ROTATOR CUFF TEARS: THE DIAGNOSTIC ROLE OF ULTRASONOGRAPHY.

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DEDICATION

This dissertation is dedicated to my parents. My mother Imelda-Kuhaliba Nkaluwa and my father, the late Mzee Nkoyera Mzigo Lisokotala who taught me the value of persistence and hard-working and who sacrificed a lot to enable me earn a living.

ABSTRACT

TITLE: Rotator Cuff Tears: The Diagnostic Role of Ultrasonography.

Subject:

Patients with rotator cuff tears diagnosed by ultrasonography and magnetic resonance imaging (MRI) and confirmed by operative findings.

Summary:

The overlap of symptomatology due to various shoulder pathologies such as inflammatory processes, degenerative conditions and traumatic entities, makes the clinical diagnosis of rotator cuff tears challenging and difficult. However recent advances in diagnostic technology have greatly improved the diagnosis of rotator cuff tears in the developed countries. On the other hand developing countries are non-beneficiary of modern diagnostic technologies such as magnetic resonance imaging and arthroscopy. They are too expensive to acquire and maintain and also they require highly skilled manpower. Therefore they are compelled to look for cheap but reliable diagnostic technologies. It is the author's opinion that, this cheap and reliable diagnostic technology, at the present time is ultrasonography.

Ultrasonography is used routinely as a screening diagnostic procedure for rotator cuff tears at the Schulthess clinic in Switzerland. In the period of October to December 1999, 50 consecutive patients were ultrasonographically diagnosed to have rotator cuff tears. These patients were then investigated by magnetic resonance imaging. Operation for rotator cuff tear was subsequently performed only on those with positive MRI findings. The operation findings confirmed the preoperative ultrasonography and MRI diagnosis. Ultrasonography

was therefore, found to have a diagnostic sensitivity of 100 per cent in this study and also proved to be appreciably accurate in predicting the location and extent of the cuff tear.

It is recommended from the basis of this study that ultrasonography should be adopted for the diagnosis of rotator cuff pathology at the Muhimbili Orthopaedic Institute.

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1.0 INTRODUCTION

Rotator cuff tear can be defined as a disruption whether in part or in total of any of the tendons which form the musculo-tendinous cuff of the shoulder joint, namely the supraspinatus, infraspinatus, subscapularis and teres minor tendons. [1] Rotator cuff tear is part of a much broader and non-specific clinical entity termed, rotator cuff disease, which is characterized by pain and impairment of the normal function of the shoulder joint [1]. In clinical practice however, many shoulder conditions such as inflammatory processes, degenerative conditions, traumatic entities and rotator cuff tears of whatever origin, present with more or less similar symptomatology. This explains why the clinical diagnosis of rotator cuff tears is ever challenging and difficult [1].

In the early 20th century when surgical repair of the rotator cuff was for the first time described by Codman,[2] the diagnosis of rotator cuff tears depended solely on history and clinical examination. In 1962 Mclaughlin [3] emphasized the importance of careful history taking and clinical examination of well-relaxed patients in the diagnosis of cuff tears. Norwood and colleagues [4] however found no direct correlation between the characteristic of pain, the site of tenderness and weakness to resisted abduction, to the extent or size of the tear. Lyons and Tomlinson [5] compared clinical and operative findings in 45 patients and reported sensitivity and specificity for clinical examination of 75% and 95% respectively. However over dependence on examiner's experience and lack of standardization, have made clinical evaluation non-reproducible in most cases.

The emergence of modern diagnostic facilities such as arthrography, bursography, magnetic resonance imaging (MRI) and ultrasonography have in one way or another revolutionized the diagnosis of rotator cuff tears. However despite the presence of these new diagnostic tools, challenges encountered in the diagnosis of rotator cuff tears have not yet been completely overcome.

Arthrography, which is useful in diagnosing full-thickness and articular side partial-thickness tears, can not diagnose bursal side tears. In addition it exposes patients to risks of radiation, infection and allergy.[6] Subacromial bursography can demonstrate bursal side partial thickness tears, however its interpretation is said to be difficult and subtle. [7,8]

Magnetic resonance imaging (MRI) is said to be sensitive, specific and accurate in diagnosing rotator cuff tears. However it is expensive and its accuracy is highly dependent on the skill and experience of the radiologist. [9,10]

Shoulder ultrasonography was first introduced by Seltzer and co-workers [11] in 1979 and improved for rotator cuff tear diagnosis by Matsen and Kilcoyne [12] in 1983. Ever since, although still in its infancy, ultrasonography has been accepted as part of the armamentarium for the diagnosis of rotator cuff tears. [13-18] Despite the fact that it is less sensitive and specific as compared to magnetic resonance imaging, and operator dependant, it is cheap, easily operable [13] and is readily available in most third world countries.

In developed countries diagnostic challenges associated with the diagnosis of rotator cuff tears are about to be historical or a problem of the past. This is because their strong economies allow faster adaptation of new sophisticated and more accurate diagnostic facilities, such as magnetic resonance imaging and arthroscopy. That is,

rapid advances in diagnostic capabilities coupled with the abundance of skilled man-power have enabled developed countries to change the outlook of rotator cuff tear diagnosis from "this is probably" or "most likely", to "this is a cuff tear" with little or no doubt within a few decades.

The situation in the majority of developing third world countries is quite to the contrary as revealed by the example below. The author retrospectively reviewed the case notes of 180 patients who attended the outpatient department of the Muhimbili Orthopaedic Institute as new cases from October to December 1999. Thirty (30) or 17% of these had shoulder related conditions, and 6 of them were clinically suspected to have rotator cuff tears. The diagnosis was confirmed by shoulder ultrasonography in only one patient who happened to travel abroad for other businesses, and an open surgical repair of the tear was eventually performed.

This small data reveals the existence of the problem i.e. rotator cuff tears in Tanzania, although its magnitude needs to be investigated further. Secondly it shows how difficult it is to diagnose rotator cuff tears in Tanzania i.e. proper diagnosis can only be made if one is referred abroad. Thus, deliberate efforts are needed in order to improve / enhance the diagnosis of rotator cuff tears in Tanzania through the use of cheap and relatively accurate diagnostic aids such as ultrasonography. Indeed ultrasonography is not new in Tanzania, as many hospitals have been using it for more than a decade in the diagnosis of obstetric and gynecologic conditions, intra-abdominal tumors, visceral injures in cases of blunt abdominal trauma etc. However, suprising enough, its use in orthopaedics until today is still non-existent. This calls for deliberate efforts to widen the spectrum of ultrasonographic diagnosis in the country to include the diagnosis of orthopaedic conditions, especially rotator cuff tears. This

paper is therefore aimed at determining the role of ultrasonography in the diagnosis of rotator cuff tears according to the experience of Schulthess clinic in Switzerland, and to see if a similar protocol could be adopted in Tanzania, specifically at Muhimbili Orthopaedic Institute.

2. LITERATURE REVIEW.

2.1 Rotator Cuff Anatomy.

2.1.1 Gross anatomy.

Four muscles form the rotator cuff of the shoulder joint. These are from anterior to posterior the subscapularis, the supraspinatus, the infraspinatus and teres minor muscles. All these muscles arise from the scapular and are inserted into the tuberosities of the humerus. Their broad and flat tendons fuse intimately with the joint capsule of the shoulder to form the musculo-tendinous cuff.

Superiorly the supraspinatus arises from the supraspinatus fossa of the scapula and inserted into the highest impression on the greater tuberosity of the humerus. It is innervated by suprascapular nerve (C_5). Anteriorly the subscapularis arises from the anterior surface of the scapular and inserted into the lesser tuberosity of the humerus. It is supplied by upper and lower subscapular nerves (C_6 and C_7).

Posteriorly the infraspinatus originates from the infraspinous fossa of the scapula and inserted into the middle impression of the greater tuberosity of the humerus. It is supplied by suprascapular nerve (C_5).

Posteriorly and inferiorly the teres minor innervated by the axillary nerve ($C_{5,6}$), takes its origin from the dorsal surface of the upper two thirds of the axilliary border of the scapula, and inserted into the inferior most impression of the greater tuberosity of the humerus.[19,20,21]

2.1.2. Microscopic anatomy

Microscopically rotator cuff tendons (particularly the supraspinatus and subscapularis tendons), have been described as consisting of 5 layers (Fig.1).[21,22] Externally the coracohumeral ligament forms the first layer. The 2nd layer is formed by large bundles

of closely packed parallel tendon fibres. A thick tendinous structure, consisting of smaller and less uniformly oriented tendon fascicles, constitute the third layer. The fourth layer consists of the deep extension of the coracohumeral ligament, and its fibres run perpendicular to the primary tendon fibres. The last and the innermost layer, is the capsule of the shoulder joint proper, forming a continuous cylinder between the glenoid and humerus. Its fibres are uniformly oriented. [21,22]

The various fibre orientations and multiple layer structure of the rotator cuff have been thought to be a source of significant shear stresses that might play a role in cuff tear pathogenesis.[22] Similarly intratendinous interdigitations and variations in cuff structure have been considered important in the pattern and propagation of partial thickness and intratendinous tears. [22]

Figure 1: Schematic diagram of a sugittal section showing various layers of the rotator cuff.



Chl: Coracohumeral ligament SP: Supraspinatus IS: Infraspinatus

1: Layer 1 – coracohumeral fibres.

2: Layer 2 } Supraspinatus and infraspinatus fibres.

3: Layer 3 }

4: Layer 4 – Deep extension of coracohumeral ligament.

5: Layer 5 – Joint capsule proper.

2.1.3. Vascular anatomy.

The vascular anatomy of the rotator cuff have been a subject of interest due to its suggested link to the pathogenesis of rotator cuff tears.[1] Several arterial sources supply the rotator cuff. The suprascapular and posterior circumflex humeral arteries

supply much of the blood to the infraspinatus and teres minor muscles.[23] The supraspinatus receives its blood supply from branches of suprascapular and subscapular arteries, and from branches of the anterior circumflex humeral artery. Branches from the subscapular and anterior circumflex humeral arteries supply the subscapular muscle in conjunction with the thoracoacrominal artery and a variable distal branch, the suprahumeral artery.[23,24] Most of the tears in the supraspinatus tendon occur at the critical portion of Codman [1] which is located just proximal to its insertion. This is an area of arterial anastomosis or watershed of blood vessels, and is considered to be hypovascular. [24].

2.2. Functions of the Rotator Cuff.

The rotator cuff functions as a dynamic stabilizer of the glenohumeral joint and a depressor of the humeral head. [25] The rotator cuff muscles also play a role in movements of the humeral head. The teres minor and infraspinatus muscles are primary external rotators of the arm, and 80 per cent of the external rotation force is provided by these muscles.[26] The subscapularis acts as an internal rotator and anterior stabilizer of the shoulder joint,[27] while the supraspinatus provide about 50 per cent of the abduction force.[28]

The rotator cuff have also been described to play a nutritive role to the articular cartilage by providing a water - tight joint space maintaining synovial fluid mechanics. [1,29]

2.3. Rotator Cuff Kinematics.

According to more recent studies the interaction of rotator cuff muscles in glenohumeral movements have been found to be extremely complex. The contribution of each muscle or part of it, depends upon the position of the glenohumeral joint, moment arms and line of action.

Otis and associates [30] used a cadaveric model to study changes in moment arms of the rotator cuff and deltoid muscle in abduction and rotation. According to them the abductor moment arm of the posterior portion of the supraspinatus decreased with external rotation, whereas that of the anterior portion decreased with internal rotation. Internal rotation was displayed by the subscapularis, which was found to have the greatest adductor arm moment in its superior portion. External rotation enhanced the ability of the superior portion of the subscapularis to elevate the arm. The infraspinatus is an abductor as well as an external rotator. The performance of its superior portion as an abductor was increased by internal rotation, whereas the ability of the same portion as an external rotator was decreased by abduction.

The effect of cuff failure in relation to rotator cuff kinematics, have also been studied. Shoulders with massive rotator cuff tears may have either normal or impaired kinematics. A model has been proposed in which a balance of forces anteriorly and posteriorly might preserve stability. Similarly a hypertrophied free edge of the cuff tear, might transmit stresses simulating a sound cuff. [31] It has also been observed in cadaveric models that supraspinatus tears may increase the deltoid force needed to lift the arm but does not alter the kinematics. [32]

Further similar studies have shown that full-thickness supraspinatus tendon defects impaired centering of the humeral head and in some even elevation. [33] However

superior translation of the humeral head was reduced (decreased) and full active elevation of the arm was possible, when pain inhibition was simulated, by leaving the supraspinatus intact, without applying a force to it. This difference has been thought to be due to the passive spacer effect of the supraspinatus tendon. [33]

Superior translation of the humeral head has been found to be directly proportional to the size of the simulated cuff tear.[33] Application of a force to an intact long head of biceps tendon have been found to reduce the superior translation of the humeral head seen in large cuff tears and often restores full active shoulder elevation. [33] That is, a force in the long head of biceps tendon, whether passive [34] or active [35] and the spacer effect of the tendon itself, help to stabilize the humeral head in massive cuff tears. Therefore to sacrifice the biceps tendon at rotator cuff surgery may impair the fulcrum for arm elevation.

The role of the coracoacrominal ligament in stabilizing the shoulder, has also been investigated in cadaveric models. Transection of this ligament in the presence of massive cuff tears allowed for the greatest superior humeral head subluxations. This could be explained probably by the loss of the buffering contact between the undersurfaces of the ligament and the humeral head, and loss of tethering between the coracoid process and the anterior acromial tip allowing the acromion to deform upwards. The coracoacromial ligament has been therefore considered to be an important passive stabilizer of the glenohumeral joint. [33,36]

2.4. Pathogenesis of Rotator Cuff Tears.

The pathogenesis of rotator cuff tears is multi-factorial with both extrinsic and intrinsic factors playing a role. Extrinsic factors considered here include impingement (subacrominal or internal), repetitive stress and tensile overload; while aging, alteration in tendon matrix composition and material properties and hypovascularity constitute intrinsic factors. [37,38,39]

2.4.1. Tendon degeneration.

Rotator cuff tendons have been described to degenerate as aging proceeds. This probably explains why the majority of cuff tears occur in patients of over 40 years old. [1] In the young healthy cuff, the tendon is said to be stronger than bone, explaining why avulsion fractures of the greater tuberosity of the humerus are more common than tendon tears. Thus even if trauma is involved, most cuff tears are believed to occur through tendons already weakened by degeneration. [40,41]

Microscopically degeneration has been defined as the presence of thinning of the tendon fibres, reflecting the degree of atrophy, presence of granulation tissue at the site of insertion being evidence of attempted healing, incomplete, or partial tearing of tendon fibres denoting the existence of microtears.[39,42] Sano and colleagues [43] studied 58 fresh cadaveric shoulders and observed degeneration in all three cuff tendons, i.e. the supraspinatus, infraspinatus and subscapularis tendons, to an equal extent. Degeneration was also found to be more pronounced on the articular half than the bursal half of the three cuff tendons. Granulation tissue was found predominantly in fibro-cartilage close to bone in the midpoint of tendon insertion. Thus they concluded that degeneration at the tendon insertion was a primary intrinsic change, starting on the articular side.

2.4.2. Hypovascularity

Fukuda and associates [44] studied surgical specimens from 12 patients with bursal side tears and observed that all 12 tears occurred at the critical point of Codman in the supraspinatus tendon. There was also lack of blood vessels in all 12 proximal stumps, associated with widespread replacement of tenocytes by chondrocytes as a sign of low oxygen tension.

Microinjection studies also support the existence of a hypovascular zone in the supraspinatus tendon. [25,45,46] Vascularity of cuff tissue has also been demonstrated by microvascular studies to decrease with age, i.e. cuffs of younger individuals are more vascular than those of older persons.[44]

However, other workers elsewhere had conflicting results. Swiontkowski and colleagues [47] reported hypervascularity of the supraspinatus tendon after using microvascular techniques, with laser Doppler flowmetry in living patients. Brooks and associates,[48] failed to locate a hypovascular area in the supraspinatus tendon. Thus these other studies dispute the role of hypovascularity in the pathogenesis of rotator cuff tears.

2.4.3. Impingement

Impingement, which can be defined as a focused acromial contact compressing the supraspinatus tendon, was first implicated by Meyer [49] as a predisposing factor in the pathogenesis of rotator cuff tears. Three stages of impingement were then described by Neer.[50]

Stage I: Present in patients under 25 years, and consists of reversible oedema and haemorrhage.

Stage II: This is a stage of fibrosis and tendinitis of the rotator cuff, and affects patients aged 25 to 40 years.

Stage III: Consists of the formation of bone spurs and tendon ruptures and occurs in individuals over 40 years of age.

Impingement can either be outlet (primary or roof), or non-outlet (secondary). Primary or outlet impingement, has been said to be caused by narrowing of the supraspinatus outlet. The latter may be narrowed by a prominence of the undersurface of the acromion, the shape or slope of the acromion, or an anterior acrominal spur.[50] The anterior third of the undersurface of the acromion, the acromioclavicular joint and corocoacrominal ligament are areas that may compress and damage the rotator cuff tendons.

Bigliani and colleagues [51] studied lateral shoulder radiographs tilted 10^0 cephalic (supraspinatus outlet view) in 140 cadavers, and described 3 types of acromial morphology (figure 2). Type I or flat acromion was found in 17 per cent, type II or curved acromion in 43 percent, and type III or hooked acromion in 40 per cent of cadavers. They reported a significant increase of rotator cuff tears in shoulders with type III acromial shape, with anterior acromial spurs and with acromions with greater angulation of anterior slope. In a subsequent study Morrison and Bigliani[52] reported that in those patients with positive arthrograms for rotator cuff tears, 80 per cent of them had type III acromial morphology . Wuh and Snyder [53] measured acromial thickness at the junction of the anterior and middle third and modified the Bigliani classification as follows:-

Type A acromion:- less than 8 mm thick.

Type B acromion:- between 8-12 mm thick.

Type C acromion:- greater than 12 mm thick.

The manner in which the rotator cuff comes into contact with the coraco-acromial arch have been investigated using articulated cadaveric shoulders, [54] dye compression and pressure sensitive films[55] and by optical sterephotogrammetric techniques.[56] It has been found that contact between the acromial tip and the supraspinatus tendon was greatest between 60 and 120 degrees of arm elevation and more shoulders were found to be in contact when the arm was 20^0 internally rotated. Acromion type III, have also been found to increase the number of contacts.

Extrinsic compression by subacromial impingement have been found to generate high stress concentrations sufficient to cause a tear in and around the critical zone of the supraspinatus tendon.[57] In other words impingement can generate high stress on the bursal side, on the articular side or within the tendon, as might be expected when a soft tissue is being compressed between two hard objects, in this case a tendon, being compressed between two bones, the humerus and the acromion.

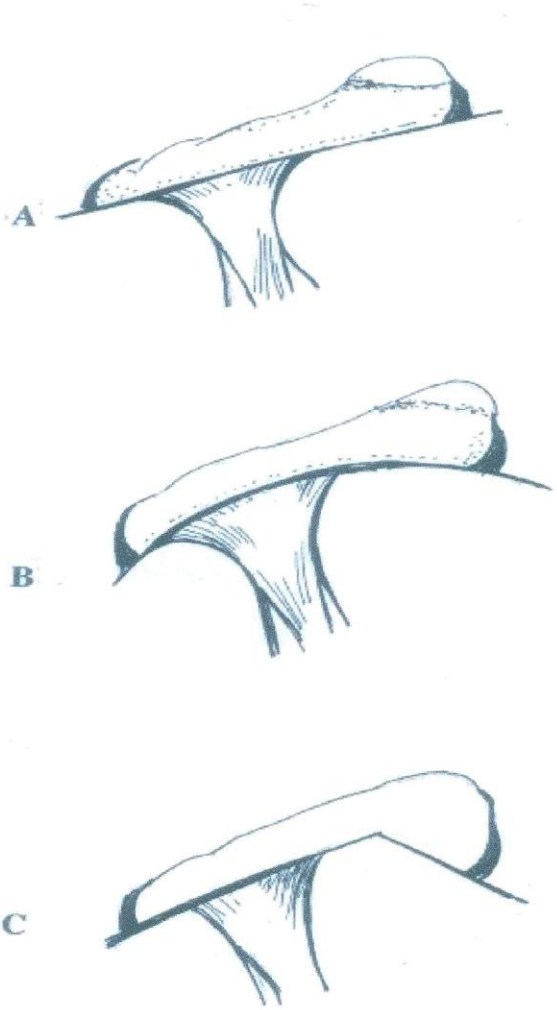
Subcoracoid impingement

In this uncommon condition a laterally placed coracoid process impinges on the proximal humerus, during forward flexion and internal rotation. This condition can be diagnosed by CT scan with the arm in the provocative position.[58]

Internal impingement.

Impingement can occur between the posterior labrum and cuff in throwing athletes during external rotation and anterior translation. [58]

Figure 2: Acromial morphology according to Bigliani.



A: **Type I**

B: **Type II**

C: **Type III**

2.5. Classification of Rotator Cuff Tears.

Rotator cuff tears can be classified according to the aetiology, duration of the tear, size of the tear / extent of the tear and the location of the tear in the cuff or topographic anatomy.

2.5.1. Aetiology

This is well covered in the section of pathogenesis. Cuff tears can be either traumatic or degenerative although in most cases these two factors act together in a vicious cycle.

2.5.2. Duration of the tear.

The length of time the tear has been present can be estimated from the history and the condition of the cuff at operation.[6] This means assessment of the degree of tendon retraction, muscle atrophy and fibrosis at the cuff defect edges, can enable the surgeon to estimate how old the tear is. Four types of tears have been categorized by Ellman and associates.[59]

I Acute tears:- Less than six weeks old.

II Subacute tears:- Six weeks to six months old.

III Chronic tears:- Six months to one year old.

IV Old tears:- More than one year old.

In Ellman and associates [59] series of 50 patients 12% of the tears were acute, 10% were subacute, 32% were chronic, and 46% were old tears.

2.5.3. Extent of the tear.

Rotator cuff tears can either be complete or incomplete. Complete tears are those with a direct communication between the subacromial space and the shoulder joint, while those with no direct communication are incomplete tears. The incidence of rotator cuff tears in cadavers according to Fukuda[1] has been variously reported with a range of 6-19% for complete tears and 6-33% for incomplete tears. That is incomplete thickness tears appear to be twice as common.

2.5.3.1 Incomplete or partial thickness tears.

There are subdivided into 3 types:-

I Those tears in which only the bursal side of the tendon is involved, or bursal side tears.

II Tears limited to the tendon without any communication with either the shoulder joint or the subacromial space, or intratendinous tears.

III Tears involving only the articular or joint side of the tendon or articular side tears. [1,60]

In a study involving 249 cadaver shoulders, Yamanaka and Fukuda [60] reported an incidence of 7 percent for complete thickness tears, and a 13 percent incidence for incomplete thickness tears. Regarding the nature of the incomplete thickness tears, 2.4% were bursal side, 7.2% were intratendinous, and 3.6% were articular side tears.

2.5.3.2 Compete thickness tears.

According to Post and Silver classification as quoted by Montgomery and colleagues [61] 4 categories are recognized.

I Small tears:- less than 1cm in diameter.

II Medium tears:- 1 to 3 cm in diameter.

III Large tears:- 3 to 5 cm in diameter.

IV Massive tears:- greater than 5cm in diameter.

2.5.4 Topographic location of the tear.

According to Warner and Gerber [62] rotator cuff tears can be located either postero-superiorly or antero-superiorly.

2.5.4.1 Posterior – superior tears.

These involve the supraspinatus and infraspinatus tendons, and commonly occur in individuals in their sixties or older. Gradual tendon atrition from outlet impingement and age related degeneration, are thought to be the major aetiological factors.

2.5.4.2 Anterior – superior tears.

These consist of variable lesions involving the supraspinatus, subscapularis and biceps tendons and the coracohumeral and glenohumeral ligaments. Trauma is the major aetiological factor, and men in their 5^{th} and 6^{th} decades of life are predominantly affected. [60] The mechanism of injury is usually a sudden external rotation or hyperextension force applied to the shoulder with the arm to the side. [63]

2.5.5 Patte`s Comprehensive Classification of Rotator Cuff Tears.

In 1989, Patte [64] proposed a classification system, which took into consideration the extent of the tear, its topography in the sagittal and frontal planes, the trophic quality

of the muscles and the integrity of the long head of the biceps tendon. Patte's classification is hereby reproduced.

Table 1: Classification of tears.

Extent of the tear.	
Group I:	Partial thickness tears or full-substance tears measuring less then 1 cm in saggital diameter at bony detachment.
	a. Deep, partial tears
	b. Superficial tears.
	c. Small full substance tears.
Group II:	Full thickness tear of entire supraspinatus.
Group III:	Full thickness tear involving more than one tendon.
Group IV:	Massive tears with secondary osteoarthritis.

Topography of the tear in the sagittal plane.	
Segment 1:	Subscapularis tear
Segment 2:	Coracohumeral ligament tear
Segment 3:	Isolated supraspinatus tear
Segment 4:	Tear of entire supraspinatus and one half of infraspinatus.
Segment 5:	Tear of supraspinatus and entire infraspinatus.
Segment 6:	Tear of subscapularis, supraspinatus and infraspinatus.

Topography of the tear in the frontal plane.

Stage 1: Proximal stump close to bony insertion.

Stage 2: Proximal stump at level of humeral head.

Stage 3: proximal stamp at level of glenoid

Quality of muscles

State of long head of biceps tendon

Extent of the tear.

Group I: The cuff remains watertight in incomplete tears. Surgery is rarely indicated. Physiotherapy is successful in majority of cases, and incidence is low.

Group II: Tears limited to supraspinatus, with sagittal diameter at tendon insertion approximately 2 cm. Coracohumeral ligament often involved. The incidence in Patte's series was 26%. Repair is easy and a plastic procedure is rarely indicated.

Group III: These are large defects, that involve the supraspinatus, but at times the subscapularis and usually the infraspinatus. Sagittal extent of the lesion 4 cm or more, early repair is indicated, and one third of cases will require a plastic procedure. They constitute 49% of cases in Patte's series.

Group IV: These are massive tears associated with secondary degenerative osteoarthritis of the glenohumeral joint. An acromiohumeral arthrosis also develops as complication of superior migration of the humeral head. Degenerative changes in these lesions limit the possibility of tendon repair and therefore shoulder

arthroplasty becomes necessary. Patte did 28 such shoulder arthroplasties and reported mediocre results with respect to function, and satisfactory results in terms of pain relief.

Topography in the sagittal plane (figure 3).

Topographic assessment of the tear in the sagittal plane is important for anatomic and clinical correlations, and for the proper choice of surgical technique. Posteriorly situated tears interfere more with function, whereas anterior lesions are more painful.

Segment 1: Isolated subscapularis tears, are generally caused by traumatic avulsions, and often are associated with medial dislocation of the long head of biceps, and seldom exclusively degenerative.

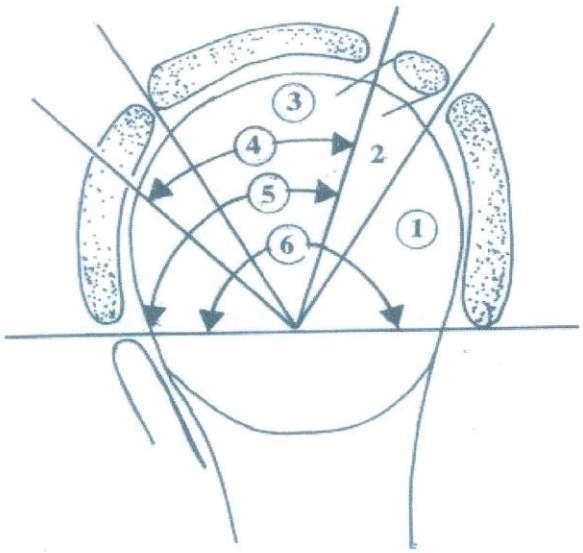
Segment 2: Isolated coracohumeral ligament tears are traumatic in nature, and have little bearing to cuff pathology.

Segment 3: When associated with segment 2 tear, constitute a superior defect found in 33% of Patte's cases. When segment 1 is also involved, an antero-superior defect forms and noted in 10% in Patte's series.

Segment 4 and 5: These are also termed postero-superior defects and represented 45% of operated shoulders in Patte's series.

Segment 6: Constituted 14% of case in Patte's series and secondary osteoarthritis is common in these lesions.

Figure 3: Topography of tear in sagittal plane



Segments 1, 2 and 3: constitute antero-superior lesions.

Segments 2 and 3: superior lesions.

Segments 4 and 5: posterosuperior lesions.

Segment 6: total cuff tears.

Topography in the frontal plane.

This is important for the proper choice of surgical technique. In stage 1, reattachment to bone is easy, in stage 2, preoperative planning is difficult because it is impossible to determine the extent of necrosis in the proximal stump, and in stage 3 a plastic procedure for repair is needed.

In the frontal plane, progression of tears occurs in a horizontal direction i.e. from stage 1 to stage 3,and in the sagittal plane progression occurs from segment 2 to segment 4.

Trophic quality of the muscle.

In this classification the trophic quality of the muscle is based on the degree of fatty degeneration as measured by computed tomography (CT). Four stages can be defined depending on which predominates between clear streaks (fat) and dark streaks (muscle), i.e. clear streaks can be either minimal in extent, or less equal or greater than dark streaks.

State of the long head of biceps tendon.

The importance of the long head of biceps tendon in massive cuff tears has already been discussed above in relation to rotator cuff kinematics. In antero-superior defects, in which internal rotation is maintained, biceps tendon lesions have no apparent importance. In massive cuff tears however, biceps lesions accelerate superior migration of the humeral head, and thus influence the functional outcome.

In the literature several classifications are used. However, the Post and Silver and the modified version of Patte`s classifications are commonly referred to, probably because they are concise and simple. Schulthess clinic in Switzerland uses the modified Patte's classification.

Table II

Schulthess clinics modified Patte's classification.[65]

I^0	≤ 1cm-supraspinatus mainly
II^0	Between 1-2cm
III^0	> 2cm (supraspinatus plus subscapularis or infraspinatus)
	A: Direct repair possible
	B: Direct repair possible only with tendon/muscle mobilization .
	C: Direct repair not possible without the use of grafts.
IV^0	Tear associated with cuff tear arthropathy.

2.6. Diagnosis of Rotator Cuff Tears.

2.6.1. Clinical features.

Age: Rotator cuff tears are very rare below the age of 40, and common after 50 years. [1] Patients with complete impingement tears average 59 years while those with incomplete tears average 52 years.

Trauma: Codman [36] considered the history of trauma as important in the diagnosis of rotator cuff tears. However it is now apparent that the incidence of trauma in patients with full thickness tears is less than 50%.[50] The incidence of cuff tears and impingement has been reported to be high in throwing athletes due to repetitive overuse, predisposing to micro-tears.

Pain: Pain whether spontaneous or emotional is commonly present, but it is non-specific. The severity of pain correlate more to the degree of inflammation, rather than to the size of the tear. [1]

Fluid sign: This was first described by Codman[36] and denotes accumulation of fluid in the subacromial bursa. This is often present in complete thickness chronic tears and less so in bursal side incomplete tears. May also present in rheumatoid arthritis.

Arch of pain: This is positive when pain is elicited when the arm passes between 70^0 and 120^0 during elevation. The outcome of the test is improved by internally rotating the arm.[1]

Distraction test: This test intends to re-confirm the presence of impingement. Longitudinal traction is applied to the arm against the patients axilla, while the arm is being elevated. This manoeuvre will cause the arch of pain to disappear. [1]

Impingement sign: This is another test to confirm the presence of impingement, and is positive if pain is elicited when the patient's scapula is depressed while the arm is being elevated. May also be positive in acromio-clavicular joint arthritis, glenohumeral instability, and in frozen shoulder.[1]

Impingement test: This test, which is also known as Browns procaine test, was popularized by Neer. [50] It is performed by injecting 10mls of lidocaine in the sub-acromial space. The test is positive when complete temporary relief of pain is achieved. Failure to relieve pain indicates the presence of other pathology rather than impingement.

Drop arm sign: To elicit this sign the arm is elevated passively and let go. It is positive if the arm drops with gravity against the patients will, and indicates the presence of a large tear involving both the supraspinatus and

infraspinatus or paralysis of C_5 nerve root. May be negative in tears confined to the supraspinatus alone.[1]

Crepitus: More marked in stage III impingement and in full- thickness cuff tears. It may also present in early stages of impingement or advanced arthritis of the glenohumeral joint [1]

Muscle weakness: May not be appreciated until the tear becomes massive. Pain may hinder proper muscle strength testing. [1]

Muscle atrophy: Atrophy of the supraspinatus and infraspinatus appears from 2 to 3 weeks following acute tears.[1]

Contracture: According to Codman [36] there is preservation of passive motion and absence of contracture in complete-thickness cuff tears. However contracture tend to develop in incomplete thickness cuff tears. No explanation has so far been given, however the inflammatory process associated with the latter is a possible culprit.

Hawkins test: The arm is flexed forward 90^0 and internally rotated, if pain is produced, impingement is present. [58]

Supraspinatus test of Jobe: The patient is seated with both shoulders abducted to 90^0 and flexed 30^0 in the horizontal plane, and arms internally rotated. The patient is then asked to abduct the arms against resistance. In lesions of the supraspinatus abduction power will diminish(figure 4).[58]

Figure 4

Supraspinatus test [Jobe].



Abduction against resistance.

Infraspinatus test of Patte:

The patients shoulder and elbow are flexed to 90^0 one hand of the examiner supports the arm and the other tests the power of external rotation (figure 5).[58]

Figure 5

Infraspinatus test [Patte].



External rotation in abduction.

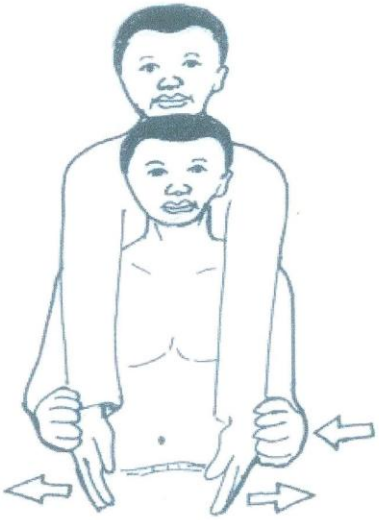
A similar test can be performed with the arm at 0^0 of abduction, and the elbow flexed 90^0, and arm externally rotated 45^0. The patient is then asked to externally rotate the arm against resistance.

Subscapularis test (Gerber).

The patient is seated with arms at 0^0 abduction and elbows flexed 90^0. The patient is then internally rotates the arms versus resistance (figure 6).[58]

Figure 6

Subscapularis test [Gerber].



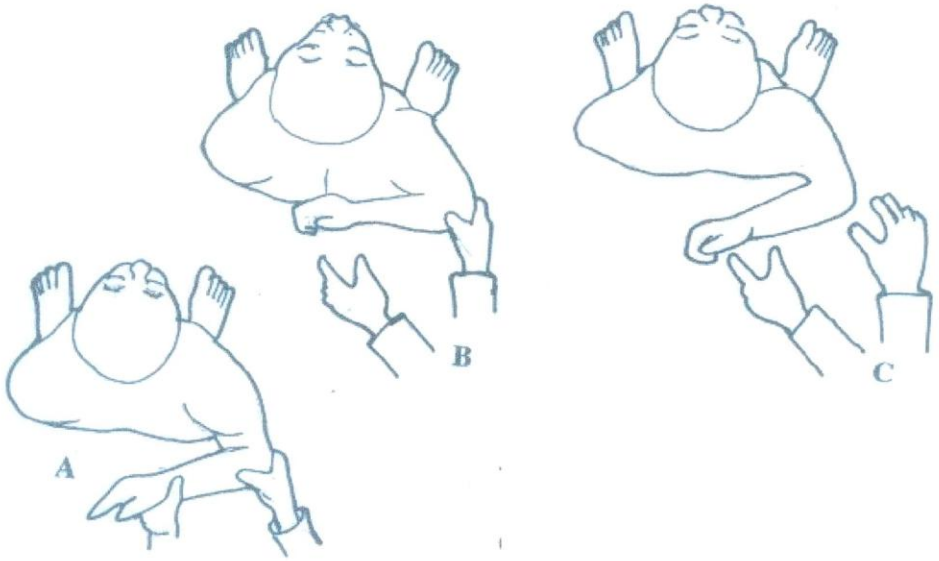
Internal rotation in adduction versus resistance.

Lift of test (Gerber)

The arm is put in internal rotation with the hand resting on the patients back, the examiner then pulls the forearm further posteriorly from the back, if the forearm can not be maintained in its new position and drops to its original position, this denotes lesions of the subscapularis (figure 7).[58]

Figure 7

Lift-off-Test [Gerber]: The forearm behind the back, pulled posteriorly by the examiner.



A: Performing the test.
B: Positive test (forearm falls to back).
C: Negative (forearm remains where it was before left by the examiner).

Horn Blower's sign.[66]

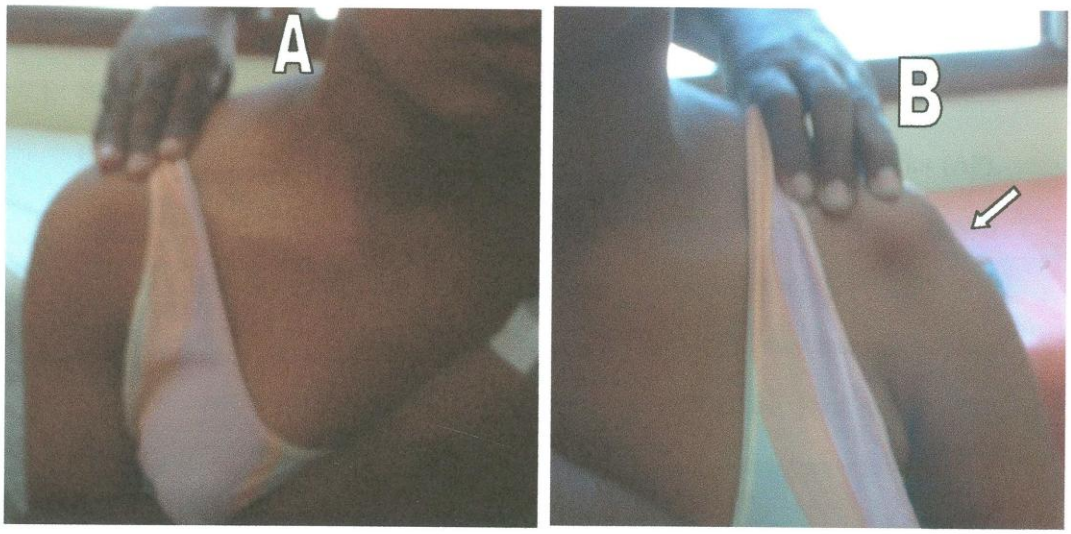
The patient is asked to put both hands on his mouth. A positive sign is shown by failure to put the affected hand directly on the mouth without first abducting the arm. This means the patient's ability to externally rotate the arm is impaired, and indicates lesions of the infraspinatus and/or teres minor.

Other clinical signs which may be part of cuff tear symptomatology.

Sulcus sign:

This sign indicates inferior instability of the shoulder and implies the presence of a sulcus between the coraco-acrominal arch and the humeral head when downward traction is applied to the arm (figure 8).

Figure 8: Demonstration of Sulcus sign.



A: Normal right shoulder.

B: Positive sulcus sign. Patient has inferior instability of the left shoulder.

Anterior apprehension test.

Is positive if the patient becomes apprehensive when the arm is abducted 90^0 and externally rotated. It indicates an anterior shoulder instability.[58]

Relocation test.

This is another sign for anterior shoulder instability. The patient lies supine and he/she becomes apprehensive when a direct postero-anterior force is applied to the shoulder.[58]

Posterior apprehension test.

Passive forward flexion and internal rotation is applied to the affected shoulder. Apprehension indicates the presence of posterior instability.[58]

2.7. Imaging Investigations.

2.7.1. Radiographs

Routine radiographs recommended in rotator cuff tears include, anteroposterior (AP), supraspinatus outlet, and axillary lateral views. [67,68] In small cuff tears and in early stages of impingement plain radiographs are less informative. [1] In advanced impingement, and in massive cuff tears radiographic findings may include, superior migration of the humeral head, inferior acromio-clavicular joint osteophytes, subacromial spurs, sclerosis of either the anterior acromion or the greater tuberosity of the humerus, calcification of the supraspinatus tendon, prominence of the greater tuberosity, and wear of the greater tuberosity, anterior third of the acromion and acromioclavicular joint. [50]

Hamada and associates [68] observed these progressive radiological changes in 5 out of 7 patients with massive rotator cuff tears treated conservatively and followed for more than 8 years. One of them subsequently developed cuff tear arthropathy. Thus they postulated on the possibility of some massive rotator cuff tears progressing to cuff tear arthropathy through various pathomechenical processes related to the corresponding radiological changes.

The distance between the inferior cortical surface of the acromion and the superior aspect of the humeral head, i.e. the acromiohumeral interval or distance as measured on routine AP views with the x-ray beam at the level of the shoulder joint is 7-14 millimeters. [69,70] Massive rotator cuff tears have been found to be associated with reduction of the acromiohumeral interval, to less than 6-7mm. [68] In 1989 Fukuda and co-workers [71] introduced a new radiological projection, "the push up view" which demonstrates the acromiohumeral distance more accurately and is easily reproducible. Ellman and associates [59] in a study involving 50 proved rotator cuff tears, observed a reduction of the acromiohumeral distance in 48% of the shoulders. They also reported a direct correlation between this distance and the degree/severity of the preoperative impairment of shoulder function. That is to say the smaller the acromiohumeral distance, the lower the functional rating of the shoulder.

2.7.2. Shoulder arthrography.

This is probably the most practical and reproducible method of diagnosing full thickness rotator cuff tears.[1] However it can not pick-up superficial incomplete thickness tears located on the bursal side of the cuff. Superficial lesions on the articular side of the cuff can be diagnosed by arthrograms.

It demonstrates cuff lesions by showing spillage of contract material in the subacromial bursa or pooling of material in the articular side of the cuff. Unfortunately it is invasive, painful, and can miss lesions of the subscapularis. Furthermore, it exposes patients to risks of radiation, infection and allergy. The reported sensitivity and specificity for shoulder arthrography is 87%and 57% respectively. [1,6]

2.7.3. Bursography.

This was introduced by Lindblom in 1939, and advanced by Mikasa in 1979, [7] for the purpose of evaluating the superficial surface of the rotator cuff.

Bursography is indicated in patients with persistent symptoms, despite a negative arthrogram. Radiologically it shows pooling of contrast medium in the cuff tissue i.e. in the bursal side.[7,8] Fukuda and colleagues [8] diagnosed six cases of bursal side incomplete-thickness tears by bursography, and two thirds of their bursographic findings correlated well with surgical findings. However the interpretation of a bursogram is said to be time consuming and difficult.

2.7.4. Magnetic resonance imaging (MR1).

Magnetic resonance imaging is currently the most sensitive, specific and accurate available non-invasive investigation. [9] It has been reported to have a sensitivity and specificity of 100% and 95% respectively. [9,10] However its has been reported by Zlatkin and associates,[72] to have low sensitivity and specificity for partial thickness cuff tears. It may be particularly useful in confirmation of the size of the rotator cuff tear and in assessing the degree of muscle atrophy and fatty degeneration in patients suspected to have massive rotator cuff tears.[73] It has the disadvantage of being expensive and its accuracy is highly dependent on the skill and experience of the radiologist and may not pick-up small lesions.

2.7.5. Shoulder arthroscopy / bursoscopy.

No one can question the value of arthroscopy in the diagnosis of rotator cuff tears. As it involves direct visualization of either side of the cuff, it has the capability of diagnosing full-thickness tears as well as partial thickness tears on the articular and

bursal sides of the cuff. Arthroscopy/bursoscopy can either be diagnostic or therapeutic.

The use of arthroscopy as a routine diagnostic procedure is hampered by the fact that it is an invasive surgical procedure requiring strict aseptic theatre techniques and good regional or general anaesthesia. Thus its use as a diagnostic tool is limited to few cases where the diagnosis from other investigations remains unclear.

2.7.6. Shoulder ultrasonography.

Shoulder ultrasonography was first introduced by Setzer and co-workers [11] in 1979 and improved for rotator cuff tears diagnosis by Matsen and Kilcoyne [12] in 1983. This is a non-invasive investigation and can be applied to the contra-lateral shoulder for comparison. Rotator cuff defects are revealed as absence of the normal tissues echoes and failure of the tissue or torn tendon to move synchronously with the humeral head, when the latter is made to move passively in the line of action of the affected cuff tendon.

According to Wallny and associates, [17] ultrasonomorphological findings in order of decreasing frequency include discontinuity of the homogenous echogenicity of the cuff without thinning, focal thinning of the cuff and a central echogenic band within the rotator cuff tendon. The latter denotes the presence of intratendinous lesions. Bursal side partial thickness tears are delineated by minimal flattening on the bursal side of the tendon, while articular side partial thickness tears are demonstrated by hypoechogenic or a mixture of hyper and hypoechogenic defects on the deep or articular side of the cuff.

In 1988 Mack and co-workers [13] studied ultrasonographic findings versus surgical findings in 141 patients and reported a sensitivity and specificity for ultrasonography of 91% and 98% respectively. However the sensitivity and specificity of ultrasonography reported elsewhere ranges from 58 – 85% and 93 – 97% respectively [13, 14, 15].

The main advantage of ultrasonography is that, it is a non-invasive procedure, thus is painfree and obviates the risks of infection and allergy. Others include absence of radiation exposure, easy operability and cheapness of the equipment. Disadvantages include, equipment and operator dependency, difficulty in distinguishing calcification from tears, and the possibility of missing smaller lesions. [13,14,15]

2.8. Management of Rotator Cuff Tears.

Rotator cuff tears can be managed either by non-operative or operative regimens, depending on the underlying pathology, size of the tear, age of the patient and other co- existing illnesses.[1] This means acute traumatic tears in young individuals require a more aggressive approach, than degenerative tears occurring in elderly patients. Similarly cuff tears in medically frail patients should not be managed by surgical intervention. However it should be stressed that, treatment of rotator tears like that of other medical conditions, should be individualized.

2.8.1. Non-operative management.

Conservative management in rotator cuff tears aims at relieving pain, reducing disability and strengthening compensatory mechanisms. In non-traumatic or degenerative tears, conservative treatment is recommended, before embarking on operative management. Depending on the stage of the disease and the surgeon, non-

operative management can be carried out for a period of from 2 to 6 months, before operative management is instituted. [1]

Non-operative regimens in the management of rotator cuff tears include local rest, application of heat or cold massage, non-steroidal anti-inflammatory medication, acupuncture and subacromial steroid injections. Others include modification of activities, shoulder exercises to improve range of motion and rotator cuff muscle strengthening.[1,58]

Although Fukuda and associates [44] had disputed Codman's earlier claims that rotator cuff tears do heal spontaneously, [36] wonderfully Fukuda himself [1] has agreed to have observed many clinical cures in arthrographically proven full-thickness tears. This could be explained by the fact that physical therapy was able to alleviate the symptoms caused by inflammation (pain) and those due to the torn tendon itself, by enhancing compensation of the residual cuff muscles and prime movers or extrinsic muscles of the shoulder. Thus it is advisable to prescribe muscle-strengthening exercises after pain alleviation has be attained.

Conservative treatment is recommended in athletes, [74] because of the observation that chances of athletes returning to active competitive life after surgical management is not as great as was initially thought. [75]

Conservative treatment offers satisfactory results in about 35-59 per cent of patients.[4] It is effective in relieving symptoms due to inflammation, and in patients with torn tendons satisfactory results can be obtained in 50 per cent or less. [1]

2.8.2. Operative treatment.

Operative treatment of full-thickness rotator cuff tears, was first described by Codman in 1911.[3] Since then a lot has been written regarding the appropriate treatment of rotator cuff tears. The main controversy was centered on non-operative management versus surgical repair. This was particularly so following initial claims that spontaneous healing of these lesions occurred us a rule. [36] However after it was disputed by histological studies that this was not the case, [44] operative repair become a more logical choice. Montgomery and associates [61] in a prospective comparative study involving 87 patients, reported better results with surgical repair of full thickness rotator cuff tears, versus decompression and debridement alone. Therefore in consideration of these results and advances in surgical techniques surgical repair is recommended in the majority of cases. [61,76,77]

The indications for operative treatment include persistent pain and disability following adequate conservative management for a period of 3 to 6 months and acute traumatic tears in young patients. [78,79] According to Baset and Cofield [80] acute tears should be repaired within 3 weeks before significant tendon retraction and scaring and muscle atrophy develops.

Operative management of rotator cuff tears may involve either open surgical procedures or closed arthroscopic surgery depending on the size of the tear and the surgical procedure intended to be carried out.

2.8.2.1 Subacromial decompression.

Essentially surgical treatment of rotator cuff tears aims at restoring continuity of torn tendon(s) and relieving symptoms caused by impingement. The latter is achieved by performing subacromial decompression, i.e. removal of subacromial spurs and coracoacromial ligament, resection of the anterior edge of the acromion and at times resection of the acromio-clavicular joint.[58,81] The objective of this procedure is to create more space beneath the anterior acromion and acromio-clavicular joint, and can be done either arthroscopically, or as an open procedure. The outcome of which is said to be the same.[58,82] Subacromial decompression however, is not recommended in young patients with history of significant trauma and signs of shoulder instability and to whom, full thickness rotator cuff tears are noted at surgery. Subacromial decompression can be done either alone or can be combined with tendon repair.[61] Neer [81] performed acromioplasty in patients with frayed or partially torn rotator cuff tendons and obtained 94 per cent satisfactory results. Similarity Thorling and associates,[83] reported good to excellent results in 33 out 55 patients on whom subacromial decompression alone had been done. More satisfactory results were reported for arthroscopic debridement and decompression without rotator cuff tendon repair.[84,85] However, long term results of subacromial decompression alone for full thickness rotator cuff tears have been found to be unsatisfactory. [61, 77]

2.8.2.2 Rotator cuff tendon repair.

Repair of torn rotator cuff tendons can be achieved by applying either tendon to tendon or tendon to bone sutures, and at times a combination of the two.[1,59] Before repair is performed, it is essential that, thorough debridement of irregular edges and

fibrotic tissues is done, and chronically retracted tears are well mobilized by blunt dissection.[59] Neer and associates [86,87] described a technique of mobilizing and releasing chronically retracted tears. They recommend first the division of the coracohumeral ligament, followed by sharp division of the interval between the superior labrum and rotator cuff, then a periosteal elevator is passed into this interval to elevate the supraspinatus from the lateral supraspinatus fossa. If still insufficient tendon is obtained for repair, an interval slide can be performed, by dividing tissues in rotator cuff intervals e.g. at the interval between subscapularis and supraspinatus tendons. [88]

In cases where the retracted tendon is difficult to visualize, resection of the acromioclavicular joint is recommend. In instances where the above mobilization maneuvers fail to produce sufficient tendon, for tendon to bone repair, mobilization of entire muscle bellies of the supraspinatus and infraspinatus had been advocated. [89]

Some authors however, recommend the use of biological and/or prosthetic grafts in the repair of such large cuff defects. Biological grafts that can be used include free biceps tendon, the fascia lata, coracoacromial ligament, freeze-dried rotator cuff, fascia on the deep surface of the deltoid [1] and latissmus dorsi transfer. [90] Similarly, transposition of biceps and subscapularis tendons is a mentioned alternative. [1]

Synthetic materials that have been used as prosthetic grafts in the repair of big rotator cuff defects include Carbon, Teflon felt, Teflon fabric and Marlex mesh. [1,91] Ozaki and colleagues [91] used synthetic materials in the treatment of 25 patients with big cuff defects, and reported satisfactory results in 23 patients. They also found out that the thicker the material used the better the results, and Teflon felt 3-6mm thick offered superior results.

In situations where the proximal tendon stump can reach the anatomical neck of the humerus (with or without mobilization) the current trend is towards tendon to bone fixation. [86,92] This is because of the appreciation that the remaining stump on the greater tuberosity might be insufficient to offer a sound repair. The technique of tendon to bone fixation, include the preparation of a shallow trough [86] or a debrided raw area [93] at the anatomical neck of the humerus. This is in accordance to Mclaughlin's [94] belief that, tendon cannot be expected to heal in naked cortical bone or cartilage or to a raveled tendon stump remaining on the greater tuberosity. The creation of a bony trough or raw area was thus believed to provide a vascular bed for tendon healing.

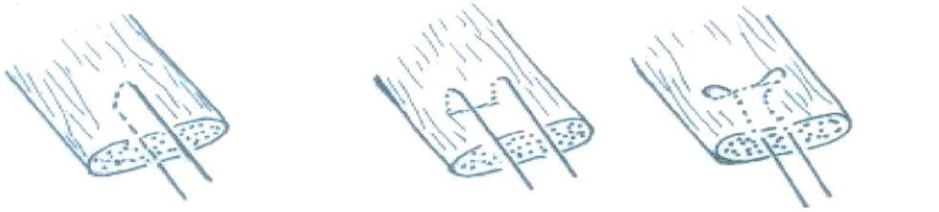
2.8.2.3 Suture materials and tendon anchorage and grasping techniques.

In terms of tendon grasping, simple, mattress, modified Mason-Allen and a variety of other suturing techniques have been used (figure 9). However according to Gerber and associates, [95] the Mason-Allen suture provide the much-needed stronger grip, with minimal associated tissue strangulation. Gerber and associates [95] also did an extensive and exhaustive study on suture materials and reported that braided polyester has the necessary stiffness, and excellent tensile strength and it can maintain its properties for the duration of tendon to bone healing. Braided synthetic materials such as Dexon Plus and Vicryl have been found to have similar properties, but loose about 50% of their mechanical strength within 2 months after implantation. Regarding tendon anchorage, single transosseous, double transosseous, augmented transosseous and other fixation methods, have been used (figure 10). The augmented double transosseous suture has been found to offer better fixation strength, limited only by the mechanical properties of the suture material used.[95]

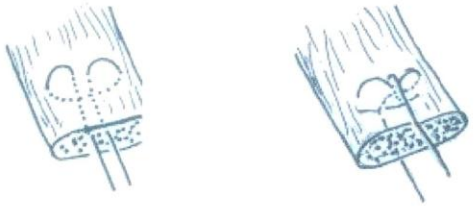
In an attempt to determine the practice of shoulder surgeons, 10 members of the European Shoulder and Elbow society, and 20 American shoulder surgeons were interviewed. The results were that all except one of the American Surgeons, and 6 of the European Surgeons used non-absorbable suture materials and all 30 surgeons used non-augmented transosseous sutures. Concerning tendon grasping, simple stitches were used by 10 American and 2 European surgeons, mattress sutures were used by 6 American versus 5 European, and modified Kessler 1 suture by 1 American and 3 European surgeons. [94]

The ideal repair according to Gerber and associates [95] is the one which has the highest initial fixation strength, that allows minimal gap formation, and maintain stability until solid healing.

Figure 9: Some of the tendon grasping techniques used in rotator cuff repairs.



Simple stitch **Mattress** **Kessler 1**



Modified Kessler 2 **Modified Mason -Allen**

Figure 10: Some of the tendon to bone fixation techniques used in rotator cuff repairs



Single transosseous **Double transosseous** **Membrane augmented double transosseous**

2.8.2.4 Outcome of rotator cuff repairs.

The outcome of rotator cuff repairs have been reported to be the same in the young (<40 years) and in the elderly (>40 years). [92] Good or excellent functional results have been reported in 66-99% of patients.[76,77,89,96] Rokito and associates[97] used the University of California at Los Angeles Shoulder Score (UCLA) and reported patient satisfaction and an increase in shoulder strength in 100% of cases. They further pointed out that functional recovery is a slow process and a period of more than one year is required for the shoulder to regain full strength.

Table III

University of California at Los Angeles Shoulder Score.	**POINTS**
PAIN	
Present all of the time and unbearable; strong medication frequently ……	1
Present all of the time but bearable; strong medication occasionally ……	2
None or little at rest, present during light activities; salicylates frequently……	4
Present during heavy or particular activities only: salicylates occasionally……	6
Occasional and slight……	8
None……	10
FUNCTION.	
Unable to use limb……	1
Only light activities possible……	2
Able to do light housework or most activities of daily living……	4
Most housework, shopping, and driving possible; able to do hair and dress and undress, including fastening brassiere……	6
Slight restriction only; able to work above shoulder level ……	8
Normal activities……	10

ACTIVE FORWARD FLEXION

150 degrees or more.....5

120 to 150 degrees.....4

90 to120 degrees.....3

45 to 90 degrees.....2

30 to 45 degrees.....1

Less than 30 degrees 0

STRENGTH OF FORWARD FLEXION (MANUAL MUSCLE – TESTING)

Grade 5 (normal)..... 5

Grade 4(good)..... 4

Grade 3 (fair).....3

Grade 2 (poor).....2

Grade 1 (muscle contraction).....1

Grade 0 (nothing)..... 0

SATISFACTION OF THE PATIENT

Satisfied and better.....5

Not satisfied and worse.....0

Maximum score, 35 points.

Minimum score 2.

Grading:

Score: 34 – 35- Excellent results.

29 – 33 - Good results.

≤ 28 - Unsatisfactory

Other functional grading systems.

Neer [81] graded the outcome of rotator cuff repairs as satisfactory and unsatisfactory. Unsatisfactory results are probably equivalent to a score of 28 points or less in the UCLA score.

The grading elsewhere is excellent, good, fair and poor,[80] to which the excellent and good results may be regarded to be equivalent to a score of 29 points or more on the UCLA scoring system.

2.8.2.5 Integrity of rotator cuff repairs.

The integrity of rotator cuff tendons following surgical repairs, has been extensively studied by various investigators, using ultrasonography and magnetic resonance imaging (MR1). The reported re-rupture rate ranged from 20% to 33%.[98-101] Tendon re-ruptures have been found to be influenced by the size and chronicity of the lesion before repair, muscle atrophy, degeneration, anchorage of hypertrophied bursal tissue instead of tendon, deltoid denervation, osteoporosis of the humeral head and surgical technique. [95,102-104]

Fortunately no direct correlation have been observed between tendon repair integrity and functional outcome. [101,102] That is to say many patients with rotator cuff re-ruptures remain significantly better compared to their pre-operative states.

THE PRESENT STUDY.

3. OBJECTIVES

3.1. Main Objective

To determine the role of ultrasonography in the diagnosis of rotator cuff tears.

3.2. Specific Objectives.

1. To study the general epidemiological characteristics of patients with rotator cuff tears.
2. To determine the sensitivity of ultrasonography in the diagnosis of rotator cuff tears.
3. To study the reliability of specific tendon lesion diagnosis according to ultrasonography and magnetic resonance imaging (MRI), versus intra-operative surgical findings.

4. MATERIALS AND METHODS.

This is a retrospective study involving 50 patients with rotator cuff tears managed at Schulthess clinic in Zurich, Switzerland from October to December 1999. The computer database of Schulthess clinic was used to retrieve the case notes of all 50 patients. These were then scanned manually to obtain the necessary details. A pre-prepared questionnaire was used to fill in all the required patient details (See appendix page 77).

Ultrasonography.

At Schulthess clinic ultrasonography is used as a screening procedure to all patients suspected to have rotator cuff lesions. This is a dynamic investigation and normally is conducted to both shoulders for comparison. The examination is done while the patient is seated and the examiner standing behind or in front. Defects in the cuff tendons, are demonstrated by absence of normal tissue echoes and failure of the affected tissue/tendon, to move synchronously with the humeral head when the arm is moved passively in the line of action. The diagnosis criteria are:

I. Failure to visualize the torn tendon secondary to complete avulsion and retraction of the proximal stump under the acromion.

II. Visualization of a focal defect in the tendon caused by retraction of the torn ends.

III. Visualization of either joint fluid or thickened bursal tissue on the deep surface of the deltoid muscle occupying the torn cuff defect.

IV. Focal thinning of the cuff tendon in cases of bursal or articular side partial thickness tears.

V. Central echogenic band for intratendinous cuff lesions.

Magnetic resonance imaging (MRI) was done as a confirmatory investigation in all patients before surgery was undertaken.

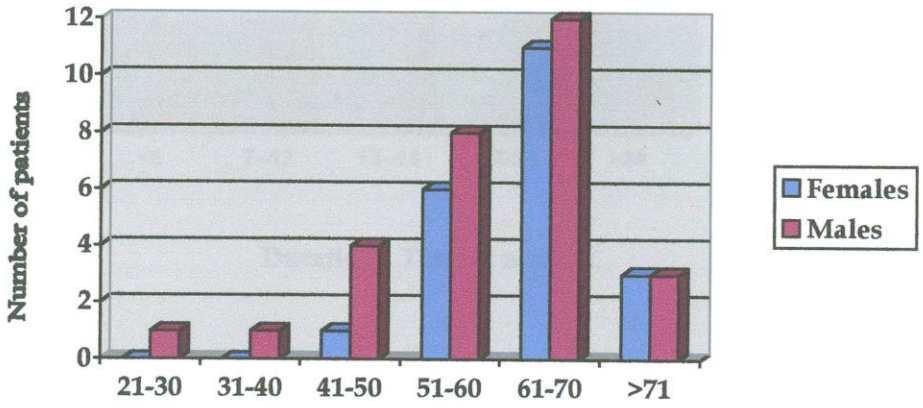
Data analysis.

In this study data was analyzed by tally tables and a hand calculator.

5. RESULTS

Table IV

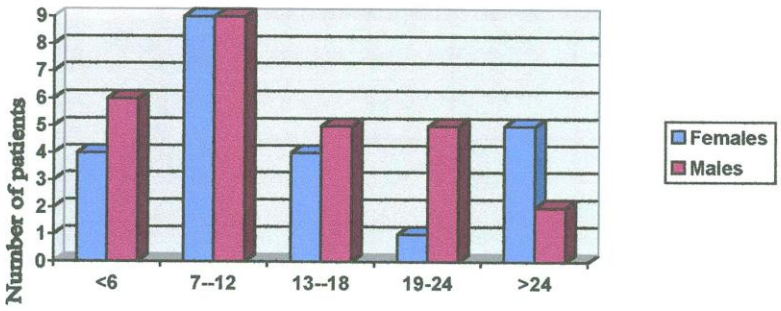
Sex and age distribution.



- None of the patients was below 20 years
- Rotator tears are rare below 40 years.
- Peak incidence is between 50 and 70 years.
- Male to female ratio of 1.4:1.

Table V.

Duration of symptoms before treatment was instituted.



Duration: Time in months.

This figure shows that 56% of patients were treated within the first 12 months since the onset of clinical symptoms, 86% within 24 months and only 14% were treated after 24 months since on set of symptoms

Table VI

History of Trauma.

	POSITIVE	NEGATIVE	TOTAL
Male	20	9	29
Female	11	10	21
Total	**31**	**19**	**50**
Percentage	62	38	100

A positive history of trauma was obtained in 62% of patients.

Trauma was more common in males then female in 69% and 52% respectively.

Table VII

Type of Trauma in 31 patients with positive history of Trauma.

	MALE	FEMALE	TOTAL	PERCENTAGE
Sports	10	4	14	45.2%
Fall	9	5	14	45.2%
Road traffic accidents	1	1	2	6.4%
Others	-	1	1	3.2%
Total	**20**	**11**	**31**	**100%**

Sports and falls were the commonest type of trauma, in both males and females. Road traffic accidents were rare causes.

Table VIII

Frequency of recorded positive signs in patients with rotator cuff tears.

N=50

SIGN	FREQUENCY	PERCENTAGE
Impingement test (Neer)	18	36
Horn-blower's sign	2	4
Dropping arm sign	10	20
Lift of sign (Gerber)	12	24
Supraspinatus test (Jobe)	25	50
Infraspinatus test (Patte)	2	4
Apprehension test (anterior)	4	8
Subscapularis lag sign	7	14

Some patients had more than one positive clinical signs.

Supraspinatus test of Jobe and Neer's impingement test were positive in 50 and 36 per cent of patients respectively.

Table IX.

Side involved or affected.

	DOMINANT SIDE	NON-DOMINANT SIDE	TOTAL
Males	21	8	29
Female	15	6	21
Total	**36**	**14**	**50**
Percentage	72	28	100

The dominant shoulder is more frequently involved than the non-dominant side in both males and females.

Table X.

Ultrasonographic findings.

	FREQUENCY	PERCENTAGE
Tear demonstrable	50	100
No tear demonstrable	0	0
Total	**50**	**100**

Ultrasonographic diagnosis of rotator cuff tears from this table had a sensitivity of 100%.

Table XI

Magnetic resonance imaging (MRI) findings

	FREQUENCY	PERCENTAGE
Tear demonstrable	50	100
No tear demonstrable	0	0
Total	**50**	**100**

All patients were found to have rotator cuff tears by MRI.

Table XII

Intra-operative surgical findings.

	FREQUENCY	PERCENTAGE
Tear seen	50	100
Non tear seen	0	0
Total	**50**	**100**

Intra-operatively all 50 patients were confirmed to have rotator cuff tears and open surgical repairs were performed.

Table XIII.

Tendon involvement according to ultrasonography.

TENDON INVOLVED	FREQUENCY	PERCENTAGE
Supraspinatus	30	60.0
Infraspinatus	1	2.0
Subscapularis	4	8.0
Supraspinatus plus infraspinatus	6	12.0
Supraspinatus plus subscapularis	3	6.0
All three major tendons	6	12.0
Total	**50**	**100.0**

The supraspinatus is the most commonly involved tendon in rotator cuff tears followed by combined lesions of the supraspinatus and infraspinatus, and massive lesions involving all three tendons.

Table XIV.

Tendon involvement according to MRI findings.

TENDON INVOLVED	FREQUENTLY	PERCENTAGE
Supraspinatus	31	62.0
Infraspinatus	0	0.0
Subscapularis	3	6.0
Supraspinatus plus infraspinatus	6	12.0
Supraspinatus plus subscapularis	4	8.0
All three major tendons	6	12
Total	**50**	**100**

Here again the supraspinatus is the most commonly involved tendon, while lesions of the infraspinatus in isolation seem to be rare or non-existent.

Table XV.

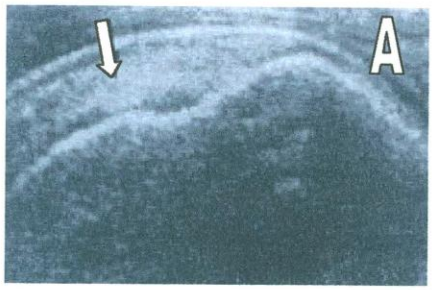
Tendon involvement according to intra-operative findings.

TENDON INVOLVED	FREQUENCY	PERCENTAGE
Supraspinatus	31	62.0
Infraspinatus	0	0
Subscapularis	4	8.0
Supraspinatus plus infraspinatus	6	12.0
Supraspinatus plus subscapularis	3	6.0
All three major tendons	6	12.0
Total	**50**	**100.0**

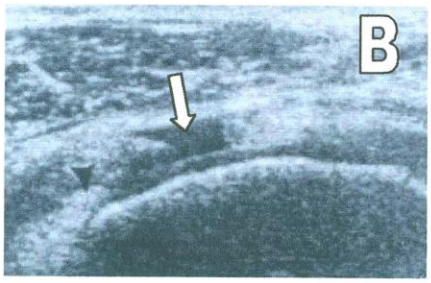
Intra-operatively all 50 patients were confirmed to have cuff tears and surgical repairs were performed. The supraspinatus was confirmed to be the most frequently torn rotator cuff tendon, while no lesion of the infraspinatus in isolation was identified.

6. ILLUSTRATIONS

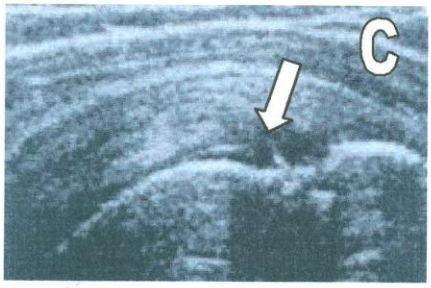
Figure 11: Ultrasonomophological features.



A: Arrow points at an intact cuff tendon.



B: A complete thickness cuff tear, with fluid accumulation between the torn tendon ends.



C: Partial thickness articular side tear.

7. DISCUSSION

7.1. Sex and Age Distribution

The age range of 23-76 years, with mean age of 60 years, and peak incidence between 50-70 years was similar to that reported by Ellman and colleagues.[59] However the male to female(M:F) ratio of 1.4:1 as observed in this study was somehow lower, compared to that of 3.5:1 reported by Ellman and associates [59] and similar to that of Lyons and Tomlinson.[5] Despite the difference in actual figures, rotator cuff tears generally show a male preponderance. Although Ellman and colleagues attributed the high male to female ratio to the high proportion of male patients attending their hospital, studies elsewhere offered no satisfactory reasons.[5] Furthermore even if, it is accepted that age is more important in the pathogenesis of rotator cuff tears,[1,50] it can not as yet be explained why more males than females are involved in rotator cuff tears.

7.2. Duration of Symptoms.

The mean duration of symptoms of 21 months (range 3 weeks to 84 months) obtained in this study was shorter compared to that of 37 months reported by Knudsen and colleagues, [101] and about twice as much of that in Fukuda and associates series.[44] Unfortunately very little have been discussed regarding this subject in the literature, however it is apparent that most rotator cuff tears are chronic entities. This is in agreement with Naviaser [104] observations that, the diagnosis and ultimately the treatment of rotator cuff tears is often delayed, probably due to the insidious nature of most lesions.

7.3. History of Trauma.

According to Codman as quoted by Fukuda,[1] The history of trauma was considered important in the diagnosis of rotator cuff tears, however recent studies have shown the incidence of trauma to be lower than was originally thought, and is about 50% according to Neer.[86] The incidence as reported elsewhere ranges from 25 up to 76%.[59,64,76,96,101,104] The incidence of 62% obtained in this series, conforms to what have been reported in the literature.

7.4. Clinical Diagnosis

Codman [2] the father of rotator cuff surgery and Mclaughlin [3] emphasized on the dependance of history and clinical examination of well-relaxed patients in the diagnosis of rotator cuff tears. Ellman and associates [59] in a study involving 50 patients, observed that, pain or tenderness was present in all 50 patients, subjective weakness of the shoulder in 86%, atrophy of the supraspinatus or of the supraspinatus, infraspinatus, and deltoid muscles in 56%, tenderness around the acromioclavicular joint in 16%, and crepitus during shoulder motion was elicited in 66% of patients. Lyons and Tomlinson [5] palpated for cuff defects and subjectively estimated the power or strength of the supraspinatus and infraspinatus muscles during resisted abductions and external rotation respectively in 50 patients. They reported a sensitivity and specificity of 91% and 75% respectively. Fukuda and colleagues [44] in a series of 12 patients with bursal side partial thickness tears, observed evidence of subacromial impingement in all 12 patients. In a more recent series involving 64 patients, pain on shoulder movements was complained by all patients,[17] 45 of these were later confirmed to have rotator cuff tears intra-operatively. Night pain was

complained by 43 of the 45 patients, with intra-operatively confirmed rotator cuff tears. Subacromial impingement was positive in 60 (94%) of all patients, and in 42 (93%) of those with cuff tears. Crepitus was elicited in 49 (77%) of all patients, and in 33 (73%) of those with cuff tears. A weakness in abduction was present in 31 (48%) of all patients and in 23 (51%) of those with tears. Reduction in range of shoulder movement was observed in 26 patients, with abduction to 100^0 and internal rotation to 50^0.[17]

The reported positive clinical signs in this series are as shown in table VIII. The low frequency of some of these recorded signs, particularly the impingement test of Neer, could be explained by inconsistence in reporting. This being a retrospective study, what was reported depended solely on the interest of the attending surgeon(s).

7.5. Side Involved.

In this series rotator cuff tears occurred in the dominant shoulder in 72% of patients. This is similar to what have been reported in the literature,[76,101,104] and could be explained by the fact that micro-tears secondary to repetitive micro-trauma and tensile overload have been implicated in the pathogenesis of rotator cuff tears. [106]

7.6. Ultrasonographic Diagnosis of Rotator Cuff Tears.

Careful review of the literature tell us that, ultrasonography is not widely used as diagnostic tool by orthopaedic surgeons while dealing with rotator cuff pathology. The wide range of sensitivity (58-100%) and specificity (63-97%) reported in the literature,[14-17,107-111] probably offers an explanation to the slow acceptance of ultrasonography by orthopaedic surgeons, in the diagnosis of rotator cuff tears. However according to Teefey and coworkers, [107] investigators who reported poor

results used an ultrasonographic criteria that is no longer acceptable, employed a scanning technique that offered poor visualization of the cuff, and used older equipment and transducers with lower frequency than is currently available. In other words refinements in the scanning techniques, improvement in the resolution capability of the equipment, and clarification of the diagnosis criteria has a positive impact on the role of ultrasonography in the diagnosis of rotator cuff tears. This is reflected in the few studies cited below.

In a series involving 106 patients, Milddleton and associates,[16] reported a 91 per cent sensitivity and specificity for ultrasonographic diagnosis of rotator cuff tears. Ultrasonography was also found to be superior to arthrography in detecting abnormalities of the biceps tendon. Wallny and colleagues [17] utilized hypertrophic compensatory changes of the long head of the biceps tendon associated with chronic massive rotator cuff tears to develop a diagnostic index. The index was the ratio of the diameter of the biceps tendon to the diameter of the rotator cuff (i.e. supraspinatus + infraspinatus). This ratio was found to be 0.7 or less in normal shoulders and higher in those with rotator cuff tears, and a ratio of 0.8 or more was found to be diagnostic. The sensitivity and specificity of ultrasonography with this technique were reported to be 97.8 and 63.2 per cent respectively.

Teefey and co-workers [107] evaluated 100 shoulders in 98 patients with shoulder pain using high-resolution ultrasonography to whom arthroscopic examination was subsequently performed. The diagnoses according to arthroscopic findings were, full-thickness tears in 65 shoulders, partial thickness tears in 15, rotator cuff tendinitis in 12, frozen shoulder in 4, acromioclavicular joint arthrosis in 2 and superior labral tear

and calcific bursitis in one shoulder each. Two full thickness cuff tears had large partial thickness components. Ultrasonography correctly picked up all 65 full-thickness rotator cuff tears, incorrectly identified a full-thickness tear in three shoulders with partial thickness tears, correctly diagnosed seven of the fifteen partial thickness tears, and correctly demonstrated absence of a tear in 17 out of 20 arthroscopically normal shoulders.

Regarding the size and extent of the tear arthroscopically 26 tears involved the supraspinatus tendon alone and were less than 1.5 cm in diameter, 37 involved both the supraspinatus and infraspinatus tendons and were more than 1.5cm wide, and 7 shoulders had isolated subscapularis tears. Ultrasonography correctly estimated the extent of the tear in 81 per cent of the 26 shoulders with isolated supraspinatus tears, and in 89% of the 37 shoulders with combined supraspinatus and infraspinatus tears, and correctly diagnosed 6 out of 7 subscapularis tears. Overall, ultrasonography correctly estimated the size and extent of the tear in 86 per cent of the shoulders with full thickness rotator cuff tears.

Ultrasonography was also used in evaluating post-operative rotator cuff integrity and found to be of great value. Mack and associates [13] investigated the validity of ultrasonography in this regard. In a group of 25 symptomatic shoulders, which were subsequently re-operated, ultrasonography correctly diagnosed recurrent tears in all 25 shoulders and confirmed cuff integrity in 10 out of 11 shoulders. Harryman and coworkers [98] used ultrasonography to correlate the integrity of the cuff with functional status following 105 chronic cuff repairs in 89 patients at an average interval of five years post-operatively. The percentage of intact cuff repairs at follow up were as follows:- 100% of partial thickness repairs were intact, while 80% of full

thickness supraspinatus and 57% of combined supraspinatus and infraspinatus tears, and less than one-third of massive tears involving the three major cuff tendons (i.e. supraspinatus, infraspinatus and subscapularis) were intact at follow-up ultrasonography. The overall re-rupture rate was 35%. Suprisingly patients were generally satisfied with the results of surgery even when follow-up ultrasonography demonstrated recurrent lesions.

In this study as in Teefey and co-workers series,[107] ultrasonography was found to be highly accurate in picking up full-thickness rotator cuff tears. All 50 shoulders which were diagnosed to have rotator cuff tears by ultrasonography in this series, were later confirmed by magnetic resonance imaging (MRI) and at surgery to have rotator cuff lesions, giving a sensitivity of 100%.

In terms of the ability of predicting the location and extent of the tear, ultrasonography compares favorably with magnetic resonance imaging and intra-operative findings. The high incidence of 60% or more of isolated supraspinatus tears, demonstrated by ultrasonography in this series, was also revealed by magnetic resonance imaging and intra-operative findings. Also all 6 massive tears which involved all the three major rotator cuff tendons, and all 6 combined supraspinatus and infraspinatus lesions as revealed by intra-operative findings, were correctly demonstrated by ultrasonography. However in contrast to Teefey and co-workers series, isolated supraspinatus lesions were more common in this study instead of combined supraspinatus and infraspinatus lesions. One isolated supraspinatus lesion in this study was ultrasonographically mistaken for an isolated infraspinatus tear. This could be caused by the close proximity of the lesion to the infraspinatus tendon. Also one combined supraspinatus and subscapularis tear with more involvement of the latter tendon and a small

extension into the former was ultrasonographically mistaken for an isolated subscapularis tear.

The results from this series showed clearly that ultrasonography can accurately predict the location of a cuff tear in 75 to 100% of cases. These results are in agreement to what have been reported by Teefey and associates.[107]

The role of ultrasonography in dealing with partial- thickness rotator cuff tears can not be discussed from this study, because all cases in this study were full-thickness lesions. However while Brenneke and Morgan [108] reported a low ultrasonographic sensitivity for detecting partial thickness tears, more recent studies demonstrated a sensitivity of more than 90%. [109,110]

It is apparent from this study as in Teefey and coworkers series,[107] that ultrasonography is highly accurate in diagnosing full-thickness rotator cuff tears. Ultrasonography can as well precisely predict the location and extent of the tear in the majority of the cases, and the bigger the lesion the more accurate the prediction. Ultrasonography is probably less precise in predicting the location and extent of small rotator cuff tears.

8. CONCLUSION

The diagnosis of rotator cuff tears in developing countries such as Tanzania is difficult. This is because modern sophisticated diagnostic facilities such as magnetic resonance imaging and arthroscopy are not available. These are either too expensive to purchase and maintain or the expertise for their use (arthroscopy) is not available. Even if they were available they would probably be too expensive for the majority of patients to afford.

Clinical diagnosis of rotator cuff tears on the other hand is demanding and subjective especially when muscle strength testing is involved, less reliable, and highly observer dependant.

Shoulder ultrasonography as revealed in this study is an acceptable investigation for the diagnosis of rotator cuff pathology. Indeed it is highly accurate in diagnosing full-thickness rotator cuff tears, and proved to be appreciably accurate in predicting the location and the extent of the tear. Furthermore it is cheap and easy to operate. That is, it does not require highly skilled manpower to operate like magnetic resonance imaging. Indeed orthopaedic surgeons can successfully perform shoulder ultrasonography provided they are trained through short courses. In addition patient acceptance is 100 percent, because it is non-invasive and can be performed within a very short time by an experienced examiner.

In actual fact it is encouraging to note that ultrasonography is not new to Tanzania, as many hospitals have been using it for about a decade now. Currently in Tanzania ultrasonography is used mainly in obstetric and gynecologic diagnosis, in the assessment of intra-abdominal and visceral cancer spread. Furthermore it is also used in urology in the diagnosis of prostatic hyperplasia, urolithiasis, hydronephrosis,

hydro-ureters and urinary bladder tumors. In blunt abdominal trauma it is being used in the diagnosis of visceral injuries.

However, despite the extensive use of ultrasonography in Tanzania, its use in orthopaedics is still non-existent. The author recommends that deliberate efforts should be made to introduce ultrasonography in the diagnosis of rotator cuff tears in Tanzania. This is because of the following reasons:-

i. The results obtained in this study showed clearly that ultrasonography is capable of diagnosing rotator cuff tears with a high degree of accuracy.

ii. Ultrasonography is easy to perform, its equipment is portable and cheap to purchase and maintain.

iii. The fact that diagnostic ultrasonography is being used successfully in the diagnosis of other medical conditions in the country, it is the authors opinion that its introduction and use in orthopaedics will not result into any major problems.

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