Arthroscopy of the shoulder

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in het openbaar te verdedigen
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door

Hendrikus Johannes Arens

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INTRODUCTION

In his first book Hippocrates (91) warns the physician to be wary, because the patient expects of the doctor a knowledge of the cause of his disease. The sick do not expect that the physician can cure all diseases, but they do expect an accurate prognosis based upon expert knowledge and experience gathered over a long period of time. This statement is as true nowadays, as it was 2400 years ago and it is especially pertinent when considering afflictions of the shoulder.

The complaint of pain in the shoulder, with or without pain radiating into the upper extremity, is common in general and orthopaedic practice and may present both the general practitioner, and the orthopaedic surgeon with confusing diagnostic problems.

In most cases, shoulder pain arises from a precise anatomical structure within the the shoulder region but it is also recognised that shoulder pain may be caused by pathological processes that lie in the domain of the neurologist, chest physician, cardiologist, gastro-enterologist, general and vascular surgeon. If this study is to consider the intrinsic causes of shoulder pain, then the differential diagnosis must also include a discussion of the extrinsic causes.

Although many surgeons have contributed to the study of shoulder surgery, Amory Codman (50) is the first one to have studied the shoulder in its entirety. His book "The Shoulder", published in 1934 was the first book to deal solely with the shoulder. His interest in the shoulder started during a trip in Europe. Whilst in Vienna he read the book of E. Albert, who described the subacromial bursa, a structure not described by Codman's teachers. Thereafter he studied the anatomy of the shoulder and researched its clinical problems. The works of Duplay, Hans Schaer, White (77) and contemporaries had found their sequel.

In 1961, Padberg (149) presented a clear analysis of the different causes of pain in the shoulder region and also dealt with the psychological problems of the neck, shoulder and arm.

copy of the shoulder are discussed and a survey is given of the possible pathological findings in a diseased shoulder using the arthroscope.

Chapter 5 contains an analysis of the information obtained in the group of 210 patients. Subdivisions are made according to the diagnosis formulated after open operation of the shoulder.

Furthermore an account is given of the results of the performed operations.

In chapter 6 firstly the reliability of arthroscopy will be discussed using the arthroscopic and operative findings to determine the specificity, sensitivity, predictive positive and predictive negative value of the arthroscopy of the shoulder and an interval of confidence of the probability to obtain a false positive or false negative result will be provided. Secondly the diagnostic value of arthroscopy of the shoulder will be discussed by analysing the diagnoses before arthroscopy, after arthroscopy and after operation and by comparing the subsequent outcomes.

In chapter 7 the preoperative diagnosis will be reviewed. A decision model will be developed based on the data of the first treated 210 patients. This model will be tested on a new group of 102 patients with intrinsic shoulder pain.

Furthermore a summary in English, Dutch and French will be presented.

The references will be followed by the summaries.

CHAPTER 1

ANATOMY

1.1 INTRODUCTION

The basic precepts of modern medicine dictate that to treat a diseased organ intelligently, the physician first must understand the normal physiology of that organ and in addition the alterations of physiology that occur in various pathological states. If one considers the shoulder as a subsystem of the human body, then the function of the shoulder is the output of this subsystem.

The subsystem consists of the anatomical structures of the shoulder, receiving their input through the nervous and vascular pathways arising in the central nervous system and the cardiopulmonary system. To understand both the normal physiology and the pathological changes of the shoulder, a knowledge of the anatomy of the shoulder is a prerequisite.

In this chapter the normal descriptive anatomy will be discussed as far as is necessary to understand normal shoulder function, the pathological states in shoulder disease, and the normal and the pathological findings during both arthroscopy and surgery of the shoulder. Especially profound study of the literature with respect to the capsular, ligamentous and tendinous structures of the shoulder was done with special emphasis on the vascular supply of the rotator cuff, as these structures are mostly involved in disorders of the shoulder joint. For a more general description we refer to the current textbooks of anatomy (12,78,179,181).

1.2 THE JOINTS OF THE SHOULDER

Four bones are involved in shoulder movement: the manubrium sterni, the clavicle, the scapula and the humerus. The shoulder cannot be looked upon as a joint in a narrow sense like the other joints of the human body. The junction of the upper limb with the trunk consists of three true and two pseudo joints. In several papers one can find more or less detailed analyses (48,63).

The true joints are the glenohumeral joint, the acromioclavicular joint and the sternoclavicular joint. The pseudo-joints are the scapulothoracic gliding system and the subcoraco-acromial gliding system.

Fig. 1.1 The joints of the shoulder.
 1. clavicle, 2. coracoid process, 3. trapezoid lig.,
 4. conoid lig., 5. first rib, 6. sternum, 7. costal face of
 scapula, 8. acromion, 9. humerus.

1.2.1 The glenohumeral joint

The glenohumeral joint consists of the humeral head and the glenoid fossa. The head of the humerus shows a relative inclination in respect to the shaft of the humerus and a relative retroversion in respect of the distal end of the humerus. The angle of inclination ranges from 133 to 150 degrees. The average angle of retroversion is 20 degrees (Saha, Testut (166,168,169)). The articular surface of the head of the humerus has an average surface area of

one third of an irregular sphere. The vertical diameter is on average 48 mm. and the transverse diameter measures on average of 45 mm. The oval glenoid fossa has an average vertical diameter of 35 mm and an average transverse diameter of 25 mm. The slightly concave glenoid fossa is approximately one fourth of the convex humeral head. The joint itself has no intrinsic stability. The glenoid labrum does not deepen the glenoid fossa substantially.

Mosely and Overgaard (128,131) concluded from a study on 45 embryo joints and joints obtained from cadavers, that the labrum must be considered as a superfluous part of the capsule. Its composition consists of dense fibrous tissue without cartilage except for a thin margin near the glenoid fossa. The shape of the labrum changes during rotation of the humeral head. They observed that the anterior part of the labrum disappears during external rotation.

Fig. 1.2

Lateral aspect of the shoulder joint.

1. coracoid process, 2. coraco-acromial lig.,
3. acromion, 4. humeral head.

The glenohumeral capsule and ligaments

The glenohumeral articular surfaces are kept apposed by the glenohumeral capsule, its ligaments and the tendons of the rotator cuff. The upper segment of the glenohumeral capsule and the coracohumeral ligament contribute to the vertical stability of the humeral head. The coracohumeral ligament will be described together with the rotator cuff. The superior, middle and inferior glenohumeral ligament are mere thickenings of the glenohumeral capsule.

These ligaments reinforce the capsule on its anterior aspect preventing excessive external rotation of the humerus. The ligaments are clearly visible from the inside of the glenohumeral joint as thickened bands in the capsule. The superior glenohumeral ligament arises from the root of the coracoid process and the upper portion of the labrum. It is situated in front and just below the coracohumeral ligament. It inserts into the fovea capitis humeri between the upper segment of the lesser tuberosity and the surface of the joint. The middle glenohumeral ligament arises from the anterior portion of the labrum immediately below the superior ligament. Turkel et al. (187) describe the origin as arising between the middle and the inferior third of the anterior border of the glenoid labrum. The ligament passes downward and laterally. More distally it broadens and inserts immediately medial to the lesser tuberosity below the tendon of the subscapularis muscle. It also interlaces with this muscle. The middle glenohumeral ligament is not always present and if present it has a varying width and thickness.

Fig. 1.3

Ligaments of the shoulder.

1. coraco humeral lig., 2. superior glenohumeral lig., 3. middle glenohumeral lig., 4. inferior glenohumeral lig., 5. long head of the triceps muscle, 6. coracoid process.

The inferior glenohumeral ligament is the longest and strongest ligament. It reinforces the inferior part of the capsule lying between the subscapularis and the teres minor muscle. The ligament arises from the antero-inferior border of

the labrum and inserts into the medial and inferior portion of the anatomical and surgical neck of the humerus.

Synovial recesses may be present in varying size and incidence between the glenohumeral ligaments.

Mosely and Overgaard (131) classified the incidence of synovial recesses as follows:

- Type I : a synovial recess above the medial glenohumeral ligament (6.7%).
- Type II : a synovial recess under the medial glenohumeral ligament (2.7%).
- Type III : a synovial recess above as well as underneath the medial glenohumeral ligament (89.3%).
- Type IV : a large synovial recess above the inferior glenohumeral ligament (3%).

A study on 96 shoulders by DePalma (63) identified six variations:

- Type I : one synovial recess above the middle ligament (30.2%).
- Type II : one synovial recess below the middle ligament (2.04%).
- Type III : one recess above and one below the middle ligament (40.6%).
- Type IV : one large recess above the inferior ligament (9.03%).
- Type V : presents the middle ligament as two small synovial folds (5.1%).
- Type VI : no synovial recesses (11.4%).

These studies emphasize the anatomical fact that, when large synovial recesses are present, the fibrous capsule is not directly continuous with the anterior part of the labrum but rather it extends towards the base of the coracoid process, from which point it returns along the anterior aspect of the neck of the scapula as a thin fibrous sheet that finally blends with the anterior portion of the labrum.

The fibrous capsule of the glenohumeral joint is a loose redundant structure and comprises a number of creases, which vary in size and location depending on the position of the upper limb. The capsule inserts into the scapula on the outer margin of the glenoid labrum. At the upper pole the capsule surrounds the supraglenoid tubercle and the origin of the biceps tendon. The capsule inserts here into the upper portion of the neck of the scapula and eventually into the root of the coracoid process.

The long head of the biceps muscle passes through the joint from its origin and leaves the intra-articular space between the lesser and the greater tuberosi-

ty. The intra-articular portion of the biceps tendon contributes to the vertical stability of the glenohumeral joint. Strictly speaking the intra-articular part of the biceps tendon is an extra-articular structure as the biceps tendon is surrounded by a synovial sheath.

A synovial recess accompanies the biceps tendon distally into the bicipital groove and is then reflected proximally onto the biceps tendon, forming an open communication between this recess and the glenohumeral joint. Only proximally is the synovial lining firmly connected with the osteofibrous elements of the bicipital groove. More distally this recess is completely loose. The biceps tendon is connected with this recess by a short strong mesotendon. This structure permits easy gliding of the humeral head in respect of the biceps tendon during movements of the upper limb.

The articular capsule is loose and abundant in the inferior region of the humeral neck. With the arm in the zero position it forms a large nictitating fold in this region. As the upper limb is abducted, this fold becomes smaller and disappears when full abduction is attained.

The coracohumeral ligament

An important component of the rotator cuff is the coracohumeral ligament. This ligament originates from the outer border of the horizontal limb of the coracoid process and passes forward and downward in the interval between the supraspinatus and the subscapularis muscles. Here its fibres interlace with those of the fibrous capsule and insert with the capsule into both tuberosities bridging the bicipital groove. In this position it functions as a suspensory ligament of the humeral head. Its most proximal fibres are so arranged that they unwind and elongate on external rotation of the shaft of the humerus, functioning as a checkrein to external rotation.

1.2.2 The acromioclavicular joint

The acromioclavicular articulation is a plane joint composed of the outer end of the clavicle and the articular facet of the acromion (1,63,67). The articular facet of the acromion is directed upward and medially providing an area for the articular facet of the distal clavicle to rest on. The joint may contain an intra-articular meniscoid disk. This disk is often not fully developed and is sometimes completely absent such that the joint seldom consists of two compartments (Sobotta (179)). The ends of the bones are connected by a weak relaxed capsule. The capsule is reinforced above by the superior acromioclavicular ligament and below by the inferior acromioclavicular ligament. The former is the stronger structure.

The coracoclavicular ligament is an important extra-articular component of this joint. This ligament binds the scapula to the clavicle. It is a reinforcement of the acromioclavicular joint.

The coracoclavicular ligament is composed of two tough fasciculi, the triangular conoid ligament, and the trapezoid ligament. The conoid ligament is arranged at a virtual right angle to the trapezoid ligament. The ligaments insert onto the undersurface of the clavicle just where its outer third curves posteriorly, with the trapezoid on the anterior part of the undersurface and the conoid on the posterior part of the undersurface of the clavicle. This manner of attachment provides a mechanism capable of producing further outward rotation of the scapula.

Fig. 1.4 The acromioclavicular joint.
1. clavicle, 2. acromion.

1.2.3 The sternoclavicular joint

The sternoclavicular joint is formed by the medial end of the clavicle (78), the articular facet on the posterolateral aspect of the manubrium sterni and the cartilage of the first rib. The articular facet of the medial end of the clavicle is larger than the articular surface of the manubrium so that it protrudes a considerable distance above the manubrium sterni. A pronounced lack of congruency of the articular surfaces is compensated for by the interposition of a stout fibrocartilaginous disk. This disk divides the joint into two completely separate compartments. The interarticular disk is convex-concave; its circum-

ference is slightly thicker than its center. It is attached to the upper and posterior aspect of the clavicle over a broad circular area, and below it fuses with the cartilage of the first rib at its junction with the sternum. This arrangement makes this disk the chief stabilizing element of the sternal end of the clavicle, preventing abnormal elevation of the clavicle.

Fig. 1.5 The sternoclavicular joint.
1. clavicle, 2. first rib, 3. sternum.

The articular surfaces are enclosed in a fibrous capsule, which is also attached to the edges of the disk. The capsule is reinforced by the strong anterior and posterior sternoclavicular ligaments. Stability of the joint is further accomplished by interclavicular and costoclavicular ligaments. The costoclavicular joint comprises oblique spiral fibres directed upward and outward between the first costal cartilage and the undersurface of the proximal end of the clavicle adjacent to the joint. When the shoulder is elevated these fibres unwind; they also prevent abnormal elevation of the clavicle and, hence, of the scapula.

1.2.4 The scapulothoracic gliding system

The scapulothoracic gliding system is not a true joint (59,72,74). The scapula is connected to the trunk on the one side by strong muscles and on the other by means of the clavicle. The gliding motion is possible over a large area between the anterior serratus muscle and the chest wall. The presence of very

loose connective tissue, having the same properties and function as a bursa, between these two structures enables this motion to take place.

1.2.5 The subcoraco-acromial gliding system

The subcoraco-acromial gliding system consists of the undersurface of the acromion, the coraco-acromial ligament, the coracoid process and the subdeltoid fascia on the one side and the humeral head with the overlying capsule and rotator cuff tendons on the other. Movements between these pseudo joint surfaces are possible thanks to the presence of the subacromial bursa.

1.3 THE MUSCLES OF THE SHOULDER

In this part those muscles will be discussed as far as is necessary to understand the basic biomechanical mechanisms of shoulder motion, and the surgical procedures.

1.3.1 The deltoid muscle

The deltoid muscle is a triangular muscle that drapes itself around the anterior, lateral and posterior aspects of the outer third of the clavicle; the lateral border of the acromion and the lower border of the spine of the scapula. Its fibres converge distally to form a stout short tendon that inserts into the deltoid tuberosity. The arrangement of the anterior and posterior fibres, which arise from the clavicle and the spine of the scapula differs from that of the lateral fibres, which arise from the acromion. The lateral muscle mass consists of oblique fibres that arise in a pinnate fashion from either side of four or five tendinous bands whose proximal ends are attached to the acromion. These fibrous septa proceed distally and parallel to one another and become lost in the muscle substance. From the tendinous insertion of the deltoid, three or four similar tendinous strands pass upward into the muscle substance, alternating with those passing downward. The oblique fibres arising from the descending septa insert in the ascending septa. Such a complex scheme does not exist in the anterior and posterior portions of the deltoid muscle. This arrangement permits less change in length for a given contraction of the muscle fibres than would occur if the fibres were orientated in a parallel pattern; it also produces greater power.

At its origin on the clavicle, acromion, and scapular spine the deltoid is tendinous. These tendinous fibres blend with the periosteum of the bony structures. Between the adjacent borders of the deltoid and the pectoralis major muscle is

a distinct interval. The cephalic vein traverses this interval, the deltopectoral groove, and is a landmark in surgical procedures.

1.3.2 The rotator cuff

The rotator cuff consists of four muscles: the supraspinatus, the infraspinatus, the teres minor and the subscapularis. The muscles end in broad flat tendons whose fibres fuse with those of the fibrous capsule. So complete is the interlacing of tendon and capsular fibres that it is impossible to separate the two structures by sharp dissection.

Fig. 1.6 The rotator cuff.

1. biceps, 2. teres minor muscle, 3. infraspinatus muscle, 4. supraspinatus muscle, 5. subscapular muscle, 6. coraco-acromial lig., 7. acromion, 8. coracoid process.

The supraspinatus muscle

The supraspinatus muscle is small but relatively strong. This muscle arises from the medial two-thirds of the supraspinous fossa and the overlying fascia. Its tendon of insertion is intimately associated with the capsule and is attached to the highest of three facets on the greater tuberosity. The tendon is part of the floor of the subacromial bursa. The supraspinatus is supplied by the suprascapular nerve.

The infraspinatus muscle

The infraspinatus muscle is covered in its upper part by the deltoid laterally and the trapezius medially. Its lower part is superficial. The muscle arises from the medial two-thirds of the infraspinous fossa and the lower surface of the scapular spine. Its tendon, which becomes closely associated with the capsule, inserts into the middle facet of the greater tuberosity. The infraspinatus is supplied by the suprascapular nerve.

The teres minor muscle

The teres minor, which may be inseparable from the infraspinatus, arises from an elongated area along the lateral margin of the infraspinous fossa. Its tendon is at first adherent to the capsule and is then attached to the lowest facet of the greater tuberosity and to the area just below it. The teres minor is innervated by the axillary nerve.

The subscapularis muscle

The subscapularis muscle arises from the whole of the subscapular fossa, except for an area near the neck. Its tendon of insertion passes in front of the capsule of the shoulder joint, to which it is adherent, and is attached to the lesser tuberosity. The subscapular nerves supply this muscle.

1.4 THE BURSAE OF THE SHOULDER

There may be more than 150 bursae in the human body. The subacromial bursa is the largest one. The bursae of the shoulder are situated between the humerus and the capsule of the shoulder joint on one side and the coracoacromial ligament and the acromion on the other.

A large portion of the tendons of the subscapular, supraspinatus and infraspinatus muscle is covered by the subacromial bursa.

The bursa mostly consists of several compartments. These compartments show important intra- and inter-individual variation. In a number of cases there is an open connection between the subacromial and the subcoracoid bursa as demonstrated by Strizak et al. (1955), who found a communication in 20% of their patients. The subcoracoid bursa is situated between the subscapular muscle, the coracoid process and the tendons of the coracobrachialis muscle and the short head of the biceps muscle. The supracoracoid recess is situated at the upper end of the coracoid process. The extent and size of this bursa is considerably dependent on the form of the coracoid process. A similar form-function relationship applies to all bursae. A separate subscapular bursa may sometimes be present between the subscapular and deltoid muscle.

Prakke et al. (155,156) emphasize the distinction between the subacromial bursa and the subdeltoid bursa. The subacromial bursa is the cranio medial continuation of the subdeltoid bursa, deep to the acromion. A distinction between the subdeltoid and subacromial bursa is only valid in the anatomical position. This is the position in which the arms are next to the body. By abducting or internally rotating the upper limb, part of the subdeltoid bursa moves beneath the acromion. Consequently a specific location can only be ascribed to subacromial bursa when the arm is in the anatomical position. Bursae only develop in areas where structures glide over one another. As there is no friction between the rotator cuff and the medial portion of the acromion a bursa is absent in that location. As there is friction between the rotator cuff and the lateral and anterior part of the acromion and the coraco-acromial ligament, a bursa is present. Pathological changes of the bursa may be expected in these areas produced, for instance, by osteophytes of the acromion or changes in the critical zone of the rotator cuff. These will be discussed later on. For the sake of clarity when discussing the arthroscopic and operative findings, the word subacromial bursa will be used to mean the anatomical terms, subacromial bursa and subdeltoid bursa.

1.5 THE ARTERIAL SUPPLY OF THE ROTATOR CUFF

In order to understand the alteration of physiology that occurs in the various pathological states of the shoulder joint, a further analysis of the arterial supply of the rotator cuff is justified, as there is a relationship between pathological states and the arterial patterns.

Most investigators agree, that the area of the rotator cuff which is prone to degenerative changes, is located in the tendon of the supraspinatus muscle near its insertion. This area is usually referred to as the "critical zone" of the rotator cuff. Pathological changes, ranging from tendinitis to partial and complete rupture, are common in this region. Furthermore it should be noted that this "critical zone" extends anteriorly and posteriorly. A small portion of the adjacent tendon of the infraspinatus muscle posteriorly, along with the tuberosities with the interjacent biceps tendon are usually involved in this process. A critical study of the vascular patterns of this "critical zone" is essential to the understanding of the above mentioned pathological states.

The early anatomists described accurate pictures of the blood supply of the shoulder region but, in almost all instances, neglected to define the detailed arterial patterns of the rotator cuff tendons.

In 1916, Leo Maier (77) dispelled the idea that tendon was a bloodless organ. He showed that tendon derived its blood supply from three sources:

1. muscular branches,
2. direct arteries to the tendon,
3. arteries arising from the bony insertions.

D. Edwards and Brockis (161) gave the first detailed accounts of the intratendinous arterial patterns.

McMaster showed that when a normal muscle tendon is stressed, muscle will tear before tendon. One half of the tendon had to be divided before it would become the initial site of failure. However, if the blood supply to the tendon was interrupted, trauma and stress would lead to a rupture.

Mosely (128) investigated the arterial pattern of the rotator cuff in 72 cadavers and concluded that there was no evidence of decreased vascularization in that area of the rotator cuff which is prone to degenerative changes. He does state that the "critical zone" of the rotator cuff corresponds with the zone of anastomoses between the osseous and tendinous vessels. He felt that age was not an influence on the morphology of the vascular pattern.

Richard, Rothman et al. (161) demonstrated the precise opposite. They showed that the "critical zone" positively corresponds with an area of decreased blood supply.

Rothman et al. (161) observed that not five, as were known till then, but six arteries were involved in the blood supply of the rotator cuff:

1. the suprascapular artery,
2. the anterior circumflex humeral artery,
3. the posterior circumflex humeral artery,
4. the thoraco-acromial artery,
5. the subscapular artery,
6. the till then unknown suprahumeral artery.

The suprascapular, the anterior circumflex humeral and the posterior circumflex humeral arteries are present in all cases. The thoraco-acromial, the suprahumeral and the subscapular arteries are present in a descending order of frequency.

The posterior circumflex humeral and suprascapular arteries form an interlacing system on the posterior part of the rotator cuff with several large anastomoses (fig. 1.7). These vessels are the predominant arteries to the teres minor and the infraspinatus tendons.

The anterior circumflex humeral artery approaches the anterior aspect of the rotator cuff over the subscapularis muscle (fig. 1.8). It frequently forms a major anastomosis with the posterior circumflex humeral artery over the tendon of the long head of the biceps. A large branch of the anterior circum-

flex humeral artery was found to enter the bicipital groove to form its major blood supply. This branch also provides the blood supply to the tendon of the long head of the biceps before it enters the synovial cavity of the glenohumeral joint.

A large branch of the thoraco-acromial artery also forms a significant part of the blood supply of this area (fig. 1.9). It supplies the anterosuperior portion of the rotator cuff and particularly the supraspinatus tendon. It frequently anastomoses with both circumflex humeral arteries.

Fig. 1.10 shows the characteristic pattern of the subscapular and the thoraco-acromial arteries as they supply the rotator cuff. The subscapular is the more distal branch of the axillary artery, and only a small portion of its distribution goes to the cuff.

The suprahumeral artery takes its origin from the 3rd portion of the axillary artery and supplies the anterior portion of the rotator cuff and the lesser tuberosity of the humerus (fig. 1.11).

In the distal portion of the supraspinatus tendon, and just proximal to its insertion, is an area which is markedly poorly vascularized in relation to the remainder of the cuff.

Rothman, Wesley and Park (161) found in their study that the hypovascular areas were distributed as follows:

1. In 63% of the cases, the hypovascular area is in the distal part of the supraspinatus tendon.
2. In 37% of the subjects, the hypovascular area is in the distal part of the supraspinatus and infraspinatus tendon.
3. In 7% of the cases, the region of hypovascularity is in the distal portion of the subscapularis tendon.

Fig. 1.7 1. posterior circumflex humeral artery, 2. supra-scapular artery.

Fig. 1.8 anterior circumflex humeral artery.

Fig. 1.9 thoraco-acromial artery.

Fig. 1.10 1. thoraco-acromial artery, 2. subscapular artery.

Fig. 1.11 supra humeral artery.

The supraspinatus tendon is affected most frequently, with the infraspinatus and the subscapularis tendon being implicated in a descending order of frequency.

1.6 THE NERVE SUPPLY TO THE SHOULDER

Both the superficial and deep structures of the shoulder are richly innervated by a network of nerve fibres derived chiefly from the C5, C6 and C7 nerve roots, although the C4 root may also provide a minor contribution (78).

It is an established anatomical rule that nerves crossing a joint give off branches to the joint. Therefore the nerves supplying the ligaments, the capsule and the synovial membranes are the axillary, suprascapular, subscapular, and musculocutaneous nerves; in some instances branches from the posterior cord also reach the joint. The size and number of nerve fibres to the joint are not constant. In some cases the joint may receive a greater supply from the axillary than from the musculocutaneous nerve; in others the reverse is true. The skin is supplied by the supraclavicular nerves derived from the C3 and C4 nerve roots and the terminal fibres of the sensory branch of the axillary nerve the lateral brachial cutaneous nerve. The latter nerve is a continuation of the posterior branch of the axillary nerve, which divides into anterior and posterior branches at its exit from the quadrangular space. The deep structures of the joint proper are innervated by branches of the axillary nerve and to a lesser degree, by contributions from the suprascapular nerve. In some instances the musculocutaneous nerve is involved too. In addition either the subscapular or the posterior cord may send some fibres to the anterior aspect of the joint after piercing the subscapularis muscle. The suprascapularis nerves supply the skin of the superior and the upper

posterior aspects of the shoulder. The lower posterior and lateral aspects are innervated by the lateral brachial cutaneous nerve. Superiorly, the deep structures derive some of their nerve supply from the two branches of the suprascapular nerve. One branch proceeds to the coracoid process and the coraco-acromial ligament; the other reaches the posterior aspect of the joint. In addition, the axillary and musculocutaneous nerves and, in some instances, branches from the lateral anterior thoracic nerve contribute to the nerve supply of the superior aspect of the joint. Posteriorly the chief nerves are the suprascapular nerve, which supplies the upper region, and the axillary nerve, which supplies the lower region of the joint.

1.7 SHOULDER MOTION

Shoulder motion depends on a complex cooperation of five joints and the attached muscles (61,68,72,74,166,169).

Scapula stability is achieved by the deltoid, trapezius, rhomboids, levator scapulae, serratus anterior and pectoralis minor muscles. In order to obtain a clear picture of the complex interrelationship of the shoulder muscle system, an analysis of the individual muscles and the synthesis of their coordinated contractions is helpful. A consideration of the action of some of the muscles may be obtained from a study of some pathological states. A few examples are presented.

Paralysis of the deltoid prevents abduction beyond 30°.

Failure of the trapezius allows the acromion and glenoid to drop to a lower level and the superior angle to lie at a higher level. The median border is displaced away from the midline.

In the presence of failure of the levator scapulae muscle, the median border of the scapula moves an abnormal distance inferiorly, as the outer end of the scapula is elevated.

Winging of the scapula is produced by a serratus anterior paralysis. The scapula is displaced toward the vertebral column during abduction of the arm.

The pectoralis minor depresses the point of the shoulder downward and medially. Weakness results in abnormal elevation of the scapula during abduction.

Paralysis of the rhomboids permits displacement of the scapula away from the midline.

The movements and the required muscle action to achieve these motions will be described as far as they illustrate the functional analysis used in the physical examination of the shoulder.

Abduction

The range of abduction is from 0° to 180°. The trapezius, serratus anterior, deltoid and rotator cuff muscles are the prime movers (78). In the literature one finds that the so called "setting phase" of the scapula occurs in the first 20° to 30° of abduction (61). In that phase the scapula finds its most stable position by moving medially or laterally. Once stability is attained, the rotator cuff muscles and the deltoid muscle

continue to act. The deltoid muscle is the most important abductor, whereas the prime function of the rotator cuff is to depress the humeral head. The supraspinatus is a specific abductor. At 90° of abduction, external rotation of the arm is necessary to avoid impingement of the greater tuberosity against the acromion. By externally rotating the arm, the humeral head slips under the arch. During abduction from 30° to 180° , the scapula accounts for $1/3$ and the glenohumeral joint $2/3$ of the range of motion. The scapula trajectory involves lateral rotation and twisting. The serratus anterior rotates the scapula by pulling on its inferior angle, while the trapezius muscle stabilizes the axis. The clavicle rotates during the whole abduction range by 50° . A "tipping upward" of the clavicle occurs during this movement with the total range of movement being about 40° .

Adduction

The muscles involved in arm adduction are the latissimus dorsi, the sternocostal portion of the pectoralis major and the teres major. On forced adduction the muscle contraction becomes evident on electromyographical studies (81).

Extension

The combined action of the posterior part of the deltoid, the latissimus dorsi, the sternocostal portion of the pectoralis major and the teres major is responsible for the first 30° of backward motion of the arm. At this point the scapula is stabilized again and the clavicle has rotated downward on its long axis. The teres major, infraspinatus and triceps now contribute to the extension.

Flexion

Forward elevation of the arm is only possible over a range of 180° , if the arm is internally rotated. On external rotation of the arm the range of motion is restricted to 135° . At this point internal rotation avoids impingement against the arch and permits the arm to continue the forward movement. Flexion is achieved by a combined action of the anterior portion of the deltoid, the clavicular portion of the pectoralis major, coracobrachialis and both heads of the biceps.

Internal and external rotation

Although many muscles participate during internal rotation the prime movers are the latissimus dorsi and the subscapularis.

The infraspinatus, teres minor, and posterior deltoid are the principal external rotators. While abducting the arm the supraspinatus becomes an external rotator.

CHAPTER 2

Shoulder affections and disorders of the neck causing shoulder pain

2.1 INTRODUCTION

As stated Caillet (42) terminology used in reference to the shoulder, especially with regard to the pathology of the shoulder is vague, nonspecific and arbitrary. Many hackneyed terms have gained dignity of specificity but are loosely employed, devoid of real meaning, and without physiologic or pathologic basis. In this study no attempt will be made to give a more exact terminology. Reviewing literature shows that most of the authors, who tried to do so have contributed to more confusion in this field, because they introduced new terms in an attempt to simplify the classification of shoulder pathology with the result that several terms are used for the same pathologic entity and that similar terms are used for different pathologic states.

In the history of medical science the cause of this confusion can be discovered. The following will elucidate the cause of this disarrangement.

A term still leading to much confusion is humeroscapular peri-arthritis. Since the apparition of the paper of Duplay (77) a century ago, in which the term "peri-arthritis scapulohumerale" was introduced, there is still misapprehension concerning this expression a century later.

Duplay thought that the cause of intrinsic shoulder pain was based on the drying out of the subacromial bursa. In Germany the condition was described only in the beginning of the twentieth century. The German authors also assumed that the condition was caused by drying out of the subacromial bursa

Examination

If the pain is very severe precise palpation is impossible. Otherwise the supraspinatus tendon is tender with often spreading to the upper portion of the subscapularis tendon and occasionally to the infraspinatus tendon. Tenderness of the insertion of the deltoid muscle is nearly always present. Pain may prohibit motion, but the restriction is not arthrogenic. If full motion is possible there is a painful arc between 60° and 120° of abduction. The scapulo-humeral rhythm is disturbed and all movements are painful at the end of the range.

X-ray

A calcification is always present in the supraspinatus tendon or the adjacent tendon area. Other features are sclerosis of the greater tuberosity and cysts in the greater tuberosity. Very often these features are absent.

Treatment

Non steroid anti-inflammatory drugs,
Local anaesthetic injections,
Steroid/Local anaesthetic injections,
Ice applications,
Rest.

If conservative means do not achieve the therapeutic aims operative decompression with evacuation of calcification if present is proposed.

Operative Findings

Haemorrhagic inflammation of the subacromial bursa and rotator cuff with sometimes spreading to the biceps tendon.

2.2.2 Chronic tendinitis of the rotator cuff*History*

The symptoms in chronic tendinitis usually come on gradually, although an acute tendinitis also may develop into a chronic tendinitis. The patient's age mostly varies from 45 - 65 years.

The patient complains initially of pain at certain positions or movements. Especially abduction backward extension motions, like closing a door, putting on a coat and working above shoulder level are troublesome.

A trauma may unchain the complaints, but normally no causal determinant can be discovered.

Nightpain and inability to sleep on the affected side is present as in acute tendinitis. The pain has a dull character.

Examination

On examination the shoulder looks normal. Tenderness is present in the "critical zone" and in the area in front and behind it. Tenderness is also present at the insertion of the deltoid muscle. Movements may be restricted by pain or may be partially arthrogenic. The painful arc in chronic tendinitis of the rotator cuff is much more outspoken than it is in acute tendinitis and the disturbed scapulohumeral rhythm is always present.

X-ray

The same features as in acute tendinitis of the rotator cuff may be present, like a calcific deposit, sclerosis and cyst formation in the greater tuberosity. Besides these radiologic signs also osteoarthritic changes may be observed.

Arthrogram

If there is filling of the subacromial space with the contrast medium after injection of the glenohumeral joint there is a partial or complete rupture of the rotator cuff tendons co-existent. When the biceps tendon is involved in the pathologic process the bicipital recess usually is not filled with the contrast agent.

Treatment

The conservative treatment consists of non steroid anti-inflammatory drugs, injections of local anaesthetic with or without steroid and physiotherapy. If conservative treatment procures not enough pain relief operation is considered. The operation of choice is decompression of the rotator cuff by osteotomy of the anterolateral undersurface of the acromion and section of the coraco-acromial ligament. During the same procedure adhesions in the subacromial space (if present) are removed. A thickened subacromial bursa is removed.

Operative findings

The bursal synovial tissue is swollen, adhesions may be present. The rotator cuff normally shows degenerative changes with superficial defects in the tendinous layer. Full thickness ruptures may also be existent. The undersurface of the cuff shows possibly an irregular synovial lining and this synovial layer may be thickened. The biceps tendon may be involved. The tendon may show degenerative changes and resulting from the degenerative changes partial ruptures.

2.2.3 Acute bursitis of the subacromial bursa

Acute bursitis shows exactly the same features as the above mentioned tendinitis as both are concomitant affections of the shoulder.

2.2.4 Chronic bursitis of the subacromial bursa

Chronic bursitis being a part of the pathologic state in which also the rotator cuff and eventually the biceps tendon is involved shows the same clinical picture as described for chronic tendinitis.

2.2.5 Rupture of the rotator cuff

History

The patient is usually aged 45-65. Frequency of occurrence is more important in man as in women.

The history may be exactly the same as in chronic tendinitis. In that case the rupture of the rotator cuff is just a fortuitous finding on an arthrography. In this instance no trauma can be elicited in the patient's case history. The rupture must be considered to be an aspect of natural degeneration of the musculotendinous rotator cuff. One should keep in mind that here one has to deal with a partial full thickness rupture. If the rupture increases, the patient tells that he cannot lift his arm anymore.

On the other hand the history may reveal more reliable information. The patient mentions, that he had suddenly felt pain in his shoulder lifting a heavy object or that he sprained his shoulder while protecting himself from falling. The pain is felt immediately, radiating from the deltoid insertion, and he is unable to lift his arm. The patient may gradually recover, partially recover, develop a frozen shoulder or keep a persistent inability of active abduction.

Examination

On inspection the shoulder appearance is normal.

In case of a partial degenerative full thickness rupture no symptoms at all may be present. In case of an acute rupture in the younger patient the arm can be raised actively to about 45° by the deltoid, after which elevation of the arm is accomplished by the shrugging mechanism. The pain is most severe in the arc from 45° to 90° .

If the arm is elevated passively above the horizontal abduction is possible with very little discomfort.

The strength of abduction is proportional to the size of the tear.

If the tear is extensive, abduction is weak and is performed through a small range.

If the tear is small, the range of motion may be complete.

X-ray

In the early acute case the X-ray is negative.

In the chronic case the X-ray reveals developing bony changes in the greater tuberosity.

Treatment

When preservation of the strength for physical activity is desirable, the tendon should be repaired immediately. In the degenerative cuff rupture the tear may be left alone or a subacromial decompression may be performed.

2.2.6 Adhesive capsulitis (frozen shoulder)

History

The onset of a frozen shoulder is insidious and develops during a period of relative inactivity in use of the shoulder. Some vague antecedent injury may be blamed for the increasing pain and stiffness.

The pain is located over the anterolateral aspect of the shoulder.

Discomfort is worse at night.

Examination

Tenderness is generalized about the humeral head and over the bicipital groove.

Active and passive motions are limited in all directions, pain being accentuated at the extremes of motion. Muscle spasm may be observed. The arm is held protectively at the side in a position of internal rotation.

Signs of reflex sympathetic dystrophy often develop in the hand.

X-ray

On X-ray no abnormality may be found or the same findings as in tendinitis of the rotator cuff.

Treatment

- Conservative:

rest, application of heat, sedatives.

- Operative:
manipulation under general anaesthesia.

2.2.7 Tendinitis of the long head of the biceps muscle

History

The patient complains of pain and loss of active function. The pain is localized at the front of the shoulder and irradiates in the area of the biceps muscle. In general there is no trauma in the past history. Unusual activities may be mentioned.

The information obtained can also be exactly the same as in tendinitis of the rotator cuff.

Examination

The area of the long head of the biceps tendon is tender on palpation, especially in the intertubercular sulcus. On contraction of the biceps muscle and while externally rotating the arm the complaints can be reproduced. Mostly it is impossible to obtain such clear data, as the rotator cuff generally is involved at the same time.

X-ray

Normally no abnormalities are seen. Occasionally osteophytes may be observed in the intertubercular groove.

To see this osteophytes, special projections are necessary.

Arthrogram

The bicipital recess may not be filled with the contrast agent, caused by adhesions of the synovial lining.

Treatment

Conservative treatment in the form of corticosteroid injections is administered and temporary rest in a sling is prescribed.

If conservative treatment is given to no avail the biceps tendon may be fixed in the bicipital groove by stapling.

Operative findings

Inflammatory changes of the biceps tendon; haemorrhagic inflammation or adhesions accompanied by degenerative changes of the tendon.

2.2.8 Dislocation of the biceps tendon

History

The patient complains of pain and a clicking sensation during contraction of the biceps muscle in combination with rotation of the arm. The patient declares that the pain is located at the front side of the shoulder. Complaints are not present in rest, but are evoked by moving the arm. The pain is caused by undue tension and repetitive irritation of the biceps tendon. No specific factors can be pointed at; there is no history of trauma.

Examination

The area of the biceps tendon may be tender. The examiner can detect the phenomena of dislocation by palpating the tendon, while he asks the patient to flex the elbow and to rotate the arm at the same time. In general there is no restriction of motion of the shoulder. The before mentioned symptoms may be minimal.

X-ray

Radiologic examination of the bicipital groove shows a shallow intertubercular fossa.

Arthrography

Special projections of the arthrography demonstrate that the biceps tendon is displaced laterally or medially from the bicipital groove.

Treatment

Surgical treatment is the therapy of choice as conservative means procure no lasting result. During operation the biceps tendon is fixed to the bicipital groove with a staple and the tendon is stitched to the adherent structures.

Operative findings

The biceps tendon is not in the bicipital fossa or dislocation of the tendon is quite easy.

2.2.9 Rupture of the biceps tendon

History

Male patients are more prone to suffer from a ruptured biceps tendon than women. In general the age ranges from 45 to 65. The patient feels a sudden

crack and pain while in the area of the biceps tendon, while lifting an object. The object is not necessarily a heavy one.

Examination

On examination the investigator observes an abnormal thickened and shortened biceps muscle in the ventrodistal part of the arm. Forced flexion of the elbow increases the thickening. The flexion force of the biceps muscle is weakened. The function of the shoulder is not disturbed.

X-ray

An X-ray does not reveal important information. Occasionally osteophytes are demonstrable in the bicipital groove.

Treatment

In recent ruptures surgery is performed. The long head of the biceps tendon is fixed into the intertubercular fossa by a staple and the tendon is sutured to the surrounding tendinous tissue.

Operative findings

The biceps tendon is ruptured at the level, where it normally leaves the glenohumeral joint. The tendon also shows considerable degenerative changes.

2.2.10 Dislocation and subluxation of the acromioclavicular joint

History

There is always a history of trauma. A fall onto the outstretched hand or a direct trauma may cause a disruption of the acromioclavicular ligament. If there is slight subluxation we may conclude that a lesion of the acromioclavicular ligaments has occurred. In the case of gross deformity we may presume, that the trapezoid and conoid ligament are ruptured too.

Examination

On inspection a swelling is noted in the area of the distal end of the clavicle. Spontaneous pain is present in the acromioclavicular region and on palpation this area is tender. Abnormal movements are detectable. A step can be felt. Pressing onto the distal end of the clavicle produces a piano key like effect. Abduction and elevation of the arm is painful; especially above 90°.

X-ray

An X-ray confirms the diagnosis.

Treatment

Conservative treatment consist of reduction and immobilization. In surgical treatment internal fixation is performed.

Operative findings

Disruption of the acromioclavicular ligaments, rupture of the intra-articular disc and in the case of full dislocation, rupture of the conoid and trapezoid ligaments.

2.2.11 Osteoarthritis of the acromioclavicular joint

History

The patient is 40-60 years of age. The condition is mostly found in male patients. A dislocation or subluxation may be elucidated in the past history, although often no historical clue is revealed at all. There is no pain at rest. Pain is felt on abduction and elevation of the arm.

Examination

The acromioclavicular joint is tender on palpation and a step may be felt. Movements are painful above 90° of elevation and above all in the trajectory 160°-180° of abduction.

X-ray

Radiologic examination reveals osteoarthritic changes of the joint; narrowing of the joint space, osteophytes, cysts, sclerosis and deformity.

Treatment

Injections with corticosteroids are administered. If no success is achieved with conservative treatment resection of the distal end of the clavicle is performed.

Operative findings

All features of osteoarthritis may be present.

2.2.12 Traumatic anterior dislocation of the shoulder

History

The patient is in general involved in a roadtraffic accident, a trauma at work or a sport injury is the cause of this condition. He is unable to move the shoulder. Often a fall on the hand with an outstretched arm is cited.

2.4 DIFFERENTIAL DIAGNOSIS

A. INTRINSIC**Synoviocapsular shoulder pain:**

Musculoskeletal, ligamentous and fractures of:

clavicle
scapula
humerus

Dislocation of:

glenohumeral joint
causalgia
acromioclavicular joint
sternoclavicular joint

Acute rupture of:

biceps tendon
rotator cuff

Inflammation

by rheumatoid arthritis
by gout
by infection
by irritative arthritis, bursitis

Tumors of:

bone
soft tissue

Osteoarthritic changes of:

humeral head
bicipital groove
glenoid fossa
anterolateral acromion border
acromioclavicular joint
sternoclavicular joint

Degenerative tendinitis of:

subscapularis tendon
supraspinatus tendon

infraspinatus tendon
teres minor tendon
biceps tendon
degenerative tendon tears

Degenerative changes of:

capsules
ligaments
labrum glenoidale
intra-articular discs
bursae

B. EXTRINSIC**Local neurological shoulder pain**

Penetrating wound

Neuroma

Nerve inflammation

Neuralgia of Sluder and Vidianus

Neurogenic muscle dystrophia

Glomus tumor

Reflex sympathetic dystrophia

Referred neurologic shoulder pain

Nerve root compression:

by cervical spondylosis
by herniated disk
by fracture of cervical vertebra
by dislocation of cervical vertebra
by extramedullary tumors

Brachial plexus compression:

by scalenus anticus syndrome
by claviculocostal syndrome
by cervical rib
by pectoralis minor syndrome
by adenitis

Brachial plexus injury

by traction

by penetrating object

Brachial plexus inflammation

Central nervous system:

by tumor

by cyst

by syringomyelia

by amyotrophic lateral sclerosis

by multiple sclerosis

by myelopathy

by trauma

Peripheral nerves:

by carpal tunnel compression

by ulnar nerve compression

Vascular shoulder pain

Acute arterial occlusion

Chronic arterial occlusion

Raynaud disease

Aneurysm

Arterio-venous fistula

Thrombophlebitis

Chronic venous failure

Acute lymphangitis

Chronic lymphedema

Referred visceral pain

Lung top:

pancoast tumor

neurofibroma

inflammation

Heart:

coronary sclerosis

myocardial infarction

pericarditis

tachycardia

Aorta:

aneurysma dissecans

inflammation of the aorta

Mediastinum:

tumor

inflammation

Oesophagus:

tumor

inflammation

Diaphragm:

hernias

pleurisy

lung embolism

Diaphragm to the left shoulder:

spleen injury

pancreatitis

pancreas tumor

ruptured peptic ulcer

Diaphragm to the right shoulder:

gallbladder disease

liver affection

subphrenic abscess

ruptured peptic ulcer

ruptured intestines

CHAPTER 3

History, examination, further investigation

3.1 INTRODUCTION

The physician has at his disposal an enormous variety of clinical data to serve as a guide to decision making. Some pieces of clinical information derive from diagnostic tests, which in some cases may be expensive or risky. Other valuable information can be provided by simply observing the patient or his or her response to treatment. The purpose of clinical information, however it is obtained, is to aid the physician in making a proper diagnosis and thereby in choosing the best treatment.

In order to form a diagnosis and to plan treatment, data collection is needed. Starting with the major complaint, various investigation pathways are selected which may produce valuable diagnostic information. The data thus collected can be classified in three main groups:

1. Data collected by taking a history from the patient,
2. Data collected from the examination of the patient,
3. Data collected from supplementary investigations.

The case history consists of the history of the local complaint and questions about the general health of the patient. The next step is the examination of both the shoulder and those areas which may be responsible for referred pain. The clinical investigations may include radiographs of the shoulder and the cervical

spine, an arthrogram of the glenohumeral joint and/or subacromial bursa, arthroscopy, electromyography, bone scanning, ultra-sonography, C.T. scanning, magnetic resonance imaging.

3.2 HISTORY

The combination of the general history and the history of the local complaint may help to exclude clinical disorders causing referred shoulder pain or suggest investigations of other organ systems.

Demographic data such as the date of birth, age, sex, and occupation will make it possible to investigate patient populations.

The patient himself provides valuable information in the way he gives his history and any gaps in the history should be filled in, by the examiner asking carefully selected questions. The answers provided by the patient may suggest a diagnosis, and some descriptions of the symptoms can make the probability of a particular diagnosis very high. In the following scheme questions are tabulated in the first column and a range of possible answers in the second.

History of the local complaint

What is the major complaint?	pain, aching, grinding, stiffness, instability, weakness, locking.
What is the cause?	trauma, overuse, inflammation, unknown.
Localization?	neck-shoulder-arm, neck shoulder, shoulder-arm, whole shoulder, specific area of shoulder.
What was the onset?	acute and severe, acute but moderate, gradually worsening.
Frequency?	intermittently, continuous.
Complaints provoked by?	rest, movement.

After the history of the specific shoulder complaint, the clinician will check the other organ systems that produce identical symptoms. So the following questions may produce valuable data:

Is there any heart disease?

Is the patient known to have pulmonary problems?

Does the patient have a pathological condition arising from under the diaphragm?

Has the patient a neurological deficit?

Are any vascular problems present?

Does the patient have a generalized bone or joint disease?

Can a metabolic disorder be ruled out?

3.3 EXAMINATION OF THE SHOULDER

3.3.1 General examination

The body is inspected for any obvious problems. Poor posture may lead to muscle fatigue and consequently pain in the muscles of the shoulder girdle. Possible causes of shoulder pain in the upper extremity are looked for in the cervical spine, the chest and the subdiaphragmatic region. The general examination may rule out causes of referred shoulder pain or indeed may direct the investigator's attention to other organ systems.

3.3.2 Local examination

The local examination provides additional data about the shoulder area. The local examination consists of the inspection of the shoulder both with the patient at rest and whilst putting the arm through a full range of movement. This is followed by palpation, auscultation and then specific clinical tests.

Inspection

The inspection is done both from the anterior and the posterior. The investigator is placed at some distance from the patient in order to better observe areas of muscle atrophy. It is important to study the facial expression of the patient during the physical examination as the face may signal painful movements or areas of tenderness. It is also important throughout the examination to compare the affected shoulder to the other as all the information assembled has a relative value due to the natural differences of individuals. Discolouration from either a bruise or inflammation is noted. Scars will indicate previous injury or surgery.

Inspection also includes the bony prominences and special attention is paid to any abnormal prominence of the acromioclavicular joint, the sternoclavicular joint and potential winging of the scapula. Prominence of the scapular spine at the affected side may result from supraspinatus, infraspinatus or trapezius atrophy. Inspection during movement provides information about the range of abduction, adduction, forward flexion, depression, backward extension, horizontal flexion, horizontal extension, internal rotation, external rotation. A method to pinpoint the exact position of the arm in relation to the various planes of the trunk is needed. The method proposed by the American Academy of Orthopaedic surgeons in 1965 is applied in this study.

Abduction

Upward motion of the arm away from the trunk in the coronal plane.

range: 0° to 180°

Adduction

The opposite motion; the arm moves downward toward the midline of the body and beyond it in an upward direction.

range: 0° to 75°

Forward flexion

Upward and forward motion of the arm in the anterior sagittal plane of the body.

range 0° to 180°

Depression

The opposite motion of forward flexion; the arm moves downward to the zero position.

range: 180° to 0°

Backward extension

Upward and backward motion of the arm in the sagittal plane.

range: 0° to 60°

Horizontal flexion

Motion of the arm in the horizontal plane anterior to the coronal plane across the body.

range: 0° to 135°

Horizontal extension

Motion of the arm in the horizontal plane posterior to the coronal plane.

range: 0° to 45°

Internal rotation

The arm is abducted to 90° and the elbow is flexed to 90° and in the transverse plane. The palm is turned downward.

range: 0° to 90°

External rotation

Same position of the arm and forearm as for internal rotation; the palm is turned upward.

range: 0° to 90°

The contribution of the glenohumeral and the scapulothoracic motion is best studied by inspection from behind. The patient with a frozen shoulder or a total cuff rupture tends to hunch or elevate the scapulothoracic area without glenohumeral movement.

While moving the arm one can determine the limits of motion, the onset and the disappearance of pain.

Palpation

The palpation is started by testing the passive motions of the shoulder. The same sequence is followed as in testing the active shoulder motions in order to compare the potential differences in range of movement. Before starting the palpation of the shoulder the patient is asked to point to the most tender spot. The investigator starts gentle palpation around the tender area towards the painful spot to avoid muscle spasm. Palpation can also indicate induration, scars, oedema, or increased heat. The muscles and ligaments are considered next. In following order the regions of the trapezius, deltoid, subscapularis, supraspinatus, infraspinatus, teres minor and biceps tendon are examined. The muscles are also palpated during contraction to demonstrate weakness or impedance of muscular function. It is usually impossible to palpate a cuff rupture through the bulk of the deltoid muscle. Next the clavicle, humerus and scapula are palpated to detect deformities or tender trigger points. The acromioclavicular joint, the sternoclavicular and glenohumeral joint are felt for swelling caused by osteophytes, synovitis, instability, subluxation or dislocation.

The axillary artery, the brachial, ulnar and radial artery are palpated to exclude any vascular impairment. Sensory testing of the skin of the shoulder is now performed.

Auscultation

Auscultation is performed during both active and passive motion of the shoulder to localize the area of crepitus. The axillary artery is also auscultated to rule out turbulence caused by a vascular stricture.

Specific manoeuvres

Painful arc test

The patient is asked to bring the arms up in front of him and once 180 degrees of anteversion are reached to bring down his arm at the side. The patient describes whilst lowering the arm the point at which he feels pain, and the level at which the pain disappears.

Test for scapulohumeral rhythm

The investigator observes the patient from behind.

The patient is asked to abduct his arms. Both scapulae should move easily with a smooth continuous rhythm from beginning to end of abduction.

Apprehension test

The examiner fixes the scapula with one hand on the anterior side (coracoid process) and the posterior side (posterior aspect of the acromion). With the other hand he grasps the arm from the medial side while touching the humeral head with the second and third finger in the axilla. By moving the arm forward and backward slight instability anteriorly and posteriorly can be detected.

Adson's test

The subject holds the arm at the side and rotates his head so that the chin points to the ipsilateral shoulder. Next he takes a deep inspiration and holds it while the examiner palpates the radial pulse. The result is positive if the pulse is obliterated. The test is positive in the scalenus anterior syndrome.

Allen's test

With the forearm flexed to 90° and the arm abducted to 90°, the arm is extended and externally rotated; the head is rotated so that the chin points to the opposite shoulder. If this manoeuvre causes temporary obliteration of the radial pulse, the test is positive.

Halstead's test

While the patient hyperextends the neck and rotates the head to the opposite shoulder, the examiner places and holds downward traction on the extremity and palpates the radial pulse. A positive result is recorded if the pulse is obliterated.

Hyperabduction Syndrome test

Hyperabduction may bring the neurovascular bundle tightly around and beneath the coracoid process; the bundle is compressed by the pectoralis minor muscle. Disappearance of the radial pulse on hyperabduction indicates a positive test.

Costoclavicular manoeuvre

The shoulders are thrown backward and downward. At the same time, the wrist pulses become reduced in amplitude while a bruit develops along the course of the axillary and subclavian artery. The test may be positive in abnormalities of the first rib, alterations of the clavicle and in the presence of a cervical rib.

3.4 FURTHER INVESTIGATION

3.4.1 X-ray of the shoulder

The anteroposterior projection with the arm in external rotation reveals the anatomical position of the glenohumeral joint and the relationship of the glenohumeral articulation with the subacromial region. It brings into profile the greater tuberosity and the facet of insertion of the supraspinatus.

With the arm in the neutral position the site of insertion of the posterior part of the supraspinatus tendon is seen. The area of insertion of the subscapularis tendon into the lesser tuberosity is observed with the arm internally rotated.

Burns and Lockie (63) described a technique to view the subacromial soft tissues. The patient is positioned in the anteroposterior position with the arm in external rotation and the central ray is directed to the coracoid process at an angle of 15° towards the feet. This view will reveal calcification in the coraco-acromial ligament if it is present.

The transthoracic lateral view provides valuable information with respect to the position of the humeral head in relation to the glenoid fossa. The cassette is positioned against the affected shoulder. The opposite shoulder is raised overhead so that the supinated arm rests on the top of the head. The central ray is directed perpendicular to the plain of the film at a point just distal to the coracoid process. In the normal joint the arch formed by the axillary border of the scapula and the shaft of the humerus has a smooth dome comprising the inferior neck and head

of the humerus and the inferior neck of the humerus. In posterior dislocation the curve of the dome is narrowed. The curve of the dome is widened in anterior dislocation.

The inferosuperior axial projection is an excellent projection to determine an alteration of the configuration of the humeral head such as may be found in compression fractures accompanying recurrent dislocation of the glenohumeral joint. Fractures of the lesser tuberosity and the glenoid brim are also demonstrated.

The true lateral projection is used in patients when abduction of the arm is too painful. The projection shows the position of the humeral head in relation to the glenoid fossa. It projects the scapula as a letter Y. At the junction of the three limbs lies the glenoid fossa. In the normal subject the head of the humerus is centered at the junction. In posterior dislocation the humeral head faces posteriorly to this junction and under the coracoid process.

The supero-inferior projection shows the bicipital groove.

The West Point Projection brings the antero-inferior aspect of the glenoid brim into sight (63).

3.4.2 X-ray of the cervical spine

Pathology of the cervical spine may produce referred symptoms in the shoulder without any localizing problems in the neck. Physical examination of the neck is often not very helpful and so a radiological examination of the cervical spine is nearly always performed when the presenting complaint is in the shoulder. When looking at the cervical spine we normally use the anteroposterior, the lateral, the right and left oblique projections. The investigator looks for any X-Ray changes which may lead to nerve root compression or irritation (and thus shoulder pain), such as narrowing of the disc space, reduction of the foramina caused by disc prolapse or osteophytes and other congenital, traumatic or degenerative changes. The presence of a cervical rib may also generate shoulder symptoms.

3.4.3 Arthrography of the shoulder

The contrast agent covers the entire articular surface of the humeral head as far as the insertion of the capsule into the anatomical neck. In the anteroposterior projection with the arm in external rotation the subscapularis muscle is tense, therefore the subscapular bursae are not completely filled with contrast material. The sheath of the biceps tendon contains contrast agent and the filling defect within the sheath demonstrates the tendon. With the arm in internal rotation the

contrast medium covers the humeral head and outlines it as a hemisphere. No contrast material appears outside the limits of the joint capsule. The axillary recess is clearly visualized. The biceps tendon is rotated medially in internal rotation and its opacified sheath projects over the head of the humerus close to the joint line and is also visualized distally on the medial aspect of the neck of the humerus. The posterior portion of the glenoid labrum appears as a radiolucent oval filling defect.

The axillary view projects the subscapular recesses in an anterior position at the base of the coracoid process with the bicipital sheath projecting anteriorly. The articular surface of the head of the humerus and the glenoid fossa is discernible. The axillary pouch in the capsule is obliterated in this arm position. The glenoid labrum is demonstrable as lucent triangular filling defects at the superior and inferior aspects of the glenoid fossa. In the bicipital groove projection the opacified synovial sheath of the long head of the biceps tendon lies squarely between the greater and lesser tuberosities of the humerus. Within the sheath the biceps tendon appears as a filling defect.

Abnormal arthrogram

A complete tear of the rotator cuff means the defect in the cuff traverses its entire thickness and thereby establishes a direct communication between the joint cavity and the subacromial bursa. When the contrast agent is injected into the glenohumeral joint, it will flow through the cuff defect and fill the subacromial bursa. A double contrast arthrogram can show the extent of the lesion. Partial tears are seen as irregular defects in the rotator cuff.

In a fresh dislocation of the shoulder the contrast material leaks outside the confines of the capsule. The capsule is pulled off the inferior neck of the humerus or the antero-inferior aspect of the glenoid. Recurrent dislocations cause a stretching or redundancy of the inferior capsule. The redundant capsule is readily demonstrable on the arthrogram. These features are more apparent in internal rotation and axillary projections.

The lucent defect produced by the biceps tendon in the opacified synovial sheath is absent in the case of a rupture of the tendon because both ends of the tendon retract after rupture. A displacement of the biceps tendon and its synovial sheath is best revealed by external projections, which show medial displacement in relation to the bicipital groove. If the bicipital sheath is not detectable on an arthrogram then it is suspicious of a tendinitis of the biceps tendon accompanied by formation of adhesions.

Adhesive capsulitis causes a marked reduction of the volume of the joint capsule. The volume of the capsule is also reduced following operative procedures for

instability of the glenohumeral joint. The external projection also shows a small axillary recess.

Synovitis of the glenohumeral joint reveal on arthrography a contracted joint capsule whose surface is irregular.

Loose bodies within the glenohumeral joint can best be demonstrated by double contrast arthrography. In the single contrast arthrography they appear as filling defects. The origin of loose bodies may be osteochondral or chondral fractures. Large amounts of loose bodies may be produced by synovial chondromatosis.

3.4.4 Electromyography

Electromyography is a tool in the diagnosis and management of neuromuscular disease. Electromyography uses a wide variety of techniques including evoked potentials, late responses, blink reflexes, single fibre and, macro electromyography, measurements of muscle force and acoustic electromyography. The electromyography can answer questions as to the completeness of a lesion, the proportion of motor and sensory fibres involved, the time the lesion occurred etc. The characteristic conduction delay through the carpal tunnel in the carpal tunnel syndrome is readily demonstrated. When the clinical examination points to a lesion involving a single nerve root, concentric needle electromyography, that shows denervation in at least two muscles within its distribution, strongly supports the presence of a lesion at that side. Electromyography also can establish whether generalized muscle weakness is due to a disease of the anterior horn cell, peripheral motor fibres, neuromuscular junction, or if it is due to disease primarily within muscle.

In the investigation of shoulder problems the function of the electromyography may be in ruling out those neuromuscular diseases that produce equivocal historical and clinical data and may mimic pathological states of the shoulder. This may be especially so in the presence of such radiological changes in the cervical spine as narrowing of one or more disc spaces or narrowing of foramina by osteophytes and could lead to further investigation of the nerve roots.

In the case of shoulder pain with radiation into the neck and the arm an electromyogram could exclude nerve compression.

In conclusion electromyographical studies of the neck and shoulder region may demonstrate nerve lesions leading to muscular dysfunction and atrophy.

3.4.5 Bonescanning

Radionuclide scintigraphy is useful in detecting a metabolic bone disease, arthritis of a joint, osteomyelitis, tumours and other bone diseases causing an increased

turn-over of osteogenic and osseous tissue. As most of the diseases of this study do not fit into these categories a bone scan is normally not necessary. Osteoarthritic changes also cause pathological findings on a bone scan, but a plain X-ray usually provides sufficient information to make a diagnosis without resorting to a scan.

3.4.6 Ultra-sonography

Ultra-sonography of the shoulder is a non-invasive technique. The method is useful for the detection of rotator cuff lesions and biceps tendon lesions. Ultra-sonography is rapid, save and inexpensive.

3.4.7 Computed tomography scanning

Computed tomography of the shoulder especially with the use of contrast may procure, useful information of the condition of the rotator cuff, the humeral head, the glenoid labrum and capsule.

The technique also enables an assessment of the quality of the tissues.

3.4.8 Magnetic resonance imaging

The M.R.I. is a relatively new very promising diagnostic instrument. The literature (71) about the M.R.I. concerning the diagnostics of shoulder complaints are at the moment still to minor and preliminary. So further investigation needs to be done to justify its place in the evaluation of shoulder complaints.

3.5 DISCUSSION

In order to form a diagnosis in shoulder pathology, the history and examination of the patient are the most important. Some authors (48) claim to obtain more correct diagnoses with the help of special tests during examination of the patient. Furthermore several additional investigations may lead to a correct diagnosis. The reason to perform additional investigations is based on the physicians incertitude concerning the interpretation of the data collected during the history and examination of the patient.

The purpose of this study is not to compare the different additional investigations, but to compare the information collected during the history and the examination of the patient with the information of the arthroscopy of the shoulder.

CHAPTER 4

The diagnostic arthroscopy of the shoulder: technique, normal findings and pathological changes

4.1 TECHNIQUE

In order to be clinically useful, arthroscopic examination of the shoulder must be both systematic and reproducible. It may present more difficulties than arthroscopy of the knee joint, because the knee is more accessible by virtue of its anatomy. In the shoulder a space has to be created to allow arthroscopy; furthermore the bony landmarks of the shoulder are more deeply buried and difficult to palpate. The joint is surrounded by several layers of muscles, which makes finding the position of the glenohumeral joint difficult. In general, bursoscopy is less complicated due to the more superficial position of the sub-acromial bursa and the availability of good palpable landmarks.

Once in the joint, the structures are as easy to reach as in arthroscopy of the knee and unlike the knee, finding loose bodies is relatively easy due to the absence of "hiding places".

Experience in this field has been gained by several pioneers of endoscopic surgery of the shoulder. The earliest reviews of this topic are written by Watanabe (194), Johnson (98), Wiley and Older (199). Ha'eri (85) has shown that in 24 patients with a frozen shoulder, intra-articular adhesions were absent, confirming the impressions of Neviaser (141), and Lundberg (118), and that the

pathology in these patients was localized in the soft tissues surrounding the glenohumeral capsule. Caspari (45) describes arthroscopic synovectomy of the shoulder joint. Andrews (11) has described intra-operative stimulation of the biceps tendon to allow visualization of partial tears of the rotator cuff. Matthews et al. (122) present a description of the technique of shoulder arthroscopy and mention its indications. In their report the authors compared the findings using double contrast arthrography and arthroscopy. Those patients with negative arthrograms demonstrated pathological lesions such as Hill-Sachs defects, labral tears and Bankart lesions at arthroscopy.

Although they suggest that arthroscopy can differentiate between the clinically identical symptoms of subluxation, a displacing bucket handle labral tear, radiolucent loose bodies and atypical impingement, they offered no proof of their findings. The indications are not based on research, but are mere hypothetically. The article of Andrews (11) describes the technique but is more reserved as regards the value of the procedure. In order to fully assess the possible indications for arthroscopy, it is necessary to first discuss the technique and its limitations.

Several portals are described to allow access to the glenohumeral joint. In this study the anterior and posterior approach were mainly used. Arthroscopic surgical instruments were introduced into the shoulder via a superior portal between the clavicle and acromion or the anterior portal.

4.1.1 The equipment

The equipment used in this study consisted of a light source, a fibre optic light cable, an arthroscope, camera, recorder, colour video monitor, a 35 mm camera and arthroscopic surgical instruments.

The light source

A Storz TTL-Computer Flash Unit, type 600 BA, 220 volt, 40-60 Hz, consisting of flash generator synchronization cable and cold light fountain.

The light cable

A Storz Fibre Optic light cable. Size 3.5 mm. 495 NL.

The arthroscope

A 7200 B Hopkins 30 degree forward-oblique telescope. Fibre optic light transmission is incorporated in the telescope.

A 7200 C 70 degree lateral telescope .

Other arthroscopic instruments

Arthroscope sheath.

Sharp and blunt trocar.

Probe.

Atraumatic grasping forceps.

Basket cutting forceps.

Irrigation drain.

2 liter bags of normal saline or lactated Ringer solution.

Video equipment

A video recorder.

A video camera.

A colour monitor.

35 mm camera

A single lens reflex camera with T.T.L. metering.

4.1.2 The operating theatre

In the theatre, all the sterile equipment, the surgeon, the assistant and the scrub nurse are positioned on one side of the operating table. The anaesthetist and his equipment are on the opposite side, while the non sterile equipment, including video recorder, television screen, light source and drip stand with irrigant are located at the head end of the table. Waterproof drapes are advisable, as the operating field is invariably wet. The assistant stands next to the surgeon and can therefore manipulate the arm of the patient. As many tubes and cables cross both the sterile and non-sterile areas, the assistant can help prevent tangling and contamination.

The operating room layout for an arthroscopy of the right shoulder is shown in fig. 4.1.

Fig. 4.1 Operating room set-up

4.1.3 The anaesthesia

Local anaesthesia

In the anterior approach local anaesthetic may be administered and to avoid bleeding lignocaine 1% with adrenalin 1 : 100,000 is used. If this is the preferred method, then joint irrigation through the scope is used. The site of injection is found by palpating the skin just lateral to the coracoid process. A 10 cc syringe fitted with a spinal needle, having a diameter of 0.8 mm and 90 mm long is used, and after preparation of the skin, the local anaesthetic is injected into the skin, subcutaneous tissue and deltoid muscle. 3 cc of anaesthetic are injected into the subacromial bursa, and then the subscapularis muscle, capsule and glenohumeral cavity are infiltrated with the remaining lignocaine.

General anaesthesia

If the posterior approach is used, general anaesthesia is mandatory. The position of the patient, the effects of the traction on the arm, the introduction of the scope and irrigation system would be too painful for the patient. A very useful advantage of general anaesthesia is the availability of good muscle relaxation, and if this proves to be necessary during anterior instrumentation, then general anaesthesia is also recommended for the anterior approach.

4.1.4 The operation technique

Arthroscopy via the anterior approach

Positioning of the patient

The patient is supine on the operating table, with the arm free to permit manipulation.

In this position both local and general anaesthesia can be used comfortably. A thin small pillow is placed between the scapulae. This makes the anterior glenohumeral joint space more prominent and makes palpating the coracoid process easier, as the humeral head drops backwards and the coracoid process rotates forward.

Introduction of the arthroscope

With the patient in a supine position, the point just lateral to the coracoid process is marked. A 5 mm incision is made and the sheath with its sharp trocar is introduced in a slightly cranio-medial direction. After piercing the subcutaneous tissues and subscapularis muscle and the capsule of the glenohumeral joint, the sharp trocar is exchanged for the blunt one. The sheath and blunt trocar are gently pushed forward until it is felt to easily enter the joint. The surgeon is able to feel the cartilaginous surfaces of the joint. The blunt trocar is now replaced by the arthroscope. No separate outlet drain is used, but irrigation of the joint is controlled by a two tap system built into the sheath of the arthroscope. Once the arthroscope is in the joint, the light cable, camera, inflow and outflow tubings are connected. Inspection of the joint is now possible.

Arthroscopy via the posterior approach

Positioning of the patient

After induction of general anaesthesia the patient is placed in the lateral decubitus position with the involved side up. Adequate stabilization is necessary and a deflatable Olympic Vac Pac is very effective. The same position can be

obtained by using hip rests. Skin traction is applied to the forearm using elastic adhesive tape and a traction spreader. A traction pole with a pulley is attached to the foot of the operating table on the side away from the surgeon. The arm is then suspended with traction at 45-60 degrees of abduction using not more than 3 kilograms of weight. In smaller patients less weight is needed. Slight forward traction is important to facilitate posterior entry into the shoulder joint. The traction pole is fixed to the table, so that moving of the table will not influence the traction angle and it is important to make sure that no undue force is applied to the arm. Preparation and draping is accomplished in a routine fashion. Waterproof drapes should prevent contamination. The arm in traction is wrapped in a sterile half sheet and the weight and traction pole are not draped.

Introduction of the arthroscope

A point is identified 1 cm medial and 2 cm below the posterolateral edge of the acromion. An incision is made, 5 mm long. The arthroscope sheath with its sharp trocar is introduced in a slightly medial direction, piercing the subcutaneous tissues and the infraspinatus muscle, to enter the glenohumeral joint. Palpation of the coracoid process provides an additional guide with the tip of the sharp trocar pointing to the base of the coracoid process. When the capsule has been pierced, the sharp trocar is replaced by the blunt trocar in order to avoid damage of the cartilage of the glenohumeral joint. Safe manipulation is now possible and further insertion of the trocar is performed until the tip of the blunt trocar reaches the anterior capsule. The blunt trocar is exchanged for the sharp one, and the capsule, subscapularis muscle and subcutaneous tissue are transfixed. The sharp trocar is removed and a small incision is made over the palpable sheath. The sheath is pushed forward till the top of the sheath is visible and the outlet drain is inserted into the sheath. Subsequently the sheath is retracted till the drain is freely mobile in the glenohumeral joint. The arthroscope is now introduced into its sheath and the light cable, inflow and outflow tubing are now connected. The video camera is attached to the arthroscope. Then inspection of the joint is started.

Arthroscopy of the subacromial space

Once the glenohumeral joint has been inspected, the arthroscope is replaced by the blunt trocar. The subacromial space can be reached by retracting the trocar out of the joint until the resistance provided by the capsule and rotator cuff can be felt to lessen. At this point the tip of the trocar is pushed underneath the acromion, gaining entry into the subacromial space. The trocar is then exchanged for the scope and the bursa can be explored. If bursoscopy is performed without

inspection of the glenohumeral joint, then the same incisions are made as for the anterior or posterior approach. After transfixion of the deltoid muscle the sheath and trocar is directed under the acromion and its undersurface is palpated with the tip of the trocar. The consistency of the bone is a reliable guide to the placement of the arthroscope in the subacromial bursa.

4.2 NORMAL FINDINGS AND PATHOLOGICAL CHANGES

Like all other joints the glenohumeral joint and subacromial space have to be examined in a systematic fashion. The best landmark for orientation in the joint is the biceps tendon and especially the attachment of the tendon to the supraglenoid tubercle. The following are a list of the visible structures in order of their appearance:

1. The biceps tendon and bicipital groove,
2. The superior and posterior capsule and rotator cuff,
3. The articular surface of glenoid fossa,
4. The anterior and posterior glenoid labrum,
5. The inferior recess,
6. The anterior capsule, subscapularis tendon and recesses,
7. The humeral articular surface,
8. The subacromial space.

4.2.1 The biceps tendon and bicipital groove

Normal appearance

The biceps tendon is followed from its attachment on the superior aspect of the glenoid to the area where it enters the bicipital groove. It is the best intra-articular reference structure with which to start the examination. The biceps tendon is visible as a bright white tendon and the tendon fibres are clearly visible. The synovial covering produces the glossy surface. The attachment of the tendon on the superior notch of the glenoid is seen to smoothly blend into the superior glenoid labrum. The diameter of the tendon is such that from a relatively short distance, its upper and lower margin are visible. This in contrast with the subscapularis tendon. The subscapularis tendon may seem at first sight to be the biceps tendon, but it is much larger and this becomes more obvious by retracting the arthroscope.

Fig. 4.2 normal biceps tendon

Fig. 4.3 biceps tendon with inflammatory changes

Pathological findings

The biceps tendon may be affected by both traumatic and degenerative lesions. An acute rupture is rarely seen but if it is present, the ends of the tendon show well defined cut tendon fibres. The intact parts of the tendon retain their normal thickness and their appearance is pale and glossy with a smooth surface. The degenerative tendon is thickened, the synovial covering has an opaque appearance and an irregular surface has developed. The tendon fibres have become thickened and fibrous tissue may have replaced parts of the tendon fibres. Areas of hypervascularity may be found. In cases of acute inflammation of the biceps tendon the total intra-articular portion of the tendon is covered by a thickened hypervascular synovium which is still transparent. Eventually areas of haemorrhage appear. In chronic tendinitis microlesions producing partial and complete ruptures may result. Inflammation or degeneration of the biceps tendon usually involves the adjacent part of the rotator cuff as well.

4.2.2 The superior and posterior capsule and rotator cuff

Normal appearance

The superior and posterior rotator cuff tendons with the interlacing capsule present as a continuous white or slightly yellow structure covered with translucent glossy synovium.

The margins of the rotator cuff tendon may be visible as grooves in the inner aspect of the cuff. If local anaesthesia is applied the patient is able to contract the muscles of the rotator cuff actively. The grooves appear then even more obvious. After inspection of the biceps tendon, the scope is rotated upward and immediately the upper cuff is seen. To inspect the posterior capsule a 70 degree forward oblique scope may be necessary.

The attachment of the capsule to the humeral head and glenoid labrum shows a distinct change of appearance. Normally the capsule with a synovial lining shows a smooth appearance.

Fig. 4.4 normal superior capsule

Fig. 4.5 degenerative changes of the rotator cuff

Pathological findings

Anatomical studies have shown that the area of the rotator cuff most prone to pathological alteration is the "critical zone".

The changes in the rotator cuff that may be present are acute inflammation, calcific deposits, chronic inflammation with degenerative changes and eventually a partial or total cuff rupture. Acute rupture is mentioned in the literature but in this study no acute rupture of the rotator cuff was found.

In acute inflammation the undersurface of the superior capsule and cuff is covered with an hypervascular irregular synovial lining. The synovium is thickened, but still translucent. Calcific deposits show as white homogeneous spots within the tendon structure. In the acute stage no major changes of the fibre pattern of the cuff is detectable. The transition to chronic degenerative changes is dependant on the progression of the disease. In the beginning, minor changes

in the pattern of the tendon fibres are visible as a slight irregularity of the tendon surface, accompanied by minor fibre ruptures, and reparative fibrous changes. As time goes by, more obvious irregularities are detectable such as major structural changes of the tendon tissue resulting in partial or complete cuff ruptures. The borders of a small rupture can be traced with the arthroscope. In large ruptures the undersurface of the acromion and deltoid muscle are seen. The margins of degenerative ruptures are smooth and rounded. In the case of rotator cuff rupture caused by a dislocation of the glenohumeral joint the margins of the defect are abrupt and irregular.

4.2.3 The articular surface of the glenoid fossa

Normal appearance

The slight concave glenoid fossa has a smooth cartilaginous surface. It appears white and shiny. Following the borders of the glenoid the piriform shape of the articular surface is conspicuous. On the superior part, the attachment of the biceps tendon constitutes the margin of the articular surface and so most of the border consists of the glenoid labrum.

Fig. 4.6 normal glenoid fossa

Fig. 4.7 glenoid fossa with chondropathy

Pathological findings

Dislocation of the glenohumeral joint may lead to a chondropathy of the ovoid glenoid surface with an abrasion fracture of the anterior or posterior part of the

glenoid. Defects of the central glenoid surface may be seen as a result of direct trauma.

4.2.4 The anterior and posterior glenoid labrum

Normal appearance

The fibrocartilaginous glenoid labrum is obvious by its slightly different colour. The appearance is slightly darker than the bright white cartilage of the glenoid fossa. The triangular cross section of the labrum produces a more inclined edge than the articular surface.

Fig. 4.8 normal labrum

Fig. 4.9 labrum with traumatic changes

Pathological findings

The pathological changes affecting the labrum depend upon the initial trauma. Possible deformities consist of irregularities, transverse or longitudinal ruptures with or without degenerative changes. In an anterior dislocation of the shoulder the whole antero-inferior part of the labrum may be avulsed, and likewise the posterior part in a posterior dislocation.

In the case of a total avulsion, the labrum lies like a meniscus in the glenohumeral joint.

4.2.5 The inferior recess

Normal appearance

With the arm next to the body the inferior recess appears as a deep cavity with a folded wall. The appearance is the same as the other parts of the capsule with a translucent synovial covering overlying a whitish capsule. When the arm is abducted the recess disappears and becomes a smooth expanded structure.

Pathological findings

In cases of frozen shoulder, adhesions may be seen in the axillary recess. These adhesions have a translucent or opaque white appearance and consist of fibrinoid septa. Also a retraction of the capsule is sometimes seen as a result of long-standing shoulder pain leading to loss of motion. Furthermore the synovial lining may show the above mentioned features of inflammation. Loose bodies in the glenohumeral joint are usually seen in the axillary recess. Arthroscopy of the recess is best performed whilst abducting and adducting the arm. This operation enables the investigator to judge the tension of the inferior capsule and to assess the restriction of movement due to the adhesions.

4.2.6 The anterior capsule, subscapularis tendon and recesses

Normal appearance

Before studying the anterior capsule and the variety of recesses, knowledge of the differences in the architecture of the anterior wall of the glenohumeral joint avoids misinterpretation of the arthroscopic findings. The various anatomical variations are discussed in chapter 2.

The anterior capsule demonstrates the same smooth surface as the other parts of the capsule. The subscapularis tendon is often clearly visible as a horizontal strand anterior to and slightly below the biceps tendon making confusion with the subscapularis tendon easy. The attachment of the capsule is clearly seen at the side of the anterior labrum. If a recess or more recesses are present, the scope can be pushed into them. If this is tried, the capsular wall feels much thinner. Differentiation between a recess and capsular tear is apparent from close inspection of the capsular fibres. If a recess is present, the capsular fibres are continuous, whereas the presence of a capsular tear results in discontinuity and mal-alignment of the fibres. The margins of the tear are irregular and mostly thickened.

Pathological findings

In cases of shoulder instability, arthroscopy may reveal tears of the anterior capsule. In a fresh rupture, the borders are clear cut whereas in older cases the borders become rounded and reparative scar tissue may fill the gap. The normal recesses of the shoulder can be confused with a capsular tear. However in the presence of recesses precise anatomical borders are seen without irregularities and/or scar tissue formation. When instability is present, repetitive irritation can also lead to a synovitis. This is demonstrated arthroscopically as a thickening of the synovium, formation of synovial flocks, hyperaemia and the eventual formation of inflammatory tissue.

4.2.7 The humeral articular surface

Normal appearance

The humeral head is easily seen with its convex surface white and glistening. It is not always possible to inspect the whole surface and occasionally the 70 degree forward scope is necessary.

Palpation of the cartilage with a probe during arthroscopy gives additional information about the quality of the hyaline cartilage.

In the transitional areas between cartilage and capsule, villous synovium may be present.

Fig. 4.10 normal aspect of the humeral head

Fig. 4.11 chondropathy of the humeral head

Pathological findings

The articular surface may show a defect on the posterosuperior aspect of the humeral head, caused by an anterior dislocation of the glenohumeral joint. A chondropathy ranging from grade 1 to 4 may be seen on the entire surface. On several occasions severe chondropathy was present on arthroscopy, whilst radiographic examination did not show any abnormality.

4.2.8 The subacromial space*Normal appearance*

The subacromial bursa and the undersurface of the acromioclavicular joint show several features. Underneath the acromion the synovial lining is perceptible as a thin translucent layer that cannot be separated from the bony structure. In the subdeltoid area the synovial layer is seen to be adherent to the subdeltoid fascia. The appearance of the roof of the bursa is white or a very pale yellow. Once the superior aspect of the bursa has been inspected the arthroscope is turned 180 degrees to the diaphanous synovial covering of the superior side of the rotator cuff. The pale glossy fibres of the tendinous cuff clearly demonstrate the direction of the tendons. A distinct groove between supraspinatus and subscapularis tendon must not be confused with a rotator cuff tear. The border between supraspinatus tendon and infraspinatus tendon is less discernable. One or more septa may be present in the subacromial bursa appearing as semi translucent or opaque thin walls easily transfixated with the arthroscope. After having pierced the subacromial bursa in a medial direction the acromioclavicular joint with its inferior layer of capsule and the inferior ligament can be seen at the medial and anterior end of the bursa.

The varieties of bursal size, shape and presence of bursal septa are discussed in the anatomical description of the subacromial bursa in chapter 2.

Fig. 4.12 normal subacromial space

Fig. 4.13 bursitis of the subacromial bursa

Pathological findings

In the diseased subacromial space changes can be detected on the undersurface of the acromion, the distal aspect of the acromioclavicular joint and the rotator cuff.

It may be necessary to first remove scar tissue with a shaver in order to allow a clear vision. The undersurface of the acromion may show inflammatory changes. The surface is then irregular, showing haemorrhagic inflammation or degenerative changes with the formation of scar tissue. The anterior border may be thickened caused by an osteophyte. The undersurface of the acromioclavicular joint is sometimes thickened also caused by the formation of osteophytes. This thickening of the capsule also may be caused by instability of this joint.

The synovial lining of the rotator is thickened in the case of bursitis. The synovial lining may become opaque.

In the case of acute bursitis it has a reddish aspect caused by haemorrhagic inflammation. In the case of chronic bursitis the degenerative changes, the scar tissue formation and adhesions are predominant. Careful inspection of the rotator cuff may reveal a partial rupture of some tendon fibres, more extensive partial ruptures till complete ruptures. In the case of large complete cuff ruptures the glenohumeral joint is visible in its entirety.

CHAPTER 5

Analysis of the data collected in 210 patients with shoulder pain

5.1 INTRODUCTION

In the preceding chapter a survey was given of the technique and possible findings of arthroscopy of the shoulder. In this chapter a survey of data collected in a group of 210 patients will be presented. For each patient a proforma was completed. The collection of data started at the first visit of the patient at the Outpatients Department and stopped after a follow up of two years.

The arthroscopies in these patients have been performed from October 1982 until March 1987.

The collection of data has stopped at a prior fixed deadline (December 1989). The material and method are explained in section 5.2. Also in- and exclusion conditions are described.

The structure of the proforma is explained in section 5.2.1.

In section 5.3 an analysis is given of the data collected before the arthroscopy. The findings obtained at arthroscopy are presented in section 5.4 and these findings are compared with the findings at operation.

All the patients are followed for a certain period after the operation and the data of this follow up are presented in section 5.5.

In section 5.6 the collected data will be discussed.

5.2 MATERIAL AND METHOD

In the period January the 1st 1982 until January the 1st 1990 each patient with shoulder complaints was included in the study. During the first visit at the Outpatients Department a first selection was executed. If there was a reason to think of an acute extrinsic cause of the shoulder pain the patient was excluded, if not the patient was treated conservatively, i.e. physiotherapy, non steroid anti inflammatory drugs or steroid injections.

If conservative treatment was to no avail further measures were taken. This point was the proper start of the study. Of each patient with this history a proforma was completed. A condition of inclusion is that the patient was between 10 and 80 years old. The patient's history was taken and a physical examination was performed. Also additional examinations were executed.

Based on the results of these examinations the group of patients with shoulder complaints caused by extrinsic factors were excluded.

The next step in the study was to come to the decision what kind of operation had to be performed. An arthroscopy of the shoulder was done to help in decision making. The determination of the importance of the arthroscopy was the main target of this study and is discussed later on. The diagnosis formulated after the arthroscopy was noted on the proforma and this diagnosis was compared with the diagnosis made after the operation. The patient was followed during two years after hospital discharge. The information obtained from every visit of the patient at the Outpatients Department was noted on the proforma, with special emphasis on the function, pain and satisfaction score.

5.3 THE PROFORMA

This paragraph explains the structure of the proforma. See for the entire proforma Appendix 1.

The proforma consists of 5 major parts:

part 1

The basic information of the patient like name, date of birth, dates of the successive interventions and respective made diagnoses are listed in this part.

part 2

This part contains the history of the patient, the physical examination and further investigation.

- **History:** All the features of the presenting complaint: start date of the complaint, duration, provocative moments, aggravation, localization, irradiation, intensity and causal factors are noted.
Furthermore the information about restriction of movement, previous therapy and complaints other than shoulder pain are listed.
- **Physical examination:** In this part the information of the inspection, palpation, auscultation, passive and active movements and special maneuvers of the neck and shoulder are listed. In addition to this relevant findings of the general examination are noted.
- **Further investigation:** The findings of the radiographs of the cervical spine and shoulder, the arthrogram and electromyography are listed in this part.

part 3

In this section the findings of the arthroscopy are noted. A total of 10 pathological states are listed and for each item the answer can be yes or no in order to describe the pathology of the subacromial space and the glenohumeral joint.

part 4

In this section a list of the same 10 pathological states is given to describe the pathological findings at operation.

part 5

This part describes the follow up of the patients after the operation and is concentrated on 3 items: the function of the shoulder, the painscore and the subjective interpretation of the complaints. These data are noted at several time points: before the operation, at 1 month, 3 months, 6 months and at the end of the follow up. The function is graded from 0 to 10; 0 means no function at all and 10 represents 100% function. The visual analog painscore is used to grade the pain (96,115,172). The subjective interpretation of the complaint (satisfaction) is graded from 1 to 4. 1 = 'bad', 2 = 'fair', 3 = 'good' and 4 = 'excellent'. Furthermore questions concerning occupation, disablement and satisfaction are listed in this section.

5.4 ANALYSIS OF THE DATA OBTAINED BEFORE ARTHROSCOPY

From January the 1st 1982 to January the 1st 1990 210 patients were included in the study, 108 males and 102 females. The average age of the male patients was 42.8 years (STD 12.8) and of the female patients 42.6 years (STD 12.3). The age distribution has been about the same and no significant differences have been found between them (see fig. 5.1).

Fig. 5.1 Age distribution for men and women.

In all the patients there was no relief by conservative treatment. The duration of symptoms prior to arthroscopy ranged from 3 to 120 months, the average was 21.8 months, (STD 19.8).

The cause of the shoulder pain was in 34 cases a trauma, in 53 cases there was an overuse of the shoulder, in the other cases the cause was unknown. A continuous pain was present in 68 patients.

In 182 cases the pain was present while moving the shoulder. In 28 patients the pain was present in rest as well as while moving the shoulder.

In 160 cases the pain had a progressive character.

174 patients complained of nightpain.

The localization of the pain is shown in table 5.1.

Table 5.1 Localization of shoulder pain (N=210)

neck/shoulder	4
neck/shoulder/arm	49
shoulder	46
shoulder/arm	111
<i>specified for the shoulder:</i>	
top of the shoulder	90
back of the shoulder	2
front of the shoulder	59
biceps area	32
insertion deltoid	70
whole shoulder	36

Physical examination

In 172 cases a painful arc was detected.

161 patients had a disturbed scapulothoracic rhythm.

Additional examination

In all patients an X-ray of the shoulder and cervical spine was taken. On X-ray of the shoulder no abnormality was found in 132 cases. The X-ray of the cervical spine showed no abnormality in 167 cases.

All patients had an arthrography of the glenohumeral joint.

With an arthrography a cuff rupture, other pathology or no abnormality can be detected. In 24 of the 210 patients a cuff rupture was detected. This result is important as it will be used in chapter 6 for the evaluation of the additional value of arthrography of the shoulder in combination with arthroscopy, also it is an important number to compare the arthrography with the arthroscopy.

Based on the history, physical and additional examination a decision was made concerning the operation to be carried out.

In a number of cases no exact diagnosis could be formulated.

In 72 cases there was no certainty about the diagnosis and the kind of operation to be performed.

Especially when the complaints of the patient were based on micro-instability it appeared to be difficult to choose the right kind of operation.
In all 210 patients an arthroscopy of the shoulder was performed.

5.5 DATA OF ARTHROSCOPY AND OPERATION

After the arthroscopy of the shoulder the findings were noted on the proforma. Table 5.2 shows 10 pathologic findings and their respective frequencies.

Table 5.2 Pathologic findings and their frequencies.

	pathologic finding	frequency
1	bursitis	168
2	cuff degeneration	135
3	cuff rupture	26
4	biceps pathology	59
5	capsule/labrumtear	31
6	chondropathy	28
7	Hill-Sachs lesion	5
8	loose bodies	1
9	adhesions	33
10	synovitis	39

During and after arthroscopy no complications were observed.

In order to analyze the results in a sensible way the patient population has to be divided in subdivisions of patients who have undergone a certain surgical procedure.

In the 210 patients the following operations were performed:

- Operation I The "Neer" subacromial decompression.
- Operation II The "Neer" + cuff repair.
- Operation III The "Neer" + Resection of the distal end of clavicle.
- Operation IV The procedure of "Putti-Platt".
- Operation V Fixation of the biceps tendon.
- Operation VI Manipulation of the shoulder under anaesthesia.

In the "Neer" procedure (82,133,183) an osteotomy is performed of the undersurface of the anterolateral part of the acromion. In addition the coraco-acromial ligament is removed. Partial resection of the subacromial bursa is executed if necessary, calcific deposits may be removed.

A cuff repair can be carried out by direct repair of the defect. In larger defects special procedures are performed (55,60,180). Resection of the distal end of the clavicle consists in the removal of 1 cm of the distal clavicle, while taking care that as much of the a-c capsule and ligaments remain intact (67,92). The procedure of "Putti-Platt" (25,37,147) consists in shortening of the anterior capsule and subscapularis tendon. In the case of avulsion of the anterior labrum this defect is also repaired ("Bankart" procedure) (127,163). In the event of a dislocation of the biceps tendon the tendon is fixed in the bicipital groove with a staple (63). The Manipulation of the shoulder Under Anaesthesia (MUA) consists in moving the shoulder under anaesthesia in all directions in order to tear up adhesions.

The successive operations correspond with the post operative diagnoses as follows:

Operation I	with bursitis and cuff ruptures not needing repair.
Biceps tendon changes may be present.
Operation II	with bursitis and cuff ruptures needing repair.
Biceps tendon changes may be present.
Operation III	with acromioclavicular pathology with or without bursitis.
Biceps tendon changes may be present.
Operation IV	with anterior instability of the shoulder, loose bodies.
Operation V	with dislocation of the biceps tendon.
Operation VI	with adhaesive capsulitis with or without bursitis, with or without a cuff rupture and changes of the biceps tendon.

For the above mentioned surgical procedures the subsequent results are presented in the following sections. For practical reasons the performed operations will be represented by respectively Op.I, Op.II, Op.III, Op.IV, Op.V and Op.VI in the cross tables and figures.

The distribution of the performed operations is shown in fig. 5.2.

Fig. 5.2 Distribution of performed operations.

Operation I,II,III,V and VI are the operations for impingement. Operation IV represents the operation for instability of the shoulder. In fig. 5.3 the age distribution is shown for the patients with instability of the shoulder and the group of patients with impingement.

Note that instability is found at a relatively young age (average age 27.6 yrs, STD 7.1) and that the impingement is mostly seen in relatively older patients (average age 45.4 yrs, STD 11).

The interval between arthroscopy and operation was on average 3 months (range 0 -13 months).

Fig. 5.3 The operation for instability of the shoulder.

During the operation was looked for the presence or non presence of the same 10 items as mentioned for the arthroscopy.
It was only possible to check the glenohumeral joint in 124 patients (see chapter 6 section 6.1.2).

Table 5.3 shows the differences between the arthroscopic and operative findings.

Table 5.3 Faulty observations made during arthroscopy.
 (+ false positive, – false negative)
 Q = number of positive observations made during operation.

	Op.I	Op.II	Op.III	Op.IV	Op.V	Q
bursitis	–	–	–	–2	–	91
cuff deg.	–1	–	–	–	–	82
cuff rupt.	–1	–4	–	–	–	27
biceps path.	–	–	–	+3	–1	49
caps/labr.	+1	–	–	–1	–	31
chondropathy	+1	–	–	–	–	21
H-S lesion	–1	–	–	–1	–	6
loose bodies	+2	+1	–	+1	–	2
adhaesions	+2	–	–	–	–	18
synovitis						29
total						357

In graph 5.1 to 5.5 the results for each operation group are shown. In graph 5.3 considerable difference can be seen for respectively item 3 and 9. In graph 5.5 the difference between the arthroscopic and operative item 4 is not that impressive as the number of patients in this group is only 3.

Graph 5.1 Percentage of positive observations at arthroscopy and operation for
 the Neer procedure

Graph 5.2 Percentage of positive observations
Neer + cuff repair

Graph 5.3 Percentage of positive observations
Neer + resection of distal end clavicle

Graph 5.4 Percentage of positive observations
Putti Platt

Graph 5.5 Percentage of positive observations
Fixation of biceps tendon

5.6 FOLLOW UP

For each patient before the operation three scores were noted on the proforma:

1. the function score,
2. the pain score,
3. the satisfaction score.

The function score is graded from 0 to 10. 0 represents no function at all and score 10 represents 100% function. The linear visual analog pain score was used to grade the pain (115). The satisfaction score was graded from 1 to 4 : 1 = "bad", 2 = "fair", 3 = "good" and 4 = "excellent".

These three scores were noted on the proforma at 5 time points: before the operation (represented by the letter A), 1 month after the operation (represented by the letter B), 3 months (represented by the letter C), 6 months (represented by the letter D), 2 years after the operation (represented by the letter E).

At the end of the follow up the patient was asked:

if he felt better or worse concerning the shoulder then before surgery,
if he had resumed his previous occupation and
if he was receiving a disablement pension.

Crosstab 5.1 to 5.6 show the results of the respective operations.

The correlation coefficient, "Pearson's moment product r ", is calculated respectively for the variables function and satisfaction and for the variables pain and satisfaction.

Crosstab 5.1 Follow up versus average scores
"Neer" procedure (N=143)

Rows : follow up time points.
Columns : average function, pain and satisfaction score.

	function	pain	satisfaction
A -before surgery.	8.5	6.2	1
B -1 month postop.	6.2	4	2
C -3 months postop.	8	1.8	2.6
D -6 months postop.	8.9	1.7	3
E -end date of study	9.2	1.2	3.1

Pearson's r correlation between function and satisfaction ($r=0.42$)
correlation between pain and satisfaction ($r=-0.98$)

Crosstab 5.2 Follow up versus average scores
"Neer" procedure and cuff repair (N=18)

Rows : follow up time points.
Columns : average function, pain and satisfaction score.

	function	pain	satisfaction
A -before surgery.	8	8.4	1
B -1 month postop.	5.9	5.6	2
C -3 months postop.	7.7	3.9	2.6
D -6 months postop.	8.4	3.6	2.8
E -end date of study.	8.6	2.5	2.9

Pearson's r correlation between function and satisfaction ($r=0.31$)
correlation between pain and satisfaction ($r=-0.99$)

Crosstab 5.3 Follow up versus average scores
"Neer" and resection distal end of clavicle (N=8)

Rows : follow up time points.

Columns : average function, pain and satisfaction score.

	function	pain	satisfaction
A -before surgery.	9.8	7.5	1
B -1 month postop.	7	5.4	1.9
C -3 months postop.	8.9	3.1	2.6
D -6 months postop.	9.6	2.5	2.8
E -end date of study.	9.8	2	3

Pearson's r correlation between function and satisfaction ($r=0.15$)
correlation between pain and satisfaction ($r=-0.95$)

Crosstab 5.4 Follow up versus average scores
"Putti Platt" operation (N=32)

Rows : follow up time points.

Columns : average function, pain and satisfaction score.

	function	pain	satisfaction
A -before surgery.	9.7	6.5	1.1
B -1 month postop.	1	3.3	2
C -3 months postop.	7.2	2.8	2.8
D -6 months postop.	9	1.5	3.4
E -end date of study.	9.3	1.7	3.2

Pearson's r correlation between function and satisfaction ($r=0.20$)
correlation between pain and satisfaction ($r=-0.98$)

Crosstab 5.5 Follow up versus average scores
Fixation of biceps tendon (N=3)

Rows : follow up time points.
Columns : average function, pain and satisfaction score.

	function	pain	satisfaction
A -before surgery.	9.3	7.5	1
B -1 month postop.	8.3	0.8	3
C -3 months postop.	9.7	0.8	3.7
D -6 months postop.	9.7	0	3.7
E -end date of study.	9.7	0	3.7

Pearson's *r* correlation between function and satisfaction ($r=0.31$)
correlation between pain and satisfaction ($r=-0.97$)

Crosstab 5.6 Follow up versus average scores
Manipulation under Anaesthesia (N=6)

Rows : follow up time points.
Columns : average function, pain and satisfaction score.

	function	pain	satisfaction
A -before surgery.	5.5	8.3	1
B -1 month postop.	6.7	3.8	2.2
C -3 months postop.	7.7	3.0	2.8
D -6 months postop.	8.3	2.0	3.2
E -end date of study.	8.5	0.8	3.5

Pearson's *r* correlation between function and satisfaction ($r=0.994$)
correlation between pain and satisfaction ($r=-0.988$)

Graph 5.6 to 5.11 show the results of crosstab 5.1 to 5.6 in a more surveyable way.

Graph 5.6 Follow up versus average scores
Neer

Graph 5.7 Follow up versus average scores
Neer + cuff repair

Graph 5.8 Follow up versus average scores
Neer + resection of distal end clavicle

Graph 5.9 Follow up versus average scores
Putti Platt

Graph 5.10 Follow up versus average scores
Fixation of biceps tendon

Graph 5.11 Follow up versus average scores
Manipulation under anaesthesia

Graph 5.6 shows that the first increase of the satisfaction score is mainly due to the decrease of pain. In the period 3 months post operatively until the end date of the study the increase of the satisfaction score is mainly caused by the improvement of the shoulder function. For the operation "Neer and cuff repair" (graph 5.7) at 1 month post operatively the satisfaction score increases despite a decrease in function. At this time point the increase of the satisfaction score is caused by the diminution of the pain. At the end date of the study the function of the shoulder is about the same as before the operation. The degree of satisfaction is obviously caused by pain relief.

When the operation "Neer and cuff repair" is compared with the "Neer procedure and resection of the distal end of the clavicle" (graph 5.8) a striking feature is an excellent function and a low pain score at the end date of the study concerning Op.III, but the satisfaction score is only slightly better than for Op.II, though the function score for Op.II is significantly lower and the pain score is higher at the end date of the study. The very low function score for the Putti Platt operation at 1 month post operatively is caused by the complete immobilization for 4 weeks after this operation.

In graph 5.10 we observe a dramatic decrease of the pain score. The increase of the satisfaction score is mainly caused by the diminution of pain.

For the manipulation of the shoulder (graph 5.11) the satisfaction score is much higher than for the "Neer" procedure though the increase of function and the diminution of pain is less important in the last operation. On the whole it is obvious that there is in general a strong correlation between the satisfaction score and the pain as well as the function score.

Graph 5.12 to 5.17 show that in general the percentage of patients with a good/excellent function score is high. The decrease in function at time point B, 1 month post operatively, is due to the operative procedure. It is so obvious that the size of the group with a low pain score corresponds with the size of the group with a high satisfaction score. A striking feature for Op.VI (manipulation under anaesthesia) is the increase of function from less than 20% at 1 month after the operation till 100% at the end date of the study.

Graph 5.12 Percentage of patients with good scores
Neer

Graph 5.13 Percentage of patients with good scores
Neer + cuff repair

Graph 5.14 Percentage of patients with good scores
Neer + resection distal end clavicle

Graph 5.15 Percentage of patients with good scores
Putti platt operation

Graph 5.16 Percentage of patients with good scores
fixation biceps tendon

Graph 5.17 Percentage of patients with good scores
Manipulation under anaesthesia

During the last visit at the outpatients clinic the patient was asked if he felt better than before the operation, if he had resumed his previous occupation and if he received a disablement pension. The results of these questions are listed in table 5.4.

Table 5.4 The end results of the operations.

- A. percentage of patients feeling better then before surgery
- B. percentage of patients resuming their previous occupation.
- C. percentage of patients benefiting a disablement pension

	A	B	C
I. "Neer"	81	67	26
II. "Neer"/cuff repair.	78	72	22
III. "Neer"/dist.cl.res.	63	50	38
IV. "Putti-Platt".	88	81	13
V. Fixation biceps .	100	100	0
VI. Manipulation.	100	67	33
All	82	70	24

The results of table 5.4 are represented in graphs 5.18, 5.19 and 5.20.

Graph 5.18 Percentage of patients
Feeling better than before operation

Graph 5.19 Percentage of patients
Resuming their previous occupation

Graph 5.20 Percentage of patients
Benefiting a disablement pension

5.7 DISCUSSION

As mentioned before we need valuable information to come to a diagnosis. The proforma has to contain all the items that can lead to the different possible diagnoses. A certain combination of the results will lead to a particular diagnosis. Sometimes the historical data are a strong indication towards a particular diagnosis. The physical examination then confirms the earlier made presumption. In general the more data we collect the stronger becomes the confidence that we are dealing with a particular pathology.

In this chapter we worked the other way round as we normally do enabling a clear analysis. The operation being the end result of a diagnostic procedure and a reflection of the pathological state of the patient is a good item to divide the patient population in classes.

It is obvious that not in all cases a particular diagnosis has all the features normally described in the orthopaedic textbooks. For example in the patients who underwent the "Neer" operation 18.6% did not have a disturbed scapulo-thoracic rhythm. So an important conclusion to make is that not all the characteristics of a particular disorder need to be positive to come to a diagnosis. (This will be discussed further in chapter 7.) Considering the graphs

of the arthroscopic and operative findings we see in general a considerable conformity. The differences between the results of the arthroscopy and operation will be discussed in chapter 6.

There is a strong correlation between the satisfaction and pain score. The operation results are in general good and in accordance with the results mentioned in literature. Neer (1965) claims good results of the neer procedure in 82% of the patients. Equal values as in Op II and Op III are found by Cotton in 1964, Dewar in 1965.

For the operation of Putti Platt the same applies (Kessel 1982). For operation V and VI our results are better, but the numbers are too low to do a reliable pronouncement.

CHAPTER 6

Reliability and diagnostic value of shoulder arthroscopy

6.1 RELIABILITY OF THE SHOULDER ARTHROSCOPY

6.1.1 Introduction

In order to examine the reliability of shoulder arthroscopy one has to compare the findings obtained at arthroscopy with findings obtained from direct vision of the anatomical structures. This direct inspection of the anatomical structures is only possible during open surgery of the shoulder. Open surgery of the shoulder is in this comparison the so called "golden standard". Of the patients, who underwent arthroscopy of the shoulder direct inspection of the shoulder joint was not possible in 6 cases, because they had a manipulation of the shoulder under anaesthesia. From the remaining group ($N = 204$) we were able to explore the subacromial space in all cases. Direct visualization of the glenohumeral joint was possible in those patients, who needed an operation for instability. Also if the diagnosis before arthroscopy justified exploration of this joint verification was possible. It is obvious that if a cuff rupture was present inspection of the glenohumeral joint was possible during operation.

6.1.2 Material and method

To come to an estimate of the reliability of shoulder arthroscopy, 10 arthroscopic items were compared with the same 10 items at operation. This

10 items are listed in table 6.1. Of the 210 patients of the first study 6 patients had a manipulation of the shoulder, so they were not available for the study. The remaining 204 patients all had an exploration of the subacromial space. In 124 out of these remaining 204 patients exploration of the glenohumeral joint was performed as well. The indications for opening the glenohumeral joint are listed in table 6.2.

Table 6.1 The 10 items used to compare the arthroscopy and operation.

1.	bursitis
2.	cuff degeneration
3.	cuff rupture
4.	biceps pathology
5.	capsule/labrum tear
6.	chondropathy
7.	Hill-Sachs lesion
8.	loose bodies
9.	adhesions
10.	synovitis

Table 6.2 Indications for exploration of the glenohumeral joint.

1.	recurrent dislocation
2.	biceps tendinitis
3.	loose bodies
4.	cuff rupture
5.	calcific deposits
6.	labrum lesion
7.	capsule lesion
8.	micro-instability

By making crosstabs of the arthroscopic items and the operative findings one obtains the true positive, true negative, false positive and false negative findings. With these results the specificity, sensitivity, predictive positive and predictive negative value can be calculated. As a reminder the above mentioned terms have the following meaning:

- True positive (TP) : the disorder is present (D+) and the test is positive (T+).
- True negative (TN) : the disorder is absent (D-) and the test is negative (T-).
- False positive (FP) : the disorder is absent (D-) and the test is positive (T+).

False negative (FN) : the disorder is present (D+), but the test is negative (T-).

The sensitivity or true positive rate is the frequency of positive test results given the disorder is present. In probability notation we write $P[T+/D+]$. An estimate of this probability from a 2x2 table derived from a study sample is: $TP/(TP + FN)$.

The specificity of a test or the true negative rate represents the frequency of negative test results in those cases, where the disorder is really absent. In probability notation we write $P[T-/D-]$. An estimate of this probability from a 2x2 table derived from a study sample is represented by $TN/(TN+FP)$.

The predicted positive value is the frequency of disorder in those with positive test results: $P[D+/T+]$.

The predicted negative value is the frequency of nondisorder in those with negative test results: $P[D-/T-]$.

In order to be able to do a prediction of the size of the false positive and false negative rate we will use the following method.

Assume we want to measure the reliability of test A. The result of the test can have as an outcome two different and independent values: i.e. positive or negative.

In N persons a test T is performed. Afterwards it is verified (with a 100% reliable test; i.e. the golden standard) whether a person is really positive or negative; in other words the outcome of the second test shows us with 100% certainty if the disorder is present (D+) or not (D-). In this way the patient population can be divided in four groups.

Test T positive (T+), disorder present (D+).

Test T positive (T+), disorder absent (D-).

Test T negative (T-), disorder present (D+).

Test T negative (T-), disorder absent (D-).

As a measure of the reliability of the test we calculate the false positive and the false negative rate. We describe here a method to estimate the false positive rate and at the same time we determine an upper limit underneath which this false positive rate is located, with a prior fixed reliability of, for example 95%. (It is obvious, that the method is analogous for the false negative rate.)

Assume there is a sample of N persons without the disorder. This is afterwards verified with a 100% reliable test. Also assume n test results out of this

sample are found to be positive with test T . An obvious point estimate of the false positive rate is n/N . We also want to determine an upper limit of the probability of a false positive result; a limit underneath which the likelihood of error is located with large probability. Such a limit is determined in the following way: Suppose the real probability of a false positive result is p . This probability p can be considered to be a test dependent fixed number.

Now, compute p by solving the equation.

$$Q(n, p) = \sum_{k=0}^n \binom{N}{k} p^k (1-p)^{N-k}$$

In appendix II we will prove that the real probability p to obtain a false positive result will be less than p with $100(1-\varepsilon)\%$ certainty. For instance, when $\varepsilon = 0.05$, we derive in this way a 95% confidence interval of p .

6.1.3 Results

The patient population can be subdivided in the following way:

- I. Those, who did not have open surgery ($N = 6$).
- II. The patients, who had an exploration of the subacromial space ($N = 204$).
- III. The patients, who had an exploration of the subacromial space as well as an inspection of the glenohumeral joint ($N = 124$).

It is obvious, that in group I, although arthroscopy was performed, no comparison was possible with open surgery.

In group II we are able to compare the items; bursitis, degenerative changes of the rotator cuff and cuff rupture at arthroscopy and open surgery. Computation, along the lines suggested above, gives us an estimate for the reliability of arthroscopy of the subacromial space.

In group III we are able to compare the items degenerative changes of the rotator cuff, cuff rupture, biceps pathology, capsule and/or labrum tear, chondropathy, Hill-Sachs lesion, loose bodies, intra-articular adhesions, synovitis. With the results of these items we can achieve an estimate for the reliability of arthroscopy of the glenohumeral joint. In group II we can compare $3 \times 204 = 612$ arthroscopic findings with 612 operative findings. In group III. $9 \times 124 = 1116$ arthroscopic findings can be compared with 1116 operative findings. Firstly the sensitivity, specificity, predicted positive value

and predicted negative value of the observations done in the subacromial space at arthroscopy will be calculated. Secondly this will be done for the arthroscopic items of the glenohumeral joint.

Furthermore the 95% confidence interval will be calculated for the false negative and false positive rates as a measure for the reliability of the different tests. In the discussion we will examine if we are allowed to join the respective TP, TN, FP and FN results of the different items in order to come to an overall pronouncement.

Reliability of arthroscopy of the subacromial space

Exploration arthroscopically as well as operatively was performed in 204 patients. With the help of 2x2 tables we are able to calculate the true positive, true negative, false positive and false negative rate. This will successively be done for the items

1. bursitis,
2. degenerative changes of the rotator cuff,
3. rupture of the rotator cuff.

Also a 95% confidence interval will be calculated for the false negative and false positive rate of these items.

Crosstab 6.1 The finding bursitis

rows : finding bursitis at arthroscopy.
columns : finding bursitis at operation.

	yes	no	ALL
yes	163	0	163
no	4	37	41
ALL	167	37	204

TP: 163
TN: 37
FP: 0
FN: 4

Out of this 2x2 table we can see that there are 163 true positive, 37 true negative, 0 false positive and 4 false negative results.

With the results of this crosstab we can compute the sensitivity, the specificity, the predictive positive value, the predictive negative value and the confidence intervals.

sample are found to be positive with test T . An obvious point estimate of the false positive rate is n/N . We also want to determine an upper limit of the probability of a false positive result; a limit underneath which the likelihood of error is located with large probability. Such a limit is determined in the following way: Suppose the real probability of a false positive result is p . This probability p can be considered to be a test dependent fixed number.

Now, compute p by solving the equation.

$$Q(n,p) = \sum_{k=0}^n \binom{N}{k} p^k (1-p)^{N-k}$$

In appendix II we will prove that the real probability p to obtain a false positive result will be less than p with $100(1-\epsilon)\%$ certainty. For instance, when $\epsilon = 0.05$, we derive in this way a 95% confidence interval of p .

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In group III we are able to compare the items degenerative changes of the rotator cuff, cuff rupture, biceps pathology, capsule and/or labrum tear, chondropathy, Hill-Sachs lesion, loose bodies, intra-articular adhesions, synovitis. With the results of these items we can achieve an estimate for the reliability of arthroscopy of the glenohumeral joint. In group II we can compare $3 \times 204 = 612$ arthroscopic findings with 612 operative findings. In group III. $9 \times 124 = 1116$ arthroscopic findings can be compared with 1116 operative findings. Firstly the sensitivity, specificity, predicted positive value

and predicted negative value of the observations done in the subacromial space at arthroscopy will be calculated. Secondly this will be done for the arthroscopic items of the glenohumeral joint.

Furthermore the 95% confidence interval will be calculated for the false negative and false positive rates as a measure for the reliability of the different tests. In the discussion we will examine if we are allowed to join the respective TP, TN, FP and FN results of the different items in order to come to an overall pronouncement.

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Exploration arthroscopically as well as operatively was performed in 204 patients. With the help of 2x2 tables we are able to calculate the true positive, true negative, false positive and false negative rate. This will successively be done for the items

1. bursitis,
2. degenerative changes of the rotator cuff,
3. rupture of the rotator cuff.

Also a 95% confidence interval will be calculated for the false negative and false positive rate of these items.

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rows : finding bursitis at arthroscopy.
columns : finding bursitis at operation.

	yes	no	ALL
yes	163	0	163
no	4	37	41
ALL	167	37	204

TP: 163
TN: 37
FP: 0
FN: 4

Out of this 2x2 table we can see that there are 163 true positive, 37 true negative, 0 false positive and 4 false negative results.

With the results of this crosstab we can compute the sensitivity, the specificity, the predictive positive value, the predictive negative value and the confidence intervals.

SENSITIVITY : 98%
SPECIFICITY : 100%
PREDICTED + VALUE : 100%
PREDICTED - VALUE : 90%

Probability of a false negative result:
estimate : $p = 0.023$
95% confidence interval : $p < 0.054$

Probability of a false positive result:
estimate : $p = 0.000$
95% confidence interval : $p < 0.078$

Crosstab 6.2 The finding degenerative changes of the cuff.

rows : finding degeneration at arthroscopy.
columns : finding degeneration at open surgery.

	yes	no	ALL
yes	130	1	131
no	6	67	73
ALL	136	68	204

TP: 130
TN: 67
FP: 1
FN: 6

In this crosstab we see, that there are 130 true positive, 67 true negative, 1 false positive and 6 false negative results.

The results for the finding cuff degeneration are:

SENSITIVITY : 95%
SPECIFICITY : 99%
PREDICTED + VALUE : 99%
PREDICTED - VALUE : 92%

Probability of a false negative result:
estimate : $p = 0.044$
95% confidence interval : $p < 0.085$

Probability of a false positive result:

estimate : $p = 0.014$
95% confidence interval : $p < 0.068$

Crosstab 6.3 The finding rupture of the rotator cuff.

rows : finding cuff rupture at arthroscopy.
columns : finding cuff rupture at open surgery.

	yes	no	ALL
yes	24	1	25
no	5	174	179
ALL	29	175	204

TP: 24
TN: 174
FP: 1
FN: 5

For the item cuff rupture the result is: 24 true positives, 174 true negatives, 1 false positive and 5 false negatives.

The results for the finding cuff rupture are:

SENSITIVITY : 83%
SPECIFICITY : 99%
PREDICTED + VALUE : 96%
PREDICTED - VALUE : 97%

Probability of a false negative result:

estimate : $p = 0.172$
95% confidence interval : $p < 0.328$

Probability of a false positive result:

estimate : $p = 0.006$
95% confidence interval : $p < 0.027$

The calculated values of these three items show, that arthroscopy for the item bursitis and degenerative changes is quite reliable.
For the item cuff rupture we found a sensitivity of only 83%.
As the literature concerning the arthrography of the shoulder (44,53,66,75,137) claims a higher percentage of reliability with regard to the detection of cuff

ruptures, we would be inclined to prefer an arthrogram, rather than an arthroscopy.

The reliability of arthroscopy of the glenohumeral joint

The same procedure as performed for the determination of the reliability of arthroscopy of the subacromial space will be used for the determination of the reliability of the arthroscopy of the glenohumeral joint. The observations made in this joint included 9 pathological entities: namely degenerative changes of the rotator cuff, cuff rupture, biceps pathology, capsule and/or labrum tear, chondropathy, Hill-Sachs lesion, loose bodies, intra-articular adhesions and synovitis. Once again we can create crosstabs of these items using the database of the 124 patients concerned. It is obvious, that the item cuff rupture, and degenerative changes of the cuff can be used for the determination of the reliability for the arthroscopy of the subacromial space as well as for the determination of the reliability of arthroscopy of the glenohumeral joint, because the rotator cuff is visible on both occasions. Using the database of the patient population we obtain the following crosstabs. The true positive, true negative, false positive and false negative results are mentioned on the right of the crosstab, the rows show the arthroscopic findings and in the columns the observations at open surgery are enumerated.

Crosstab 6.4 The finding degenerative changes of the cuff.

rows : finding degeneration at arthroscopy.
columns : finding degeneration at operation.

	yes	no	ALL
yes	81	0	81
no	1	42	42
ALL	82	42	124

TP: 81
TN: 42
FP: 0
FN: 1

The results for the finding degenerative changes are:

SENSITIVITY : 99%
SPECIFICITY : 100%
PREDICTED + VALUE : 100%
PREDICTED - VALUE : 98%

Probability of a false negative result:

estimate : $p = 0.012$
95% confidence interval : $p < 0.056$

Probability of a false positive result:

estimate : $p = 0.000$
95% confidence interval : $p < 0.069$

Crosstab 6.5 The finding cuff rupture.

rows : finding cuff rupture at arthroscopy.
columns : finding cuff rupture at operation.

	yes	no	ALL
yes	22	0	22
no	5	97	102
ALL	27	97	124

TP: 22
TN: 97
FP: 0
FN: 5

The results for the finding cuff rupture are:

SENSITIVITY : 81%
SPECIFICITY : 100%
PREDICTED + VALUE : 100%
PREDICTED - VALUE : 95%

Probability of a false negative result:

estimate : $p = 0.185$
95% confidence interval : $p < 0.351$

Probability of a false positive result:

estimate : $p = 0.000$
95% confidence interval : $p < 0.030$

Crosstab 6.6 The finding biceps pathology.

rows : finding biceps pathology at arthroscopy.

columns : finding biceps pathology at operation.

	yes	no	ALL
yes	46	5	51
no	3	70	73
ALL	49	75	124

TP: 46

TN: 70

FP: 5

FN: 3

The results for the finding biceps pathology are:

SENSITIVITY : 94%

SPECIFICITY : 93%

PREDICTED + VALUE : 90%

PREDICTED - VALUE : 96%

*Probability of a false negative result:*estimate : $p = 0.061$ 95% confidence interval : $p < 0.151$ *Probability of a false positive result:*estimate : $p = 0.066$ 95% confidence interval : $p < 0.135$ **Crosstab 6.7** The finding capsule/labrum tear

rows : finding capsule/labrum tear at arthroscopy.

columns : finding capsule/labrum tear at operation.

	yes	no	ALL
yes	33	1	34
no	1	122	123
ALL	34	90	124

TP: 33

TN: 122

FP: 1

FN: 1

The results for the finding capsule/labrum tear are:

SENSITIVITY	: 97%
SPECIFICITY	: 99%
PREDICTED + VALUE	: 97%
PREDICTED - VALUE	: 99%

Probability of a false negative result:

estimate	: $p = 0.029$
95% confidence interval	: $p < 0.132$

Probability of a false positive result:

estimate	: $p = 0.011$
95% confidence interval	: $p < 0.051$

Crosstab 6.8 The finding chondropathy.

rows : finding chondropathy at arthroscopy.
columns : finding chondropathy at operation.

	yes	no	ALL
yes	21	1	22
no	0	102	102
ALL	21	103	124

TP: 21
TN: 102
FP: 1
FN: 0

The results for the finding chondropathy are:

SENSITIVITY	: 100%
SPECIFICITY	: 99%
PREDICTED + VALUE	: 95%
PREDICTED - VALUE	: 100%

Probability of a false negative result:

estimate	: $p = 0.000$
95% confidence interval	: $p < 0.207$

*Probability of a false positive result:*estimate : $p = 0.009$ 95% confidence interval : $p < 0.045$ **Crosstab 6.9** The finding Hill-Sachs lesion.

rows : finding Hill-Sachs lesion at arthroscopy.

columns : finding Hill-Sachs lesion at operation.

	yes	no	ALL
yes	5	0	5
no	1	89	90
ALL	6	118	124

TP: 5

TN: 89

FP: 0

FN: 1

The results for the finding Hill-Sachs lesion are:

SENSITIVITY : 83%

SPECIFICITY : 100%

PREDICTED + VALUE : 100%

PREDICTED - VALUE : 99%

*Probability of a false negative result:*estimate : $p = 0.166$ 95% confidence interval : $p < 0.582$ *Probability of a false positive result:*estimate : $p = 0.000$ 95% confidence interval : $p < 0.025$

Crosstab 6.10 The finding loose bodies.

rows : finding loose bodies at arthroscopy.
columns : finding loose bodies at operation.

	yes	no	ALL
yes	1	0	1
no	1	122	123
ALL	2	122	124

TP: 1
TN: 122
FP: 0
FN: 1

The results for the finding loose bodies are:

SENSITIVITY : 50%
SPECIFICITY : 100%
PREDICTED + VALUE : 100%
PREDICTED - VALUE : 99%

Probability of a false negative result:

estimate : $p = 0.500$
95% confidence interval : $p < 0.974$

Probability of a false positive result:

estimate : $p = 0.000$
95% confidence interval : $p < 0.024$

Crosstab 6.11 The finding adhesions.

rows : finding adhesions at arthroscopy.
columns : finding adhesions at operation.

	yes	no	ALL
yes	18	4	22
no	0	102	102
ALL	18	106	124

TP: 18
TN: 102
FP: 4
FN: 0

The results for the finding adhesions are:

SENSITIVITY : 100%
 SPECIFICITY : 96%
 PREDICTED + VALUE : 89%
 PREDICTED - VALUE : 100%

Probability of a false negative result:

estimate : $p = 0.000$
 95% confidence interval : $p < 0.153$

Probability of a false positive result:

estimate : $p = 0.038$
 95% confidence interval : $p < 0.084$

Crosstab 6.12 The finding synovitis.

rows : finding synovitis at arthroscopy.
 columns : finding synovitis at operation.

	yes	no	ALL
yes	28	3	31
no	1	92	93
ALL	29	95	124

TP: 28
 TN: 92
 FP: 3
 FN: 1

The results for the finding synovitis are:

SENSITIVITY : 97%
 SPECIFICITY : 97%
 PREDICTED + VALUE : 90%
 PREDICTED - VALUE : 99%

Probability of a false negative result:

estimate : $p = 0.034$
 95% confidence interval : $p < 0.154$

Probability of a false positive result:

estimate : $p = 0.032$

95% confidence interval : $p < 0.080$

Considering the values calculated for the 9 different items we are allowed to state that, arthroscopy of the glenohumeral joint is reliable for the items degenerative changes of the rotator cuff, biceps pathology, chondropathy of the glenohumeral joint, a capsule and or labrum tear, intra-articular adhesions and synovitis.

The sensitivity in the case of cuff rupture is here again rather low (83%) (see the results of the arthroscopy of the subacromial space).

The sensitivity is low for the items Hill-Sachs lesion and loose bodies, but we have a too small proportion of true positive and false negative results to allow us to feel confident about these values.

6.1.4 Discussion

Having studied the outcome of the different items we would like to do an overall pronouncement about the arthroscopy of the subacromial space and the glenohumeral joint. We would like to avoid the problems of interpretation we met in dealing with the item Hill-Sachs lesion and the item loose bodies. We are also having problems with the considerable amount of false negative results of the item cuff rupture. So we really would like to be permitted to join the respective TP, TN, FP and FN results in order to obtain a better pronouncement about the sensitivity, specificity, predicted + and predicted - value and to obtain a smaller 95% confidence interval.

To allow for joining the results of the separate items we have to assume that each different observation in one patient is independent of the others. Furthermore we have to assume, that the probability that the result is FP is the same for each item and that the probability that the result is FN is the same for each item.

The question now is: Are we allowed to accept such an assumption?

In chapter 4 we have seen, that the technique of shoulder arthroscopy is basically not difficult. Once the scope is introduced into the glenohumeral joint or subacromial bursa, we can easily reach any particular area of these spaces. Furthermore the scope gives an excellent view of the inspected area. We also feel quite confident in saying that, for example, a bursitis is as easy to detect as pathology of the biceps tendon or a pathological or non-pathologi-

cal state of any other item. Looking at the items this way we have some support for the assumption.

Yet we have to admit, that there is a relation between the items.

For example "the observation Hill-Sachs lesion present" will normally coincide with the positive observation "capsule/labrum tear". This may be true, but we are dealing with two different unique observations and the judgements of these pictures are completely independent from each other. In both cases we have the independent choice of giving the answer present or not present. So although the items are interlaced, the interpretation of the unique events are independent. In other words, it is not the presence or non presence of pathological changes that determines the result, but the judgement of the observer.

So let us assume, that the observations of the different items are independent, and that the error of judgement of the observations is equally likely for each item and that the probability to obtain a false negative or false positive result is also equally likely.

In that case we obtain for the arthroscopy of the subacromial space 317 TP, 278 TN, 2 FP and 15 FN results.

By computation we obtain the following values:

SENSITIVITY	: 95%
SPECIFICITY	: 99%
PREDICTED + VALUE	: 99%
PREDICTED - VALUE	: 95%

Probability of a false negative result:

estimate	: $p = 0.045$
95% confidence interval	: $p < 0.069$

Probability of a false positive result:

estimate	: $p = 0.007$
95% confidence interval	: $p < 0.022$

With these results we would be very pleased.

If we accept the previous mentioned assumptions we expect the likelihood of error to be equal for the FP and FN rate.

But, considering the false positive and false negative rate we discover, that the estimates of likelihood of error of the false positive and false negative rate differ considerably. With the null hypothesis : "the likelihood of error is the

same in the positive and negative observations" (using the chi square test), we can show, that this statement, is very unlikely ($p < 0.001$). This makes the assumption less likely with regard to the amalgamation of the respective observations and the subsequent computations.

Let us now assume, that the observations done in the glenohumeral joint are independent.

Addition of the respective items results in 255 TP, 834 TN, 14 FP and 15 FN results.

Computation gives the following outcome.

SENSITIVITY	: 95%
SPECIFICITY	: 98%
PREDICTED + VALUE	: 96%
PREDICTED - VALUE	: 98%

Probability of a false negative result:

estimate	: $p = 0.055$
95% confidence interval	: $p < 0.08$

Probability of a false positive result:

estimate	: $p = 0.016$
95% confidence interval	: $p < 0.03$

With this result we would also be very contented.

Here again, we would expect the likelihood of error to be the same for the FP and FN rate.

But the estimates of the false negative and false positive rates differ. And with the null hypothesis: "the likelihood of error is the same for the false positive and false negative observations" (using the chi square test), we can calculate that this is very unlikely ($p < 0.001$).

So the addition of the respective observations, as well as the pronouncements about the sensitivity and the other values calculated for the results of the 9 items together of the arthroscopy of the glenohumeral joint, are discutable to some degree. But although we know that corrections need to be made concerning the occurrence of false positive and false negative results and the fact that the items are not completely independent, we know intuitively, that these corrections will influence the end results of the added items in a rather minor degree. Therefore we may state that the end results of the overall calculations

crosstab comparing the postoperative diagnoses with the diagnoses after arthroscopy.

Table 6.3: List of possible diagnoses.

A.	a-c pathology
B.	bursitis
C.	bursitis, a-c pathology
D.	bursitis, cuff rupture
E.	bursitis, biceps tendinitis
F.	adhaesive capsulitis
G.	loose bodies
H.	instability of the shoulder
I.	dislocation biceps tendon
J.	tendonitis biceps tendon
K.	no certainty

The crosstab for the diagnoses before arthroscopy and the diagnoses after open surgery shows the following distribution.

The characters (A to K) above and on the left of the crosstab represent the respective diagnoses as mentioned in table (6.3).

The diagnosis loose bodies (G) and dislocation of the biceps tendon (I) was not made initially and the diagnosis tendinitis of the biceps tendon (J) was not made after operation, but was always joined with the diagnosis "bursitis".

Table 6.4 Crosstab of the diagnosis prior to arthroscopy versus operation.

rows : initial diagnosis.

columns : diagnosis at open surgery.

Diagn.	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	ALL
A.	1	0	0	0	0	0	0	0	0	0	0	1
B.	0	49	1	17	2	1	0	2	0	0	0	72
C.	0	0	0	0	0	0	0	0	0	0	0	0
D.	0	1	0	4	0	0	0	0	0	0	0	5
E.	0	0	0	0	0	0	0	0	0	0	0	0
F.	0	0	0	1	1	0	0	0	0	0	0	2
G.	0	0	0	0	0	0	0	0	0	0	0	0
H.	0	1	0	0	0	0	0	11	0	0	0	12
I.	0	0	0	0	0	0	0	0	0	0	0	0
J.	0	4	0	1	1	0	0	3	2	0	0	11
K.	0	0	0	4	0	0	2	14	1	0	0	21
ALL	1	55	1	27	4	1	2	30	3	0	0	124

In this crosstab we can read that the diagnosis before arthroscopy was correct in 65 patients (52%).

The following crosstab shows the diagnosis after arthroscopy plotted against the diagnosis after open surgery.

Table 6.5 Crosstab of the diagnosis after arthroscopy versus operation.

rows : diagnosis after arthroscopy.

columns : diagnosis after open surgery.

Diagn.	A.	B.	C.	D.	E.	F.	G.	H.	I.	J.	K.	ALL
A.	1	0	0	0	0	0	0	0	0	0	0	1
B.	0	54	0	5	0	0	0	0	0	0	0	59
C.	0	0	1	0	0	0	0	0	0	0	0	1
D.	0	0	0	22	0	0	0	0	0	0	0	22
E.	0	0	0	0	4	0	0	0	0	0	0	4
F.	0	0	0	0	0	1	0	0	0	0	0	1
G.	0	0	0	0	0	0	1	0	0	0	0	1
H.	0	0	0	0	0	0	1	29	0	0	0	30
I.	0	0	0	0	0	0	0	0	3	0	0	3
J.	0	0	0	0	0	0	0	0	0	0	0	0
K.	0	1	0	0	0	0	0	1	0	0	0	2
ALL	1	55	1	27	4	1	2	30	3	0	0	124

Looking at this crosstab we can see that the diagnosis after arthroscopy was correct in 116 patients (94%).

As the crosstabs are not very surveyable, we represent the results obtained at the three successive stages by the following histogram (fig. 6.1). The 11 different diagnoses are listed on the x axis and plotted against the number of correct diagnoses. The first column represents each time the diagnosis made prior to arthroscopy, the second column the diagnosis made after arthroscopy and the third column, the final diagnosis.

What is striking, is the considerable difference between the first and the second column, and the slight difference between the second and the third.

Fig. 6.1 The respective diagnoses plotted against the number of correct diagnoses

6.2.4 Discussion

The results of the comparison of the diagnoses before and after arthroscopy, and after open surgery shows clearly that arthroscopy of the shoulder is valuable. We have seen that before arthroscopy we were able to formulate a correct diagnosis in 65 patients (52%). After arthroscopy we reached a number of 116 correct diagnoses (94%).

We have to realize that the information of the arthrogram was not used for the formulation of the diagnosis before the arthroscopy.

We did not use this information on purpose, in order to have the opportunity to compare the correct diagnoses obtained by performing an arthrogram and the correct diagnoses obtained by the arthroscopy and to calculate the additional value of an arthrogram, by use of arthroscopic technique. The information of the arthrogram, (see chapter 5, section 5.4) increased the number of correct

diagnoses to 80 (64%). After arthroscopy, with the additional information of the arthrogram, we reach a correct diagnosis in 118 cases (95%).

The calculation of the additional value of the arthrography was made as follows:

Table 6.4 shows that before arthroscopy a cuff rupture was diagnosed 5 times. By performing an arthrography, 24 ruptures were diagnosed and 3 missed. So the minimal increase of correct diagnoses is 19 if all 5 initially diagnosed cuff ruptures were diagnosed by the arthrography. ($p = 0.3$). The maximal increase is 22 correct diagnoses if of the initially diagnosed cuff ruptures, 3 were missed by the arthrography. ($p = 0.001$). So the increase in correct diagnoses caused by the arthrography may range from 19 till 22 = 15.3% till 17.7%. Consequently the percentage of correct diagnoses before the arthroscopy increases using the information of an arthrography from 52% till 67-69%.

During operation, a cuff rupture was diagnosed 27 times in 124 patients. Arthrography demonstrated a cuff rupture in 24 patients (= 88.8% of the cuff ruptures).

During arthroscopy the diagnosis of cuff rupture was made 22 times (= 81% of the cuff ruptures).

There is an increase of 2 correct diagnoses if all 22 diagnoses at arthroscopy were also confirmed at arthrography (minimal increase). A maximal increase of 5 correct diagnoses is present if the 3 cuff ruptures missed by the arthrography were found during arthroscopy. So the minimal increase is from 116 till 118 correct diagnoses (= 95%) and the maximal increase is from 116 till 121 (= 97%).

So the following conclusions can be drawn:

1. The diagnosis based on the case history, physical examination and X-ray of shoulder and cervical spine is correct in 52%.
2. The use of an arthrogram increases the percentage till 64%.
3. The diagnosis based on the case history, physical examination, X-rays and arthroscopy gives a correct diagnosis in 94% of the cases.
4. The use of an arthrogram and arthroscopy gives a correct diagnosis in 95% of the cases.

This means that the arthroscopy of the shoulder is a valuable diagnostic tool and that the additional value of an arthrogram (if one uses the arthroscopic procedure) is minimal.

The use of the arthroscope instead of an arthrogram gives an increase of correct diagnoses of 30%.

Considering the low percentage of correct diagnoses before the arthroscopy we have to admit that we were very strict in the procedure of accepting a diagnosis or refraining from formulating a diagnosis. We already mentioned before that we only accepted a diagnosis if the information pattern of the patients history and examination matched the pattern linked with a certain diagnosis described in the orthopaedic textbooks and further literature. Yet we wondered if we could not diminish the doubt and increase the amount of correct diagnoses using the information of the collected data, because we had expected to obtain a larger amount of correct diagnoses prior to arthroscopy at the begin of the study. For this reason we reviewed the information obtained before arthroscopy in the 210 patients and we developed a decision model, based on this information in order to come to a more objective pronouncement. The developed model and the testing of it will be discussed in the next chapter. In the following chapter we also will return back to the discussion about the arthroscopy and the arthrogram with respect to the choice between the two procedures.

Delimitation of the indication of shoulder arthroscopy

7.1 INTRODUCTION

In the previous chapter it was concluded that arthroscopy of the shoulder is a reliable diagnostic tool. It enables us to achieve a correct diagnosis in 94% of all cases. If we rely on the physical findings, the correct diagnosis is made in about 52% of all cases. This percentage is increased to 64% if use is made of an additional arthrogram.

Looking at these figures one is inclined to say that before operating upon a patient, he should always first undergo arthroscopy to come to a reliable diagnosis. This is certainly a safe procedure in which very few mistakes will be made. However, arthroscopy is rather costly and it is an invasive medical intervention. Therefore unnecessary arthroscopies need to be avoided.

In order to determine the indication of arthroscopy of the shoulder a diagnostic decision model for shoulder disorders was developed. The purpose of this decision model was to diminish the number of arthroscopies and arthrograms without affecting the reliability of the diagnosis. In section 7.2 a diagnostic tool is described, which only uses information of the findings obtained during physical examination of the patient. This diagnostic tool is used to classify patients into a group for which a correct diagnosis can be formulated with great reliability and a group for which further examination (arthrogram or arthroscopy) is needed. In section 7.3 three different protocols for further examination are formulated. These protocols are compared in terms of

reliability, number of arthrograms that have to be made and the number of arthroscopies that have to be performed.

7.2 A DIAGNOSTIC TOOL BASED ON PHYSICAL EXAMINATION

Of all 210 patients in this study the findings of the patients history and physical examination were registered. In section 7.2.2 a method is presented which uses these findings to diagnose the nature of the shoulder disorders. This method enables us to identify a group of patients for which a diagnosis can be formulated with great reliability and to separate this group from a group for which further examination is needed. Since the method uses the data from the 210 patients in this study it would have been incorrect to apply the method on the same group of 210 patients to test its reliability. Therefore the method was applied to on another group of 102 patients with shoulder pain. The results are discussed in section 7.2.3. A discussion of the method follows in section 7.2.4.

7.2.1 Method

Classification of data

During physical examination a number of simple tests is performed on a patient, in order to get an impression of the nature of the shoulder disorder. 8 of these tests were selected for the diagnostic tool. These tests were:

- T_1 range of the painful arc
- T_2 tenderness of the acromioclavicular joint
- T_3 tenderness of front of shoulder
- T_4 disturbed scapulothoracic rhythm
- T_5 localization of pain within the shoulder area
- T_6 cause of the shoulder pain
- T_7 the presence of night pain
- T_8 the range of passive abduction

For the method used it is necessary that the result of a test has a limited number of values. Test T_1 and T_8 do not satisfy this requirement. For example the result of test T_1 is an angle, which can take an infinite number of values. In this case it is necessary to group the possible results in a restricted number of classes. The following classification was made.

- T_1 range of the painful arc
1. no painful arc
 2. start of pain < 100 degrees, end of pain < 140 degrees
 3. start of pain < 100 degrees, end of pain $\geq$ 140 degrees
 4. start of pain $\geq$ 100 degrees, end of pain < 140 degrees
 5. start of pain $\geq$ 100 degrees, end of pain $\geq$ 140 degrees
- T_2 tenderness a-c joint
1. yes
 2. no
- T_3 tenderness front of shoulder
1. yes
 2. no
- T_4 disturbed scapulothoracic rhythm
1. yes
 2. no
- T_5 localization of pain in the shoulder area
1. front
 2. whole of shoulder
 3. other than 1 or 2
- T_6 cause of the shoulder pain.
1. trauma
 2. other cause
- T_7 presence of night pain
1. yes
 2. no
- T_8 range of passive abduction
1. < 120 degrees
 2. $\geq$ 120 degrees

Both the selection of the tests $T_1, T_2, \dots, T_8$ and the classification of possible results of these tests were to some extent arbitrary. We tried however to select tests with a high distinguishing power. The selection of test $T_1, \dots, T_8$ was obtained as follows. All the tests of the proforma were checked with respect to their specificity and sensitivity. We searched for those tests with a high degree of sensitivity for one disorder and a high degree of specificity for another. These tests have a high distinguishing power for the different disorders. If we had to classify the possible results of a test, we tried to do so without affecting the distinguishing power too much.

We classified the shoulder disorders occurring in the 210 patients as follows.

- A_1 bursitis
 A_2 bursitis, cuffrupture
 A_3 bursitis, tendinitis biceps tendon
 A_4 bursitis, a-c osteoarthritis
 A_5 a-c osteoarthritis
 A_6 adhaesive capsulitis
 A_7 loose bodies
 A_8 instability of the shoulder
 A_9 dislocation of biceps tendon
 A_{10} no abnormality

In the following crosstabs the distribution of test results are registered for each combination of test and shoulder disorder.

Crosstab 7.1 Test T_1 : range of the painful arc.

rows : diagnoses

columns : painful arc trajectories.

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	TOTAL
1	8	1	0	0	0	0	1	25	2	1	38
2	29	12	1	0	0	7	0	1	0	0	50
3	75	14	3	4	0	0	0	2	0	3	101
4	0	0	0	0	0	0	0	0	0	0	0
5	9	1	0	2	3	0	0	3	1	2	21
TOTAL	121	28	4	6	3	7	1	31	3	6	210

Crosstab 7.2 Test T_2 : tenderness acromioclavicular joint.

rows : diagnoses
columns : tenderness a-c joint. (1=yes, 2=no)

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	TOTAL
1	48	12	3	6	3	5	0	6	0	3	86
2	73	11	1	0	0	2	1	25	3	3	124
TOTAL	121	28	4	6	3	7	1	31	3	6	210

Crosstab 7.3 Test T_3 : tenderness front of shoulder.

rows : diagnoses.
columns : tenderness front of shoulder. (1=yes, 2=no)

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	TOTAL
1	95	23	3	4	1	7	0	23	0	5	161
2	26	5	1	2	2	0	1	8	3	1	49
TOTAL	121	28	4	6	3	7	1	31	3	6	210

Crosstab 7.4 Test T_4 : disturbed scapulothoracic rhythm.

rows : diagnoses.
columns : disturbed rhythm. (1=yes, 2=no)

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	TOTAL
1	99	25	4	6	2	7	0	4	1	3	151
2	22	3	0	0	1	0	1	27	2	3	59
TOTAL	121	28	4	6	3	7	1	31	3	6	210

Crosstab 7.5 Test T_5 : localization of pain within shoulder area.

rows : diagnoses.

columns : localization of pain. (1=front, 2=whole of the shoulder, 3=other than 1 or 2)

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	TOTAL
1	18	6	1	0	1	0	0	29	2	2	59
2	22	3	0	1	0	4	1	2	1	2	36
3	81	19	3	5	2	3	0	0	0	2	115
TOTAL	121	28	4	6	3	7	1	31	3	6	210

Crosstab 7.6 Test T_6 : cause of shoulder pain.

rows : diagnoses.

columns : cause of shoulder pain. (1=trauma, 2=other)

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	TOTAL
1	9	1	0	0	2	0	1	21	0	0	34
2	112	27	4	6	1	7	0	10	3	6	176
TOTAL	121	28	4	6	3	7	1	31	3	6	210

Crosstab 7.7 Test T_7 : presence of night pain.

rows : diagnoses.

columns : night pain. (1=yes, 2=no)

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	TOTAL
1	109	28	4	6	3	7	0	10	2	5	174
2	12	0	0	0	0	0	1	21	1	1	36
TOTAL	121	28	4	6	3	7	1	31	3	6	210

Crosstab 7.8 Test T_8 : passive abduction.

rows : diagnoses.

columns : range of passive abduction (1=<120 degrees, 2=>120 degrees)

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	A_{10}	TOTAL
1	3	2	1	0	0	4	0	0	0	0	10
2	118	26	3	6	3	3	1	31	3	6	200
TOTAL	121	28	4	6	3	7	1	31	3	6	210

Formulating a diagnosis based on one test

Suppose a patient presenting with a shoulder problem is examined and that test T is performed during this examination. Assume that the result of the test can take the values 1, 2, ..., n and that for this specific patient the outcome was j . We would like to obtain a diagnosis for this patient using the information of test T only. We are interested in the probability of this patient suffering from shoulder disorder $A_1, A_2, \dots, T_{10}$ given the fact that the outcome of test T was j . We denote the probability of having disorder A_i given test T had outcome j by $IP(A_i|T=j)$.

Now, if for one of the shoulder disorders A_i this probability is extremely high, say at least 95%, we feel justified to diagnose this patient as having shoulder disorder A_i . If none of the probabilities is high enough no diagnosis is made.

The probabilities $IP(A_i|T=j)$ are not known exactly, but using the information of crosstabs 7.1 to 7.8 simple estimates can be made:

divide the number of people having shoulder disorder A_i and testresult $T=j$ by the total number of people having testresult $T=j$.

Example

Suppose a patient has a painful arc starting < 100 and ending ≥ 140 . Using crosstab 7.1 we come to the following estimates.

The most probable disorder is A_1 : bursitis. We feel however that this probability is not high enough to come to a diagnosis.

$$\begin{aligned}
\text{IP}(A_1|T_1 = 3) &= 0.75 \\
\text{IP}(A_2|T_2 = 3) &= 0.14 \\
\text{IP}(A_3|T_3 = 3) &= 0.03 \\
\text{IP}(A_4|T_4 = 3) &= 0.04 \\
\text{IP}(A_5|T_5 = 3) &= 0.00 \\
\text{IP}(A_6|T_6 = 3) &= 0.00 \\
\text{IP}(A_7|T_7 = 3) &= 0.00 \\
\text{IP}(A_8|T_8 = 3) &= 0.02 \\
\text{IP}(A_9|T_9 = 3) &= 0.00 \\
\text{IP}(A_{10}|T_{10} = 3) &= 0.02
\end{aligned} \tag{7.1}$$

Formulating a diagnosis based on several tests

During the examination of a patient not just one test, but several tests are performed. We would like to combine the test results in order to come to a more reliable diagnosis than is possible with each test separate.

Assume test $T_1, \dots, T_8$ are performed on a patient and the testresults were $j_1, \dots, j_8$ respectively. We are interested in the probability of this patient having shoulder disorder A_i given the test results were $T_1=j_1, \dots, T_8=j_8$. We denote this probability by $\text{IP}(A_i|T_1=j_1, \dots, T_8=j_8)$. An obvious estimate for this probability is: divide the number of people having shoulder disorder A_i and testresults $T_1=j_1, \dots, T_8=j_8$ by the total number of people having the combination of testresults $T_1=j_1, \dots, T_8=j_8$. For practical reasons this estimate cannot be used. There are 960 possible combinations of testresults. With a databank of only 210 patients each combination will occur only a few times at the most. So this approach gives an unreliable estimate due to lack of data. To avoid this problem the following assumption can be made.

Assumption 1

Within a group of people having the same shoulder disorder the tests $T_1, \dots, T_8$ are statistically independent.

This assumption expresses that for instance the fraction of test results $T_1=j_1$ among people with disorder A_i and testresults $T_2, \dots, T_8$ is the same as the fraction of testresults $T_1=j_1$ among the whole group of people having shoulder disorder A_i . A mathematical consequence of the assumption is that

$$IP(T_1 = j_1, \dots, T_8 = j_8 | A_i) = IP(T_1 = j_1 | A_i) \dots IP(T_8 = j_8 | A_i) \quad (7.2)$$

7.2 offers us a simple equation to estimate the probabilities $IP(A_i | T_1=j_1, \dots, T_8=j_8)$. We only have to estimate the probabilities $IP(T_k=j_k | A_i)$ and $IP(A_i)$ and substitute them in 7.2.

$$\begin{aligned} & IP(A_i | T_1 = j_1, \dots, T_8 = j_8) = \\ & IP(A_i) IP(T_1 = j_1, \dots, T_8 = j_8 | A_i) / IP(T_1 = j_1, \dots, T_8 = j_8) = \\ & IP(A_i) \prod_{k=1}^8 IP(T_k = j_k | A_i) / IP(T_1 = j_1, \dots, T_8 = j_8) \end{aligned} \quad (7.3)$$

Estimates for these probabilities can be found in the tables 7.1 to 7.8. Note that it is not necessary to estimate the probability $IP(T_1=j_1, \dots, T_8=j_8)$. This probability can easily be calculated using the additional constraint

$\sum_{i=1}^{10} IP(A_i | T_1=j_1, \dots, T_8=j_8) = 1$, which expresses that a patient must suffer from exactly one of the shoulder disorders. Using this constraint we can express $IP(T_1=j_1, \dots, T_8=j_8)$ in probabilities for which we already have estimate:

$$IP(T_1 = j_1, \dots, T_8 = j_8) = \sum_{i=1}^{10} IP(A_i) \prod_{k=1}^8 IP(T_k = j_k | A_i) \quad (7.4)$$

Now that we are able to give estimates of the probabilities $IP(A_i | T_1=j_1, \dots, T_8 = j_8)$ the most obvious protocol for diagnosing a patient is as follows. If one of the estimates $IP(A_i | T_1=j_1, \dots, T_8=j_8)$ exceeds the value $1-\epsilon$ we accept diagnosis A_i . Otherwise no diagnosis is made. $1-\epsilon$ is called the level of acceptance.

However this protocol was not exact enough. It turned out that this implementation produced an unacceptable number of wrong diagnoses, even if we took 99% as the level of acceptance. The reason for this is that the estimates of these probabilities are not completely reliable (see the discussion in 7.2.3).

There are 960 possible combinations of 8 testresults. So usually the probability that a specific combination will occur is about 0.001. A diagnosis will only be formulated if the combination of testresults is likely enough, say if

$IP(T_1=j_1, \dots, T_8=j_8)$ exceeds δ . δ is called the level of credibility. The protocol for diagnosing a patient became as follows. If one of the probabilities $IP(A_i | T_1=j_1, \dots, T_8=j_8)$ exceeds the level of acceptance and $IP(T_1=j_1, \dots, T_8=j_8)$ exceeds the level of credibility we accept diagnosis A_i . Otherwise no diagnosis is made.

7.2.2 Results

We choose the parameters ϵ and δ such that no wrong diagnoses were made in the databank of 210 patients. We fixed the parameters on these values ($1-\epsilon = 97.5\%$, $\delta = 0.0025$). Afterwards we tested the method on the new databank of 102 patients. The results are in tables 7.1-7.7. We see that very few diagnoses were made. The general picture is that only instability of the shoulder can be detected with enough reliability. The reason for this probably is that the tests cannot distinguish among the various bursitis disorders.

Table 7.1 Diagnoses obtained with the decision program versus final diagnoses. (Distinction is made between bursitis and bursitis, cuffrupture.) (group of 210 patients.)

rows : diagnoses obtained with decision program.
columns : post operative diagnoses.

	bursitis	capsule\labr.tear	no diagnosis	TOTAL
bursitis	10	0	145	155
capsule/labrum tear	0	23	8	31
other	0	0	24	24
TOTAL	10	23	177	210

Table 7.2 Diagnoses obtained with the decision program versus final diagnoses.
(Distinction is made between bursitis and bursitis, cuffrupture.)
(group of 102 patients.)

rows : diagnoses obtained with decision program.
columns : post operative diagnoses.

	bursitis	capsule\labr.tear	no diagnosis	TOTAL
bursitis	0	0	80	80
capsule\labrum tear	0	10	1	11
other	0	1	10	11
TOTAL	0	11	91	102

If the disorder is A_1 : bursitis or A_2 : bursitis + cuffrupture, this will lead in both cases to a neer operation. If a cuffrupture is present it will be detected during the operation, so it is not really necessary to have this information before the operation. Therefore, we applied our method again, but this time we did not distinguish between A_1 and A_2 . We added up the probabilities of A_1 and A_2 and took this addition as the probability of bursitis. The parameters ϵ and δ remained the same. The results are in tables 7.3 and 7.4.

Table 7.3 Diagnoses obtained with the decision program versus final diagnoses.
(No distinction is made between bursitis and bursitis, cuffrupture.)
(group of 210 patients.)

rows : diagnoses obtained with decision program.
columns : post operative diagnoses.

	bursitis	instability	no diagnosis	TOTAL
bursitis	57	0	98	155
instability	0	23	8	31
other	0	0	24	24
TOTAL	57	23	130	210

Table 7.4 Diagnoses obtained with the decision program versus final diagnoses.
(No distinction is made between bursitis and bursitis, cuffrupture.)

(second group of 102 patients.)

rows : diagnoses obtained with decision program.

columns : post operative diagnoses.

	bursitis	instability	no diagnosis	TOTAL
bursitis	66	0	14	80
instability	0	10	1	11
other	0	1	10	11
TOTAL	66	11	25	102

7.2.3 Discussion

The results of these predictive tests are rather poor if we explicitly want to distinguish among the various bursitis disorders. In the control group a diagnosis is formulated in only 11 cases and one of these diagnoses is wrong. When we are satisfied to diagnose a bursitis even if a cuffrupture is present, the picture improves considerably. In the control group 77 diagnoses are formulated, one of them is wrong. In this way physical examination becomes a valuable diagnostic tool.

Comparing the results of the two databanks we see that for the original group of 210 patients a diagnosis is formulated in 38% of all cases, while in the control group a diagnosis is formulated in 75% of all cases. Somehow it seems that diagnosing a patient in the control group is easier than in the original group. The first group consists of patients who entered our practice consecutively during the period 1982 until 1987. The control group consists of patients who consecutively entered during the period 1987 until 1990. The only explanation we can give for the difference between the two groups is that apparently the stream of patients is not stationary over time. We believe that it is a strong point in favour of our diagnostic tool that its diagnosis remains reliable even when the composition of the group of patients changes.

We stated earlier on that the most natural protocol for diagnosing a patient would have been: Accept a diagnosis if the probability exceeds the level of acceptance, otherwise make no diagnosis.

This would indeed be a good protocol if our estimates of these probabilities were accurate. Since this protocol proved to be unsatisfactory, we must conclude that our estimates are inaccurate and can only be viewed as indications of these probabilities.

There are two possible explanations for this. First, it might be that our estimates for the probabilities $IP(A_i)$ and $IP(T_k=j_k | A_i)$ are unreliable due to lack of sufficient data.

Second, the assumption of independency of tests may be incorrect. If the first explanation was the right one, the problem could easily be overcome by collecting more data. However, if the assumption of independency is incorrect, this is a more serious problem. Therefore we tried to get some validation for this assumption. We selected a pair of tests (T_2 and T_3) and tried to find a correlation between the two tests within the group of patients having bursitis. In crosstab 7.5 we see for each combination of testresults the number of observations. In crosstab 7.6 we see the expected number of observations under the independency assumption.

Table 7.5 Number of observations for each combination of test results of test T_2 and T_3

rows : result of test T_2
columns : results of test T_3

	yes	no	TOTAL
yes	43	5	48
no	52	21	73
TOTAL	95	26	121

Table 7.6 Expected number of observations under the independency assumption.

rows : expected observations of test T_2 .
columns : expected observations of test T_3 .

	yes	no	TOTAL
yes	37.7	10.3	48
no	57.3	15.7	73
TOTAL	95	26	121

Looking at these tables we suspect that independency of T_2 and T_3 is unlikely. Indeed, using the χ^2 -test, we find that the independency assumption can be rejected with great certainty (>98%).

We chose to use a heuristic in order to improve the reliability of the diagnosis. As we have seen this is simple and it works very well in practice. Another approach might be to give estimates of the correlation between pairs of tests. This information could then be used to improve the diagnosis. We have not yet experimented with this approach.

7.2.4 Protocols for diagnosing shoulder disorders

When a person with shoulder complaints first visits a specialist the standard treatment is conservative: the person is sent home with medication or physiotherapy. In our study we dealt with patients who had undergone the conservative treatment without success. For these people it was already decided that they were possible candidates for an operation, but a reliable diagnosis had to be made to decide which operation would be appropriate. For such a group of people some medical protocol is needed in order to reach a reliable diagnosis. We assume here that we have three diagnostic tools at our disposal: physical examination, arthrogram and arthroscopy. The question is: which of these diagnostic tools should be used on a specific patient and in which order should they be used. Two guidelines for such a protocol are obvious. Firstly all patients will undergo physical examination and secondly once an arthroscopy is performed no further examination is necessary, because of the great reliability of this diagnostic tool.

We propose three possible protocols and we will compare these protocols in the next section.

The first protocol encloses the situation in which we are not interested in the detection of cuffrupture. Therefore in this protocol an arthrogram is never made.

Protocol 1 *First a physical examination is performed. Stop if a reliable diagnosis can be made based on this examination or if the only doubt is between a bursitis and a bursitis + cuffrupture. Otherwise perform an arthroscopy.*

The following two protocols include the situation in which it is desired to detect whether a cuffrupture is present or not.

Protocol 2 *First a physical examination is performed. Stop if a reliable diagnosis can be made based on this examination. If the examination indicates a doubt between bursitis and bursitis + cuffrupture, make an arthrogram to detect a possible cuffrupture and stop. Otherwise perform an arthroscopy.*

Of course, a cuffrupture can also be detected by an arthroscopy. The third protocol uses this instrument to detect a cuffrupture.

Protocol 3 *First a physical examination is performed. Stop if a reliable diagnosis can be made based on this examination. Otherwise, perform an arthroscopy.*

For each protocol we analyzed which diagnostic decision procedures would have been used on the patients if this protocol had been followed. The results are shown in table 7.7.

Table 7.7 The number of missed cuff ruptures, faulty diagnoses, arthrographies and arthroscopies to be performed using the 3 different protocols.
(No of patients: 210)

	Protocol 1	Protocol 2	Protocol 3
not detected cuff ruptures	30	8	5
faulty diagnoses	0	0	0
decision to make an arthrography	0	47	0
decision to perform an arthroscopy	130	130	177

Table 7.7 shows, that whatever protocol is used no faulty diagnosis is obtained. The main problem to be dealt with is the detection of a cuff rupture.

Using protocol 1 thirty cuff ruptures are not detected, using protocol 2 eight, and employing protocol 3 only five. On the other hand it is shown in this table, that to diminish the number of missed cuff ruptures from 30 till 8 it is at the expense of 47 arthrographies. To diminish the number of not detected cuff ruptures from thirty till five 177 arthroscopies of the shoulder need to be performed instead of 130. So the question really is: "Is it worthwhile to perform 47 arthrographies to detect an extra 22 cuff ruptures, or to execute 47 arthroscopies to detect an extra 25 cuff ruptures?"

In chapter 2, section 2.2.3 and section 2.2.5, is mentioned, that the distinction between an impingement syndrome caused by a bursitis or bursitis and degenerative cuff rupture is mostly not possible. Only in the case of a total cuff rupture the patient is not able to lift his arm. In the instance of a partial tear the patient usually is not restricted in his range of motion, except in the case of a total cuff rupture. In literature support as well as opposition can be found for the option of repairing degenerative cuff ruptures (13,36,50,58,64,105,116,121,130,146,181). We have chosen for the option not repairing the degenerative cuff ruptures as we found that the results of a decompression of the subacromial space with repair of the cuff rupture were as good as the results of decompression, while leaving the cuff rupture alone and as we estimated the arguments of the opponents stronger than the arguments of those who were in favour of the operative repair of the degenerative cuff rupture. Furthermore in the presence of a total cuff rupture the diagnosis is obtained easily as in that instance active abduction of the arm is impossible and the passive range of motion is normal. (Palsy of the shoulder muscles have on that occasion to be excluded.) So we come to the following conclu-

sion: "We are not really concerned about not detecting a degenerative cuff rupture and choose for protocol 1". In this way another 47 arthrographies or 47 arthroscopies can be cancelled.

APPENDIX 1

PROFORMA

I BASIC INFORMATION

name:	
age (at arthroscopy):	... years
sex:	male/female
occupation:	
date of arthroscopy:	
date of operation:	
operation:	
diagnosis before arthroscopy:	
diagnosis after arthroscopy:	
diagnosis after open operation:	

II HISTORY

affected shoulder:	right/left
duration of symptoms:	... months
aetiology:	☐ trauma ☐ overuse ☐ unknown
periodicity of symptoms:	☐ intermittently ☐ always

symptoms present (motion):	☐ while moving ☐ at rest
progression of symptoms:	☐ progressive ☐ non-progressive
presenting complaints:	☐ pain ☐ weakness ☐ grinding
loss of motion:	yes/no
instability:	yes/no
night pain:	yes/no
<i>localization of pain:</i> general specified for the shoulder:	☐ neck-shoulder-arm ☐ neck-shoulder ☐ shoulder-arm ☐ top of shoulder ☐ back of shoulder ☐ front of shoulder ☐ biceps area ☐ insertion deltoid ☐ whole shoulder
relief by conservative treatment:	☐ temporarily ☐ not at all
previous therapy:	☐ physiotherapy ☐ injections ☐ tablets
sports:	
other diseases:	

Examination of the neck

examination of the cervical spine:	☐ deformity ☐ loss of motion ☐ tenderness ☐ muscle waisting
------------------------------------	--

Examination of the shoulder

inspection:	☐ swelling ☐ muscle waisting ☐ deformity
<i>active movements</i> abduction: adduction: forward flexion: backward extension: internal rotation: external rotation:	... degrees ... degrees ... degrees ... degrees ... degrees ... degrees
<i>passive movements</i> abduction: adduction: forward flexion: backward extension: internal rotation: external rotation:	... degrees ... degrees ... degrees ... degrees ... degrees ... degrees
<i>painful arc</i> begin: end: trajectory:	... degrees ... degrees ... degrees
disturbed scapulothoracic rhythm	yes/no

V FOLLOW UP DATA

pre operatively function:	(0-10) ...
painscore:	(0-10) ...
satisfaction:	(1-4) ...
post operatively function (1 month):	(0-10) ...
painscore:	(0-10) ...
satisfaction:	(1-4) ...
post operatively function (3 months):	(0-10) ...
painscore:	(0-10) ...
satisfaction:	(1-4) ...
post operatively function (6 months):	(0-10) ...
painscore:	(0-10) ...
satisfaction:	(1-4) ...
post operatively function (last visit):	(0-10) ...
painscore:	(0-10) ...
satisfaction:	(1-4) ...
interval arthroscopy-last follow up	... months

Patient response during last visit

better than before surgery:	yes/no
worse than before surgery:	yes/no
return to work:	yes/no
disabled:	yes/no
return to sports activities:	yes/no

APPENDIX 2

The reliability of a test

Assume a test is available enabling to detect the presence or absence of a certain disorder and assume this test can have two results: positive, indicating the disorder is present or negative, indicating the disorder is absent. As a measure for the reliability of this test the probabilities to obtain a false positive and a false negative test result may be used. In this appendix a method is presented in which way these probabilities of error can be estimated. Furthermore a method is presented how to determine an upper limit underneath which the probability of error is located with a prior fixed reliability (for example 95%). It is assumed that a so called "golden standard" test is available, i.e. a test, which determines whether the disorder is present or not with a 100% certainty.

Assume the "golden standard" test has detected a group of N persons without the disorder, and that n persons in this group had a positive test result using the other test. An estimate for the probability to obtain a false positive test result is n/N .

Except from this estimate one also wants to determine an upper limit for the probability of error: i.e. a limit underneath which the probability of error is situated with high likelihood. Such an upper limit is determined as follows:

Assume the probability to obtain a false positive result is p . The probability that in N negative persons exactly i persons are found to have a positive test result is:

$$\binom{N}{i} p^i (1-p)^{N-i}$$

The probability of obtaining at the most k false positive test results is denoted as $(Q(k,p))$ and it applies, that

$$Q(k, p) = \sum_{i=0}^k \binom{N}{i} p^i (1-p)^{N-i}$$

For every possible value of p , define $K(p)$ as the largest integer for which $Q(K(p), p) < 0.05$ and for every possible value of k , define $P(k)$ as the probability for which $Q(k, P(k)) = 0.05$. It is clear that $Q(k, p)$ is ascending in the variable k . Also the function $Q(k, p)$ is descending in the variable p . The last statement is not mathematically trivial, but a proof of it is omitted as it is intuitively evident. It follows that both the functions K and P are ascending. Furthermore it is easy to see that $K(P(k)) = k$ for every value of k . Recall that n is the number of false positive results. We claim that $P(n)$ is an upper limit underneath which the probability is shown as follows:

$$\begin{aligned} \text{IP}(p < P(n)) &\geq \text{IP}(K(p) < K(P(n))) = \\ &= \text{IP}(K(p) < n) = 1 - \text{IP}(n \leq K(p)) = \\ &= 1 - Q(K(p), p) \geq 0.95 \end{aligned}$$

The conclusion is that the upper limit can be found as the solution of the equation $Q(n, p) = \epsilon$.

It is evident that an analogous procedure can be used if one wishes to determine an upper limit for the probability to obtain a false negative result.

Example

Assume in a group of $N = 20$ persons without a certain disorder $n = 2$ persons had a positive test result. (Positive means that the disorder was expected to be present).

The estimate for the probability of obtaining a false positive test is $2/20 = 0.1$. In the graph below the probability of obtaining of at the utmost 2 false positive test results ($Q(n, p)$) is plotted against the probability of error.

Looking at the graph one can see, that $Q(n, p) < 0.05$ for $p > 0.28$. So with a reliability of 95% can be said, that the probability of obtaining a false positive test result is less than 0.28.

Figure: Limit of probability of error

$+ = p$; $\Delta = \varepsilon$

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SUMMARY

The object of this study is to investigate the technique, reliability and diagnostic value of shoulder arthroscopy. Also a decision model is developed in order to define the indications for arthroscopy of the shoulder.

In chapter 1 those anatomical structures of the shoulder are discussed as far as is necessary to understand normal shoulder function, the pathological states in shoulder disease and the normal and pathological findings during both arthroscopy and surgery of the shoulder.

In chapter 2 a survey is presented of shoulder affections causing shoulder pain. These disorders cause intrinsic shoulder pain. Also some causes of extrinsic shoulder pain are discussed as one has to realize that the origin of shoulder pain may be localized far from the shoulder joint itself.

At the end of this chapter a survey is given of the different causes of shoulder pain.

In chapter 3 the examination of the patient with shoulder pain is discussed: the information from the history and physical examination of the patient, and the possible outcome of additional investigations.

In chapter 4 the technique, normal and pathologic findings of the arthroscopy of the shoulder is dealt with. All the structures, which can be studied during arthroscopy of the glenohumeral joint and the subacromial space are reviewed.

In chapter 5 a general analysis is presented of a group of 210 patients with shoulder complaints. All these patients underwent an arthroscopy of the shoulder and had an operation after this procedure. The patients are classified according to the operation they had undergone. For these different subgroups several diagnostic items are analyzed. Furthermore the arthroscopic findings and the findings at operation are compared. Also the follow up data of the different surgical procedures are presented.

In chapter 6 the reliability and the diagnostic value of arthroscopy of the shoulder is examined. During arthroscopy 10 arthroscopic items are noted and these ten items are compared with the same 10 items observed during open surgery of the shoulder. Using confidence intervals the reliability of the

arthroscopy of the shoulder is examined. The diagnostic value of shoulder arthroscopy is obtained by comparing the diagnoses formulated before arthroscopy, the diagnoses formulated after arthroscopy and the diagnoses obtained during open surgery of the shoulder.

In chapter 7 a decision model is developed in order to determine the indications for shoulder arthroscopy.

The database of the before mentioned 210 patients is used to develop the model. Once the decision model developed it is tested on another group of 102 patients with shoulder pain.

Out of the proforma 8 tests are selected for the decision program. The tests selected have a high degree of sensitivity for one and a high degree of specificity for another disorder. A diagnosis is formulated based on these test results using "Bayes formula for several test results". By means of the decision model protocols can be formulated for diagnosing shoulder disorders. In this way the necessity of an arthroscopy of the shoulder can be determined.

SAMENVATTING

Het doel van deze studie is de techniek, de betrouwbaarheid en de diagnostische waarde van schouderarthroscopie te onderzoeken. Tevens wordt er een diagnostisch beslismodel ontwikkeld om de indicaties voor een arthroscopie van de schouder te bepalen.

In hoofdstuk 1 worden de anatomische structuren besproken, die nodig zijn om de normale schouderfunctie, de pathologische schouderbeelden, en zowel de normale als de pathologische bevindingen tijdens arthroscopie en operatief ingrijpen van de schouder te begrijpen.

In hoofdstuk 2 wordt een overzicht gegeven van de schouderaandoeningen, die schouderpijn veroorzaken. Deze afwijkingen veroorzaken de zogenaamde intrinsieke schouderpijn. Tevens worden er enkele oorzaken van extrinsieke schouderpijn besproken, daar men zich dient te realiseren dat de origine van de schouderpijn ook buiten het schoudergewricht gelegen kan zijn. Aan het eind van dit hoofdstuk wordt een overzicht gegeven van de verschillende oorzaken van schouderpijn.

In hoofdstuk 3 wordt het onderzoek van de patiënt met schouderpijn besproken: t.w. de informatie verkregen door anamnese en lichamelijk onderzoek en de mogelijke uitkomst van hulp onderzoeken.

In hoofdstuk 4 worden achtereenvolgens de techniek, de normale en pathologische bevindingen van de schouderarthroscopie behandeld. Alle structuren, die men tijdens de scopie van het glenohumeraal gewricht en de subacromiale ruimte kan bestuderen, worden besproken.

Hoofdstuk 5 bevat de algemene analyse van een groep van 210 patiënten met schouderklachten. Alle patiënten ondergingen zowel een arthroscopie van de schouder als een operatieve interventie. De classificatie van de patiënten vond plaats naargelang de operatie die zij ondergingen. Voor de op deze wijze geselecteerde subgroepen worden de diagnostische items geanalyseerd. Vervolgens worden de bevindingen van de arthroscoopie en de operatie met elkaar vergeleken. Tevens worden de followup data van de verschillende operatieve procedures gepresenteerd.

In hoofdstuk 6 wordt de betrouwbaarheid en de diagnostische waarde van de schouderarthroscopie onderzocht. Tijdens de arthroscopie worden 10 arthroscopische bevindingen genoteerd en deze bevindingen worden vergeleken met dezelfde 10 items, die geobserveerd worden tijdens de operatie. Met gebruikmaking van betrouwbaarheidsintervallen wordt de betrouwbaarheid van de schouderarthroscopie onderzocht. De diagnostische waarde van de schouderarthroscopie wordt verkregen door de diagnose voor en na de arthroscopie en de diagnose verkregen tijdens de operatie met elkaar te vergelijken.

In hoofdstuk 7 wordt een beslismodel ontwikkeld om de indicaties voor een arthroscopie van de schouder te bepalen. De database van de eerder genoemde 210 patiënten wordt gebruikt om het model te ontwikkelen. Nadat het beslismodel is ontwikkeld, wordt het vervolgens getest op een groep van 102 patiënten met schouderpijn. Uit de patiëntengegevens worden 8 testen geselecteerd die zowel een hoge graad van sensitiviteit hebben voor een bepaalde aandoening, als een hoge mate van specificiteit hebben voor een andere aandoening. Een diagnose wordt geformuleerd op basis van deze testen met behulp van de 'formule van Bayes'. Aan de hand van dit beslismodel kunnen er protocollen worden geformuleerd voor de diagnosestelling van schouderklachten. Op deze wijze kan de 'noodzaak' van een schouderarthroscopie worden bepaald.

RÉSUMÉ

Cette étude a pour objectif d'examiner la technique, la fiabilité et la valeur diagnostique de l'arthroscopie de l'épaule. En outre un modèle décisionnel a été élaboré pour déterminer les indications de l'arthroscopie de l'épaule.

Dans la chapitre 1 sont décrits les structures anatomiques d'un fonctionnement normal de l'épaule, ses aspects pathologiques ainsi que les résultats normaux et pathologiques rencontrés durant l'arthroscopie et l'intervention chirurgicale.

Dans la chapitre 2 il est présenté un sommaire des affections douloureuses de l'épaule. Ces anomalies provoquent la douleur soi-disant intrinsèque de l'épaule. En outre on étudie certaines causes de douleur extrinsèque de l'épaule pour démontrer que l'origine de la douleur de l'épaule ne se trouve pas forcément dans l'articulation elle-même. En fin de ce chapitre les différentes causes de la douleur de l'épaule sont signalées dans un sommaire.

Dans la chapitre 3 on discute de l'examen d'un patient souffrant de l'épaule on recueille les informations lors de l'anamnèse, ceux de l'examen clinique et les résultats éventuels d'examens complémentaires.

Dans la chapitre 4 on étudie successivement la technique, les résultats normaux et pathologiques de l'arthroscopie de l'épaule et tous les aspects qu'il est possible d'examiner durant la scopie de l'articulation glenohumérale et de l'espace subacromial.

Dans la chapitre 5 on présente l'analyse générale d'un groupe de 210 patients souffrant de l'épaule. Tous les patients ayant subi une arthroscopie de l'épaule ainsi qu'une intervention chirurgicale ont été classifiés en sous-groupes, selon certains critères de diagnostic. Puis on évalue les résultats de l'arthroscopie et ceux de l'intervention selon le suivi des données des différentes interventions chirurgicales.

La fiabilité et la valeur diagnostique de l'arthroscopie de l'épaule sont examinés dans le chapitre 6. Durant l'arthroscopie on note 10 résultats et on les compare aux 10 points constatés pendant l'intervention chirurgicale. En utilisant des marges de fiabilité on étudie la fiabilité de l'arthroscopie de l'épaule. La valeur diagnostique de l'arthroscopie de l'épaule est obtenue en

comparant le diagnostic avant et après l'arthroscopie et le diagnostic obtenu pendant l'intervention.

Dans la chapitre 7 un modèle decisionnel est élaboré en vue d'une arthroscopie de l'épaule. Une base de données de 210 patients précédemment cités est utilisée pour l'élaboration du modèle. Ce modèle est testé sur un groupe de 102 patients souffrant de l'épaule. Parmi les données des patients 8 tests qui montrent un haut degré de sensibilité pour certaines affections ainsi qu'un haut degré de spécificité pour d'autres affections ont été sélectionnés. A l'aide de la formule de Bayes on établit un diagnostic s'appuyant sur ces tests. A l'aide de ce modèle, des protocoles de démarche diagnostique seront établis pour les douleurs de l'épaule. Ainsi on détermine la nécessité d'une arthroscopie de l'épaule.

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