs, or in groups. These findings support the previous research of Kolts et al. (1994), Barthel et al. (2003), Merila et al. (2008), and Kordasiewicz et al. (2016), who found that fibrocartilaginous tissue is located in the sliding areas of the ligament and its origin and insertion regions. Between the origin and insertion regions is dense connective tissue with parallel-oriented bundles of collagen fibres and typical fibrocytes.

The main blood supply source to the superior glenohumeral ligament in all specimens was the infrequently studied subcoracoid artery. The subcoracoid artery is a single direct branch of the axillary artery that courses towards the coracohumeral ligament and divides into two smaller main branches, which spread between the collagen fibre bundles. The direction of the subcoracoid artery blood flow correlates with the results Gohlke et al. (1994), who found that the vessels in the capsular layer of the rotator cuff run in the direction of the coracohumeral fibre bundles and lie between them. Data from the present study indicates that the subcoracoid artery supplies blood to the structures of the rotator interval and to the coracohumeral and superior glenohumeral ligaments. This result supports those of Fallon et al. (2002), who suggested that the rotator interval is generally well vascularised.

After the separation of the superior glenohumeral ligament from the coracohumeral ligament, the small artery branches of the superior glenohumeral ligament became partly invisible with the dissection microscope. To investigate the vascularisation of the superior glenohumeral ligament in the regions where the blood vessels became barely visible, the immunohistochemical method was used. The results of the immunohistochemistry indicate that the middle third of the superior glenohumeral ligament is well vascularised, whereas the blood supply of the medial and lateral thirds is considerably less dense. This data was in agreement with the histological results, explaining the different structure of the superior glenohumeral ligament in the three regions investigated; the middle dense connective tissue and the medial and lateral fibrocartilaginous tissue are well vascularised. These results corroborates those of Kolts et al. (1994), and Tillmann and Gehrke (1995), who found that the fibrocartilaginous tissue is not completely avascular.

According to Determe et al. (1996), direct branches from the axillary artery („suprahumeral artery") run to the subscapular muscle. These authors confirmed that the rotator interval is only slightly vascularised by small vessels from the axillary artery. This was not supported by the present results. The unofficial term „suprahumeral artery" was also used in the study of glenohumeral joint vasculature by Löhr and Uhtoff (1990), but without any description of the origin and course of the artery. The „subcoracoid artery" was mentioned in a study by Garza et al. (1992). Unfortunately, the region of the blood supply of the „subcoracoid artery" was not described; therefore, their findings are not comparable with the results of the present study.

In the previous studies of glenohumeral joint vasculature, the majority of the investigators focused on the „hypovascular zone" of the supraspinatus tendon (Ling et al., 1990; Löhr and Uhthoff, 1990; Determe et al., 1996; Katzer et al., 1997; Biberthaler et al., 2003). The vascular network of the joint capsule and ligaments has received of less interest, with a few exceptions (Cooper et al., 1992; Werner et al., 2002; Fallon et al., 2002; Yepes et al., 2007). In a study by Ling et al. (1990), the course and branches of the anterior circumflex humeral artery in correlation with the vasculature of the supraspinatus tendon is described, but their role in the vasculature of the rotator interval is undefined.

6.3. The posterosuperior part of the shoulder joint capsule

The glenocapsular ligament consisted of two parts, mediosuperior and posterosuperior. The mediosuperior part varied in shape and was absent in 12 of 28 cases. The results of the present study support the previous finding of a new, glenocapsular ligament within the posterosuperior part of the shoulder joint capsule (Kolts, 2000).

Burkhart et al. (1993) described a new intraarticular band-like structure within the superior shoulder joint capsule and named it the „rotator cable". Later it was described by Kolts et al. (2000) as a capsular „semicircular humeral ligament". According to Rahu et al. (2016), the inferior fibres of the supraspinatus tendon attach to the semicircular humeral ligament. Kolts et al. (2000) have stated that the semicircular humeral ligament is the place of origin of the coracohumeral ligament. The results of the present study indicate that the glenocapsular ligament also inserts into the semicircular humeral ligament. The posterior fibres of the glenocapsular ligament run parallel with the fibres of the semicircular ligament to their insertion region between the middle and inferior facets of the greater tubercle of the humerus.

The underlying deep layer of the joint capsule and the glenocapsular ligament itself are supplied with blood by the circumflex scapular artery. The data of the present study are partly in alignment with the results of Andary and Petersen (2002), who indicated, using a schematic illustration, that the posterior part of the joint capsule is mostly supplied via the suprascapular and circumflex scapular arteries. We also partly concur with Cooper et al. (1992), who claimed that the whole shoulder joint capsule was supplied by the branches from the suprascapular, circumflex scapular, and posterior circumflex humeral arteries.

6.4. Clinical relevance

Open, mini-open, and arthroscopic surgeries can be used to perform rotator cuff repair and acromioplasty (Burkhart, 2000; Weber et al., 2002; Denard et al., 2011; Millett et al., 2012; Mook et al., 2014; Petri et al., 2016). The open rotator cuff repair is often performed using a lateral deltoid-splitting approach. During this procedure, the cranial bursa border is removed while often leaving the caudal bursa completely unharmed (Millet et al., 2012; Petri et al., 2016). According to the data of the present study, it is safe to perform the skin incision in the middle third of the deltoid. This incision might expose the thoracoacromial and posterior circumflex humeral arteries to risk, but their main branches will remain intact. Hata et al. (2004) found that mini-open rotator cuff repair caused fewer deltoid muscle injuries than the standard open repair. The results of the present study also indicate that a mini-open incision approach should result in fewer vascular injuries.

It is necessary to see the rotator interval during open surgical procedures, because this region is typically barricaded by the coracoid process and coracoacromial ligament (Hunt et al., 2007; Millett et al., 2012). Burkhart (2000) claimed that arthroscopic evaluation allows much more accurate assessment of cuff tears configurations than conventional open inspection. To expand the visible area during the arthroscopic procedure, the subacromial bursa can be resected (Tischer et al., 2011; Mook et al., 2016). The present findings indicate that the blood supply of the caudal bursa and rotator cuff tendons is jeopardised during a bursectomy.

The posterior and anterior portals can be used in arthroscopic shoulder surgeries, and most shoulder joint pathologies can be treated through these portals. The arthroscopic anterior portal is typically placed between the anterolateral acromion and the coracoid process, and the portal is associated with a risk of rotator interval structure injuries (Millett et al., 2012). The results of the present study show that the rotator interval structures are supplied by the subcoracoid, anterior circumflex humeral, and suprascapular arteries. The authors hope that the vascular description given in the present study can help surgeons minimise the risk of perioperative bleedings and other complications.

Shoulder joint anatomy is of interest to orthopaedic surgeons, and the posterosuperior part has gained the attention of biomechanics (Kirchhoff and Imhoff, 2010; Adams et al., 2016; Beirer et al., 2016). Posterosuperior shoulder injuries can cause problems early in throwing athletes' careers (Burkhart et al., 2003; Nakagawa et al., 2006; Braun et al., 2009; Fessa et al., 2015; Corpus et al., 2016; Reuter et al., 2017). However, the proportion of surgeries performed on the posterior part of the shoulder is far lower compared to the anterior part. Knowledge of the vascular anatomy presented in the present study is important to incisions made to the posterior part of the shoulder. The authors hope that these new anatomical findings of the posterosuperior shoulder joint structures and their blood supply will help shoulder surgeons better understand shoulder pathologies and thus aid in selection of the optimal treatment method.

The present study had some limitations. The shoulder specimens used were from elderly donors. Therefore, the generalisability of our results to younger populations might be limited. However, it is unlikely that the vascular and ligament anatomy of uninjured shoulders can change macroscopically with age. Another limitation was the lack of measurements of length, area, and volume of the structures in this purely descriptive study.

7. CONCLUSIONS

1. The superior glenohumeral ligament is a constant anatomical structure consisting of direct and oblique parts, which have different origins and insertions areas. The direct part originates from the glenoid labrum and the oblique part from the supraglenoid tubercle. The oblique part inserts into the semicircular humeral ligament (rotator cable) under the coracohumeral ligament. The direct part inserts partly onto the lesser tubercle, partially bridges over the intertubercular sulcus, and forms the upper part of the transverse humeral ligament.
2. The superior glenohumeral ligament receives blood from the anterior circumflex humeral, suprascapular, and subcoracoid arteries. The superior glenohumeral ligament is highly vascularized, and the direct branch of the axillary artery, the so-called „subcoracoid artery", is the main blood source supplying the superior glenohumeral and coracohumeral ligaments.
3. Blood supply to the subacromial bursa in the caudal part and rotator cuff tendons on the bursal side is linked to the same arteries: suprascapular, and anterior, and posterior circumflex humeral arteries. In addition, the subcoracoid artery also supplied rotator interval structures close to the caudal bursa.
4. The glenocapsular ligament is a constant anatomical structure consisting of two parts, posterosuperior and mediosuperior. The glenocapsular ligament and the posterosuperior part of the joint capsule show high vascularisation via the posterior branch of the circumflex scapular artery.

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9. SUMMARY IN ESTONIAN

Õlaliigese kapsli ülaosa struktuur ja verevarustus

Sissejuhatus

Õlaliigeses liigestuvad omavahel suhteliselt suur õlavarreluu pea ja abaluu väike liigeseõõnsus, õlavarreluu pea suhe liigeseõõnsusesse koos liigesemokaga on suhtes 3:1-le (Lepp, 2013). Liigesekihn, mis ümbritseb õlaliigest, on avar, õhuke ja lõtv, mida tugevdavad sidemed ning lihaselis-kõõluseline rotaatormansett. Õlaliigese rohked vigastused on tingitud tema anatoomilisest ehitusest ja ulatuslikust liikuvusest. 30% üle 40-aastastest inimestest esineb õlakahjustusi ning vanusega suureneb see protsent märgatavalt. Õlaliigese patoloogilised protsessid − õlaliigese nihestused, liigesesisesed pitsumised, bursiidid, rotaatormanseti lihaste ja kõõluste rebendid kutsuvad esile ägeda või kroonilise õlavalu, mis piirab inimeste igapäevast käelist tegevust ja alandab elukvaliteeti.

Õlaliigese kapsli eesmis-ülemises osas *m. supraspinatus*'e ja *m. subscapularis*'e kõõluste vahel asub rotaatorintervall, mille struktuurideks on *lig. coracohumerale*, *lig. glenohumerale superius* ning *m. biceps brachii* pika pea kõõlus. Rotaatorintervall on kirurgiliselt oluline piirkond avatud ja artroskoopiliste operatsioonide läbiviimiseks. Seetõttu on viimasel ajal hakatud rohkem tähelepanu pöörama rotaatorintervalli moodustuvate struktuuride nagu *lig. coracohumerale* ja *glenohumerale superius*'e vigastustele. Paljudes artiklites on kirjeldatud *lig. glenohumerale superius*'e lõtvust ja selle sideme rebendit, mille tõttu võib tekkida õlaliigeses ebastabiilsus. Õlaliigese kapsli tagumis-ülemine osa pole uurijate poolt nii palju tähelepanu pälvinud kui kapsli eesmine osa. Varasemates artiklites on kirjeldatud, et viskealade sportlaste vigastused tekivad tagumis-ülemise õlaliigese kapsli piirkonnas, kuid nende vigastuste biomehaanika on tänaseni väheuuritud valdkond.

Kirjanduse andmetel on teada, et vähenenud verevarustus õlaliigese rotaatormanseti lihaste kõõlustes põhjustab degeneratiivseid patoloogilisi muutusi. Vähenenud verevarustusega piirkonda, mis asub *m. supraspinatus*'e kõõluses, kirjeldas esmakordselt Codman 1934. aastal. Hiljem on Mosely oma artiklis väitnud, et rotaatormanseti kõõlused on kogu eluaja vältel verega hästi varustatud, kuid autor „hüpovaskulaarset tsooni" välja ei too. Mosely seisukohtadele vastupidiselt on mitmed hilisemad autorid uurinud „hüpovaskulaarset tsooni", mis asub peamiselt *m. supraspinatus*´e kõõluses. 2002 aastal kirjeldasid Andary ja Petersen oma artiklis, et hüpovaskulaarne ala esineb hoopis õlaliigese kapslis, õlavarreluu pea suure köbrukese piirkonnas. Kirjanduse andmetel on mitmed autorid uurinud rotaatormanseti lihaste kõõluste ja kapsli verevarustust üldiselt, kuid keegi pole siiani kapslis asuvate sidemete verevarutust eraldi kirjeldanud. Kirjanduse ülevaatest on teada, et rotaatormanseti kõõlused moodustavad *bursa subacromialis*'e alumise seina, mistõttu rotatormanseti kõõluste verevarustus on otseselt seotud limapauna verevarustusega.

Viimase 30 aastaga on suurenenud õlaliigese artroskoopiliste operatsioonide osakaal ja on paranenud magnetresonantsdiagnostika meetodi tundlikkus, mis vajavad üha rohkem struktuuride detailset anatoomilist kirjeldust. Seetõttu keskendusime käesolevas uurimuses õlaliigese kapsli ülaosa struktuuride ja nende verevarustuse kirjeldamisele.

Uurimuse eesmärgid

Uurimuse üldeesmärgiks oli detailselt kirjeldada *bursa subacromialis*´e ja õlaliigese kapsli ülaosa tugevdavate sidemete verevarustust vanematel inimestel.

1. Uurida detailselt *lig. glenohumerale superius*´e makro- ja mikroanatoomilist struktuuri.
2. Selgitada *lig. glenohumerale superius*´e verevarustuse iseärasusi.
3. Uurida ja kirjeldada *bursa subacromialis*´e nii kraniaalse kui kaudaalse osa ning rotaatormanseti lihaste kõõluste verevarustust.
4. Anda õlaliigese kapsli tagumis-ülemise osa ja *lig. glenocapsulare* verevarustuse detailne anatoomiline kirjeldus.

Materjal ja meetod

Makroskoopiliselt uuriti *lig. glenohumerale superius*'e ja *lig. glenocapsulare* struktuuri 29 (13 naist/16 meest) fikseeritud õlaliigese preparaadil.

Makroanatoomiliselt uuriti *lig. glenohumerale superius*'e ja *lig. glenocapsulare* ning *bursa subacromialis*´e verevarustuse iseärasusi 42 (16 naist/26 meest) fikseeerimata õlaliigese preparaadil.

Histoloogiliselt ja immunohistoloogiliselt uuriti *lig. glenohumerale superius*'e struktuuri ja verevarustust 30 (11 naist/19 meest) fikseerimata õlaliigese preparaadil.

Uurimistöös kasutati annetajatelt saadud õlaliigeseid koostöös Lübecki Ülikooli Anatoomia Instituudiga.

Järeldused ja kokkuvõte

1. *Lig. glenohumerale superius* on anatoomiliselt konstantne struktuur, mis koosneb kahest osast: *pars obliqua* ja *pars directa*. *Lig. glenohumerale superius*'e kaks osa omavad erinevaid algus- ja kinnituskohti. *Pars directa* algab *labrum glenoidale*´elt ja kinnitub ühe osaga *tuberculum minus*'ele ning teine osa sellest ületab *sulcus intertubercularis*'e moodustades *lig. transversum humeri* ülemise osa. *Pars obliqua* saab alguse *tuberculum supraglenoidale*'lt ja kinnitub *lig semicirculare humeri*'le, mis asub *lig. coracohumerale* all.
2. *Lig.glenohumerale superius* on hästi varustatud verega ja verevarustusest võtavad osa järgmised arterid: *a. suprascapularis*, *a. circumflexa humeri*

anterior ja „*a. subcoracoidea*". *A. subcoracoidea* saab alguse *a. axillaris*'est ja kulgeb *lig. coracohumerale* kaudu *lig. glenohumerale superior*'isse ja on selle sideme peamiseks verevarustuse allikaks.

3. *Bursa subacromialis*'e kaudaalne osa ja rotaatormanseti lihaste kõõluste vereevarustus on seotud samade arteritega: *a. circumflexa humeri anterior* ja *posterior* ning *a. suprascapularis*. Uurimus näitas, et *bursa subacromialis*'e kaudaalsesse ossa jääb rotaatorintervall, mille struktuurse osa moodustavad *ligg. coracohumerale* ja *glenohumerale superius* ning neid siudemeid varustab verega peamiselt *a. subcoracoidea*.
4. Õlaliigese kapsli ülemis-tagumises osas asub anatoomiliselt konstantne sidemeline struktuur − *lig. glenocapsulare*, mis koosneb kahest erinevast osast: *pars mediosuperior* ja *pars posteriosuperior*. Õlaliigese kapsli ülemis-tagumine osa ja *lig. glenocapsulare* on hästi verega varustatud *a. circumflexa scapulae* tagumise haru kaudu.

Uurimistöö tulemused täiendavad meie teadmisi õlaliigese kapsli ülemises piirkonnas asuvate anatoomiliste struktuuride osas. Väitekirja autori ja kaasautorite arvates aitavad detailsed anatoomiliste struktuuride kirjeldused kirurgidel ära hoida selles õlaliigese piirkonnas avatud või artroskoopiliste operatsioonidega seotud komplikatsioone.

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PUBLICATIONS

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Education:

2011–	PhD student, University of Tartu, Faculty of Medicine
1990–1991	University of Tartu, Maarjamõisa Clinical Hospital of Tartu, intership
1984–1990	University of Tartu, Faculty of Medicine
1981–1983	University of Tartu, Faculty of Economy
1970–1981	Tartu Secondary School No3

Professional employment:

2003–	University of Tartu, Department of Anatomy, Senior Assistant
1997–2003	University of Tartu, Department of Anatomy, Assistant
1994–1997	University of Tartu, Department of Anatomy, Senior Labassistant
1990–1993	University of Tartu, Department of Anatomy, Research worker
2012–	Põlva Hospital, doctor
2012–	Tartu University Hospital, doctor
2010–2012	East Tallinn Central Hospital, doctor
2006–2009	Valga Hospital, doctor

Professional organisations:
Anatomical Society of Finland
American Association of Clinical Anatomists
Baltic-Germany Society of Doctors
Estonian Society of Doctors
Estonian Society of Internists

Scientific work:
13 scientific articles published in international journals; eight others scientific articles, 15 poster presentations, and two oral presentations at international conferences.

Publications:

1. Kask K, Põldoja E, Lont T, Norit R, Merila M, Busch LC, Kolts I. Anatomy of the superior glenohumeral ligament. J Should Elbow Surg. 2010; 19:908–916.
2. Põldoja E, Rahu M, Kask K, Bulezca T, Weyers I, Kolts I. Blood supply of the superior glenohumeral ligament: A gross anatomical and histological study. Austin J Anat 2016; 3(1): 1048.
3. Rahu M, Kolts I, Põldoja E, Kask K. Rotator cuff tendon connections with the rotator cable. Knee Surg Sports Traumatol Arthrosc 2016; 16:4148–4151.
4. Põldoja E, Rahu M, Kask K, Weyers I, Kolts I. Blood supply oft he subacromial bursa and rotator cuff tendons on the bursal side. Knee Surg Sports Traumatol Arthrosc 2016; 25:2041–2046.
5. Põldoja E, Rahu M; Kask K, Kartus JT, Weyers I, Kolts I. The glenocapsular ligament and the posterosuperior part oft he joint capsule oft he shoulder are well vascularized. Knee Surg Sports Traumatol Arthrosc 2017; 26:146–151.

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1990–1991	Tartu Ülikool, Tartu Maarjamõisa Kliiniline Haigla, intern
1984–1990	Tartu Ülikool, arstiteaduskond
1981–1983	Tartu Ülikool, majandusteaduskond
1970–1981	Tartu 3.Keskkool

Teenistuskäik:

2003	Tartu Ülikool, Anatoomia Instituut, vanemassistent
1997–2003	Tartu Ülikool, Anatoomia Instituut, assistent
1994–1997	Tartu Ülikool, Anatoomia Instituut, vanemlaborant
1990–1993	Tartu Ülikool, Anatoomia Instituut, staźöör-uurija

2012–praeguseni	AS Põlva Haigala, üldarst
2012–praeguseni	Sihtasutus Tartu Ülikooli Kliinikum, üldarst
2010–2012	AS Ida-Tallinna Keskhaigla, üldarst
2006–2009	AS Valga Haigla, üldarst

Osalemine seltsides ja ühendustes:
Soome Anatoomide Selts
Ameerika Kliiniliste Anatoomide Ühendus
Saksa-Balti Arstide Liit
Eesti Arstide Liit
Eesti Sisearstide Selts

Teadustöö:
Ilmunud 13 teadusartiklit rahvusvahelise levikuga, kaheksa muud teadusartiklit, 15 posterettekannet ja kaks suulist ettekannet rahvusvahelistel konverentsidel.

Publikatsioonid:

1. Kask K, Põldoja E, Lont T, Norit R, Merila M, Busch LC, Kolts I. Anatomy of the superior glenohumeral ligament. J Should Elbow Surg. 2010; 19:908–916.

2. Põldoja E, Rahu M, Kask K, Bulezca T, Weyers I, Kolts I. Blood supply of the superior glenohumeral ligament: A gross anatomical and histological study. Austin J Anat 2016; 3(1): 1048
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