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Recent advances and future directions in the management of knee osteoarthritis: Can biological joint reconstruction replace joint arthroplasty and when?

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Author contributions: Paschos NK developed the idea and wrote the manuscript.

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Abstract

In this article, a concise description of the recent advances in the field of osteoarthritis management is presented. The main focus is to highlight the most promising techniques that emerge in both biological joint

replacement and artificial joint arthroplasty. A critical view of high quality evidence regarding outcome and safety profile of these techniques is presented. The potential role of kinematically aligned total knee replacement, navigation, and robotic-assisted surgery is outlined. A critical description of both primary and stem cell-based therapies, the cell homing theory, the use of biologic factors and recent advancements in tissue engineering and regenerative medicine is provided. Based on the current evidence, some thoughts on a realistic approach towards answering these questions are attempted.

Key words: Osteoarthritis; Biological joint reconstruction; Total joint arthroplasty; Cartilage; Evidence-based

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Core tip: In the quest for answers for the future of joint reconstruction, this article explores how feasible is to claim today that biological joint reconstruction will soon replace artificial joint arthroplasty. Will stem cell-based therapies, biologic factors, tissue engineering and regenerative medicine be able to change orthopedic practice in the near future? What is the current evidence? On the other hand, are kinematically aligned total knee replacement, and robotic-assisted surgery able to further advance joint replacement? Based on the current evidence, some thoughts on a realistic approach for the future of joint reconstruction, biological or not, are discussed.

Paschos NK. Recent advances and future directions in the management of knee osteoarthritis: Can biological joint reconstruction replace joint arthroplasty and when? *World J Orthop* 2015; 6(9): 655-659 Available from: URL: <http://www.wjgnet.com/2218-5836/full/v6/i9/655.htm> DOI: <http://dx.doi.org/10.5312/wjo.v6.i9.655>

INTRODUCTION

Osteoarthritis represents one of the most common disorders in orthopedics. It is believed that it would be one of the main disorders affecting quality of life in the next decades due to the increasing aging of the population^[1]. Management of osteoarthritis has been improved significantly over the last years with further improvement of the current therapeutic modalities, mainly total joint replacement. In parallel, a new era of biologic joint reconstruction has been initiated with the use of biological tissue that aims to replace degenerative tissue.

In this editorial, a concise description of the recent advances in the treatment of osteoarthritis will be outlined in an attempt to highlight the emerging techniques in both biological joint replacement and artificial joint arthroplasty. The question of "how feasible is to claim today that biological joint reconstruction will soon replace artificial joint arthroplasty?" based on the current evidence will be approached. Finally, some thoughts on "how soon these changes can be constituted in clinical practice?" will be shared.

ADVANCEMENTS IN ARTIFICIAL JOINT REPLACEMENT

Kinematically aligned total knee replacement

Starting approximately 10 years ago, kinematically aligned knee replacement surprised most of us with the favorable subjective outcome scores reported^[2,3]. The goal in kinematically aligned total knee replacement is to align the femoral and tibial components so that the three axes that describe tibiofemoral and patellofemoral kinematics would be restored according to the normal joint lines. Kinematically aligned knee replacement remains very effective with comparable - if not better - results from those of mechanically aligned total joint arthroplasty^[3-5]. This led to a rather constructive criticism, and theories that could interpret these data that could be remarkably helpful in guiding further improvement of arthroplasty design and techniques^[6]. The main advantages of kinematically aligned total knee arthroplasty (TKA) is that allows proper positioning of TKA implants in order to restore the axis of both patellofemoral and tibiofemoral flexion/extension axes. As a consequence, it is independent of the femoral head and ankle position that outline the mechanical axis of the knee that is used as a reference in mechanically aligned TKA. A randomized control trial confirmed these advantages by demonstrating the superiority of the kinematically aligned TKA compared to mechanical aligned TKA in terms of almost all clinical outcomes, such as Oxford Knee and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score, as well as better flexion and reduced pain^[3]. Also a study with a mean follow up of 6 years demonstrated implant survivorship of 97.5% with an overall Oxford Knee score of 42.7^[2]. As always, time will be the judge of whether

the principles of kinematically aligned arthroplasty can be expanded and embraced in a way that they will improve outcomes and orthopedic practice.

Navigation

Navigation-assisted arthroplasty was an innovation that it is clear that improves better alignment and positioning of the arthroplasty implant^[7-9]. Specifically, in a prospective study, it was shown that computer-assisted TKA was associated with significantly less variability, resulting in a mechanical axis with more than 3 degrees difference only in 4% of the cases, which was significantly lower to the 22% of the conventional technique^[7]. Another randomized controlled trial suggested that navigation resulted in improvement in varus/valgus axis and rotation of the femoral component^[8]. However, almost ten years after the first promising reports, computer-assisted arthroplasty still struggles to prove its efficiency and establish its role in joint arthroplasty. This is due to the fact that there is not adequate support that the observed difference in alignment can be indeed translated into better subjective and outcome analysis scores^[10], especially when in other subspecialties, e.g., in spine, its beneficial role was earlier and widely accepted^[11,12]. However, more recent findings seem to demonstrate a tendency of improved outcome scores as a correlation of better implant positioning^[13,14].

Robotic technology in orthopedics

Robotic surgery is probably the application that can better depict the future involvement of technology in clinical orthopedic practice. Even though robotic-assisted surgery started its first steps more than 20 years ago, with orthopedics being one of the first specialties that used a robotic system, it was only at the last 5 years that its use has been remarkably extended. The experience reported so far with unicompartamental knee arthroplasty has shown that robotic systems can improve coronal alignment and show some improvement in clinical outcome compared to conventional unicompartamental knee arthroplasty^[15]. Several other reports suggest better alignment and accuracy with robotic-assisted surgeries^[16-18]. For TKA, early findings suggested the potential improvement in accuracy in component placement, but also highlighted the increased cost, prolonged operative time, and high complication rate during surgical learning curve^[19-22]. In a randomized control study where in patients undergoing bilateral TKA, one TKA was performed with robotic-assisted technique while the other was conventional, the statistically better alignment achieved with robotic-assisted technique was not associated with improvement in clinical outcomes^[23]. Thus, even though literature shows an improved accuracy with robotic-assisted technique, long term data are yet to be reported, and additional data from high level studies and registries are necessary^[24,25]. One of the major factors that limit their application in the near future is high cost, concerns regarding hardware and software failure, and the learning curve required^[15,24,26].

ADVANCEMENTS IN BIOLOGICAL JOINT RECONSTRUCTION

The concept of biological joint reconstruction envisions the replacement of the degenerative articular cartilage with biologic, non-artificial, material that can be fully incorporated and integrated with the remaining healthy tissue. Even though the idea is miraculous, unfortunately the regeneration of articular cartilage has proven not a simple task so far^[27]. Articular cartilage represents a tissue composed of thick collagenous extraarticular matrix maintained by chondrocytes, the only cellular component of articular cartilage. As such, articular cartilage lacks vessels and nerves, and it has a poor healing and regeneration potential. Therefore, any attempt to enhance this potential is condemned to fail, especially in an environment that led to degeneration in the first place.

During the evolution and further development of the biological approaches for joint reconstruction over the last years, there are some interesting advancements and that may be proven important milestones in further progressing the field.

Primary and stem cell-based therapies

Primary chondrocytes remain the golden standard as a cell source for treatment of cartilage lesions, 20 years after their description of autologous chondrocyte implantation (ACI) that has initiated the concept of biological joint repair^[28]. Despite the fact that ACI and subsequent modifications have been applied in clinical practice for several years, it was only recently that its superiority over microfracture was evident in meta-analyses^[29,30]. Interestingly, microfracture technique still shows favored outcome, that in certain cases seems comparable to chondrocyte implantation^[29].

Stem cells represent the other part of the dipole in the quest of appropriate cell source for biological cartilage reconstruction. Again, since the first animal report in 1994^[31], there are only few recent high-level studies validating the successful effect of mesenchymal stem cells in clinical practice^[32]. Two main stem cell populations have been widely used in animal and clinical studies with promising results, *i.e.*, bone-marrow derived mesenchymal stem cells and adipose derived stem cells^[32,33]. Another important step toward the extensive use of mesenchymal stem cells was the fact that they exhibit a relatively safe profile regarding toxicity, organ system adverse effects, infection, and malignancy in a recently published meta-analysis^[34]. The advantage of stem cells is the fact that they can potentially override primary cell donor morbidity and limited availability and they can be used in various culture technology systems^[35]. Unfortunately, only limited clinical data are available for stem cell use in cartilage reconstruction, therefore, these findings are promising but still preliminary^[36].

Cell homing

The recruitment of endogenous cells in an anatomic compartment due to various stimuli, and their contribution in tissue healing and regeneration is defined as cell homing mechanism. Even though the initial hypothesis has been stated for tissue growth and development, it seems that cell homing is a mechanism that takes place in multiple levels and various physiological processes^[37]. This concept was proven valid in musculoskeletal tissue regeneration as well. The entire articular surface of the proximal humerus was successfully regenerated *via* cell homing only, without any cell transplantation in the joint^[38].

Cell homing could be the mechanism behind the reported success of several applied techniques in musculoskeletal repair and regeneration. In one of the most widely used techniques in cartilage management, the microfracture technique, the concept of cell homing could explain in part the favorable results seen, despite its simplicity. The release of progenitor stem cells from the bone marrow into the joint, allow these cells to differentiate into the "cell in need" and to replace the defective area. However, it is important to accept the inherent limitations that "cell-homing" process has, such as the inadequacy to differentiate in all different cell types, and that cell homing is a delicate process that needs specific requirements in order to act. Further exploration of combining cell-homing with other regeneration strategies, such as biologic growth factors promises to open an entirely new field in biological cartilage joint reconstruction. It is also of paramount importance to acquire a better understanding of the exact pathways that are activated during cell homing and of the stimuli that are involved in this process.

Biologic growth factors

The extensive use of biologic factors that can enhance cartilage repair, or even prevent degeneration, is probably the most "hot topic" of the last decade. A simple web of science search combining the term "osteoarthritis" with the term "platelet rich plasma" returns 199 items within the last 5 years with more than 1780 citations according to web of science; Other terms like "autologous chondrocyte implantation" or "microfracture" return only 326 and 207 results with 2894 and 1782 citations, respectively. That means that the number of studies published about platelet rich plasma (PRP) reached the number of studies for microfracture and is approximately half of those dealing with ACI. More interestingly, the average number of citations per article is 8.94 for PRP, 8.88 for ACI, and 8.61 for microfracture. This demonstrates that PRP received more citations per article compared to either ACI or microfracture. This is indicative of the popularity that PRP has received over the last years. Studying these articles, one can easily realize that PRP is one of these modalities that has sworn enemies and sworn supporters. Despite their popularity, high quality evidence that justifies their use and supports its

effectiveness was only recently released. Unfortunately the existing evidence seems contradictory and does not clearly favor PRP use.

Tissue engineering, regenerative medicine applications and clinical biological approaches

The idea of creating tissues *in vitro* that they can be implanted to replace degenerative tissue is a fascinating approach. The field is advancing fast with significant improvement in the biomechanical properties of the engineered tissue. Two of the most appealing clinical applications that demonstrate promising data are the use of particulated juvenile articular cartilage and the use of NeoCart (TM), an autologous cartilage tissue implant^[39,40]. Both emerging techniques seem to have a favorable safety profile and they show improved clinical outcome^[39,40]. Longer term safety and effectiveness studies are required in order to verify their upcoming use in cartilage repair. The use of osteochondral allografts for large defect transplantation represents another technique that worth mentioning. In prospective studies, this technique has shown high efficacy and improved clinical outcome^[41,42]. The possibility of combining this technique with meniscus transplantation could provide an additional benefit to those patients^[43]. Lastly, several biological approaches that include osteotomy, osteochondral and/or meniscal implants can be successfully used to potentially delay osteoarthritis and provide good activity level in young patients^[44,45].

CONCLUSION

My understanding based on the above information is that the question "how feasible is to claim today that biological joint reconstruction will soon replace artificial joint arthroplasty?" could be probably misleading. The question should not be about biological reconstruction replacing arthroplasty but rather how effectively biological cartilage repair can delay total joint arthroplasty? Based on the current evidence, the answer is that biological joint reconstruction has shown promising data toward this direction. Data from registries seem to confirm a trend toward delay for primary knee joint replacement over the last decade. However, it is important to acknowledge that joint reconstruction is one of the most successful orthopedic techniques, with an average survival of more than 90% at 15 years for knee replacement and 86% survival at 22 years for hip replacement^[46,47].

In conclusion, biological joint reconstruction can serve as a transitional period prior to joint replacement in the near future. The combination of both techniques and their proper use according to their specific indications and known limitations seem to be the only viable solution for now, as well as for the future. The successful use of biological reconstruction will delay further the conventional primary joint replacement and may eliminate the need of revision surgery. As always, further research and more high level evidence

are essential in order to clarify further the advantages and disadvantages of the emerging techniques and to promote validation of their effectiveness and safety.

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Superior labral anterior posterior lesions of the shoulder: Current diagnostic and therapeutic standards

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Abstract

Surgical treatment of superior labral anterior posterior (SLAP) lesion becomes more and more frequent which is the consequence of evolving progress in both, imaging and surgical technique as well as implants.

The first classification of SLAP lesions was described in 1990, a subdivision in four types existed. The rising comprehension of pathology and pathophysiology in SLAP lesions contributed to increase the types in SLAP classification to ten. Concerning the causative mechanism of SLAP lesions, acute trauma has to be differed from chronic degeneration. Overhead athletes tend to develop a glenohumeral internal rotation deficit which forms the basis for two controversial discussed potential mechanisms of pathophysiology in SLAP lesions: Internal impingement and peel-back mechanism. Clinical examination often remains unspecific whereas soft tissue imaging such as direct or indirect magnetic resonance arthrography has technically improved and is regarded to be indispensable in detection of SLAP lesions. Concomitant pathologies as Bankart lesions, rotator cuff tears or perilabral cysts should be taken into consideration when planning a personalized therapeutic strategy. In addition, normal variants such as sublabral recess, sublabral hole, Buford complex and other less common variants have to be distinguished. The most frequent SLAP type II needs a sophisticated approach when surgical treatment comes into consideration. While SLAP repair is considered to be the standard operative option, overhead athletes benefit from a biceps tenodesis because improved patient-reported satisfaction and higher rate of return to pre-injury level of sports has been reported.

Key words: Superior labral anterior posterior lesion; Tenodesis; Superior labral anterior posterior repair; Shoulder arthroscopy; Biceps tendon

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Core tip: Superior labral anterior posterior (SLAP) lesions often lead to painful shoulder impairment and especially in overhead athletes to restriction in sport specific activity. In the context of diagnostic examination, magnetic resonance arthrography is of particular importance, not only in detection of SLAP

lesions and concomitant pathologic findings but also in differentiation from normal anatomic variants. Therapeutic options include besides conservative treatment arthroscopic SLAP repair and biceps tendon tenodesis. Decision-making in SLAP lesions remains challenging and requires a distinct evaluation of individual patient history, accurate examination and detailed analysis of imaging to meet the requirements of a personalized treatment.

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INTRODUCTION

Snyder *et al*^[1] described four types of superior labral lesions anterior to posterior (SLAP) lesions which occur as single entity or associated to additional disorders of the shoulder. Progress in detection of SLAP lesions and development of modern suture anchor systems led to an increasing number of arthroscopic SLAP-repairs.

The highest incidence of SLAP lesions is observed in the 20 to 29 and 40 to 49 years age group^[2]. Especially overhead athletes require a precise analysis of complaints and a differentiated evaluation of clinical and radiological findings to avoid postoperative persistent pain and an inability to return to previous level of activity.

PATHOPHYSIOLOGY

Anatomy

Vangness *et al*^[3] described four types of attachment of the long head of the biceps tendon to the superior glenoid rim and to the superior labrum.

Numerous anatomic variants complicate clear discrimination between normal and pathologic findings.

A sublabral recess or sublabral sulcus is defined as a sulcus between superior glenoid cartilage and capsulolabral complex with smooth edges and is usually located at 10 to 3 o'clock position. Fealy *et al*^[4] reported about the existence of sublabral recess in fetuses after 22nd week of pregnancy already. SLAP lesions may emerge from a sublabral recess by excessive stress.

In contrast, the sublabral hole or sublabral foramen is typically located at 12 to 2 o'clock position^[5] and is a result of congenital fusion failure of the labrum which attaches to the glenoid with a smooth margin or a medial slip^[6].

The Buford complex is described as a congenitally absent of the antero-superior labrum along with a thickened cord-like middle gleno-humeral ligament^[5].

Acute/traumatic SLAP lesions

Traumatic SLAP lesions are commonly caused by a fall

onto the outstretched arm or an unexpected pull on the arm, e.g., when losing grip of heavy objects or sudden traction (e.g., high bar exercises, hold off body weight in dropping rock climbers)^[7-10]. Funk *et al*^[11] reported a rate of 83% among professional rugby players with SLAP lesions following direct contact of the adducted shoulder with an opposing player or to the surface.

Chronic/degenerative SLAP lesions

Degenerative SLAP lesions can naturally develop with advanced age as a sign of wear in maturity or by increased physical stress affecting particularly overhead workers or overhead athletes. Especially overhead athletes got into center of attention and investigations revealed basic informations about cause and effect of SLAP lesions, which will be described more detailed in the following.

Glenohumeral rotation deficit

Alteration in rotational magnitude has been identified as a potential risk factor in developing shoulder injuries by changing normal glenohumeral kinematics^[12].

Overhead athletes frequently present asymmetrically decreased glenohumeral internal rotation on the dominant side which is considered to be part of positive adaptation to improved force development in conjunction with increased external rotation. The total rotational range of motion usually remains symmetric. Bony changes, capsuloligamentous factors and muscular components have been related to affect glenohumeral range of motion^[13].

When exceeding beyond certain dimensions, alterations in glenohumeral internal rotation and total rotational range of motion can obtain clinical relevance. Side-to-side asymmetries greater than 5° in total rotational range of motion are denoted total rotational range of motion deficit. Glenohumeral internal rotation deficit (GIRD) is defined as a side-to-side asymmetry in glenohumeral internal rotation greater than 18°^[14]. Both findings are implicated in increased risk of shoulder injuries by modifying normal glenohumeral kinematics^[15].

Kinetic chain

Overhead action consists of a complex series of sequential coordinated motions to achieve appropriate body position and motion, and to develop required muscle activity. According to Kibler *et al*^[14], the kinetic chain meets the following requirements: linking multiple body segments into one functional segment^[16], providing a stable base for distal arm mobility, maximizing force development of the core and transferring it to the hand, interaction of distal joints to increase force and energy capability and decrease distal joint load^[17], and reduction of deceleration forces by producing torques^[18].

Deficits in kinetic chain components have been shown to be associated with shoulder injuries in baseball players and tennis players^[19]. To maintain the same energy at ball impact in case of a 20% reduced provision of trunk kinetic energy, 33% more velocity or 70% more

mass in distal segments was necessary in mathematical calculations^[20].

Kinetic chain alterations become clinically significant by identifying components of non-shoulder deficits in shoulder injury pathogenesis, even though occurrence and mechanisms in the course of injury sequence remain unclear^[14].

Scapula dyskinesia

The scapula occupies a central position in basic movement patterns of the shoulder and there is strong evidence of scapular kinematic alteration contributing to a variety of shoulder pathologies^[21]. Scapula performance is essential to maintain functional interaction with the humerus for efficient motion, joint stabilisation, muscular capability and control^[22].

By definition, scapular dyskinesia characterizes the alteration of normal kinematics and reflects the loss of normal control of scapular motion^[23].

Subsequent internal rotation and anterior tilt can lead to increased tensile strain on the anterior ligaments, enhance the peel-back mechanism of the labro-bicipital complex and give rise to a pathologic internal impingement^[24].

The acronym scapular malposition/inferior medial border prominence/coracoid pain/dyskinesia of scapular movement (SICK) was used by Burkhart *et al.*^[25] to characterize a pattern of scapular abnormality in the disabled overhead athlete shoulder. The excessive scapular protraction leads to glenohumeral hyperangulation in external rotation increasing strain to the undersurface of the posterior rotator cuff area and the anterior-inferior capsular structures, which can intensify the peel-back mechanism^[25].

Internal impingement

Some clinical and cadaveric studies^[26,27] demonstrated that contact occurs between the undersurface of the posterosuperior rotator cuff and the posterosuperior part of the glenoid in abduction and external rotation both in symptomatic and asymptomatic shoulders. In overhead athletes internal posterosuperior impingement sometimes gets pathologic and has been associated with partial-thickness articular surface tears of the deep side of the rotator cuff and lesions of the labro-bicipital complex resulting from repetitive microtrauma due to recurrent overhead motion under extreme loading conditions^[28]. This leads to anterior microinstability caused by gradual stretching of anterior capsulolabral structures and consecutive aggravation of internal impingement^[27].

Peel-back mechanism

Burkhart *et al.*^[24] disagreed with the hypothesis of internal impingement provoking shoulder pathologies in the overhead athlete and presented a pathologic cascade leading to SLAP lesions with peel-back mechanism as an important factor.

The posteroinferior capsular contraction is assumed

to be the point of origin over the course of the above-mentioned cascade because glenohumeral rotation center migrates to a posterosuperior position with consecutive relaxation of the anteroinferior capsule. Now hyperexternal rotation is possible by reason of minimized cam effect of the proximal humerus and greater tuberosity clearance off the glenoid rim resulting in a magnified arc of external rotation before internal impingement appears.

The peel-back phenomenon^[29] has its origin in a biceps vector change in the position of abduction and external rotation resulting in torsional forces to the labro-bicipital complex. Once fatigue failure of the posterior superior labrum is nascent, it will start to progressively rotate medially over the upper rim of the glenoid. In cocking position, peel-back forces are at a maximum and additional shearing forces arise during throwing cycle from core energy which is transmitted to the shoulder^[24].

CLASSIFICATION

SLAP lesions were first described by Andrews *et al.*^[30]. In 1990 Snyder *et al.*^[1] published a classification including four types of lesion which has been extended with three additional types by Maffet *et al.*^[31]. At present ten types of SLAP lesions have been defined, although it is controversial whether extensive labral tears such as type VIII or type IX should be classified as SLAP lesion.

The primal classification by Snyder is universally accepted and used. Figure 1 shows SLAP types I to IV.

Type I : Predominantly degenerative fraying of the superior labrum without involving the origin of the long head of the biceps tendon.

Type II : Most frequent type of lesion. Both superior labrum and biceps tendon are detached from the superior glenoid rim leading to instability of the labro-bicipital complex (LBC). Morgan *et al.*^[32] sub-divided SLAP- II lesions into three subcategories: anterior extension of labral tear (type II A), posterior extension of labral tear (type II B), anterior and posterior extension of labral tear (type II C).

Type III : Bucket-handle tear with potential displacement of the mobile labral fragment into the glenohumeral joint. The attachment of the long head of the biceps tendon remains intact.

Type IV : Bucket-handle tear with extension to the biceps tendon in a variable degree of affecting the tendon's cross-section dimension.

Type V : Anterior-inferior Bankart lesion in continuity with a type II SLAP lesion.

Type VI : Combination of a type II SLAP lesion and an unstable labral flap either anterior or posterior.

Type VII : Type II SLAP lesion with extension to the capsule and the middle glenohumeral ligament (MGHL).

Type VIII : Type II B SLAP lesion with posterior labral extension.

Type IX : Complete or almost complete circumferential detachment of the labrum from the glenoid.

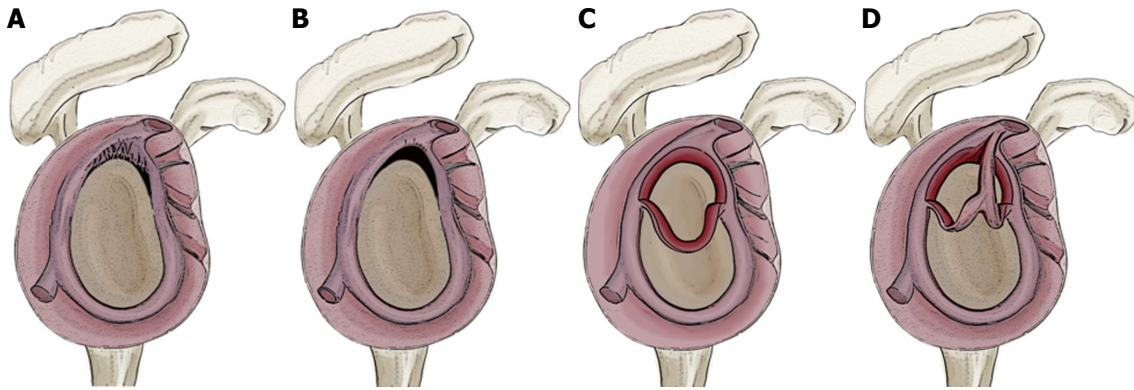


Figure 1 Superior labral anterior posterior classification. A: SLAP I lesion: Degenerative fraying of the superior labrum; B: SLAP II lesion: Detached labro-bicipital complex; C: SLAP III lesion: Bucket-handle tear; D: SLAP III lesion: Bucket-handle tear with extension to the biceps tendon. SLAP: Superior labrum anterior posterior.

Table 1 Superior labral anterior posterior classification, adapted from ref. [77]

SLAP type	Location (o'clock)	Description	Comments
Snyder <i>et al</i> ^[31]			
I	11-1	Fraying with intact biceps tendon	More significant in young people with repetitive overhead motion or patients with degenerative change
II	11-1	Tear of BLC and biceps tendon stripping	Most common SLAP type, associated with repetitive overhead motion
III	11-1	Bucket-handle tear of superior labrum with biceps tendon intact	Associated with fall on outstretched hand
IV	11-1	Bucket-handle tear of superior labrum extension to biceps tendon	Associated with fall on outstretched hand
Morgan <i>et al</i> ^[32]			
II A	11-3	Tear of BLC with more anterior extension	
II B	9-11	Tear of BLC with more posterior extension	Associated infraspinatus tendon tear may be present
II C	9-3	Tear of BLC with anterior and posterior extension	Associated infraspinatus tendon tear may be present
Maffet <i>et al</i> ^[31]			
V	11-5	Bankart lesion in continuity with type II SLAP tear	Can result from anterior shoulder dislocation
VI	11-1	Anterior or posterior flap tear of the superior labrum with biceps tendon stripping	Probably represents a bucket-handle tear (SLAP III/IV) with tear of the handle
VII	11-3	Tear extends into MGHL	Can result from acute trauma with anterior dislocation
Powell <i>et al</i> ^[78]			
VIII	7-1	Superior labral tear with posteroinferior labral tear	Associated with posterior shoulder dislocation
IX	7-5	Superior labral tear with extensive anterior and posterior extension	Global labral abnormality, probably secondary to trauma
X	11-1	Superior labral tear with extension to the rotator interval	Involving the rotator interval structures including SGHL, long head biceps tendon and CHL

BLC: Bicipito-labral complex; MGHL: Middle glenohumeral ligament; SGHL: Superior glenohumeral ligament; CHL: Coraco-humeral ligament; SLAP: Superior labral anterior posterior.

Type X: Superior labral tear in combination with extension to the rotator cuff interval or the superior glenohumeral ligament or the coracohumeral ligament.

Table 1 gives a summary of SLAP types I to X.

DIAGNOSIS

Medical history and examination

A typical symptom especially in overhead athletes is a sudden or gradual deterioration of shoulder function and concomitant pain. In the majority of cases, the predominant arm is concerned. The term “dead arm syndrome” specifies the inability to execute sports specific movements at pre-injury velocity^[33]. Other disorders are sensation of intermittent clicking or

popping during cocking phase and anterior shoulder pain. Non-specific history and medical conditions due to concomitant shoulder injuries like rotator cuff tears, capsular-labral lesions, biceps tendinopathy or internal impingement complicate any evaluation of a possible SLAP lesion^[34].

A huge number of clinical tests have been described in detection of SLAP lesions but currently no gold standard could be established with regard to sensitivity or specificity. Initial reports of specific SLAP tests appeared quite promising but mostly did not stand up to further surveys^[35,36].

In order to determine utility of clinical tests in physical examination of the shoulder, Hegedus^[37] presented a systematic review with meta-analysis. Among

Table 2 Traditional superior labral anterior posterior tests, adapted from ref. [37]

SLAP test	Sensitivity (95%CI)	Specificity (95%CI)	PPV (95%CI)	NPV (95%CI)	OR (95%CI)
O'Brien	0.67 (0.51, 0.80)	0.37 (0.22, 0.54)	1.06 (0.90, 1.25)	0.89 (0.67, 1.20)	1.19 (0.76, 1.86)
Speed	0.20 (0.05, 0.53)	0.78 (0.58, 0.90)	0.90 (0.43, 1.90)	1.03 (0.86, 1.23)	0.87 (0.35, 2.55)
Anterior slide	0.17 (0.03, 0.55)	0.86 (0.81, 0.89)	1.20 (0.22, 6.51)	0.97 (0.96, 1.36)	1.24 (0.16, 9.47)
Crank	0.34 (0.19, 0.53)	0.75 (0.65, 0.83)	1.36 (0.84, 2.21)	0.88 (0.69, 1.12)	1.54 (0.75, 3.18)
Yergason	12.4 (6.60, 20.6)	95.3 (90.6, 98.1)	2.49 (0.97, 6.40)	0.91 (0.84, 0.99)	2.67 (0.99, 7.73)
Relocation	51.6 (41.2, 61.8)	52.4 (44.0, 60.6)	1.13 (0.88, 1.45)	0.93 (0.72, 1.20)	1.23 (0.72, 2.11)
Biceps palpation	38.6 (26.0, 52.4)	66.7 (52.9, 78.6)	1.06 (0.66, 1.68)	0.95 (0.74, 1.22)	1.13 (0.51, 2.50)
Compression rotation	24.5 (13.8, 38.3)	78.0 (72.9, 82.5)	2.81 (0.20, 39.70)	0.87 (0.66, 1.16)	3.39 (0.15, 74.78)

PPV: Positive predictive value; NPV: Negative predictive value; OR: Odds ratio; SLAP: Superior labral anterior posterior.

the traditional SLAP tests, relocation test showed best sensitivity; best specificity was found in Yergason's test. The compression-rotation test presented the best positive predictive value (Table 2).

More recent tests seem to be encouraging but warrant further investigation. The passive compression test^[38] showed a sensitivity of 81.8% and a specificity of 85.7%. The positive predictive value was 87.1%, and the negative predictive value was 80.0%.

The modified dynamic labral shear demonstrated sensitivity of 72%, specificity of 98%, accuracy of 0.84, and a positive likelihood ratio of 31.57^[39]. Combinations of clinical tests provide higher accuracy, in case of labral lesions, the best combination was identified to be the modified dynamic labral shear test and O'Brien's maneuver.

As clinical tests are a key element in diagnosing SLAP lesions, there is still a great need for further studies to improve the diagnostic conclusion and allow the shoulder surgeon to be more efficient in making a firm diagnosis.

Imaging

The central element to confirm the diagnosis of a SLAP lesion is the implementation of magnetic resonance imaging (MRI) and magnetic resonance arthrography (MRA) or computed tomography arthrography (CTA).

Conventional arthrography and CTA are rarely used in detection of SLAP lesions. Specificity of CTA is in the order of 50% to 80%^[40]. Investigations comparing conventional MRI to MRA demonstrated a significant improvement in sensitivity and accuracy with little or no reduction in specificity in favor to MRA^[41-43]. MRA sensitivity is ranged from 82% to 100%, specificity from 71% to 98% and accuracy from 83% to 94%^[41,42,44]. MRA can be realized as direct or indirect MRA. Direct or intraarticular MRA needs increased logistic effort, a contrast medium is applied directly to the glenohumeral joint space by puncture. Advantages are an improved outlining of intraarticular and synovial surfaces^[45] by mild distension of the capsule. Potential disadvantages include sensation of pain, bleeding, extravasate into surrounding tissue and risk of infection due to the invasive nature of the procedure.

Indirect or intravenous MRA is non-invasive. Intra-

venous contrast medium is able to diffuse into the shoulder joint due to the lack of basement membrane^[46]. Attention is demanded because of general enhancement of all vascularized structures which may lead to overestimation of pathologies^[47]. Figures 2 and 3 give examples of SLAP lesions in MRI.

MRA has not been proven to reliably distinguish between ten types of SLAP lesions. Practically speaking, a detailed description of location, morphology, extend of abnormality and associated injuries is more valuable to the shoulder surgeon than a simple SLAP classification^[40].

MANAGEMENT

A distinct evaluation of individual patient history, accurate examination and detailed analysis of imaging should be the basis for decision-making in therapy of SLAP lesions. Global algorithms of treatment by means of SLAP classification do not exist and do not meet requirements of a personalized treatment.

Non operative treatment

In selected cases non-operative treatment can be successful. SLAP I lesions predispose to a conservative treatment in absence of other intra-articular pathologies. Non-operative treatment for SLAP tears in overhead athletes has been suggested by Edwards *et al.*^[48] who showed a 66% of throwers being able to return to play at the same or better level than before. When presenting a GIRD, further progression of external rotation gain and posterior-superior shift of the humeral head can be stopped by conservative treatment with the objective to eliminate posterior-inferior capsular tightness due to shortened inferior glenohumeral ligament. Various exercises are utilized like the "sleeper stretch" in which the patient lies on his side, flexing both the elbow and shoulder to 90° while the shoulder is passively internally rotated^[24], shoulder cross-body adduction with forward elevation^[49], capsular mobilization^[50] or towel/racquet stretches^[51]. Additionally performed exercises include strengthening programs for rotator cuff and, especially in the setting of SICK scapula, scapular stabilizers. Closed chain exercises are initially executed in order to address protraction, retraction, elevation/depression

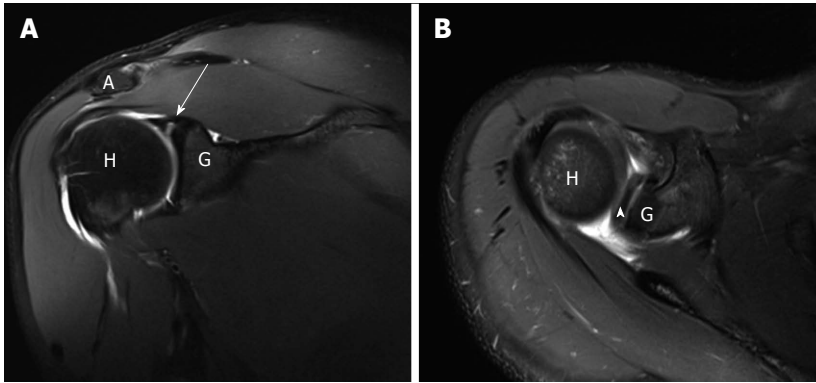


Figure 2 Superior labral anterior posterior II lesion: Findings in direct magnetic resonance arthrography. A: The coronal oblique fat saturated image (cor pd tse fs) shows the detached labro-bicipital complex from the upper rim of the glenoid. The tear is marked by the arrow; B: The transverse fat saturated magnetic resonance arthrography-image (tra pd tse fs) reveals the slight runnel of contrast agent between superior labrum (arrowhead) and glenoid. A: Acromion; H: Humeral head; G: Glenoid.

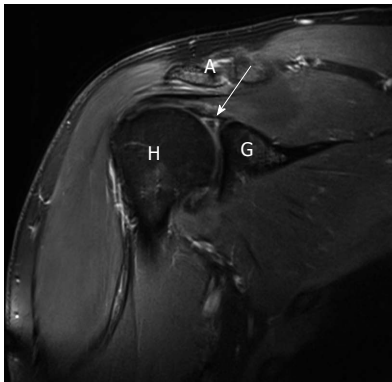


Figure 3 Superior labral anterior posterior III lesion: Findings in direct magnetic resonance arthrography. The coronal T1-weighted (cor t1 tse fs) fat-saturated image shows the separated triangle (arrow) of the bucket-handle without instability of the labro-bicipital complex. A: Acromion; H: Humeral head; G: Glenoid.

and retraction, internal rotation and elevation, and external rotation and depression^[25] followed by open chain exercises in the course. Exercises have to be individualized based on the mechanism of injury, functional demand and activity level^[33].

In case of apparent SLAP lesions, overhead athletes often require operative treatment to return to a high level of function, whereas in patients without sportive demands conservative treatment may be sufficient and definitive.

Operative treatment

Operative treatment becomes more and more frequent since arthroscopic techniques and implants have advanced. Individual variety has been shown in operative technique, patient positioning and arthroscopic access.

Several operative concepts coexist in SLAP lesions: Simple arthroscopic debridement, arthroscopic SLAP repair/refixation, arthroscopic tenotomy of the long head of the biceps tendon, arthroscopic tenodesis or open/mini-open tenodesis of the long head of the biceps tendon.

Patient positioning can either be in beach chair position or lateral decubitus position. Two or three portal techniques exist (standard posterior viewing portal, anterior portal superior to the upper border of the subscapularis tendon and optional anterosuperior rotator interval portal approximately 1 cm off the anterolateral tip of the acromion)^[52].

Isolated arthroscopic labral debridement in unstable SLAP tears demonstrated short-term improvement inside first studies in the 90s, but outcome declined over time^[53-55].

Actually, arthroscopic debridement is recommended in type I SLAP lesions. An example of a type I lesion and concomitant sublabral recess ist shown in Figure 4.

Controversial debates about surgical treatment in case of type II SLAP lesions are still in progress. Surgical reattachment of the LBC at its origin with the use of transosseous sutures, staples, metal screws, bioabsorbable tacks and bioabsorbable anchors are performed. The use of bioabsorbable tacks has been abandoned due to complications with this fixation type. Persistent postoperative pain and disability^[56] as well as dislocation and broken tacks with chondral damage have been reported. Further complications following the use of polyglycolide lactic acid tacks include foreign body synovitis and full-thickness humeral head chondral injury^[57]. Sileo *et al*^[58] demonstrated decreased bio-mechanical strength of knotless suture anchors vs standard suture anchors even though pullout strength was noted to be higher in certain knotless anchor systems^[59]. Dines *et al*^[60] suspect the bulky suture knot of standard anchors to be the source of postoperative pain in throwers due to the limited glenohumeral joint space. Positioning of the anchors is supposed to be ideal at the most superior portion of the glenoid rim because glenoid bone stock is most solid there^[61]. The anchor should be placed at a 45° angle to the osseous surface at the articular margin. Some authors warn against anchor placement anterior to the biceps tendon to avoid undesired tightening of the MGHL or closure of a sublabral foramen, which may lead to a restricted external rotation^[62].

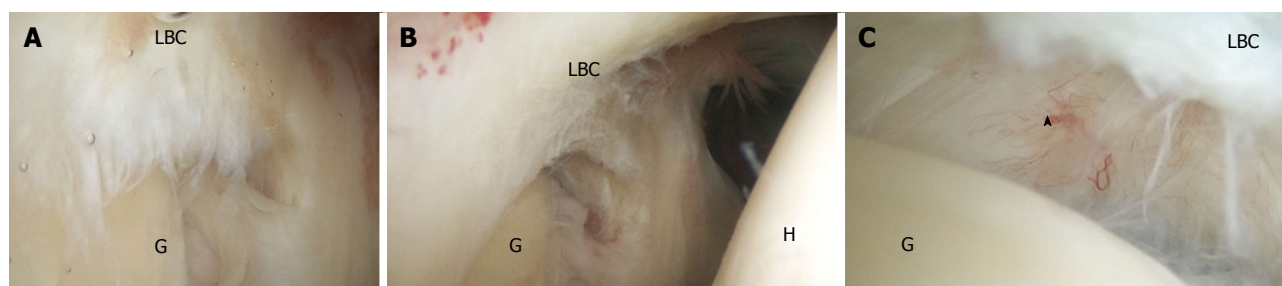


Figure 4 Superior labral anterior posterior I lesion: Intraoperative findings in shoulder arthroscopy (posterior-anterior view from the posterior portal of a right shoulder). A: A degenerative fraying of the superior labrum could be detected by diagnostic arthroscopy; B: After debridement of the superior labrum, a sublabral recess appears. The presence of a type II SLAP lesion should be excluded; C: A more detailed demonstration of the sublabral recess (arrowhead) with smooth lining without instability of the labro-bicipital complex. LBC: Labro-bicipital complex; H: Humeral head; G: Glenoid; SLAP: Superior labrum anterior posterior.

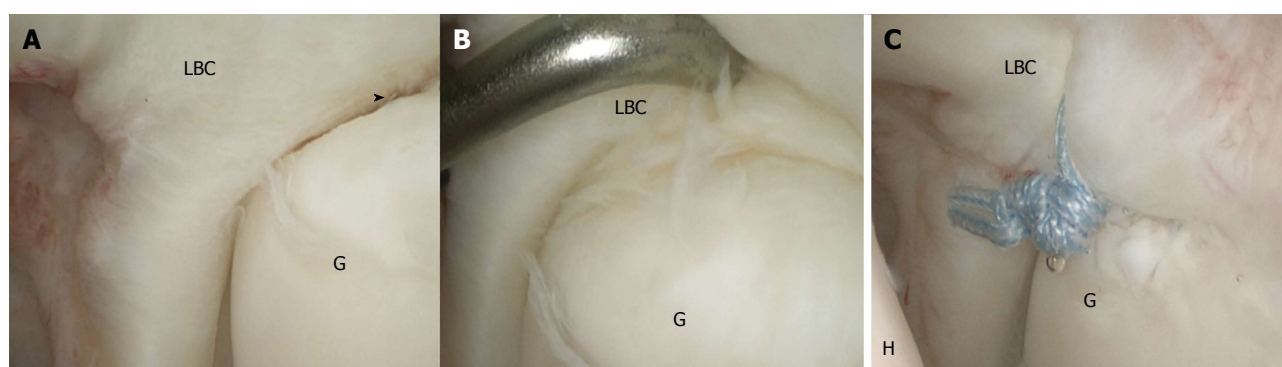


Figure 5 Superior labral anterior posterior II lesion: Intraoperative findings in shoulder arthroscopy (posterior-anterior view from the posterior portal of a left shoulder). A: Intraoperative aspect of a non-displaced SLAP II lesion (arrowhead); B: Verification by inserting a probe; C: SLAP repair by a single stitch posterior to the biceps tendon. LBC: Labro-bicipital complex; H: Humeral head; G: Glenoid; SLAP: Superior labrum anterior posterior.

Numerous biomechanical investigations exist about suture anchor location and configuration. The results are inconsistent; some consider simple sutures to be superior to mattress type configuration^[63], while others demonstrated an advantage of mattress sutures compared to simple sutures with one- and two-point fixation^[64]. Morgan *et al*^[65] found parity between one anterior and one posterior simple suture and two posterior simple sutures in resisting “peel-back” forces. No significant differences in functional scores between vertical knot technique and horizontal mattress technique could be found by Yang *et al*^[66] even though last mentioned technique seemed to be favorable with regard to pain and internal rotation at abduction. Castagna *et al*^[67] described a combined technique with one mattress stitch posterior and medial to the biceps tendon and one simple stitch anterior, which was characterized as an anatomic repair technique. Finally, most surgeons prefer simple translabral sutures with a variety of arthroscopic knots^[52]. Figure 5 demonstrates an arthroscopic SLAP repair.

Due to discouraging results in overhead athletes after arthroscopic SLAP repair, with inconsistent return to their previous level of sports participation and inconsistent subjective patient satisfaction, biceps tenodesis became more and more important^[68]. Arthroscopic tenotomy can be performed in patients without esthetic demand and high work load or sporting activities.

Tenotomy can be done without need of extraneous material for fixation but down-slippage of the long head of the biceps tendon has to be kept in mind.

During arthroscopic tenodesis, the tendon is fixed at the top of the bicipital groove with bioabsorbable interference screws or bioresorbable anchors. Alternatively a mini-open tenodesis after arthroscopic tenotomy of the long head of the biceps tendon has been described recently. The extraarticular tenodesis is located either subpectoral to preserve length and shape of the tendon and to avoid groove tenderness^[69] or above the upper rim of the major pectoral tendon^[9] which is assumed to be more favourable in justification of the biceps tendon’s tension. The intraarticular remaining superior labrum should be reattached to prevent articular entrapment. Figures 6 and 7 demonstrate the principle technique of mini-open tenodesis.

Type III SLAP lesions require the resection of the unstable bucket-handle fragment, usually no further stabilisation of the biceps anchor is necessary. If the lesion is causative from an acute trauma and located within the “red-red zone”, refixation of the torn flap analogous to meniscal tears has been recommended by some authors^[8].

Type IV lesion repair depends on biceps tendon stability after resection of the torn flap. At least half of the tendon’s calibre should be intact to preserve stability of the LBC. In case of instable biceps tendon,

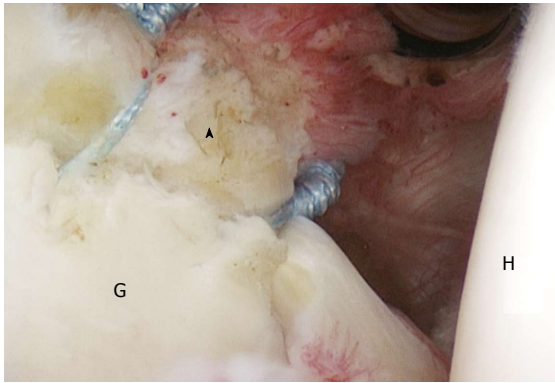


Figure 6 Superior labral anterior posterior II lesion: Intraoperative findings in shoulder arthroscopy (posterior-anterior view from the posterior portal of a right shoulder). First step in mini-open tenodesis is an arthroscopic tenotomy of the biceps tendon (arrowhead) and reattachment of the superior labrum. H: Humeral head; G: Glenoid.

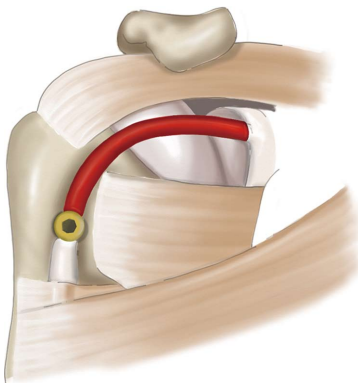


Figure 7 Mini-open biceps tenodesis: The red tagged part of the biceps tendon is resected. An extra-anatomical fixation is performed above the upper border of the tendon of the great pectoral muscle.

degenerative appearance and substantial loss of more than 50% of calibre, a tenotomy or tenodesis is performed.

Types V to X include more extended SLAP lesions and require additional treatment of concomitant pathologies.

OUTCOME

SLAP lesion and SLAP repair

Morgan *et al.*^[32] presented excellent short-term results after SLAP repair with 87% excellent results overall and 84% return to sports at previous level at 1 year follow-up. In 2010, Friel *et al.*^[70] could not observe differences in outcome between overhead athletes, non-overhead athletes, recreational overhead athletes and collegiate overhead athletes after SLAP repair. The conclusion drawn by the authors was that SLAP repair is successful regardless of occupation or athletics. Funk *et al.*^[11] analyzed the outcome in professional rugby players with isolated SLAP lesions in a retrospective cohort study. By 6 mo post-operative 89% were satisfied and 95% were able to return to pre-injury level of play. A retrospective

study published by Enad *et al.*^[71] described efficiency of SLAP repair in military (competitive recreational sports level). Seventy-six point nine percent reached an activity level equal or higher than pre-operative and 96.2% were able to stay in full active duty at final follow-up 30.5 mo after surgery.

Several investigations focused upon SLAP repair in overhead athletes. Among athletes Sayde *et al.*^[72] had 83% good to excellent results after SLAP repair and 73% return to previous level of play, but only 63% of overhead athletes could regain the pre-injury level of play. They took the higher incidence of concomitant shoulder pathologies (e.g., shoulder instability, rotator cuff injury) in overhead athletes as a reason for worse outcome. O'Brien *et al.*^[73] used a trans-rotator cuff approach for SLAP repair with only 16 of 31 patients succeeding to return to their previous level of sports, 11 returned to limited activity and two remained inactive at an average follow-up of 3.7 years. In 41 patients treated by arthroscopic type II SLAP lesion repair, only 71% were satisfied, 41% had continued night pain and merely 14 of 29 athletes were able to return to their previous level of sports^[74]. Kim *et al.*^[75] could prove, that in 34 patients (30 involved in athletic activities, 18 overhead athletes) after arthroscopic SLAP repair, overhead athletes had significantly lower shoulder scores and lower percentage of return to preoperative shoulder function than non-overhead athletes.

Overall, reported results after SLAP repair are non-homogeneous and uniform recommendations can not be imposed as a general rule for specific surgical treatment, resulting in variable rates of return to preinjury level. This might be based on multiple confounding variables not consistently accounted for including differences between studies in population demographics, surgical details related to surgical technique, surgeon experience, hardware used, and post-surgical rehabilitation parameters.

SLAP lesion and tenodesis

A prospective cohort study has been published by Boileau *et al.*^[68] dividing overhead athletes with SLAP lesion in arthroscopic SLAP repair group (10 patients) and arthroscopic biceps tendon tenodesis group (15 patients). After arthroscopic SLAP repair, only 40% were satisfied and only 20% could return to their pre-injury level of sports. As for athletes treated by arthroscopic biceps tenodesis, 93% were satisfied and 87% were able to return to their previous level of sport. As a source of failure in SLAP repair, the authors stated that the rigid reattachment of the labro-bicipital complex to the upper rim of the glenoid disables the physiological medial rolling of the biceps tendon anchor during abduction and external rotation. Due to traction to the LBC which is innervated by a dense network of sensory sympathetic fibres^[76], persistent shoulder pain is a result. Study validity is lessened by a relatively small sample size and the nonrandomized design.

Schöffl *et al.*^[9] registered excellent results in high-

Table 3 Outcomes after repair of superior labral anterior posterior tears, adapted from ref. [77]

Ref.	Study design	No. of patients	Repair techniques	Outcome summary
Morgan <i>et al</i> ^[32]	Retrospective	102	Type II repair, suture anchor	83% excellent overall; 87% excellent results in 53 overhead athletes
Friel <i>et al</i> ^[70]	Prospective cohort	48	Suture anchor fixation	54% returns to previous level of sport
Sayde <i>et al</i> ^[72]	Systematic review	506	Suture anchor, bioabsorbable tacks, staples	63% return to previous level of play
Snyder <i>et al</i> ^[53]	Retrospective	140	Type I : debridement, 56% type II : debridement, 44% suture fixation	N/A
Cohen <i>et al</i> ^[74]	Retrospective	39	Biodegradable tacks	27/39 G-E results; 14/29 return to play at preinjury level at 3.7 yr follow-up
Funk <i>et al</i> ^[11]	Retrospective	18	Suture anchor fixation	89% satisfaction rate; 95% return to play at preinjury level
Enad <i>et al</i> ^[71]	Retrospective	27	Suture anchor fixation	24/27 G-E results
Coleman <i>et al</i> ^[79]	Retrospective	± 50 acromioplasties	Biodegradable tacks	65% G-E results at 3.4 yr follow-up
Brockmeier <i>et al</i> ^[80]	Prospective cohort	47	Suture anchor fixation	41/47 G-E results at 2.7 yr follow-up
O'Brien <i>et al</i> ^[73]	Retrospective	31	Biodegradable tacks	22/31 G-E results at 3.9 yr follow-up
Kim <i>et al</i> ^[75]	Retrospective	34	Suture anchor fixation	31/34 return to play at preinjury level
Boileau <i>et al</i> ^[68]	Prospective cohort	25 (2 groups)	Suture anchor fixation (SLAP repair) <i>vs</i> interference screw (biceps tenodesis)	4/10 satisfied in SLAP repair group; 13/15 satisfied in tenodesis group
Schöffl <i>et al</i> ^[9]	Prospective cohort	6 (rock climbers only)	Mini-open biceps tenodesis	96.8% satisfaction, 100% return to preinjury level of climbing
Voos <i>et al</i> ^[81]	Retrospective	34 SLAP + RCR; 28 RCR alone	Suture anchor fixation for RCR ± SLAP	90% G-E results, 77% return to play at preinjury level
Youm <i>et al</i> ^[82]	Retrospective	10 SLAP + spinoglenoid cyst	SLAP repair, no cyst treatment	8/10 resolution of cyst and labral healing in MRI

G-E: Good to excellent; RCR: Rotator cuff repair; SLAP: Superior labral anterior posterior; N/A: Not available; MRI: Magnetic resonance imaging.

level rock climbers following mini-open tenodesis in a prospective cohort study. At a follow-up of 6 mo self-perception of shoulder function and climbing ability was at 96.8%.

Table 3 gives an overview of outcomes after repair of SLAP lesions.

CONCLUSION

Diagnosis and therapy of SLAP lesions remain a challenge despite improvement in imaging and surgical techniques and implants. In face of a various number of clinical SLAP tests, no one could bear up under the aspect of acceptable sensitivity or specificity. Interpretation of MRI requires a high degree of specialized knowledge about both pathologic findings and normal variants like sublabral recess or sublabral hole. Decision-making in SLAP lesions, may it be conservative or surgical, has to be based on multiple factors: Patient's history (acute trauma or chronic degeneration), age, level of physical activity, patient's expectations and functional demands. SLAP repair represents the standard treatment for the most common SLAP type II with excellent results especially in case of traumatic SLAP lesions. In overhead athletes poor results after SLAP repair have been reported in more focused studies with persistent shoulder pain and long-term inability to return to previous level of sports. A constant pull at the origin of the long head of the biceps tendon, degeneration of the LBC as a consequence of repetitive microtrauma and reduced blood flow are accused to be causative for poor healing tendency. In this cases tenodesis of the biceps tendon may be an appropriate alternative with proven benefit to

the patient. Concerns about humeral head migration or anterior instability after removal of the intraarticular part of the long head of the biceps tendon were disproved^[68]. As the authors deal with a statly number of overhead athletes (especially rock climbers), a mini-open tenodesis above the upper border of the great pectoral tendon is an alternative in cases with absent signs of fresh injury^[77].

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Osteitis pubis in elite athletes: Diagnostic and therapeutic approach

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Abstract

Osteitis pubis (OP) is a debilitating overuse syndrome characterizing by pelvic pain and local tenderness over the pubic symphysis commonly encountered in athletes often involved in kicking, twisting and cutting activities in sports such as soccer and rugby and to a lesser degree distance running. It is a common source of groin pain in elite athletes attributable to

pubis symphysis instability as the result of microtrauma caused by repetitive muscle strains on pubic bones. Diagnosis is based mainly on detailed sports history and a meticulous clinical examination, although occasionally is difficult to distinguish this nosological entity from other pathologies affecting the involved area which may occur concomitantly in the same patient. Radiologic examinations such as plain radiographs, magnetic resonance imaging and 3 phase bone isotope scanning may be helpful to differentiate from other clinical entities with similar clinical presentation. Most cases respond well to conservative treatment which includes several physical modalities and especially a progressive rehabilitation programmed individualized to each one of patients diagnosed with OP. Local injection therapies have been also been proposed as a non-operative therapeutic option for the efficient management of these patients. In refractory cases, surgical therapeutic strategies are warranted. These include several open or minimally invasive surgical interventions such as arthroscopic or open symphysis curettage, wedge or total resection of pubic symphysis, polypropylene mesh placement and pubic fusion. In this review a critical analysis of OP in elite athletes is performed with special focus on current concepts of diagnosis and management of this source of athletic groin pain.

Key words: Osteitis pubis; Groin pain; Sports overuse injuries; Conservative management; Surgery

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Core tip: A high degree of suspicion for the presence of osteitis pubis (OP) should be raised at the clinician involved in the investigation and management of groin pain in the elite athletes with repetitive strenuous activities on pubic bones and the surrounding soft tissues. Early recognition of this ailment is imperative to avoid mismanage and to secure early and uneventful return to full sports activities. OP is usually a self-limited pathologic condition and most of the cases

recover spontaneously or respond well to conservative treatment. However, in chronic recalcitrant cases, the surgical approach is instituted. No one of the proposed surgical therapeutic strategies until today, is proven to be superior over the other.

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INTRODUCTION

Osteitis pubis (OP) is a common source of groin pain in athletes, which was first mentioned by Beer, a urologist in 1924, as a complication of suprapubic operations, and later in 1932 this ailment was in greater detail described in an athlete by Spinelli^[1]. The term refers to a noninfectious, inflammatory overuse syndrome affecting the symphysis pubis and surrounding soft tissues such as musculature and fascia, mainly in subjects participating in strenuous athletic activities. More specifically kicking, turning, twisting, cutting, pivoting and sprinting activities associated with sports such as soccer, rugby, ice hockey, Australian rules football and distance running have been attributed to this disease^[2-4].

Groin pain is a challenging symptom commonly confronting when treating athletes. It is estimated that sports-related injury rates in the groin range from 8% in up to 25% of all injuries^[4-6] with a higher incidence in the specific athletic population of male soccer players in which accounts for 10% to 18% per year^[7]. In an epidemiological study, including soccer athletes in three seasons 3% to 5% of the total injuries were associated with OP^[8]. A higher prevalence of OP in the male gender has also been documented^[9,10].

The actual aetiology of this common in specific sports ailment has not been totally clarified. A likely mechanism is the repetitive stress forces applied on the pubic symphysis from the abdominal and adductor muscles which attach to the pubic bones and act antagonistically. The result of this cumulative microtrauma and the alter biomechanics of the affected anatomic area is the symphyseal instability and the establishment of OP lesions^[3,11].

Reduced hip internal rotation, which places a supplementary stress upon the pelvic ring when the athlete undertakes turning and twisting and fixation of the sacroiliac joint have been proposed as predisposing risk factor for OP^[12,13].

Numerous other cases of OP following pregnancy and parturition have additionally been referred. Rheumatologic disorders including ankylosing spondylitis, rheumatoid arthritis, and osteoarthritis^[14,15], and infections following urologic or gynecological procedures have also been associated with this ailment^[1,10,16].

Rodriguez *et al*^[11] classified athletes with OP into 4

stages based on clinical findings and diagnostic features (Table 1).

In this review current aspects of OP diagnosis and treatment in elite athletes are presented with additional analysis of their effectiveness.

CLINICAL DIAGNOSIS

Clinical manifestations include anterior and medial groin pain^[17], which is exacerbated by walking, pelvic motion, adductor stretching, abdominal muscle strengthening exercises, or movement from a seated to a standing position^[15,18] and may radiate into the lower abdominal muscles, perineum, inguinal region, scrotum or medial thigh^[16,17,19]. This sharp or aching pain is followed by local pubis symphysis and pubic ramus tenderness and painful adductor muscle spasms^[15]. Other symptoms such as waddling antalgic gait and crepitus on examination or daily activities may also be present^[10].

Clinical examination includes various tests such as lateral compression and cross leg test as well as pubic symphysis gap test with isometric adductor contraction^[10,11].

Verrall *et al*^[20] proposed 3 provocation tests, namely the Single Adductor, Squeeze and Bilateral Adductor tests for the assessment of chronic groin pain following athletic activity. The authors of this study conducted in Australian Rules football players postulated that the aforementioned tests if positive are strongly associated with magnetic resonance imaging (MRI) detected parasymphyseal pubic bone marrow oedema^[20].

In addition, local injections in the pubic symphysis with a corticoid and/or anesthetic may be a helpful diagnostic tool for OP^[3].

DIFFERENTIAL DIAGNOSIS

A variety of overlapping medical conditions which cause groin pain should be excluded from the initial diagnosis in order to avoid not only misdiagnose but also mismanage (Table 2). OP may be difficult to be distinguished from adductor muscle strain, and the two conditions may occur concurrently in the same patient. Other etiologies of groin pain commonly encountered not only in athletes but also in general populations, should be taken into consideration. Sports hernia, inguinal wall deficiency, iliopsoas strain, stress and avulsion fractures, intra-articular hip joint injury or other relevant pathology such as snapping hip syndrome, referred low back pain and nerve compression, genitourinary and pubic septic infection should be ruled out^[1,11,16,21,22].

It has been thought until the 1970s that a principal cause leading to OP was pelvic infection, which yet has been proven to have a minor contribution to the development of OP^[23]. Those two clinical entities, though have a similar presentation. The differential diagnosis may be challenging and the diagnosis of osteomyelitis may take even months to establish^[24]. Osteomyelitis usually results from bacterial infection secondary to

Table 1 Stages of osteitis pubis^[11]

Stage	Clinical findings
I	Unilateral symptoms, inguinal pain in the adductor muscles, pain alleviation after warm-up, pain exacerbation after the training session
II	Bilateral symptoms, inguinal pain in the adductor muscles, pain exacerbation after the training session
III	Bilateral symptoms, inguinal pain involving the adductor and abdominal muscles, pain with kicking, sprinting, directional changes, <i>etc.</i> , inability to continue sport participation
IV	Inguinal pain involving the adductor and abdominal muscles, pain referred to the pelvic girdle and lumbar spine with defecation, sneezing, and walking on uneven terrain, inability to perform activities of daily living

Table 2 Differential diagnosis of groin pain^[1,11,16,21,22]

Pubic osteitis
Pubic osteomyelitis
Adductor tendinopathy
Sports hernia
Gilmore's groin
Hockey player's syndrome
Stress fracture
Avulsion fracture
Iliopsoas bursitis
Sacroiliac dysfunction
Hip pathology (Labral tears, snapping hip, femoroacetabular impingement, loose bodies, osteoarthritis, chondral damage, <i>etc.</i>)
Referred low back pain
Nerve compression
Genitourinary system disorders

abdominal surgery or urological, gynecological operations, or may be even of a spontaneous appearance in athletes^[25,26]. The possibility of the spread of a nearby infection cannot be also excluded^[24].

Abnormal levels of C-reactive protein, sedimentation rate and white blood cell count suggest osteomyelitis but not OP^[21]. Bone isotope scanning may not be helpful to differentiate between the two pathologies. Yet joint aspiration may typically reveal pathogenic organisms such as *Staphylococcus aureus*, *Pseudomonas aeruginosa*, or anaerobic bacteria with sympysis pubis infection^[21,24,27].

Groin pain is commonly attributed to adductor strain in athletes^[12]. Adductor strain may coexist with OP and is difficult diagnosed as a separate entity. The diagnosis of this pathology is based mainly on clinical examination. Clinical findings include pain on palpation with focal swelling along the adductors, decreased adduction strength and pain on adduction against resistance^[12,16]. To clarify diagnosis an MRI can take place to reveal muscle/tendon strain or tears. The use of ultrasound is significant in revealing tears or ruptures of muscles or tendons, swelling and calcifications but its effectiveness in outlining muscle strains is limited^[28,29].

Sports hernia is another possible musculoskeletal source of chronic groin pain increasingly recognized in high-performance male athletes. This clinical entity

represents a non-palpable inguinal hernia provoked by rectus abdominal wall weakening or tearing of the posterior inguinal wall^[22,30,31]. Clinical examinations reveal tenderness of the posterior wall of the inguinal canal and the superficial inguinal ring which also presents with dilatation. Unilateral or bilateral less often diffuse, deep groin pain is characterized by an insidious onset, halts with rest and exacerbates with sudden movements, coughing, sternutation or sports activities which involve cutting, pivoting, kicking and sudden changes in direction^[12,16,22].

IMAGING

Radiographic analysis

Plain radiographic examination, although not diagnostic, especially in the early stages^[18], is of great importance as assists to rule out other sources of groin pain, namely fractures or hip pathologies such as osteoarthritis, femoroacetabular impingement, avascular necrosis of the femoral head or slipped capital femoral epiphysis in the younger heavier athletes^[1]. It consists of appropriately oriented weight bearing anteroposterior (AP) pelvis, a Dunn lateral, and a false profile view^[3]. It may depict subchondral sclerosis, symphyseal lytic changes and widening or narrowing of the joint space, especially in the chronic phase of the disease^[18,32,33]. Another proposed radiographic view, with major contribution to the pubic instability evaluation is the flamingo view in double- and single-leg stance positions^[11,34]. This examination consists of an AP view of the pelvis with the patient standing on one leg. A greater than 2 mm vertical pubic subluxation or greater than 7 mm of widening of the symphysis is considered to be pathognomic^[1,35]. It has been assumed that up to 5 mm of physiologic motion can take place at the pubic symphysis in asymptomatic individuals^[34].

It is worth mentioning that radiographic elements of OP do not represent symptomatic conditions in all the cases found and do not represent independent predictive factors of groin or hip pain^[3,36]. Increased alpha angle was found in a study to be the only independent predictor of athletic-related hip and groin pain^[37].

MRI

Bilateral or less often asymmetric subchondral plate marrow edema extending from anterior to posterior is the keystone manifestation on MRI images when OP is present^[1,32,33,38] (Figure 1). The importance of this finding is apparent since it is associated with an increased likelihood of clinically detectable focal pubic tenderness, positive provocative clinical tests, and preseason training restriction^[39]. In the chronic phase of OP bone edema may not be present. On the contrary findings originated from chronic sympysis instability, such as periosteal reaction, bone resorption, irregular contour of articular surfaces, osteophytes, and subchondral cyst formation predominate^[38].

A secondary cleft sign which is an extension of the



Figure 1 Magnetic resonance imaging - stage I osteitis pubis in a 20-year old soccer athlete.

symphyseal cleft to the adductor tendon origin is another commonly encountered MRI finding in OP^[17,33,40].

Bone scintigraphy

Bone scintigraphy may reveal markedly increased uptake of 99m technetium-methylene diphosphonate (99m Tc-MDP) in the

strength and endurance training exercises^[45].

Specific muscle groups appear to require targeted strengthening. In a recent study involving isokinetic evaluation of hip flexor strength in soccer players with OP, flexor muscle strength was found to be increased, a fact that had negative results in hip flexor/extensor torque ratio of OP^[46]. Therefore the authors of this study propose a strengthening of hip extensors as part of further strengthening of hip flexors.

In another research study comparing 25 OP soccer athletes to healthy athletes, the OP group presented with reduced concentric muscle strength of back muscle and eccentric reduction of the strength of abdominal muscles, thus altering the ratio of abdominal to back muscles^[47]. This underlines the need for specific goal setting exercise in prevention and treatment.

Although physical therapy appears to be effective in conservative OP treatment, especially in the early stages, the results are not based on randomized clinical trials and level IV studies. Further randomized trials are necessary to compare physical therapy to other treatment options, or compare elements of physiotherapy treatment. In that way, evidence regarding the significance of physical therapy in OP treatment will assist in the selection of appropriate treatment options.

Prolotherapy

In a case series by Topol *et al*^[41] 24 male elite kicking-sport athletes with chronic groin pain from OP and/or adductor tendinopathy undertook monthly injections of 12.5% dextrose and 0.5% lidocaine into pubis symphysis, the adductor complex and suprapubic abdominal insertions. Before the application of prolotherapy symptoms lasted for a mean of 15.5 mo. Pain severity was assessed by the use of the visual analog scale (VAS) for pain with sports and the nirschl pain phase scale. Based on the aforementioned scales, athletes presented with statistically significant pain reduction. A percentage of 91.7% elite rugby and soccer athletes returned to full activity after a mean period of 9 wk following the first set of injections^[41].

Corticosteroid injections

Corticosteroid injection therapy is another adjunctive to core stabilization progressive rehabilitation program for acute and chronic OP^[19,21,48,49]. Typically, the procedure encompasses 1-3 injections (mean = 1.24) into the pubic symphysis of a 1-3 cc volume mixture consisting of a combination of a corticosteroid such as dexamethasone, betamethasone or methylprednisolone with a local anesthetic such as bupivacaine and lidocaine.

In a study presented by O'Connell *et al*^[49] 14 male and 2 female elite athletes aged 21-40 years old with radiographically confirmed chronic OP, underwent pubic cleft injections with 20 mg of methylprednisolone acetate and 1 mL of 0.5% bupivacaine local anesthetic. Symphysography with fluoroscopic guidance was used both for diagnostic and therapeutic purposes. Two

months after the procedure, 31.2% of the study population had been completely symptoms alleviation symptoms and all of them remained without symptoms at 6 mo.

Choi *et al*^[21] reviewed 3 case series including totally 30 patients, 26 male and 4 female athletes with OP, who were treated with corticosteroids injections with or without local analgetic. The majority of treated with technique athletes videlicet percentages as high as 58.6% were able to return to sport. However, a significant non-responder rate (20.7%) was present^[21].

The existing data related to this curative modality is based on studies evaluating the efficacy of a variety of medications with non-standardized volume applied to heterogeneous study population samples. Furthermore, the reported return to full athletic activity is inconsistent and an assortment of results has been reported ranging from quick recovery to prolonged convalescence.

SURGICAL TREATMENT

Surgical intervention is warranted for the 5%-10% of individuals recalcitrant to conservative approaches cases lasting more than a few months^[15]. A wide range of surgical treatment options for OP has been instituted^[21] counting interventions such as wedge resection^[10,15], total resection^[50], extraperitoneal retropubic polypropylene mesh placement^[51,52], open and endoscopic curettage of the pubic symphysis^[17,53-57], and arthrodesis and plating fixation with or without grafting^[15,35,58].

Wedge resection of the symphysis pubis appears to be an effective treatment which significantly alleviates symptoms originating from OP and secures return to full activity at an average of fourteen months postoperatively^[10]. However, posterior instability and pain following this procedure may urge the need of further surgical involvement and bilateral sacroiliac arthrodesis.

Paajanen *et al*^[51] placed a polypropylene mesh into the preperitoneal retropubic space in five elite male athletes suffering from OP associated groin pain. One to two months after surgery all 5 patients were able to come back their athletic activities uneventfully. No postoperative complications associated with the procedure were recorded.

Two case series including eight male athletes who underwent pubic fusion with compression plates to address long lasting symptoms attributed to chronic OP were reviewed by Choi *et al*^[21], Williams *et al*^[35] and Vitanzo *et al*^[58]. Seven participants in this study returned to sport with approximately 6.6 mo following surgery. All seven athletes were able to return to sport all were pain free at an average of 52 mo after surgery^[35]. Nevertheless, a noteworthy percentage of postoperative complications as high as 25% were noted. More specifically haemospermia has been referred in one athlete whilst another one presented intermittent scrotal swelling during exercise^[21].

Radic *et al*^[54] retrospectively evaluated the results

of pubic symphysis curettage in 23 athletes with recalcitrant OP with a mean result of discomfort of 13.22 mo. Sixteen participants in this study were able to return to full sport activity by a mean of 5.6 mo after this surgical intervention. However, with longer follow up less satisfied results were calculated and moreover, one required late surgical fusion of the pubic symphysis.

A minimally invasive curettage of pubic symphysis which allows bleeding cancellous bone to remain while simultaneously protects the stabilizing pubic ligaments, was proposed by Hechtman *et al*^[55]. The authors of this study performed an arthroscopically assisted on four competitive football athletes diagnosed with OP after a failure of conservative treatment at least for 6 mo. All 4 patients returned to competitive athletics on average at 3 mo.

A novel operative treatment for the management of chronic groin pain in five competitive soccer players with OP with concurrent adductor longus tendinopathy introduced by Hopp *et al*^[17]. After failure of a minimum of 12 mo of conservative treatment patients underwent a two-portal arthroscopic curettage of the degenerative fibrocartilaginous disc tissue and subsequent reattachment of the soft tissues with suture anchors. All patients recovered to full activity sports after an average period of 14.4 wk without any developed pubic instability. An intraoperative bleeding complication which necessitated ligation was reported.

Finally, in a recent research, including 7 young adult patients suffering from OP with concomitant femoroacetabular impingement the results of arthroscopic surgery and endoscopic pubic symphysectomy were evaluated in a mean follow-up period of 2.9 years. The VAS score, and the non-arthritis hip score measurement revealed postoperative improved values in comparison to the preoperative ones. Postoperatively scrotal swelling that resolved spontaneously was the only complication in two male patients. Another patient underwent pubic symphyseal arthrodesis because of continued pain^[57].

Given the lack of randomized controlled trials comparing the efficacy between the different surgical treatments, are not reasonable safe conclusions about the clinical effectiveness of each one of these various invasive therapeutic strategies as well as cost-effectiveness of each of them^[1,21].

CONCLUSION

OP is a noninfectious inflammatory disease affecting the pubis symphysis which may provokes groin pain in professional athletes who participate in sports involving strenuous repetitive motions like sudden accelerations and decelerations resulting in joint hypermobility.

Most of cases respond sufficiently to usual conservative treatment for overuse injuries videlicet rest, ice, anti-inflammatory medication and physical therapy agents. However, in cases resisting to the non-operative management, surgery is considered as a therapeutic option. This includes a number of approaches such as

wedge or total symphysis resection, open or arthroscopic curettage and pubic symphysis arthrodesis. Further, significantly strong research is needed to clarify the superiority of each one of the aforementioned invasive methods over the other and the optimal therapeutic strategy for every competitive athlete.

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Vertebral fracture assessment: Current research status and application in patients with kyphoplasty

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Abstract

Imaging of the spine is of paramount importance for the recognition of osteoporotic vertebral fractures (VFs), and standard radiography (SR) of the spine is the suggested diagnostic method but is not routinely used because of the cost and radiation exposure considerations. VF assessment (VFA) is an efficient, low radiation method for identifying VFs at the time of bone mineral density (BMD) measurement. Prediction models used to indicate the need for VFA may have little predictive power in subspecialty referral populations such as rheumatologic patients or patients who underwent kyphoplasty. Rheumatologic patients are frequently at increased risk for VFs, and VFA should be performed on an individual basis, also taking in account the guidelines for the general population. Kyphoplasty is a new minimal invasive procedure for the treatment of VFs and is being performed with increasing frequency. Following kyphoplasty, there may be a risk of new VFs in adjacent vertebrae. The assessment and follow-up of patients who underwent kyphoplasty requires repetitive X-ray imaging with the known limitations of SR. Thus, VFA may facilitate the evaluation of VFs in these patients because most of the kyphoplasty patients would fulfill the criteria. In a pilot study, we measured the BMD and performed VFA in 28 patients treated with kyphoplasty. Ratios of anterior to posterior (A/P) and middle to posterior (M/P) height were measured, and Genant's method was used to classify vertebrae accordingly. Intraobserver and interobserver reliability for A/P, M/P and the Genant's method were determined. Only 1 patient did not meet the criteria for VFA. Of the 364 available vertebrae, 295 could be analyzed. Most missing data (concerning 69 vertebrae) occurred in the upper thoracic region. Three of the 69 non-eligible vertebrae were lumbar vertebrae with cement leakage from the kyphoplasty procedure. In our hands, VFA was highly reproducible, demonstrating very good agreement in terms of intraobserver and interobserver reliability. Agreement was very good on

the vertebral level, “vertebrae with kyphoplasty” level and “2 above and 1 below the kyphoplasty vertebrae” level. The application of Genant’s method to these patients also resulted in perfect agreement. We believe that the potential value of VFA in patients treated with kyphoplasty requires further evaluation, particularly comparing VFA with SR and performing a longitudinal follow-up. More research will help to adopt care processes that determine which patients require VFA and how often VFA should be performed, while also considering the impact of this technique on the cost of healthcare organizations.

Key words: Vertebral fracture assessment; Current research; Kyphoplasty; Guideline

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Core tip: Vertebral fracture assessment (VFA) is an efficient, low radiation method of identifying vertebral fractures at the time of bone mineral density measurement. Models used to indicate the need for VFA may have little predictive power in subgroups of the general population such as patients with kyphoplasty. In our hands, VFA applied in patients with kyphoplasty was highly reproducible, demonstrating very good agreement in terms of intraobserver and interobserver reliability. More research will help the adoption of care processes to determine when and how often VFA should be performed, considering also the impact of such cost on healthcare organizations.

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INTRODUCTION

Vertebral fracture (VF) is the emblem of osteoporosis and is associated with increased mortality and morbidity^[1]. The clinical symptoms include pain (acute and chronic), impaired pulmonary function, thoracic kyphosis, height loss, depression and deterioration of quality of life. Thoracic and lumbar fractures are unique because most of the fractures do not present clinical symptoms at the time of their occurrence^[2,3].

VFs commonly occur in postmenopausal women and older men, with an estimated prevalence of 10%-26% in both men and women age 50 and older, depending on the population and definition of VF utilized^[3-6]. Prevalent VFs anticipate new fractures independently of bone mineral density (BMD), as patients with one or more fractures have a 4-fold increased risk of subsequent hip fractures and a 5-fold increased risk of

further VFs^[7]. Furthermore, VFs that do not come to medical attention seem to be associated with increased back pain and functional limitation^[8].

Despite all of these facts, in a multicenter, multinational prospective study (the IMPACT trial), underdiagnosis of VFs was observed in all geographic regions (false-negative rates: North America, 45.2%; Latin America, 46.5%; and Europe/South Africa/Australia, 29.5%) with a global false-positive rate of 5%. According to the same study, underdiagnosis of VFs is a worldwide problem attributable, in part, to a lack of radiographic detection, use of ambiguous terminology in the radiology report, or both^[9].

Imaging of the spine is of paramount importance for the recognition of VFs. Standard radiography (SR) of the spine is the reference method for identifying VFs but is not used routinely because of the cost and radiation exposure considerations. Dual-energy X-ray absorptiometry (DXA) systems equipped with special software can be used for the detection of VFs obtaining lateral views of the thoracic and lumbar spine (Figure 1). Densitometric imaging of the spine allows VF analysis to be efficiently performed simultaneously, improving the overall assessment of an individual’s future fracture risk with a very low radiation dose (10 microsieverts vs 800 microsieverts for standard anteroposterior and lateral radiographs of the thoracic and lumbar spine)^[10]. Although lateral imaging of the spine with the use of X-ray absorptiometry has been previously described with different terms from the manufacturers (lateral vertebral assessment, dual vertebral assessment and instant vertebral assessment), the ISCD 2005 Official Positions replaced these terms with the label “Vertebral Fracture Assessment” or VF assessment (VFA)^[11]. Furthermore, vertebrae with an appearance consistent with a prevalent fracture on VFA images or radiographs are often characterized as deformities, implying that some of the “deformities” identified may not really be VFs^[11].

METHODS FOR VFA

There are several methods available to determine vertebral deformities (VDs) and distinguish them from vertebrae with a normal shape. The semi-quantitative technique developed by Genant *et al*^[12] is one of the most common approaches. The qualitative feature of the vertebrae shape is considered together with the approximate loss of vertebrae height. This method uses fixed values of loss of height (0.60, 0.75 and 0.80).

A plethora of quantitative morphometric methods of detecting VFs has also been described. That study determined a VF based on reductions of anterior (A) and middle height (M) relative to the posterior height (P) within the vertebra and/or on reductions of these heights relative to corresponding heights of adjacent vertebrae. Most studies also used appropriate population-based samples of men and women. McCloskey *et al*^[13] developed a quantitative technique that takes into

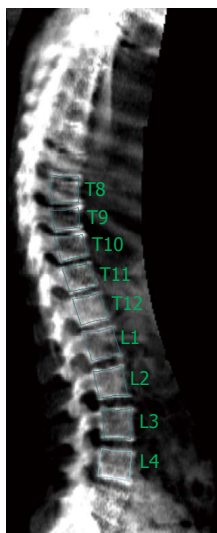


Figure 1 Vertebral fractures on a vertebral fracture assessment image.

account the size of adjacent vertebrae into assessing VFs. Eastell *et al.*^[14] defined a fracture based on the deviation of the vertebral height of > 3 SD compared with a population-based sample. Melton *et al.*^[15] used the ratio of 0.85 for the definition of VFs, with the vertebral dimensions being adjusted for the specific level. Ross *et al.*^[16] developed a method that uses Z-scores to identify VFs. A modified approach to visual diagnosis of VFs, known as the algorithm-based qualitative method (ABQ), was proposed by Jiang *et al.*^[17]. This technique focuses on the appearance of the central vertebral endplate to identify VFs without a minimum threshold of vertebral height reduction.

When used for VFA images, the Genant's method, quantitative morphometry and the most recent ABQ method result in good intraobserver and interobserver reliability, approximating that of SR^[18-20]. In a multicenter study, including 203 postmenopausal women with imaging of their spine by both DXA and SR that were independently evaluated by three experienced radiologists on two different occasions, there was good agreement with kappa values ranging from 0.64 to 0.77^[21]. Furthermore, VFA has been shown to be both sensitive and specific in several studies. In 205 women age 65 and older undergoing bone densitometry for BMD measurement, VFA compared to SR was 87%-93% sensitive and 93%-95% specific^[18]. In another study including 80 postmenopausal women, clinicians utilizing VFA with a Genant semi-quantitative method identified the vast majority of grade 2 or 3 VFs and normal vertebral bodies (with a false negative rate of 6%) but only identified 50% of grade 1 fractures^[22].

VFA has also a good negative predictive value (NPV) that reaches even 95% in some studies^[23]. However, visualization of the upper thoracic spine is of poorer quality for VFA compared to SR, and most of the studies have noted a larger percentage of vertebrae that are not visualized clearly with VFA^[24]. Non-eligible vertebrae are particularly common superior to the 7th thoracic

vertebra (T7) but there are relatively few osteoporotic VFs above T7.

INDICATIONS FOR VFA

According to the 2007 Official Positions of the International Society for Clinical Densitometry (ISCD), the candidate indications for VFA were established on the basis that documentation of a prevalent VF may alter treatment of that individual and that there is a reasonable pre-test probability that a prevalent VF is found on VFA^[11]. SR following VFA should be performed when grade 2 or milder VFs are present without more severe VFs, VDs are present in patients with a known history of malignancy and when VDs cannot be assigned to benign causes^[11].

The 2013 updated positions of the ISCD simplified the indications, and spine imaging with VFA or SR is recommended when the T-score is less than -1.0 and if one or more of the following factors are present^[25]: (1) Women age > 70 years or men age > 80 years; (2) Historical height loss > 4 cm (> 1.5 in.); (3) Self-reported but undocumented prior vertebral fracture; and (4) Glucocorticoid therapy equivalent to > 5 mg of prednisolone or equivalent per day for > 3 mo.

One of the aims of this study was to develop a regression-based prediction model to be integrated into the densitometric software so that bone technicians can proceed to a VFA in addition to the standard bone density measurement if the likelihood of prevalent VF is $> 10\%$ ^[25]. In fact, Schousboe *et al.*^[11] developed an algorithm to be used by technologists to identify patients for whom VFA should be performed, simplifying the criteria from the ISCD 2007 position statement (T-score -1.5 or worse and one of the following factors: age 65 years or older, historical height loss > 1.5 in, or systemic glucocorticoid therapy at the time of their DXA test). They concluded that such use can be feasible in clinical practice and that documentation of VFs increased the prescription of fracture prevention medication^[26]. However, there are no recommendations about the role of VFA in detecting incident fractures in patients receiving osteoporosis treatment or the interval between consecutive VFAs.

VFA IN SUBSPECIALTY REFERRAL POPULATIONS

Models used to form indications for VFA have been developed in general populations and may have little predictive power in special populations such as patients with ankylosing spondylitis (AS), rheumatoid arthritis (RA) or inflammatory bowel disease.

In rheumatology practice VFA has been shown to be useful for revealing VFs^[27]. Patients with AS or RA are at increased risk for VFs compared to the general population^[28,29]. Known risk factors include age, low BMD, use of glucocorticoids, disease duration and high levels of disease activity^[28-33].

Mohammad *et al.*^[31] performed VFA scans in a cohort of 603 patients with RA of age > 40 years. For the entire cohort, 13% (77/603) of patients had one or more vertebral deformities identified on VFA imaging: 58% of these patients were female with a mean age of 56 years. The prevalence of osteoporosis and osteopenia was 59% and 40%, respectively, with the prevalence and severity of VFs showing significant correlation with spine T-scores and femoral T-scores. In multivariable analyses VFs were significantly and independently associated with a longer duration of RA, markers of disease activity and severity^[31].

In one of the recent studies on the role of VFA in RA, 100 women underwent lateral imaging of the thoracolumbar spine by SR and VFA. All patients with a history of previous VF ($n = 13$) were visualized with VFA. The sensitivity, positive predictive value, specificity and NPV of VFA compared to SR were 57.3%, 30.9%, 89.1% and 96.1%, respectively, for the total vertebrae^[34].

There is less research conducted with regards to VFA in patients with AS. As in rheumatoid arthritis, VFA needs to be validated. Vosse *et al.*^[35] compared VFA with SR in 30 patients with AS. Although the agreement between methods in measuring vertebral wedging [expressed as (mean) A/P ratio] was good, agreement between methods in assessing whether there is a fracture was insufficient. However, as the NPV was high (97%), VFA could be of clinical value to select patients for further evaluation by SR.

According to the 2013 official positions of ISCD, VFA for these subsets populations should be performed on an individual basis taking also in account the guidelines for the general population. On 2012, the French Society for Rheumatology and the Osteoporosis Research and Information Group updated their recommendations for the pharmacological treatment of post-menopausal osteoporosis and suggested the same indications for VFA as recommended by the ISCD^[36]. Finally, the 2010 American College of Rheumatology recommendations for the prevention and treatment of glucocorticoid-induced osteoporosis suggest considering lateral imaging of the spine with SR or VFA for patients starting or currently receiving prednisolone > 5 mg/d^[37].

APPLICATION OF VFA IN PATIENTS TREATED WITH KYPHOPLASTY

Kyphoplasty is new minimal invasive procedure for the treatment of osteoporotic VFs and is being performed with increasing frequency. The technique was developed to provide relief to patients with painful VFs and entails inflation of a percutaneously delivered balloon in the vertebral body, followed by the percutaneous injection of bone cement into the cavity created by the balloon. Chemotoxicity, thermal necrosis during exothermic polymerization, and mechanical stability provided by the cured bone cement are the most likely mechanisms for pain relief in kyphoplasty^[38-41].

Through the use of a balloon, kyphoplasty is

intended to provide restoration of vertebral body height. Based on current evidence, kyphoplasty does not restore substantial vertebral body height in most patients, and the intrinsic value of vertebral body height restoration remains speculative. Patients treated with kyphoplasty are generally quite satisfied with their pain relief and rarely express disappointment in a lack of height restoration^[40,41].

There may be an additional risk of new VFs developing in adjacent vertebrae subsequent to kyphoplasty^[42]. Because new VFs can occur in osteoporotic patients simply due to disease progression rather than as a result of the kyphoplasty, it is difficult to determine the added risk of fracture resulting from this procedure^[38-41].

The assessment and follow-up of patients who underwent kyphoplasty requires repetitive X-ray imaging with the limitations of radiography in terms of radiation, cost, patient positioning and geometric distortion within vertebrae located above or below the central point of the beam (parallax effect because the endplates are projected obliquely, giving them an elliptical appearance)^[10,43,44]. Thus, VFA is a technique that may facilitate the evaluation of VFs in these patients. In fact, patients treated with kyphoplasty frequently are: (1) Osteopenic or osteoporotic patients with a T-score less than -1.0 and need regular BMD measurements; (2) Women or men age > 70 or even 80; (3) Patients that present with height loss; (4) Patients that have a history of prior VF; or (5) Patients that having an additional risk for new VFs because of the natural course of the osteoporosis or of the kyphoplasty.

Furthermore, chronic rheumatologic patients under treatment with glucocorticoids have an increased risk for VFs^[28-33] and can be treated with kyphoplasty. Considering the above criteria, most of the kyphoplasty patients would fulfill the criteria for VFA according to the 2013 ISCD Official Position^[25].

MATERIALS AND METHODS OF THE STUDY

Before any data collection, local ethics committee approval was obtained for the present cross sectional study.

Twenty-eight patients treated with kyphoplasty for acute symptomatic osteoporotic VFs were included. The patients were evaluated according to a standard protocol, which included measurement of BMD (of both nondominant hip and lumbar spine) and densitometric images of the spine with the patient in the lateral position using a Lunar Prodigy Advance densitometer (GE Healthcare Buckinghamshire, United Kingdom). For the calculation of the mean T-score, the least value between the lumbar spine and hip (femoral neck, or total proximal femur) was included for every patient. At the lumbar spine, at least 3 vertebrae (between L1 and L4) had to be evaluable, that is without kyphoplasty, for the T-score to be taken into consideration. For VFA images, the Lunar software of the densitometer was used to set

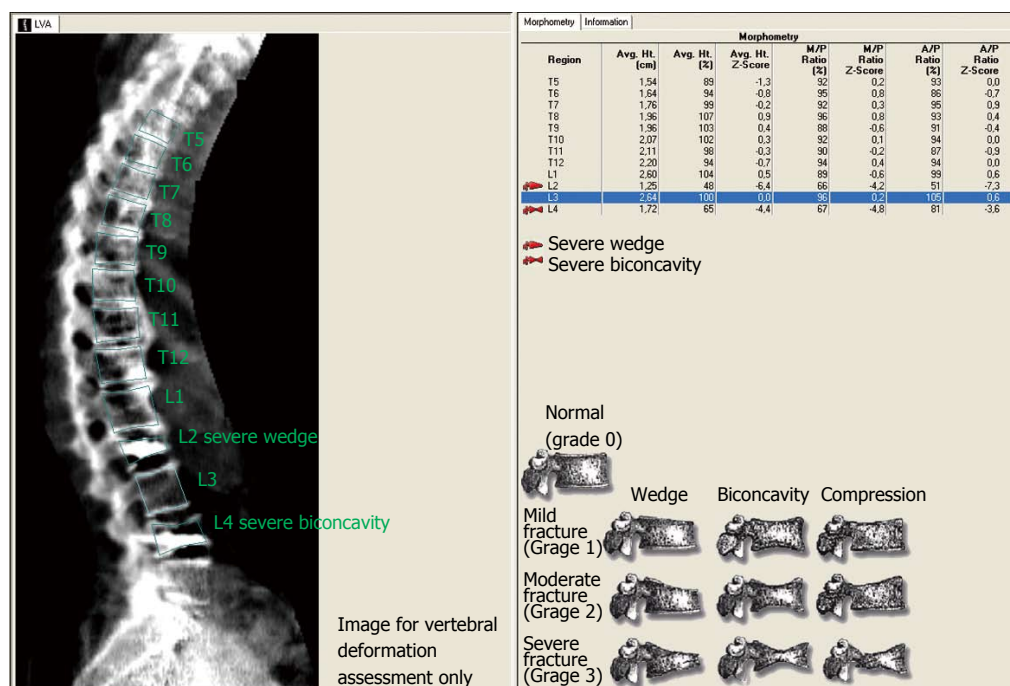


Figure 2 Vertebral fracture assessment on a patient who underwent kyphoplasty. Markers on the vertebral margins anterior (A), middle (M) and posterior (P) heights, together with their ratios, were measured.

markers on the vertebral margins by two observers (XM and ED), and anterior (A), middle (M) and posterior (P) heights together with their ratios were measured (Figure 2). VFs were assessed by calculating the A/P, M/P ratios.

To measure intraobserver reliability for A/P and M/P ratios, each observer read every densitometric image twice in a random order, evaluating vertebrae from T4 to L4. To assess interobserver reliability, VFA images were read independently from the two observers (XM and ED), who were blinded to each other's assessment.

We estimated the intraobserver and interobserver reliability for A/P and M/P ratios using the intra-class correlation coefficient (ICC) on the "vertebral level" ($n = 364$), as well as on the "vertebrae with kyphoplasty" level ($n = 49$) and adjacent to the kyphoplasty vertebrae level ("2 above and 1 below the kyphoplasty vertebrae", $n = 82$). Furthermore, following Genant's method, we used the cut-off ratios of 0.60, 0.75 and 0.80 for the A/P ratio to categorize the vertebrae as grade 0 (non fracture), grade 1 (mild), grade 2 (moderate) and grade 3 (severe) fractures and calculated Cohen's kappa value (κ) with quadratic weighting. The κ value was determined on a vertebral level with 95% confidence intervals. To interpret the level of agreement based upon Cohen's κ results the Landis and Koch guidelines were followed^[45]. Thus, a Cohen's κ value greater than 0.81 was considered almost perfect agreement; between 0.8 and 0.61, substantial agreement; between 0.6 and 0.4, moderate agreement; between 0.4 and 0.2, fair agreement; between 0.2 and 0, slight agreement; and less than zero, poor agreement. All tests were two-sided and statistical significance was set at $P < 0.05$. All analyses were carried out using the computer software SPSS for Windows (IBM SPSS Statistics 21 NY, United

States).

STUDY RESULTS

Ten patients were male, 18 patients were female and the mean age was 72.4 years (range, 54-84). Only 1 patient did not meet the 2013 ISCD criteria for VFA^[25] because of a T score > -1 . The mean T-score was -2.28 (range, -4.1 to -0.8), and the mean height was 1.52 m (range, 1.38-1.71 m). Furthermore, the mean weight was 70 kg (range, 51-98 kg), the mean body mass index was 30 (range, 22-41) and the mean follow-up from the operation date was 34 mo (range, 14-60 mo).

Of the 364 available vertebrae, 295 could be analyzed. Most instances of missing data (concerning 69 vertebrae) occurred in the thoracic T4-T6 region and were equally distributed across the two readers. Three of the 69 non-eligible vertebrae were vertebrae that had been treated with kyphoplasty. Both of the readers characterized these vertebrae as non-eligible. These vertebrae were three lumbar vertebrae (one L1 and two L2) of three different patients and had the presence of cement leakage from the kyphoplasty in common.

Intraobserver agreement for A/P ratios was very good for both readers (XM and ED), with ICC = 0.98 (95%CI: 0.977-0.988) for XM and ICC = 0.96 (95%CI: 0.957-0.973) for ED. Intraobserver agreement for M/P ratios was also very good for both readers, with ICC = 0.977 (95%CI: 0.971-0.982) for XM and ICC = 0.945 (95%CI: 0.93-0.956) for ED. Interobserver reliability (first assessments of the two readers were compared) for A/P and M/P ratios, the results were again very good, with ICC = 0.951 (95%CI: 0.938-0.961) for A/P and ICC = 0.947 (95%CI: 0.933-0.958) for M/P.

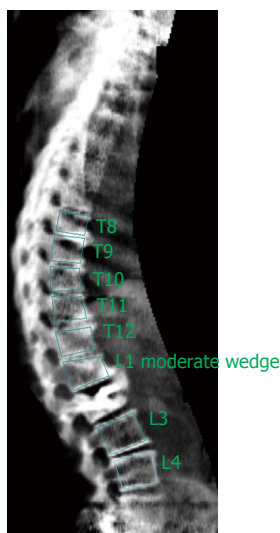


Figure 3 Non-eligible L2 vertebra with kyphoplasty and cement leakage on vertebral fracture assessment.

Agreements on the “vertebrae with kyphoplasty” level and on the “2 above and 1 below the kyphoplasty vertebrae”, were also very good. There was very good interobserver reliability for the A/P ratio on the “vertebrae with kyphoplasty” level with ICC = 0.94 (95%CI: 0.894-0.966) and for the A/P ratio on the “2 above and 1 below the kyphoplasty vertebrae” level with ICC = 0.969 (95%CI: 0.951-0.98).

With regards to Genant’s method, after using the cut-off ratios of 0.60, 0.75 and 0.80 for A/P ratio and classifying the vertebrae, interobserver agreement was almost perfect calculating a κ value with Quadratic Weighting = 0.833 (95%CI: 0.82-0.95). Furthermore, using Genant’s method and taking in account the first observer’s measurements (XM), 15 VFs were found on the “2 above and 1 below the kyphoplasty vertebrae” level. More specifically, there were nine VFs on the adjacent-superior to the kyphoplasty vertebrae, one VF on the adjacent-inferior to the kyphoplasty vertebrae and five VFs were identified in two vertebrae above the kyphoplasty. Eleven of these 15 VFs were at the thoracolumbar junction (T12-L1), three were on T11 and one was on T9. Seven more VFs were found on the rest of those not adjacent to the kyphoplasty vertebrae.

DISCUSSION

In our hands, VFA was highly reproducible when applied to patients treated with kyphoplasty, demonstrating very good agreement in terms of intraobserver and interobserver reliability. Agreement was very good on the vertebral level, “vertebrae with kyphoplasty” level and “2 above and 1 below the kyphoplasty vertebrae” level. Application of Genant’s method on these patients also resulted in perfect agreement.

With regards to the patient who did not meet the criteria for VFA, the lowest T-score = -0.9 of the hip was considered. She was a woman aged 68 years with

two kyphoplasty vertebrae (T11 and T12). Being under treatment with intravenous zoledronic acid for the last two years, post-kyphoplasty may have improved her BMD. The 69 individual non-eligible vertebrae (most of them in the thoracic T4-T6 region) were in concordance also with studies where VFA was applied in general population groups or in subgroups such as patients with ankylosing spondylitis^[24,35]. Three of the 69 non-eligible vertebrae were kyphoplasty vertebrae in 3 patients presenting cement leakage (Figure 3). In fact, cement extravasation alters vertebral shape, and as a result, it is extremely difficult for the reader to assess the vertebra.

It is still a matter of debate as to whether vertebrae neighboring the kyphoplasty are more likely to fracture^[42]. According to our database, most of the fractures on the vertebrae without kyphoplasty were on the “2 above and 1 below the kyphoplasty vertebrae” level (15 VFs), but we have no data on whether these were new fractures or present before the kyphoplasty.

We believe that the potential value of VFA in patients treated with kyphoplasty needs further evaluation, in particular, evaluations comparing VFA with SR and including longitudinal follow-up. Although we did not perform longitudinal VFA assessments, VFA has the potential to be a very useful test for longitudinal follow-up. Our pilot study demonstrated that VFA could be a valuable technique in terms of intraobserver and interobserver reliability for the determination of the height ratios of the vertebrae or using Genant’s method. A larger study, comparing the agreement between VFA and SR in patients who underwent kyphoplasty is currently underway. Moreover, considering the guidelines for monitoring BMD in populations at high risk for VFs, patients who underwent kyphoplasty should have their DXA measurement regularly at least every 1 or 2 years^[46]. In an era in which all dimensions of pathology should be accounted for, serial BMD testing and VFA should probably be part of routine practice in this at-risk population, and having a single exam that entails minimal irradiation and allows for the assessment of major structural changes certainly warrants further systematic evaluation.

Overall, assessing structural damage is essential in patients treated with kyphoplasty and has key implications for treatment outcomes. SR remains the gold standard to evaluate the spines of these patients, despite all its disadvantages and limitations. Our study demonstrates a potential for VFA in these patients. The technique of VFA is much less irradiating than standard radiographs, easily available during the BMD determination and inexpensive in the modern era of economic crisis.

CONCLUSION

Future research is needed to determine if other predictors can be established that may improve the efficiency of lateral spine imaging to identify those with

clinically unrecognized VFs. Because models used to form general indications for VFA may have little predictive power in subsets of populations, such as patients with RA or kyphoplasty, further studies are needed on new care processes within healthcare systems to identify those who should have VFA. Furthermore, although VFA has the potential to be a very useful test for longitudinal follow-up; there are currently no recommendations on how often the assessment should be repeated. It is important to also mention that, according to evidence, VFA studies revealing a VF do affect patient's and physician's fracture prevention behavior^[47,48]. In conclusion, more research will help the adoption of care processes to determine which patients require VFA and how often VFA should be performed, while also considering the impact of such cost on healthcare organizations.

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Cystic lesion around the hip joint

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Abstract

This article presents a narrative review of cystic lesions around the hip and primarily consists of 5 sections:

Radiological examination, prevalence, pathogenesis, symptoms, and treatment. Cystic lesions around the hip are usually asymptomatic but may be observed incidentally on imaging examinations, such as computed tomography and magnetic resonance imaging. Some cysts may enlarge because of various pathological factors, such as trauma, osteoarthritis, rheumatoid arthritis, or total hip arthroplasty (THA), and may become symptomatic because of compression of surrounding structures, including the femoral, obturator, or sciatic nerves, external iliac or common femoral artery, femoral or external iliac vein, sigmoid colon, cecum, small bowel, ureters, and bladder. Treatment for symptomatic cystic lesions around the hip joint includes rest, nonsteroidal anti-inflammatory drug administration, needle aspiration, and surgical excision. Furthermore, when these cysts are associated with osteoarthritis, rheumatoid arthritis, and THA, primary or revision THA surgery will be necessary concurrent with cyst excision. Knowledge of the characteristic clinical appearance of cystic masses around the hip will be useful for determining specific diagnoses and treatments.

Key words: Bursa; Cystic lesion; Ganglion cyst; Hip; Synovial cyst

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Core tip: The purpose of the present paper is to review clinical features of cystic lesions around the hip joint. Ultrasound, computed tomography and magnetic resonance imaging are useful modalities for detection of cystic lesions, but it is difficult to distinguish pathological differences between ganglion cysts and synovial cysts, including bursae. Although cysts around the hip are usually asymptomatic, enlargement of these cysts may cause pain and/or compression of the surrounding structures, such as nerves and vessels. Treatment of these cysts depends on their size, the severity of symptoms, and the nature of the underlying disease.

Yukata K, Nakai S, Goto T, Ikeda Y, Shimaoka Y, Yamanaka I, Sairyo K, Hamawaki J. Cystic lesion around the hip joint. *World J Orthop* 2015; 6(9): 688-704 Available from: URL: <http://www.wjgnet.com/2218-5836/full/v6/i9/688.htm> DOI: <http://dx.doi.org/10.5312/wjo.v6.i9.688>

INTRODUCTION

Cystic lesions may occur around any of the joints or tendon sheaths in the body. Common locations of the cyst include the wrist, hand, foot, ankle, and knee, because it could be much easier to identify cysts near the body surface. Development of cysts associated with the hip joint is a rare clinical problem, but they may be incidentally observed on clinical inspection or imaging examinations, such as ultrasound, computed tomography (CT), or magnetic resonance imaging (MRI)^[1]. Some researchers have examined the frequency of cysts in the hips of asymptomatic volunteers using MRI. Their results indicated that 5.8%-26.2% of asymptomatic hips had a cyst around the joint. In general, 15 synovial-lined bursae around the hip joint have been commonly imaged, particularly the iliopsoas bursa, which is the largest synovial bursa in the body and present bilaterally in 98% of adults^[2]. In addition, herniation of the synovium into the surrounding tissue, displacement of the synovium in the embryonal stage, and degeneration of connective tissue in an adjacent joint or a tendon sheath have been suggested as possible etiological factors^[3,4]. Histologically, there are 2 types of cysts around the joint or tendon: ganglion and synovial cysts. Ganglion cysts are generally believed to be the result of myxomatous degeneration of certain fibrous tissue structures and do not have a lining of synovial cells, whereas synovial cysts, including bursa, have a lining of synovial cells and sometimes directly communicate with the adjacent joint. Both ganglion and synovial cysts contain a similar gelatinous fluid that is highly viscous secondary to the presence of hyaluronic acid and other mucopolysaccharides or hemorrhage^[3]. It is difficult to differentiate these cysts by clinical and radiological examinations or determine if the cysts communicate with the joint cavity. Accordingly, we primarily use the term "cyst or cystic lesion" when referring to bursae, synovial cysts, and ganglion cysts in this review because they have the same appearance radiologically. Cystic lesions around the hip are usually asymptomatic but may cause pain and compression of the surrounding nerves, veins, and arteries when they become enlarged. This narrative review article includes 5 main sections: Radiological examination, prevalence, pathogenesis, symptoms, and treatment for cystic lesions of the hip joint. For this review, we searched the key words "hip cyst" or "hip ganglion" or "hip bursa" using PubMed (National Library of Medicine, Bethesda, Maryland, United States) to obtain the articles published until December 2014. 1056 articles from the key word "hip cyst", 134 from "hip ganglion", and 239 from

"hip bursa" were matched, respectively. All selected abstracts or articles were reviewed by the authors and articles without an English abstract that were not published in English were excluded. As a result searched with PubMed, total 151 articles were considered to be relevant for this review. Furthermore, we added the 140 related articles using the references of the articles, which is selected by PubMed, and finally 291 articles about cystic lesion around the hip were collected. The objective of the present article is to provide an overview of the clinical features of cystic lesions around the hip joint.

RADIOLOGICAL EXAMINATIONS

Conventional radiographs are useful for showing underlying hip joint disorders, such as osteoarthritis, rheumatoid arthritis, and acetabular dysplasia, but cannot detect cystic lesions^[5-17]. Arthrography or cystography (bursography) can be used to demonstrate localization, size, and communication with the hip joint of cysts^[9,12-15,18-33]. However, communication between cysts and the hip joint may not be demonstrated when the communication is very narrow or the root has a check valve mechanism^[31]. Ultrasonography is a useful and noninvasive imaging modality for demonstrating the fluid-filled nature of a palpable mass. Cystic lesions can appear as hypoechoic areas on ultrasound examinations^[12,15,16,34-47]. This modality may be used to guide needle aspirations and/or drug injections^[34,48,49]. In contrast, ultrasonography does not show subtle sites of joint communication and has a limited ability to evaluate associated intra-articular abnormalities. CT scan is an excellent tool for assessing abnormalities of calcified tissues because of its high spatial resolution^[8,9,11,12,16,19,25,26,35,50-58]. Cysts have lower attenuation than muscle and higher attenuation than fat. Rim enhancement may be observed after administration of intravenous contrast^[26,59]. Similar to ultrasonography, CT can be used to guide needle aspiration of cysts^[26,60]. MRI is superior to all other imaging modalities for investigating soft tissue abnormalities, particularly for demonstrating the exact location and extent of lesions around the cyst^[6,9-11,16,17,27,37,40,41,52,56,61-75]. This technique offers superior soft tissue contrast and multiplanar capabilities and is noninvasive. Imaging can depict round or ovoid cystic masses with intermediate to low signal intensities on T1-weighted images and high signal on T2-weighted images. Detection of cystic lesions is much easier on fat-suppression T2-weighted or short tau inversion recovery images. MRI with intravenous administration of the contrast agent, Gd-DTPA, on T1-weighted imaging may show rim enhancement and is more useful for diagnosing synovial cysts because synovial proliferations exhibit rapid and marked increases in signal intensity^[9,16,61,67,68,76]. However, after contrast agent injection, no enhancement of the cyst may be evident, even for synovial cysts^[61]. In addition, MRI is very accurate in depicting associated joint disorders, such as acetabular labral tears and degenerative or

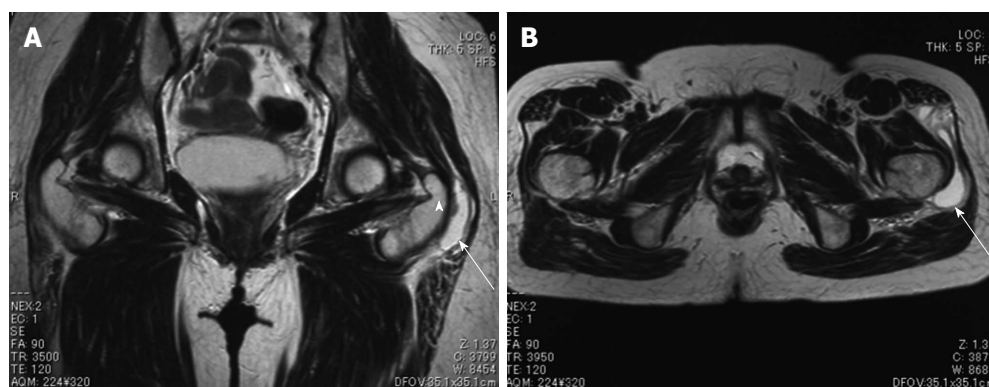


Figure 1 A 58-year-old female with greater trochanteric bursitis. Coronal (A) and axial (B) T2-weighted magnetic resonance images of a cyst located at the characteristic position of the left greater trochanteric bursa (arrow). Arrowhead: Greater trochanter.

inflammatory changes^[4]. MR arthrography can show in detail the relationship of a lesion to a joint and the surrounding structures^[77].

PREVALENCE

Most reports concerning cystic lesions around the hip joints have been single case reports, but O'Cooner^[78] stated that the true incidence is probably higher than that indicated by infrequent cases in 1933. We found 3 reports on the prevalence of cysts in asymptomatic hips on MRI. In 1998, Cotten *et al.*^[79] first reported the MR appearance of the hip labrum in asymptomatic volunteers. They described that intralabral cysts were observed in 3 labra of 52 hips (5.8%). Recently, other studies have shown a high rate of cysts around the hip. Schmitz *et al.*^[80] described cystic lesions in 11 of 42 (26.2%) and 9 of 42 (21.4%) asymptomatic hips identified by 2 different radiologists. Register *et al.*^[81] reported that cysts were identified in 6 of 45 (13%) asymptomatic participants. These results indicate that detection of cysts around the hip joint is no longer an uncommon abnormal MRI finding and the increased sensitivity of MRI has enabled identification of these cysts.

PATHOGENESIS

There are pathologically some types of cystic lesions including ganglion cyst, synovial cyst, and bursa. Ganglion cysts histologically do not have a lining of synovial cells probably because of the result of myxomatous tissue degeneration^[82]. While, synovial cysts have a lining of synovial cells because they may be caused by herniation of the synovium into the surrounding tissue or displacement of the synovium in the embryonal stage. However, the exact cause of these cysts is still unknown^[12,26,61,83,84]. Bursae are fluid-filled sac lined by synovial membrane, which normally present and provide a cushion between bones and tendons and/or muscles. At least 15 synovial bursae have been described around the hip joint, including the trochanteric, iliopsoas, obturator, and ischial bursae^[2,16,23,29,36,85-93] (Figure 1).

The iliopsoas bursa is the largest synovial bursa in the body and is present bilaterally in 98% of adults^[2] (Figure 2). This structure lies between the iliofemoral and pubofemoral ligaments, is adjacent to the thinnest and most vulnerable portion of the anterior capsule, and is the most problematic synovial bursa. In a cadaver study, Chandler found the communication between the iliopsoas bursa and the hip joint in only 14.25% (61 of 400) of adult cadavers and in as many as 40% of hips with osteoarthritis^[11,14,56,94]. The iliopsoas bursitis was first reported by Fricke in 1834 according to Finder^[95]. In 1887, Sprengel also reported a case of bursitis communicating with the hip joint, according to Gatch and Green^[94]. Thus, it is believed that cysts that occur at the anterior of the hip could be inflammation and enlargement of the iliopsoas bursa itself or herniation of the anterior capsule caused by increased intra-articular pressure and an intrinsically weak capsule secondary to underlying inflammatory or degenerative joint disease^[9,11,12,14,15,17,21-27,30,31,35,38-42,45,48,51,53,58,60,61,72,73,75,83,94,96-138]. On the other hand, a distended obturator bursa is believed to be formed by the protrusion of the posterior hip joint between the ischiofemoral capsular ligament and the zona orbicularis^[85]. Trochanteric bursa is located at the lateral aspect of the greater trochanter of the femur^[86-89]. An inflamed trochanteric bursa caused by various conditions is leading to pain in the lateral hip^[70,139-159]. Anyways, it is difficult to distinguish isolated bursitis, pure articular synovial herniation without bursal involvement, or ganglion cysts on radiological or clinical examinations.

Cysts of the hip are usually accompanied by the following various hip disorders such as trauma, avascular necrosis of the femoral head, osteoarthritis, rheumatoid arthritis, and total hip arthroplasty (THA).

Surgical capsular release for hip contracture following a spinal injury

Anterior soft tissue release of the hip is a common procedure for contracture of this joint, particularly in patients with cerebral palsy or following spinal cord injury. There has been only 1 reported case of a cyst formation communicating with the hip joint after this

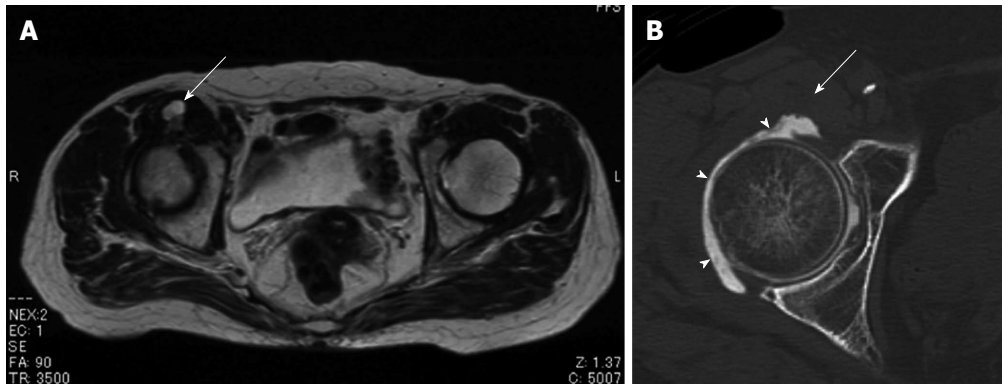


Figure 2 A 81-year-old female with femoral neuropathy caused by distended iliopsoas bursa. Axial T2-weighted magnetic resonance image shows a cystic lesion, which extends anteriorly into the iliopsoas muscle (A). Computed tomography arthrography demonstrates no communication between the cyst (arrow) and right hip joint (B). Arrowheads: Contrast material.

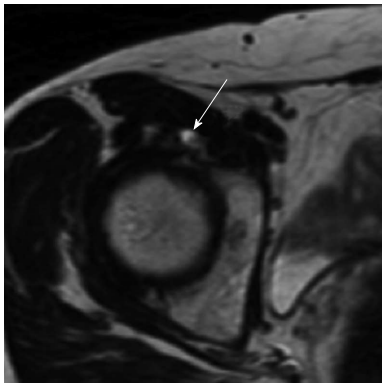


Figure 3 A 50-year-old female with a right hip pain. Axial T2-weighted magnetic resonance image shows a labral tear and paralabral cyst (arrow) at the anterior aspect of the right hip joint.

procedure^[66].

Avascular necrosis of the femoral head

Avascular necrosis of the femoral head is one of the pathogenesis of hip synovial cyst formation^[17,27,62,112,160,161]. The necrosis and deformity of the femoral head lead to joint synovitis and result in osteoarthritis of the hip. Cohen *et al*^[62] first reported iliopsoas bursitis associated with avascular necrosis of the femoral head in a 34-year-old female receiving steroid therapy for systemic lupus erythematosus. Yoon *et al*^[27] reported a similar case involving femoral neuropathy. Plain radiographs show deformity of the femoral head and narrowing of the joint space, which results in osteoarthritis^[27,56,62].

Trauma

Acute or chronic trauma and sports injuries have been mentioned as causative factors of cyst formation around the hip^[5,12,26,94,97,162-165]. O'Conner^[78] suggested that the trauma imparted to the iliopsoas bursa during vigorous hip flexion and extension was the most likely etiological mechanism^[95].

Developmental dysplasia

Lin *et al*^[10] reported a case of a 35-mo-old boy with

a hip ganglion cyst secondary to a labral tear. He was treated with adductor tenotomy, closed reduction, and a hip spica for developmental dysplasia of the hip when he was 14-mo-old.

Labral tear

When cysts around the hip joint are adjacent to the joint capsule and/or the acetabular labrum on MRI, the cause of these cysts has been believed to be synovial fluid that is forced through the labral tear *via* a one-way valve mechanism^[166]. This type of cyst is designated radiologically as a "paralabral or labral cyst"^[5,6,26,40,48,61-64,167] (Figure 3). In 1989, Haller *et al*^[5] first described the relationship between a cystic mass adjacent to the acetabulum and a labral tear. They illustrated that synovial tissue or fluid may extrude from the joint through the labral tear and lead to accumulation of fluid and cyst formation in the adjacent soft tissues as one factor in the pathogenesis of juxta-acetabular cysts. In 1994, Tirman *et al*^[168] determined that a glenoid labral tear of the shoulder was associated with a cystic mass and termed the mass a "labral cyst". The same group applied the term to similar cysts of the hip joint^[6]. Schnarkowski *et al*^[6] reported that of the 7 labral cysts, 5 were localized at the posterosuperior and 2 at the anterior. They described that the posterosuperior part of the labrum was the most vulnerable to mechanical stress and an easier site to detach by trauma, which could lead to cyst formation^[169]. Furthermore, Magee *et al*^[166] reported 10 patients who underwent surgery for labral cysts and had associated labral tears located in the area of the labral cyst. Seven of the tears occurred posteriorly and 3 occurred anteriorly. Recent reports of case series described that paralabral cysts were localized anterosuperiorly in 56% (10 of 18) of the patients, anteriorly in 22% (4 of 18), posterosuperiorly in 17% (3 of 18), anteroinferiorly in 6% (1 of 18), posteriorly in 0%, and posteroinferiorly in 0% on MR arthrographic analysis^[77]. This result was consistent with the fact that most labral tears have occurred anterosuperiorly on evaluation by MR arthrography^[170,171]. The labral cyst of the hip may be a predisposition to labral pathology. MR

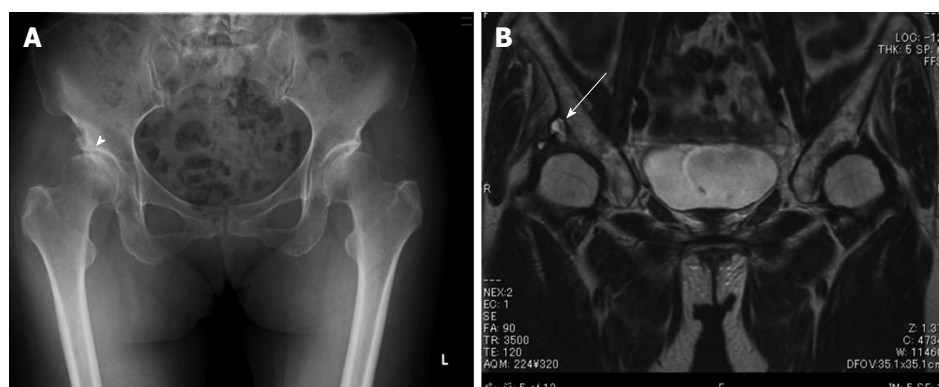


Figure 4 A 70-year-old female with a cystic lesion associated with osteoarthritis. Plain radiograph of the lower pelvis reveals the secondary osteoarthritis of right hip due to acetabular dysplasia (arrowhead) (A). Coronal T2-weighted magnetic resonance image shows a cystic mass (arrow) located superiorly, connected to the right hip joint (B).

arthrography can increase the sensitivity and accuracy for detection of the associated labral tears. Recently, arthroscopic treatment for acetabular labral tear and paralabral cyst has been reported^[63,172,173]. Tey *et al.*^[172] reported a case with acetabular labral tear and labral cyst caused by psoas impingement. In this case, the psoas tendon was released and the labral cyst was finally excised; reattachment of the labral tear was finally performed using a suture anchor. Kanauchi *et al.*^[173] also reported a combination treatment with arthroscopic labral repair and ultrasound-guided cyst aspiration for the acetabular paralabral cyst causing femoral nerve paresthesia. In contrast, Lee *et al.*^[63] described an arthroscopic treatment by cyst decompression and debridement of the degenerative labrum for labral cyst and tear. Thus, arthroscopic findings will be useful for further understanding of labral cysts.

Osteoarthritis

Osteoarthritis is a degenerative joint disease, which causes joint pain and stiffness. More than 80% of all cases of idiopathic osteoarthritis of the hip joint may be because of subtle congenital or developmental defects, which increase joint incongruity and concentrate the dynamic load (Figure 4). Dynamic loads cause displacement of synovial fluid, which in turn may cause synovial cyst development^[11,12,14,22,26,30,32,35,38,51,68,83,96,119,127,174-180].

Rapidly destructive arthrosis of the hip

Rapidly destructive hip disease (RDHD) is a rare entity that involves aggressive hip joint destruction within 6-12 mo of onset. Inflammatory arthritis is always caused by cartilage and bone destruction in such cases. Iliopsoas bursitis also has been seen in 2 reported RDHD cases^[129,135].

Rheumatoid arthritis

Rheumatoid arthritis is an autoimmune disease that results in a chronic inflammatory response of the synovial joint capsule secondary to swelling due to excess synovial fluid and development of the synovium. The occurrence of synovial cyst of the hip in patients with rheumatoid

arthritis has been reported^[7,9,12,13,21,26,28,37,45,54,56,65,72,99-101,106,114,115,130,134,135,138,160,176,178,181-190].

Coventry *et al.*^[7] described 3 cases of rheumatoid synovial cysts of the hip. Two of 3 patients had edema of the extremities due to compression of the femoral vein caused by enlarged synovial cysts. They documented 3 theories regarding the etiology of rheumatoid synovial cyst formation. First, overproduction of synovial fluid in a rheumatoid cyst may increase the intra-articular pressure and distend the joint capsule. Second, the iliopsoas bursa, which is sometimes directly connected with the hip joint, may be involved in the rheumatoid process with formation of excessive quantities of fluid^[12,24,33]. Third, necrosis of a subcutaneous periarticular rheumatoid nodule possibly could result in the formation of a juxta-articular cyst. However, the exact etiology of rheumatoid synovial cysts cannot be determined. Although some similar cases of rheumatoid cysts have been reported following Coventry's cases^[9,13,21,65], interestingly, all of the rheumatoid arthritis-associated cysts in the reported cases were localized anteriorly. This finding suggests that the iliopsoas bursa is involved in cyst formation associated with rheumatoid arthritis.

Juvenile idiopathic arthritis

Juvenile idiopathic arthritis (JIA) is an autoimmune arthritis in children less than 16 years of age. Iversen *et al.*^[41] described about the enlargement of the iliopsoas bursae communicated with the hips in a JIA patient.

Polymyalgia rheumatica

Polymyalgia rheumatica (PMR) is an inflammatory disorder that causes pain and stiffness in the neck, shoulder and pelvic girdle. Tani *et al.*^[128] reported a case of enlargement of iliopsoas bursa due to PMR.

Hip arthroplasty

In 1984, Kolmert *et al.*^[25] first reported 2 cases of cyst formation after THA. Moreover, some case reports have been published about cystic lesions after joint replacement^[8,19,20,31,50,53,64,71,83,109,123,126,132,191-231]. Initially, these cysts were believed to be subclinical infections, but

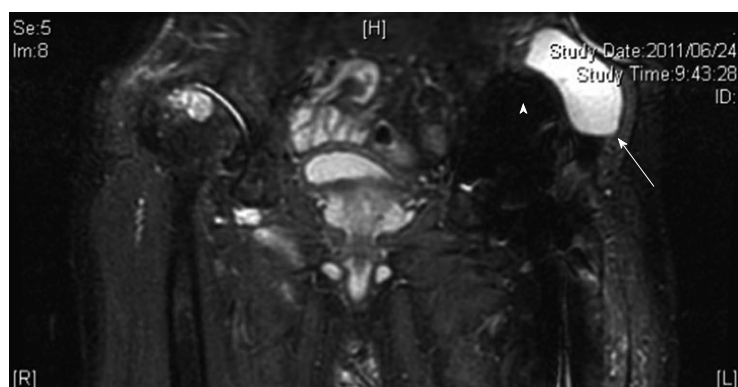


Figure 5 A 76-year-old male with a pseudotumor following cemented total hip arthroplasty, which was implanted 18 years earlier. Coronal short tau inversion recovery magnetic resonance image shows a cystic lesion (arrow) adjacent to the acetabular component (arrowhead).

currently they are called “granulomatous pseudotumor” resulting from polyethylene, metal, or cement wear debris, which is phagocytosed by inflammatory cells and macrophages that cause a foreign body reaction^[8,20,31,53,64,196,197,199-201,203-205,208,212,213,215,220-222] (Figure 5). On the other hand, some cysts may be distended iliopsoas bursitis as a tissue response to wear debris, but not newly formed granuloma^[31,50,126,132,136,137,195,198,232].

In 2005, Willert *et al.*^[214] first described the development of an inflammatory synovial reaction as a novel complication associated with metal-on-metal (MoM)-bearing hip replacements^[211,214]. A distinct histological pattern is observed and characterized by diffuse perivascular infiltrates of T and B lymphocytes, high endothelial venules, fibrin exudation, eosinophils, and necrosis. It is thought to be a variation of a type IV delayed hypersensitivity and has been termed an aseptic lymphocyte-dominated vasculitis-associated lesion (ALVAL). Adverse reactions to metal debris, including ALVAL and pseudotumor formation, should be considered as a diagnosis in any patient with unexplained groin pain or a mass following a MoM THA^[137,203,216,217,223,224,233-238]. In general, patients with pseudotumors may be asymptomatic^[193,207,208] or present with mild groin pain^[20,196,201,213,220]. If the expansive lesions are intrapelvic, they may compress the adjacent structures, including the ureters^[212], intestines^[218], vessels^[50,137,192,195,198,199,203,220,222,223], and nerves^[8,19,53,64,210,216,217,224]. Compared with cystic lesions, solid lesions can more easily cause femoral palsy and revision THA^[217]. Cystic lesions associated with THA can be one of the signals for implant failure or loosening.

Others

Gas-containing cysts of the hip have been reported infrequently. Gas may be seen on conventional plain radiography, linear tomography, or CT^[239]. This gas may be difficult to differentiate from overlying bowel gas and other causes of gas within soft tissues^[240]. Gas may be present inside distended iliopsoas bursae because of a gas-pumping mechanism, which may lead to a misdiagnosis. Silver *et al.*^[239] reported 3 cases of

gas-containing ganglia arising from the hip joints with advanced osteoarthritis. Haller *et al.*^[5] also reported that gas was demonstrated in 4 cystic lesions around the hip joint associated with degenerative hip disease.

It should be noted that a cystic mass around the hip may not be a synovial or ganglion cyst but may originate from the adventitia of the common femoral artery or vein. The latter has been called “adventitial cystic disease”, which is an uncommon type of nonatherosclerotic peripheral vessel disease and is characterized by accumulation of a mucinous substance in the adventitia^[241-244]. These substances cause symptoms of intermittent claudication or leg swelling because of obstruction of arteries or veins.

The differential diagnosis of a mass in the inguinal region includes various conditions, such as pigmented villonodular synovitis^[245,246], synovial chondromatosis^[93,108,247,248], arterial aneurisms, femoral hernias^[249,250], inguinal lymphadenopathy, and abscess^[25,33,40,60,70,90,120,140,142,145,149,151,153,154,156,181,229] (Figure 6). Careful clinical and radiological examinations will help confirm or exclude a diagnosis.

SYMPTOMS

Cysts around the hip joint are often asymptomatic^[10,11,54] (Figure 7). When cysts impinge upon nerves or vessels, they may become symptomatic.

Pain and/or swelling

Although pain is not a universal feature, it is frequently the earliest and may be the only cyst symptom, which may include bursitis^[9-11,13-15,20,25,31,32,43,56,61,63,65,74,111,113,114,118,122,141,144,174,175,196,201,213,220,228,251-253]. An inguinal mass and groin or thigh pain usually comprise the clinical presentation in some patients. Akman *et al.*^[252] reported a case of a hip ganglion presenting with symptoms of right-sided groin pain. A larger mass caused nocturnal femoral pain^[254]. Inguinal swelling also has been reported as another rare presentation of a hip cyst when the cysts grow anteriorly^[43,116,118,255,256] or posteriorly^[257]. A soft mass over the femoral triangle could be misdiagnosed

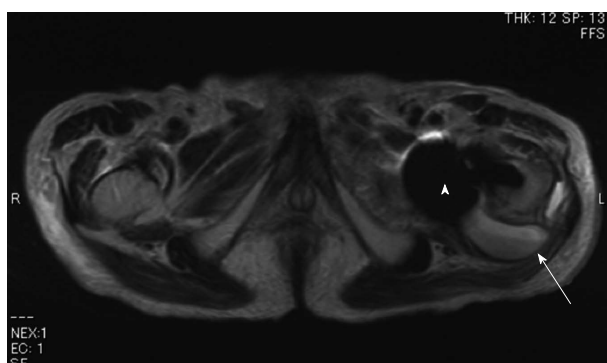


Figure 6 A 93-year-old male with an infection after hemiarthroplasty for the left femoral neck fracture. Axial T2-weighted image reveals a cystic lesion with a fluid-fluid level (arrow) adjacent to the posterior aspect of the endoprosthesis (arrowhead).



Figure 7 A 71-year-old female with the left femoral neck fracture. Coronal T2-weighted magnetic resonance image shows an asymptomatic multilocular cystic mass (arrow), which is communicated with the right hip joint.

as a femoral hernia^[249,250].

Snapping

Iliopsoas bursitis is often associated with the snapping hip syndrome^[24,29,48,49,121,143]. The snapping hip syndrome involves the iliopsoas tendon snapping over the iliopectineal eminence and the anterior hip capsule or a lesser trochanteric bony prominence. Harper *et al.*^[24] reported 2 cases with a painful audible snapping hip. In literature, the snapping was reproduced voluntarily by extending the flexed, abducted, and externally rotated hip, and iliopsoas bursography was a useful technique for diagnosis of this syndrome. Snapping could disappear by release of the tendinous portion in these cases^[21,29,49,121].

Peripheral nerve compression

Femoral nerve: Approximately 20 cases about femoral nerve compression due to a cystic lesion around the hip joint have been described in literature^[8,17,27,35,52,53,55,66,68,73,112,130,134,138,173,189,254,258-260]. The symptoms were described as radicular pain caused by compression of the femoral nerve and by hypoesthesia and/or paresthesia in the groin radiating down to the medial thigh, the anterior aspect of the knee, and the medial side of the lower leg and foot. Some patients complained of their inability to climb stairs and walking because of hip pain and muscle weakness. These symptoms mimic L2-4 radiculopathy with lumbar disorders, such as lumbar disc herniation and lumbar spinal canal stenosis^[68,258]. Physical examination may reveal tenderness over the anterior hip, limited range of motion of the affected hip joint, sensory disturbance of the femoral nerve area, and atrophy of the thigh. The iliopsoas and quadriceps femoris muscle may be weak^[27,35], accompanied by diminished patellar tendon reflexes^[8,35,53]. The hip is held in flexion with some adduction and external rotation. Pain is elicited by hyperextending, abducting, or internally rotating the hip. On radiological examinations, radiography of the pelvis may show severe degenerative hip disease, which causes iliopsoas bursitis in some cases^[17,27,35,68,112,130,134,189]. The cysts with femoral nerve compression are always located in the anterior

hip and are mostly synovial cysts because of the relationship with the iliopsoas bursa (Figure 2). On the other hand, although rare, a few cases with femoral nerve compression caused by ganglion cyst have been reported^[52,259]. Recently, a few reports have described wear debris from THA that produced a clinically detectable mass that could provoke delayed femoral nerve palsy^[8,53,173,217,261], although some cases had solid pseudotumors but not cystic lesions.

Obturator nerve: Obturator neuropathy can be caused by various conditions, such as pelvic fracture, THA, or obturator hernia, but obturator nerve compression by a cyst is extremely rare. Only 4 cases have been reported^[34,68,262,263]. In 2002, Campeas *et al.*^[262] first reported a case with obturator neuropathy caused by a ganglion cyst arising from the hip joint. In 2005, Yukata *et al.*^[34] presented a case with obturator neuropathy caused by a cyst associated with an anterior acetabular labral tear and its detailed MRI findings. Stuplich *et al.*^[68] also reported a case with combined femoral and obturator neuropathy caused by synovial cyst from moderate arthrosis of the hip. The main symptom of obturator nerve compression is pain in the right groin and anteromedial thigh^[34]. The tenderness occurs over the adductor muscles, and Patrick's sign (hip flexion, abduction, external rotation, extension position) may be positive and passive straight leg raising test is negative. The weakness of hip adductors due to pain and the absence of the adductor reflex could have been detected^[68]. MRI of the pelvis has shown a cystic lesion at the medial aspect of the right acetabulum with its stalk continuing to the anterior labral tear^[34] or extending into the obturator muscles toward the obturator nerve^[68] (Figure 8). Further, the muscles of the obturator nerve area may show atrophy and increased signal intensity on T2-weighted images, which indicates denervation^[34,263].

Sciatic nerve: Sciatic neuropathy has been reported secondary to a cystic lesion around the hip joint^[19,64,67,69,264-268]. In 1991, Juglard *et al.*^[264] first reported a case with sciatic nerve compression by a cystic lesion. In

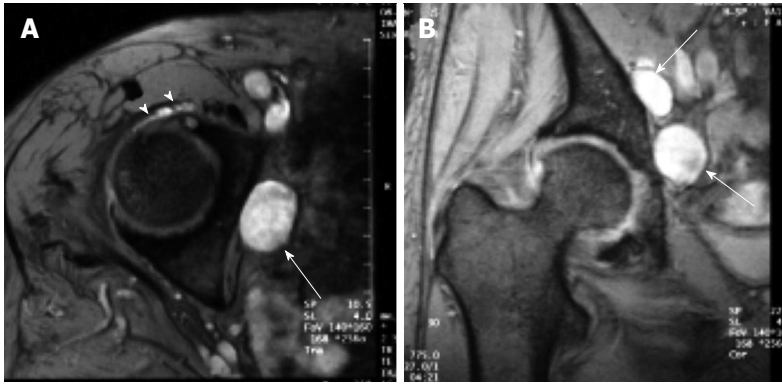


Figure 8 A 75-year-old female with obturator neuropathy. Axial (A) and coronal (B) short tau inversion recovery magnetic resonance images show that the location of the cystic masses (arrows) is consistent with the site of obturator nerve (Ref: [26]). The stalk of the cyst was connected to the anterior joint capsule (arrowheads).

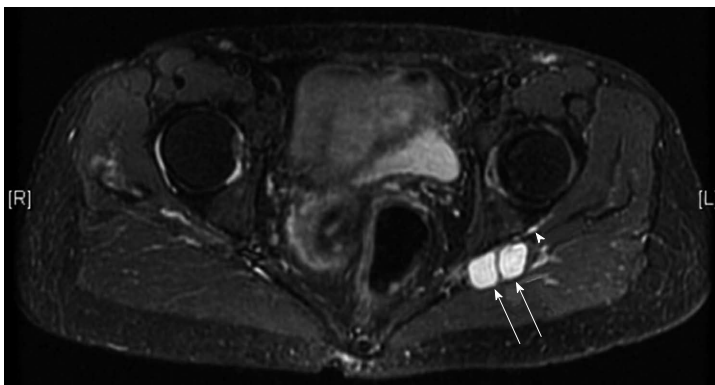


Figure 9 A 67-year-old female with a sciatica. Axial short tau inversion recovery magnetic resonance image demonstrates cysts at the posterior aspect of the left acetabulum (arrows). The stalk is connected to the posterior joint capsule (arrowhead).

addition, some similar cases have been reported until 2014^[67,69,265-267,269]. These patients presented with increasing buttock pain radiating downward to the posterior thigh and knee and the lateral aspect of the lower leg and sole, which is the so-called sciatica. The patient may have a paresthesia of the lateral calf and sole. Physical examination may reveal no sensory disturbance or muscle weakness of the lower leg, and the hip range of movement is full or mildly limited. Tenderness may be over the posterior hip. The straight leg raising test was negative in all reported cases, but the pain around the hip was elicited by hip rotations^[67,69]. MRI clearly showed a cystic mass in the sciatic notch or extending posteriorly to the femur intertrochanteric lesion. Histological evaluation of these cysts demonstrated that the cyst wall was composed of variably dense fibroconnective tissue with no lining cells, which suggests a ganglion cyst^[67,69,264,267,268], while the recent case reported by Salunke *et al.*^[265] was histologically diagnosed as a synovial cyst. Sciatic neuropathy as a late complication is sometimes caused by a cystic formation due to polyethylene or titanium wear debris after THA^[19,64,206]. Fischer *et al.*^[19] first described a patient with sciatic neuropathy following compression caused by an intrapelvic synovial cyst that formed in response to wear debris. Crawford *et al.*^[206] reported 3 cases of compression of the sciatic nerve

caused by polyethylene wear debris at the revision THA surgery. Recently, Mert *et al.*^[64] also reported that minor polyethylene wear at the edge of the liner and cracking of the titanium acetabular shell were observed at the revision THA. Histological examination showed that the resected cyst included foreign-body giant cells along with abundant titanium deposits and polyethylene particles. These cystic masses with sciatic neuropathy following THA appear to be synovial cysts connected with the joint space. We present MRI findings of an unpublished case of sciatic neuropathy due to a cystic lesion in which the patient had a 1-mo history of increasing pain in the left buttock and lower leg with an insidious onset (Figure 9).

Lateral cutaneous femoral nerve: Meralgia paraesthetica is numbness or pain in the outer thigh caused by entrapment of the lateral cutaneous femoral nerve. Only one case was reported as a compression neuropathy caused by a hip joint synovial cyst associated with rheumatoid arthritis^[270].

Artery compression

Compression of the femoral artery causes leg ischemia. Byström *et al.*^[51] reported a 75-year-old female with a large cyst that was compressing the femoral artery. The symptoms were an intermittent, unpleasant sensation of coolness in the foot and hip pain. The cyst was

communicating with a severely osteoarthritic hip joint. Beardsmore *et al*^[271] and Stanek *et al*^[272] also reported ganglion cysts arising from the hip joint or psoas sheath that compressed the artery and caused symptoms of intermittent claudication. Furthermore, Zack *et al*^[57] presented an occlusion of the external iliac artery due to a giant synovial cyst that was produced by polyethylene wear debris after THA. In such cases, angiography can demonstrate occlusions of the external iliac or common femoral artery^[57,263,264].

Vein compression

Compression of the femoral or iliac vein caused by a cyst of the hip joint results in leg swelling, which resembles that caused by deep vein thrombosis, and is called pseudothrombophlebitis. Previously, over 40 cases of vein compression due to a cystic lesion around the hip have been described in literature^[12,21,23,50,56,73,83,101-103,107,110,115,125,131,133,137,138,176,179,188,190,192,196,198,209,220,222,230,232,254,273-289]. Radiography of the pelvis was useful for observing the presence of hip disorders because rheumatoid arthritis or osteoarthritis was present in approximately two-thirds of the cases^[276]. Extrinsic compression of the external iliac and femoral veins by the mass can be observed by venography. Venography is also useful if deep vein thrombosis is suspected and needs to be excluded. A cystic lesion of the hip joint should be taken into consideration in the differential diagnosis of deep vein thrombosis.

Urinary symptoms

When a cyst compresses the ureter or bladder, the patient may complain of dysuria, frequency, and nocturia, or have no symptoms^[18,83,182,226]. Intravenous pyelography can reveal obstruction of the ureter, which results in hydronephrosis of the kidney^[212]. Watson and Ochsner reported a case with high urinary frequency and dribbling caused by compression of the lateral walls of the bladder due to a distended iliopsoas bursa^[182].

TREATMENT

Although variable therapeutic strategies have been used for cystic lesions of the hip, treatment of the cysts depends on their size, the severity of symptoms, the nature of the underlying disease or associated condition, and the presence or absence of local compression. When cysts of the hip are asymptomatic, they can be treated by observation^[22,54,253]. When an enlarged and painful cyst is suspected to be a synovial cyst or bursitis, rest, nonsteroidal anti-inflammatory medications, application of local heat, and physical therapy may provide symptomatic relief^[7,21,96,98,100]. If the cyst is a synovial cyst caused by rheumatoid arthritis, prednisone and methotrexate may be effective for decreasing the symptoms^[40,114,136,152]. In addition, injection of local anesthetic and/or corticosteroids following needle aspiration may be considered as a treatment option^[7,23,83,98,100,112,175,185,258]. When patients have compression

neuropathy or obstruction of an artery, vein, or ureter due to a cyst, they are often treated by aspiration of the cyst or surgical excision. Colasanti *et al*^[276] reviewed 27 cases with vessel compression due to cysts. Needle aspiration was initially performed in 8 of the patients, and the other 19 patients were treated by surgical removal of the cysts associated with synovectomy or capsulectomy^[12,21,23,51,68,83,101-103,110,125,131,176,188,254,273,275-280,282-284,286]. Lower limb swelling recurred in 3 of 8 patients (37%) initially treated with needle aspiration, whereas recurrence was noted in only 1 surgically treated patient (5%). This result indicated that surgical excision is a more reliable technique for prevention of recurrence^[107,130,134,147,148,189,260,290,291]. However, we still believe that needle aspiration/puncture should be the first treatment choice because simple needle aspiration/puncture has been shown to decrease the cyst size and symptoms in some cases involving vein or nerve compression^[21,83,125,131,286], it is easier to perform and less invasive than surgery, and the contents of a cyst can aid diagnosis^[34,195,286]. When a cystic lesion associated with osteoarthritis, rheumatoid arthritis, and THA is excised, primary or revision THA surgery may be necessary to relieve the pain and improve hip functions^[9,38,119,127,180].

CONCLUSION

Almost all cystic lesions around the hip joint will be asymptomatic, but recently, they are frequently discovered by CT or MRI examinations. Enlargement of a cyst, including the bursa, might cause unexplained hip pain. Furthermore, when cysts compress their surrounding structures, such as nerves or vessels, various symptoms will appear depending on the compressed tissue. In orthopaedics, leg pain, intermittent claudication, or leg edema are common symptoms in lumbar spine or vascular disorders. In such cases, cysts around the hip should be considered as the differential diagnosis.

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Basic Study

Comminuted olecranon fracture fixation with pre-contoured plate: Comparison of composite and cadaver bones

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Abstract

AIM: To determine whether use of a precontoured olecranon plate provides adequate fixation to withstand supraphysiologic force in a comminuted olecranon fracture model.

METHODS: Five samples of fourth generation composite bones and five samples of fresh frozen human cadaveric left ulnae were utilized for this study. The cadaveric specimens underwent dual-energy X-ray absorptiometry (DEXA) scanning to quantify the bone quality. The composite and cadaveric bones were prepared by creating a comminuted olecranon fracture and fixed with a pre-contoured olecranon plate with locking screws. Construct stiffness and failure load were measured by subjecting specimens to cantilever bending moments until failure. Fracture site motion was measured with differential variable resistance transducer spanning the fracture. Statistical analysis was performed with two-tailed Mann-Whitney-U test with Monte Carlo Exact test.

RESULTS: There was a significant difference in fixation stiffness and strength between the composite bones and human cadaver bones. Failure modes differed in cadaveric and composite specimens. The load to failure for the composite bones ($n = 5$) and human cadaver bones ($n = 5$) specimens were 10.67 nm (range 9.40-11.91 nm) and 13.05 nm (range 12.59-15.38 nm) respectively. This difference was statistically significant

($P < 0.007$, 97% power). Median stiffness for composite bones and human cadaver bones specimens were 5.69 nm/mm (range 4.69-6.80 nm/mm) and 7.55 nm/mm (range 6.31-7.72 nm/mm). There was a significant difference for stiffness ($P < 0.033$, 79% power) between composite bones and cadaveric bones. No correlation was found between the DEXA results and stiffness. All cadaveric specimens withstood the physiologic load anticipated postoperatively. Catastrophic failure occurred in all composite specimens. All failures resulted from composite bone failure at the distal screw site and not hardware failure. There were no catastrophic fracture failures in the cadaveric specimens. Failure of 4/5 cadaveric specimens was defined when a fracture gap of 2 mm was observed, but 1/5 cadaveric specimens failed due to a failure of the triceps mechanism. All failures occurred at forces greater than that expected in postoperative period prior to healing.

CONCLUSION: The pre-contoured olecranon plate provides adequate fixation to withstand physiologic force in a composite bone and cadaveric comminuted olecranon fracture model.

Key words: Composite bone; Fracture; Biomechanic; Cadaveric; Olecranon; Precontoured plate

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Core tip: Comminuted olecranon fractures present a clinical and surgical challenge. Fixation with traditional tension band constructs is difficult due to comminution involving the articular surface. We describe a method if achieving fixation using a precontoured olecranon plate. In our biomechanical model using composite bones as well as cadaveric specimen, this method of fixation provides fixation of comminuted olecranon fractures capable of withstanding the expected physiologic force in the early postoperative period.

Hamilton Jr DA, Reilly D, Wipf F, Kamineni S. Comminuted olecranon fracture fixation with pre-contoured plate: Comparison of composite and cadaver bones. *World J Orthop* 2015; 6(9): 705-711 Available from: URL: <http://www.wjgnet.com/2218-5836/full/v6/i9/705.htm> DOI: <http://dx.doi.org/10.5312/wjo.v6.i9.705>

INTRODUCTION

Comminuted olecranon fractures are relatively common injuries. Most displaced fractures benefit from surgical treatment. These fractures, especially unstable injuries involving the coronoid process, are not amenable to tension band fixation and benefit from open reduction internal fixation with a plate. Zuelzer^[1] first reported successful application of a hook plate in a comminuted olecranon fracture in his 1951 case report. Plate fixa-

tion is increasingly used to treat displaced olecranon fractures and therefore considered as the gold standard for treatment^[2-6]. Reports on application of plate fixation for comminuted olecranon fractures have demonstrated variable results^[2]. Reports of these contoured olecranon plating demonstrated to more positive results^[5,7-10].

Biomechanical features of plate fixation including stiffness and strength have previously been reported, for comminuted olecranon fractures^[11,12]. Despite recognized limitations, using bone substitute material makes it easier to answer some of the relevant research questions. Bone substitute materials are helpful in achieving more consistent test data than cadaveric bones due to human skeletal variability. Composite bones enable testing of several parameters at lower costs when compared to cadaveric specimen. Furthermore, the uniformity of composite bone specimens allows direct comparison of datasets.

The purpose of this study was twofold: (1) assess fixation of a comminuted intra-articular olecranon fracture with a locked pre-contoured plate in an *in-vitro* model; and (2) determine whether fourth generation composite bones are biomechanically comparable to human cadaveric bones under destructive loading conditions.

MATERIALS AND METHODS

Five samples of composite bone substitutes (Sawbones Cat#3426, large left ulna, fourth generation composite bone) per test group and five samples of fresh frozen human cadaveric left ulnas per test group were utilized for this study. A priori power analysis was performed to determine sample size. The five left fresh-frozen human cadaveric elbows were thawed prior to testing. These were five left male specimens with a mean age of 60.6 years (range 51-86 years). These specimens were subjected to dual-energy X-ray absorptiometry (DEXA) scanning to quantify the bone quality.

For the cadaveric bones, soft tissues were completely resected, with the exception of the triceps tendon. No evidence of previous injury or arthritis was found in any of the ulna cadaveric bones.

Specimens (fresh human, non-preserved) were received and stored at -20 °C prior to and following dissection. After hardware implantation, specimens were not refrozen and underwent mechanical testing.

The ulna was positioned in a custom cutting jig and locked into position with K-wires, prior to osteotomy creation^[11], of a simulated comminuted fracture. A pre-contoured olecranon plate (Stryker Trauma AG, Selzach, Switzerland) was fixed onto the posterior aspect of the ulna with five VariAx 3.5 mm locking and two VariAx 3.5 mm non-locking screws (Figures 1 and 2). In each ulna (composite and human), the screw application was kept consistent with respect to length and configuration (Figure 1 and Table 1) with one at the olecranon tip, two through the olecranon, and four distal to the fracture (Figure 2). Screw length variability was dictated by the

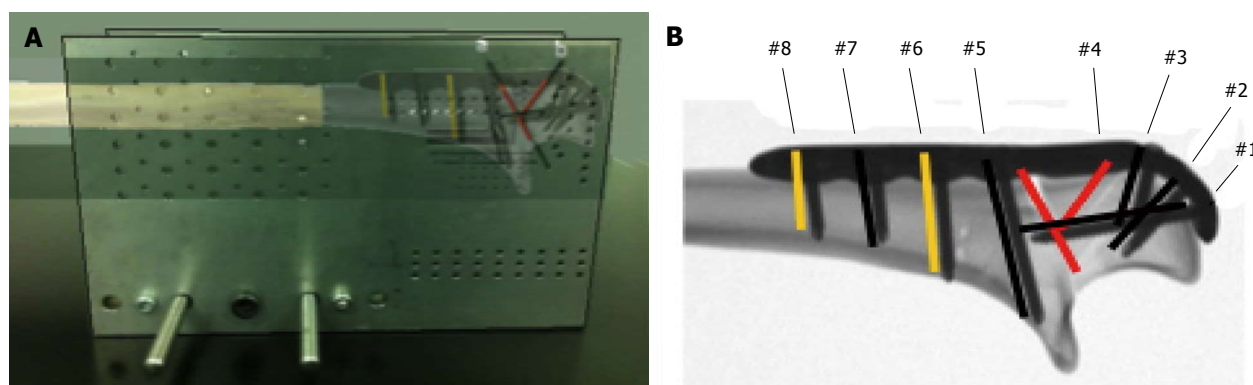


Figure 1 Custom osteotomy jig with plate and screw construct. A: Rendered photo of the jig used to create the comminuted olecranon fracture, with an overlay of the ulna, demonstrating the positioning of the bone in relation to the saw blade slots; B: A radiograph of the olecranon plate and screw construct in relation to the fracture. Screws placed in positions as indicated in Table 1.

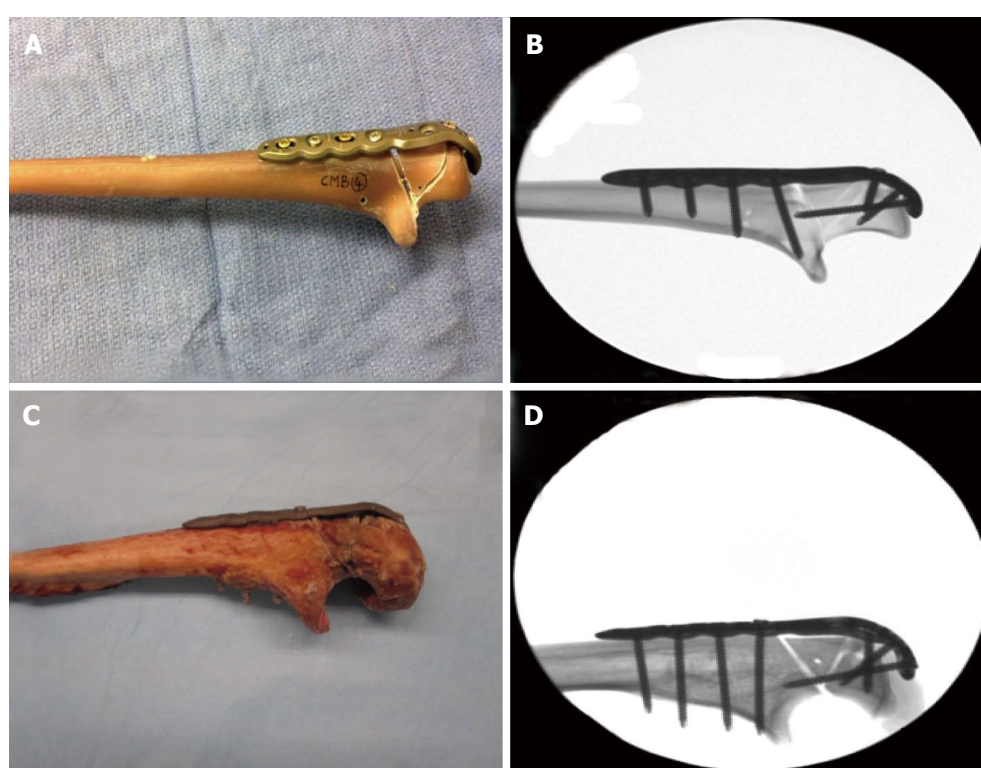


Figure 2 Fourth generation composite bone (A) and human cadaveric bone (C) with a comminuted olecranon fracture, fixed with a pre-contoured plate and screw construct, and lateral fluoroscopic radiographs of the composite bones (B) and human cadaveric ulna (D). The fracture is fixed with the olecranon plate and fixation screw.

anatomical variation of the human specimens. After fracture fixation with plate and screws, the K-wires were removed.

Tests were performed in a custom designed test apparatus (Figure 3) with the standardized osteotomy analogous to that described by Buijze *et al.*^[11] and Gordon *et al.*^[12] in their cadaveric models as well as others^[13-15]. For cadaveric bones, the triceps tendons were fixed with a soft-tissue clamp, and the proximal ulna was also fixed with a bolt similar to the composite bones for more stability. For composite bones, the proximal ulna was fixed with an olecranon tip bolt only, simulating the attachment of the triceps tendon. Cantilever bending

load was applied to the ulna with a lever-arm of 200 mm (measured from the elbow joint rotational axis to the point of load application). The starting position was 70° flexion^[11], when the cantilever force was not in contact with the bone. A differential variable resistance transducer (DVRT; MicroStrain, United States), with a $\pm 1 \mu\text{m}$ accuracy, was attached across the bony fracture site (Figure 3). Fracture displacement, as determined by the DVRT, was recorded from the fracture site before, during, at, and after load to failure was achieved.

Force was applied at the rate of 1 mm/s (actuator speed) until each specimen failed catastrophically, determined both visually and *via* live data from the

Table 1 Screw types used

Plate hole number	#1	#2	#3	#4	#5	#6	#7	#8
Screw types used in composite bones L/NL/-	L	L	L	-	L	NL	L	NL
Screw types used in cadaveric bones L/NL/-	L	L	L	-	L	NL	L	NL

L: Locking; NL: Non-locking; -: None.

Table 2 Load to failure criterion of 2 mm gapping, displacement, stiffness and bone density per specimen

	Composite bones					Human cadaver bones				
	1	2	3	4	5	1	2	3	4	5
Load to failure criteria (nm)	11.91	9.40	10.97	10.67	9.64	15.10	12.59	13.05	13.02	15.38
Displacement (mm)	1.76	2.00	1.85	2.00	1.70	2.00	2.00	1.71	2.00	2.00
Stiffness (nm/mm)	6.80	4.69	5.95	5.33	5.69	7.55	6.31	7.62	6.52	7.72
Bone density (g/cm ²)	-	-	-	-	-	0.723	0.456	0.658	0.665	0.883
Failure mode	Distal fracture	Fracture gap	Distal fracture	Fracture gap	Distal fracture	Fracture gap	Fracture gap	Triceps failure	Fracture gap	Fracture gap

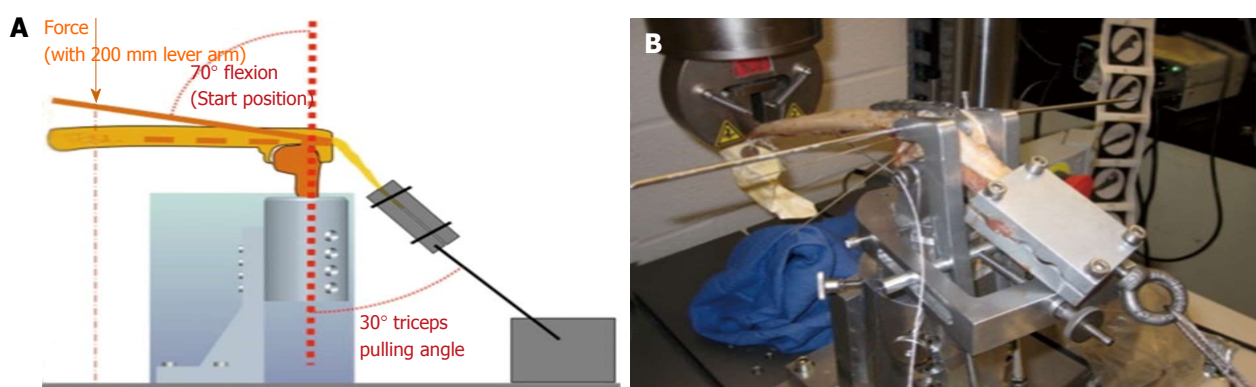


Figure 3 Custom mounting device. A: Pictorial representation of the test apparatus, demonstrating the ulna mounted on a potted distal humeral mould. The force was applied at 200 mm from the joint, and the triceps is clamped and retracted at a 30 degree angle; B: Photograph of the experimental setup, which includes the differential variable resistance transducer placed across the fracture site to measure fracture motion.

Instron graphic software. Failure load was recorded for each specimen and the mode of failure was noted. The load at ≥ 2 mm displacement was obtained from the data files.

Statistical review of the data was performed by a biomedical statistician prior to submission and peer review. The results were statistically analyzed with two-tailed Mann-Whitney-U test a nonparametric measure of statistical dependence between these 2 variables (10000 samples) with statistical significance ascribed a value of $P < 0.05$. In addition, power was calculated (2-tailed, $\alpha = 0.05$) where 80% was considered as sufficient power (IBM SPSS Sample Power 3).

The Kaplan-Meier survival function was estimated for load to failure results. The result plot estimated the cumulative survival at a certain load value (estimated survival rate at certain load application). The correlation between stiffness or failure load and bone mineral

density was analyzed with a two-tailed Spearman's rank correlation coefficient.

RESULTS

Failure was defined as either a 2 mm fracture gap or complete failure (Figure 4). The load to failure for the composite bones ($n = 5$) and human cadaver bones ($n = 5$) specimens were 10.67 nm (range 9.40-11.91 nm) and 13.05 nm (range 12.59-15.38 nm) respectively (Figure 5 and Table 1). This difference was statistically significant ($P < 0.007$, 97% power). Median stiffness for composite bones and human cadaver bones specimens were 5.69 nm/mm (range 4.69-6.80 nm/mm) and 7.55 nm/mm (range 6.31-7.72 nm/mm). There was a significant difference for stiffness ($P < 0.033$, 79% power) between composite bones and cadaveric bones (Figure 5). Displacements for these specimens were

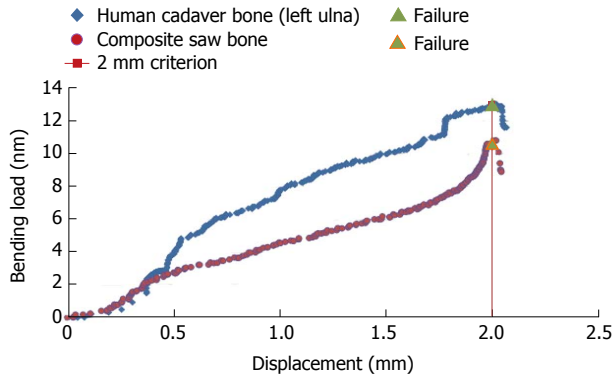


Figure 4 Sample graphs showing the force-displacement curve during destructive loading for composite bone and human cadaver bone specimens.

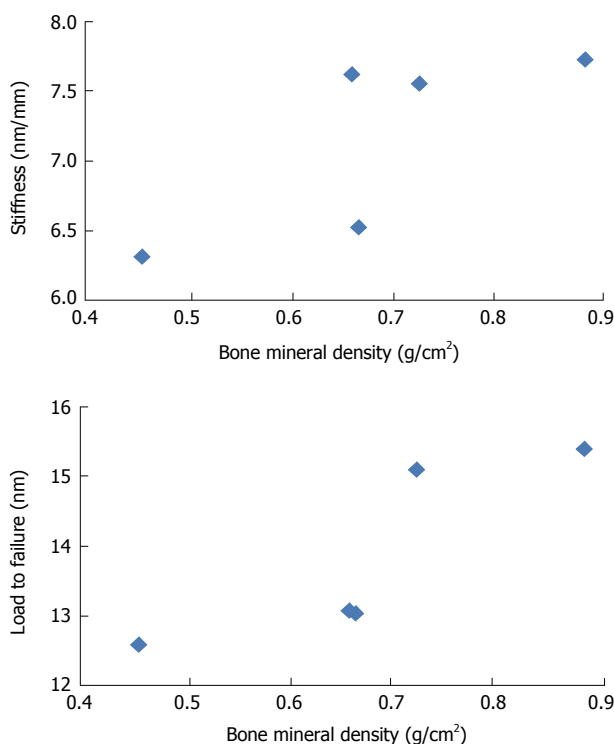


Figure 6 Bone mineral density in human cadaver bones (left ulnas), $n = 5$.

not compared, due to the 2 mm failure criterion. DEXA scans were used to assess cadaveric bone mineral density (Table 2 and Figure 6). Overall, the DEXA bone mineral density (BMD) for human cadaver specimens ranged from 0.456 to 0.883 g/cm², with a mean of 0.677 g/cm². BMD correlated with load to failure ($P = 0.037$), but did not correlate with stiffness ($P = 0.188$). Previous studies have shown that BMD significantly correlated with fracture loads in isolated human cadaveric pelvis^[16] and femurs^[17-19].

In the plated specimens, catastrophic failure occurred in 3/5 fourth generation composite bone specimens before the pre-defined 2 mm fracture gap was observed and in 2/5 cases when the fracture gap of 2 mm was observed. All complete failures (5/5) resulted from composite bone failure and not hardware failure. Failure

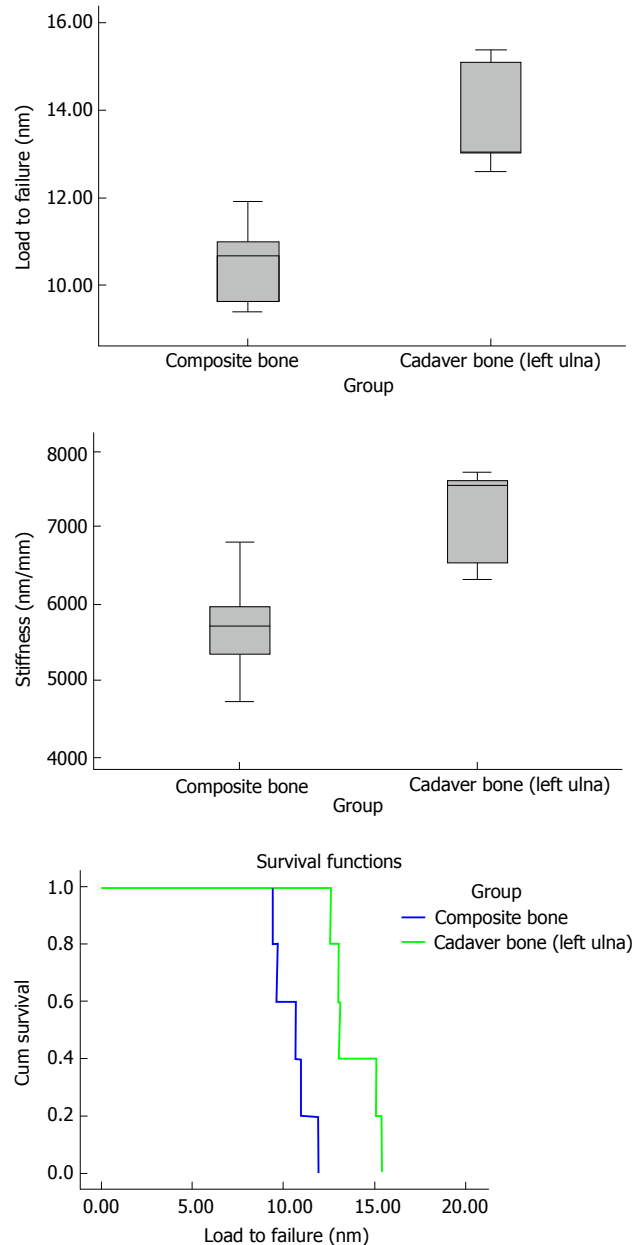


Figure 5 Load to failure criterion of 2 mm gapping, stiffness per specimen and survival function of specimens.

occurred at the most distal screw.

There were no catastrophic fracture failures in the cadaveric specimens. Failure of 4/5 cadaveric specimens was defined when a fracture gap of 2 mm was observed, but 1/5 cadaveric specimens failed due to a failure of the triceps mechanism (the triceps tendon slipped in the soft-tissue clamp, and the augmentative trans-olecranon pin bent).

DISCUSSION

There were 2 primary objectives of this study. Firstly to ascertain whether there is acceptable fixation of a comminuted olecranon fracture with a pre-contoured locking plate and screw construct in an *in-vitro* model. Secondly to directly compare synthetic composite bones

Table 3 Comparison of the results from this study (composite synthetic fourth generation bones and cadaveric bones) with previous literature studies

	Load to failure	Stiffness
Gordon	30-34.5 nm	7-13 nm/mm
Buijze	4.5-27 nm	8.8-13.3 nm/mm
This study (cadaveric)	12.59-15.38 nm	7.55 nm/mm
This study (composite)	9.40-11.91 nm	5.69 nm/mm

to human cadaveric bones under conditions of destructive loading to determine the construct strength, representing the first time this comparison has been performed. Options for fixation of olecranon fractures include casting, external fixation, and internal fixation with intramedullary nails or plates^[20]. Plate-and-screw fixation has proved to be the most reliable and successful strategy and is widely used. Clinical series have demonstrated excellent union rates with few complications^[8,21-25]. Successful plate fixation of these fractures allows for early return to function of the upper extremity.

Gordon *et al*^[12] reported that load to failure and mean stiffness values of olecranon fracture fixation was significantly greater with a posterior plate with long intramedullary screw than with dual-plated. However, no statistically significant increase in load to failure in stiffness was demonstrated when compared to posterior plates alone. Buijze *et al*^[11] compared the stiffness and strength of locking compression plate fixation to one-third tubular plate fixation in a cadaveric comminuted olecranon fracture model with a standardized osteotomy. Stiffness and load to failure values from those two studies were similar to those found in the current investigation (Table 3).

Our study demonstrates that the pre-contoured olecranon is adequate when controlling the fracture position against physiologically relevant forces. Bone mineral density affected load to failure in our model and should be considered when evaluating the results of cadaveric biomechanical studies. In addition, when comparing composite bones to human cadaveric bones, with load to failure, stiffness, and fracture gapping of 2 mm as objective criteria, composite bones were found to be inferior in their mechanical properties. This latter finding has implications when interpreting studies which utilize fourth generation composite bones.

Cantilever forces were 9.40-11.91 nm (for composite bones) and 12.59-15.38 nm (for human cadaver bones) for the fracture sites which would be considerably greater than those experienced in normal activities after fracture fixation^[11]. We conclude the following: (1) The pre-contoured plate and screw construct investigated in this model appears to withstand a force greater than the expected physiologic load in the postoperative prior to fracture consolidation. It appears to be a viable option for *in vivo* treatment of comminuted olecranon fractures; (2) Fourth generation composite bones are not a suitable model for olecranon fracture and plate stiffness testing, in a comminution model, since the

interface stresses, at the distal extent of the plate was the site of failure in 5/5 tests, prior to failure loads seen in the cadaveric specimens; (3) Pre-contoured plate and screw constructs are more than adequate to control fracture displacement, when tested in a small cadaveric cohort, with pre-defined failure (fracture gapping of > 2 mm). None of the cadaveric specimens underwent catastrophic failure; and (4) The current study is with a pre-contoured plate with locking and non-locking screws, to stabilize a comminuted olecranon fracture, whereas prior relevant literature studies utilize dual plates, one-third tubular plates, and plate/intramedullary screw constructs. Hence direct comparisons of these study results should be considered carefully.

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COMMENTS

Background

Olecranon fractures are common injuries. Simple fractures are amenable to fixation with a tension band device. Comminuted olecranon fractures pose a unique treatment challenge because tension band devices fail when the cortex opposite of the fixation construct is not intact. A pre-contoured locking plate is an option in the armamentarium for treating this challenging fracture pattern.

Research frontiers

Previous biomechanical studies have evaluated various methods of fixation for comminuted olecranon fractures. However, the optimal plate and screw configuration is unclear.

Innovations and breakthroughs

To the authors' knowledge, no biomechanical study investigating this pre-contoured locking plate has been pursued. Further, no study has investigated behavior of cadaveric vs composite bone substitute in a comminuted olecranon fracture model.

Applications

This study highlights the efficacy of a unique option for comminuted olecranon fracture fixation. It also gives context to biomechanical studies performed using composite bone substitute. Variation of results in cadaveric vs composite biomechanical may be applicable to broader applications other than a comminuted olecranon fracture model.

Terminology

Sawbones-composite physiologic strength bone substitute.

Peer-review

The authors deal about an interesting topic, plating of comminuted olecranon fractures and fixation failure with cadaveric bones and composite bones. The article is well written.

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Retrospective Study

Is two-stage reimplantation effective for virulent pathogenic infection in a periprosthetic hip? A retrospective analysis

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Institutional review board statement: Our retrospective study contained data from medical records only and thus was conducted without IRB approval (a process requiring approximately 2 mo at our university).

Informed consent statement: Our retrospective study contained data from medical records.

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Abstract

AIM: To investigate the effectiveness of two-stage reimplantation using antibiotic-loaded bone cement (ALBC) and the risk factors associated with failure to control periprosthetic joint infection (PJI).

METHODS: We retrospectively reviewed 38 consecutive hips managed using two-stage reimplantation with ALBC. The mean follow-up period was 5.4 years (range: 2.5-9 years).

RESULTS: The causative pathogens were isolated from 29 patients (76%), 26 of whom were infected with highly virulent organisms. Sixteen patients (42%) underwent at least two first-stage debridements. An increased debridement frequency correlated significantly with high comorbidity ($P < 0.001$), a lower preoperative Harris hip score (HHS; $P < 0.001$), antimicrobial resistance, and gram-negative and polymicrobial infection ($P = 0.002$). Of the 35 patients who underwent two-stage reimplantation, 34 showed no signs of recurrence of infection. The mean HHS improved from 46 ± 12.64 to 78 ± 10.55 points, with 7 (20%), 12 (34%), 11 (32%)

and 5 (14%) patients receiving excellent, good, fair and poor ratings, respectively.

CONCLUSION: The current study demonstrated that two-stage reimplantation could successfully treat PJI after hip arthroplasty. However, the ability of ALBC to eradicate infection was limited because frequent debridement was required in high-risk patients (*i.e.*, patients who are either in poor general health due to associated comorbidities or harbor infections due to highly virulent, difficult-to-treat organisms). Level of evidence: Level IV.

Key words: Two-stage reimplantation; Periprosthetic infection; Antibiotic-loaded bone cement; Debridement

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Core tip: Two-stage revision with antibiotic-laden bone cement for periprosthetic infection after total hip arthroplasty is generally recognized as the gold-standard treatment. Two-stage revision usually comprises removal of all components, including cement, and radical debridement of all suspected infectious, necrotic tissues and bone. However, despite the success of two-stage revision for the treatment of infected primary hip arthroplasties, not all causative organisms can be successfully eradicated, especially multidrug-resistant virulent microorganisms; therefore we evaluated the efficacy of two-stage reimplantation with antibiotic-laden bone cement against difficult-to-treat microorganisms as well as the risk factors associated with failure to control infection.

Yoon YC, Lakhotia D, Oh JK, Moon JG, Prashant K, Shon WY. Is two-stage reimplantation effective for virulent pathogenic infection in a periprosthetic hip? A retrospective analysis. *World J Orthop* 2015; 6(9): 712-718 Available from: URL: <http://www.wjgnet.com/2218-5836/full/v6/i9/712.htm> DOI: <http://dx.doi.org/10.5312/wjo.v6.i9.712>

INTRODUCTION

Infection following total hip arthroplasty (THA) is a serious obstacle that incurs high costs and considerably affects the physical and mental health of the patient, and causes stress for the treating surgeon. The general incidence of periprosthetic joint infection (PJI) is 1%-2% in most centers, despite the use of new antimicrobial agents and sterilization appliances in the operating room^[1].

Two-stage reimplantation with antibiotic loaded bone cement (ALBC) is the most widely performed THA procedure and has a high success rate^[2,3]. This procedure has several advantages, including a reduced infective burden, exposure of residual bacteria under the biofilm, and antibiotic elution at a high concentration to assist

with infection control. Moreover, articulating cement spacers help to preserve the limb length and normal tensile forces of the soft-tissues, thereby providing partial joint mobility^[4]. Despite the success of this technique, however, not all infections are successfully eradicated^[5]. A significant number of patients still experience difficult-to-treat complex infections, despite being treated after two-stage reconstruction^[6]. The reported success rates are lower among patients harboring gram-negative organisms, polymicrobial infections, *Enterococci*, methicillin-resistant *Staphylococci*, or any organism that elaborates a glycocalyx, which are considered highly virulent^[7,8]. Some authors recommend against the use of spacers in patients with highly virulent, difficult to treat microorganisms^[9].

The potential associations of an increased failure rate with the virulence of the infecting organism^[10-12], clinical effectiveness of ALBC^[13,14], and the etiology of treatment failure in patients with PJI^[15] remains controversial. The aim of this study was to assess the efficacy of two-stage reimplantation with ALBC against virulent difficult-to-treat microorganisms and the risk factors associated with failure to control infection.

MATERIALS AND METHODS

Research subjects

This retrospective study involved 43 patients treated between 2003 and 2011. Five patients were excluded because of death unrelated to the relevant surgery. The mean age of the remaining 38 patients (24 men and 14 women) was 63.97 ± 12.66 years (range 41-89 years). The patients had undergone primary arthroplasty (16 THA and 15 bipolar hemiarthroplasty) or revision THA (seven patients). The mean follow-up duration was 5.4 years (range 2.5-9 years). Patient comorbidity data are shown in Table 1.

Diagnostic methods

A PJI was confirmed if at least two of the following criteria were present 3 mo after arthroplasty: (1) a chronic, discharging sinus in communication with the prosthesis; (2) clinical symptoms and signs of unexplainable pain, persistent local erythema, swelling, and a high erythrocyte sedimentation rate ($\text{ESR} \geq 30 \text{ mm/h}$) and C-reactive protein level ($\text{CRP} \geq 10 \text{ mg/L}$); (3) isolation of a microorganism in one culture; and (4) the presence of purulence in the affected joint or > 5 neutrophils per high-powered field upon histopathological examination of at least two different sites^[16,17].

Surgical procedure

The first stage consisted of sinus excision and abscess drainage, if present, prosthesis removal, and extensive debridement, followed by insertion of ALBC (Figure 1). The type of antibiotics loaded in the cement was based on the result of presurgical bacterial cultures. In cases with gram-positive and negative bacterial cultures, 3 g of vancomycin was used; in cases with gram-negative



Figure 1 Pelvic radiograph of a 54-year-old man after first-stage reimplantation. This patient had a periprosthetic infection with methicillin-resistant *Staphylococcus aureus* after total hip arthroplasty. The hip prosthesis was removed, and a vancomycin-impregnated cement spacer (right hip) was inserted after debridement.

or mixed bacterial infections a combination of 2–3 g of vancomycin and 2 g of fortimicin was mixed with 40 g of bone cement (Surgical Simplex-P; Stryker, Allendale, NJ, United States). For one patient infected with tubercle bacillus and *Pseudomonas aeruginosa*, a combination of 2 g each of vancomycin, fortimicin, and streptomycin was used.

Intravenous antibiotics were given for 4–8 wk depending on the bacterial cultures. In patients with increased inflammatory markers associated with clinical findings despite a 6–8 wk antibiotic course, repeated debridement was performed. Secondary reimplantation was scheduled when the ESR and CRP levels remained within normal limits with no evidence of persistent infection for two consecutive reviews.

Clinical and radiological evaluation

All patients were examined at 1, 2, 3 and 6 mo, and then yearly. Clinical evaluations including Harris hip score (HHS) and hematological evaluations, were performed at every follow-up. Acetabular loosening was defined as a shift of the acetabulum > 4 mm, change in the inclination angle of > 5°, and a radiolucent line demarcation of > 1 mm in all three zones^[18]. The Harris criteria were used to determine loosening of the cemented femoral stem^[19]. Subsidence or radiolucency was evaluated for the cementless femoral component^[20].

Statistical analysis

A data analysis was conducted using SPSS software, version 20.0 (SPSS, Inc., Chicago, IL, United States); a modified Kruskal-Wallis test was used, as a non-parametric method to analyze factors influencing the frequency of debridement and cure rate of treatment with ALBC. The statistical significance was set at $P < 0.05$.

RESULTS

Microorganisms were identified in 29 patients (76%), including four cases with methicillin-sensitive bacteria,

Table 1 Comorbidities and frequencies

Comorbidities	No. of cases
Heart diseases, including hypertension	15
Uncontrolled diabetes mellitus	11
Liver cirrhosis	6
Repeated urinary tract infection	6
Brain lesions including stroke	4
Chronic gout	3
Psoriasis	2
Systemic lupus erythematosus	1
Chronic renal failure	2
Autoimmune hepatitis	1
Cushing's syndrome	1
Asthma	1
Chronic obstructive pulmonary disease	1

nine cases with methicillin-resistant bacteria, three cases with vancomycin-resistant *Enterococcus* (VRE), nine with multiple bacterial organisms (including methicillin-resistant and tubercular bacillus), and four cases with gram-negative bacteria such as *Pseudomonas* and *Salmonella* (Table 2).

Repeated debridement was performed in 16 patients (Table 3). Ten, one, four, and 1 patient required a second, third, fourth and seventh debridement, respectively. Ten of the 16 patients were infected with resistant bacteria (methicillin-resistant *Staphylococcus epidermidis*, VRE, and methicillin-resistant *Staphylococcus aureus*). Six patients with nine polymicrobial infections harbored resistant bacteria (Table 3) and underwent multiple debridements (two or more). The remaining four patient harboring resistant bacteria had monobacterial infections and underwent multiple debridements. A 66-year-old woman with methicillin-resistant organisms, VRE, and *Pseudomonas aeruginosa* required seven debridements, with methicillin-resistant organisms isolated during the second, third, and fourth debridements and *Pseudomonas* during the seventh debridement.

The average period of parenteral antibiotic administration was 5.6 wk (range: 4–8 wk) in 22 patients who underwent one debridement. Patients who underwent more than two debridements were subjected to antibiotic therapy for variable durations. The mean duration between primary and secondary surgeries was 5.4 mo (range: 1.2–24 mo). Secondary reimplantation could not be performed in three patients. One of these patients had a poor general condition and the other patients refused to undergo the procedure despite successful control of the infection.

Thirty-four (97.1%) of 35 patients did not show any sign of recurrence after secondary reimplantation. In one case, *Escherichia coli* infection recurred after 4 years. In that case an initial THA was performed to treat a pelvic-acetabular fracture, along with diversion colostomy.

Factors influencing the success of debridement

The rate of repeated debridement was higher in

Table 2 Analysis of factors affecting debridement and treatment of infected hip arthroplasty

Variable	No. of debridements (38 hips)			P value
	1 (n = 22)	2 (n = 10)	> 3 (n = 6)	
Mean age (yr)	61.09	68.50	68.33	0.168
Infecting organism (n)				0.002
Methicillin sensitive	2	2		
Resistant <i>Staphylococcus</i>	6	2	1	
Vancomycin-resistant <i>Enterococcus</i>	2	1		
<i>Pseudomonas</i>	1	2		
<i>Salmonella</i>	1			
Polymicrobial	1	3	5	
Negative culture	9			
Comorbidities (n)				< 0.001
0	10	1		
1	8	2	1	
2	2	5	2	
3	2	2	1	
4			1	
5			1	
Preoperative HHS				< 0.001
20-29			1	
30-39		1	3	
40-49	1	6	2	
50-59	7	1		
60-69	8	2		
70-80	6			

HHS: Harris hip score.

Table 3 Microbiological findings from 16 patients with periprosthetic hip infection who underwent multiple debridements (two or more)

Patient	Microorganism	No. of debridements
1	MRSA	2
2	<i>Streptococcus parasanguis</i>	2
3	<i>Staphylococcus haemolyticus</i>	2
4	<i>Enterococcus faecalis</i> (VRE)	2
5	MRSE	2
6	<i>Pseudomonas aeruginosa</i>	2
7	<i>Pseudomonas stutzeri</i>	2
8	MRSA, <i>Acinetobacter baumannii</i>	2
9	<i>Enterococcus faecium</i> (VRE), MRSA	2
10	<i>Serratia marcescens</i> , <i>Acinetobacter baumannii</i>	2
11	MRSE, <i>Escherichia coli</i> , <i>Staphylococcus haemolyticus</i>	3
12	MRSA	4
13	<i>Salmonella</i> , MRSE, MRSA	4
14	<i>Acinetobacter baumannii</i> , <i>Proteus penneri</i> , MRSA, <i>Enterococcus faecium</i> (VRE)	4
15	<i>Pseudomonas aeruginosa</i> , <i>Acinetobacter baumannii</i>	4
16	MRSA, MRSE, <i>Pseudomonas aeruginosa</i> , <i>Enterococcus faecium</i> (VRE)	7

MRSA: Methicillin resistant *Staphylococcus aureus*; MRSE: Methicillin-resistant *Staphylococcus epidermidis*; VRE: Vancomycin-resistant *Enterococcus*.

patients with associated comorbidities ($P < 0.001$), a low preoperative HHS ($P < 0.001$), and infection with resistant, gram-negative, and polymicrobial organisms ($P = 0.002$). We did not find any statistically significant disparity in the frequency of debridement with respect to patient age ($P = 0.168$).

Radioclinical results

The mean HHS improved from 46 ± 12.64 (range: 27-67 points) to 78 ± 10.35 points (range: 60-98

points), with 7 (20%), 12 (34%), 11 (32%), and five (14%) patients categorized as excellent, good, fair, and poor, respectively. During follow-up, a demarcation line was observed on the acetabular side in zones 1 and 2 in one patient and in zones 2 and 3 in another patient. Both of these patients presented with mild pain but required no further treatment.

Complications

Posterior hip dislocation in three patients was succe-

Table 4 Literature review: Two-stage treatment of infected hip arthroplasty

Ref.	Local cement device	Follow up (mo)	Infection control after first debridement	Infection control after reimplantation	Hips with resistant organisms	Successful control of infection
Hofmann <i>et al</i> ^[3]	Spacer	76	26/42 (62%)	26/27 (96%)	NA	NA
Salgado <i>et al</i> ^[11]	Spacer	6	28/45 (62%)	18/25 (72%)	12 (MRSA-12)	6/12 (50%)
Lim <i>et al</i> ^[35]	Spacer	54	38/45 (84%)	35/42 (83%)	24 (MRSA-14 MRCNS-10)	16/24 (67%)
Fink <i>et al</i> ^[2]	Spacer	35	40/40 (100%)	40/40 (100%)	3 (MRSA-3)	3/3 (100%)
Toulson <i>et al</i> ^[36]	Spacer	64.8	80/84 (95%)	80/84 (95%)	21 (MRSA-7, MRSE-12, VRE-2)	21/21 (100%)
Parvizi <i>et al</i> ^[25]	Spacer	12	61/127 (57%)	49/72 (67%)	66 (MRSA-34, MRSE-32)	48/66 (75%)
Romano <i>et al</i> ^[22]	Spacer	48	98/102 (96%)	98/102 (96%)	NA	NA
Leung <i>et al</i> ^[5]	Spacer	58	30/38 (79%)	30/38 (79%)	38 (MRSA-10, MRSE-26, Both-2)	30/38 (79%)
Uchiyama <i>et al</i> ^[12]	Spacer	48	33/36 (92%)	21/31 (67%)	15 (MRSA-10, MRCNS-4)	10/14 (71%)
Volin <i>et al</i> ^[10]	No spacer	48	43/46 (93%)	43/46 (93%)	9 (MRSA-2, MRCNS-7)	8/9 (89%)
Cordero-Ampuero <i>et al</i> ^[37]	No spacer	53	30/36 (83%)	20/20 (100%)	19 (MRSA-19)	17/19 (89%)
Van Diemen <i>et al</i> ^[26]	No spacer	96	118/136 (87%)	118/138 (87%)	7 (MRSA-7)	5/7 (71%)
Current study 2015	Spacer	64	37/38 (97%)	34/35 (97%)	26 (MRSA-4, MRSE-5, VRE-3, ¹ Poly-9)	25/26 (96%)

¹6 of 9 patients harbored resistant bacteria. MRSA: Methicillin resistant *Staphylococcus aureus*; MRSE: Methicillin-resistant *Staphylococcus epidermidis*; MRCNS: Methicillin-resistant coagulase-negative *Staphylococcus*; VRE: Vancomycin-resistant *Enterococcus*; NA: Not applicable; Poly: Polymicrobial infections.

successfully treated *via* closed reduction. Three patients experienced periprosthetic femoral fractures (Vancouver type C in one and B1 in two) that were successfully managed *via* open reduction and internal fixation. Limb length discrepancies of > 2 cm were observed in two patients.

DISCUSSION

Two-stage reimplantation with ALBC is a well-established procedure with a success rate exceeding 95% in recent studies^[21,22]. However, other studies have reported methicillin-resistant *Staphylococcus* infection control rates of 50%-80% with this procedure^[5,11,17]. In the present study, we achieved equivalent or better results, although first-stage debridement had to be repeated at least twice in 16 patients (42%), thus raising doubts about the effectiveness of two-stage revision with ALBC, especially for the control of virulent pathogens.

First-stage debridement was declared a failure after 6-8 wk for the following reasons: (1) a 6-8 wk course of an appropriate systemic antibiotic is sufficient for the eradication of pathogens^[23]; (2) ALBC becomes surrounded by reactive fibrous tissue, which reduces its therapeutic efficacy^[24]; and (3) repeated debridement represents the only possibility of eradicating local infection.

Studies have demonstrated persistent infection in 6%-28% of patients after first-stage debridement, thus requiring repeated debridements^[5,14,25,26]. Biofilm formation is a well-known and important step in the pathogenesis of polymer-associated infections^[27], necessitating a 1000-fold higher dose of antibiotics than that needed to eradicate a planktonic population^[28]. Although some studies demonstrated that the antibiotic levels remain well above the minimum inhibitory concentration for common microbes even several weeks after implantation^[29], in reality, the hydrophobic nature of bone cement permits effective elution of only 10%

of the antibiotic^[30]. Furthermore, ALBC has a favorable surface for bacterial growth, and long-term antibiotic use at a sub-inhibitory concentration facilitates the development of mutational resistance^[31,32].

Many studies have emphasized the emergence of bacterial strains with altered resistance profiles following adherence to ALBC in both *in vivo* and *in vitro* models^[32,33]. Therefore, the development of resistant organisms on cement spacers that lack suitable antibiotics is a matter of concern, and Giulieri^[34] suggested that, in patients with infections due to difficult-to-treat organisms such as *Enterococcus* or other multidrug-resistant organisms, two-stage reimplantation without the use of ALBC is preferred.

The most recently published success rates for a two-stage exchange without the use of ALBC were between 80% and 90%, comparable to the results of the current standard procedures that include ALBC (Table 4). The reasons for the high failure rate in our series during the first-stage remain unclear, although the overall treatment success rate was 97% despite that 26 (68%) patients were infected with virulent organisms. We found that the virulence of the causative microorganisms, including resistant microorganisms, gram-negative microorganisms (*Pseudomonas*, *salmonella*), and polymicrobial microorganisms, was associated with the persistence of infection and need for repeated debridement. Other important prognostic factors in our study were the presence of comorbidities and a low preoperative HHS. Medical conditions that impair host immunity, such as uncontrolled diabetes mellitus and liver cirrhosis, also increase the risk of persistent infection. We believe that a low HHS might predict the severity and duration of PJI.

Our study has several limitations. First, this was a retrospective study and most patients were referred; accordingly, there may have been variations in the data collection methods as well as referral bias. Second, the sample size was small, making it difficult to draw definitive conclusions. Third, we could not determine

the respective contributions of ALBC and systemic antimicrobial therapy to infection control. However, our analysis yielded some significant results. We believe that our findings are remarkable because we included an adequate number of patients for achieving statistically significant results, and the same surgeon performed all operations by using a standardized protocol.

Based on the results of this study, two-stage reimplantation can successfully treat PJI after hip arthroplasty, but the ability of ALBC to eradicate infection is limited because frequent debridements are required in some patients who are either in poor general health due to associated comorbidities or harbor infections with highly virulent, difficult-to-treat organisms.

COMMENTS

Background

Two-stage reimplantation is the preferred treatment protocol for chronic periprosthetic infection. However, the effectiveness of antibiotic-loaded cement spacers for chronic periprosthetic infection with difficult-to-treat microorganisms remains controversial. This study aimed to investigate the clinical effectiveness of two-stage reimplantation with antibiotic cement spacers for chronic periprosthetic hip infection and the risk factors associated with failure to control infection.

Research frontiers

Effectiveness of two-stage reimplantation with antibiotic-loaded bone cement and risk factors associated with failure to control periprosthetic joint infection.

Innovations and breakthroughs

Infection was controlled in 37 patients (97.3%) after the first stage. Second-stage reimplantation was possible in 35 patients (92%), and there was no evidence of infection recurrence in 34 (97.1%). Two or more first-stage debridements were performed in 16 patients (42%). A mean of 1.8 (range: 1-7) debridements were required to control infection. An increase frequency of debridement correlated significantly with increase comorbidity ($P < 0.001$), a low preoperative Harris hip score ($P < 0.001$), antibiotic resistance, and polymicrobial culture results ($P < 0.001$).

Applications

More repeated debridements were required in patients with chronic periprosthetic infections caused by resistant organisms, as well as in the patients with medical comorbidities at the time of two-stage reimplantation with antibiotic-loaded cement spacers.

Terminology

Although a few studies have demonstrated the maintenance of antibiotic levels above the minimum inhibitory concentration for common pathogens at several months after implantation, the relative hydrophobicity of bone cement allows the effective elution of only 10% of the antibiotic. Furthermore, the antibiotic-loaded cement spacer has an optimum surface for colonization, and prolonged exposure to antibiotics at sub-inhibitory levels facilitates mutational resistance.

Peer-review

This is an well-written paper.

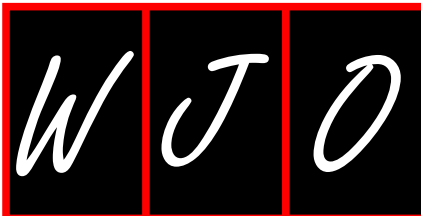
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Observational Study

Acute effects of static stretching on peak and end-range hamstring-to-quadriceps functional ratios

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Abstract

AIM: To evaluate if static stretching influences peak and end-range functional hamstring-to-quadriceps (H/Q) strength ratios in elite women athletes.

METHODS: Eleven healthy female athletes in an elite competitive level participated to the study. All the participants fulfilled the static stretching or non-stretching (control) intervention protocol in a randomized design on different days. Two static unassisted stretching exercises, one in standing and one in sitting position, were used to stretch both the hamstring and quadriceps muscles during these protocols. The total time for the static stretching was 6 ± 1 min. The isokinetic peak torque measurements for the hamstring and quadriceps muscles in eccentric and concentric modes and the calculations for the functional H/Q strength ratios at angular velocities of $60^\circ/\text{s}$ and $180^\circ/\text{s}$ were made before (pre) and after (post) the control or stretching intervention. The strength measurements and functional strength ratio calculations were based during the entire- and end-range of knee extension.

RESULTS: The pre-test scores for quadriceps and hamstring peak torque and end range values were not significantly different between the groups ($P > 0.05$). Subsequently, although the control group did not

exhibit significant changes in quadriceps and hamstring muscle strength ($P > 0.05$), static stretching decreased eccentric and concentric quadriceps muscle strength at both the 60°/s and 180°/s test speeds ($P < 0.01$). Similarly, static stretching also decreased eccentric and concentric hamstring muscle strength at both the 60°/s and 180°/s test speeds ($P < 0.01$). On the other hand, when the functional H/Q strength ratios were taken into consideration, the pre-intervention values were not significantly different between the groups both during the entire and end range of knee extension ($P > 0.05$). Furthermore, the functional H/Q strength ratios exhibited no significant alterations during the entire and end ranges of knee extension both in the static stretching or the control intervention ($P > 0.05$).

CONCLUSION: According to our results, static stretching routine does not influence functional H/Q ratio. Athletes can confidently perform static stretching during their warm-up routines.

Key words: Elite women athletes; Eccentric; Concentric; Static stretching; Functional hamstring-to-quadriceps ratio; Muscle strength

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Core tip: Despite the well-known effects of static stretching on muscle strength its effects about the characteristics of injury risk have not been investigated thoroughly. Functional hamstring-to-quadriceps (H/Q) strength ratio that reflects imbalance in thigh muscle strength is one of the etiologic risk factors for sports injuries. There are few studies in the literature investigating the relationship between static stretching and injury risk characteristics. The results of this study demonstrate that static stretching does not influence the functional H/Q ratio. Hereby, our findings also show that static stretching does not increase the risk for injury.

Sekir U, Arabaci R, Akova B. Acute effects of static stretching on peak and end-range hamstring-to-quadriceps functional ratios. *World J Orthop* 2015; 6(9): 719-726 Available from: URL: <http://www.wjgnet.com/2218-5836/full/v6/i9/719.htm> DOI: <http://dx.doi.org/10.5312/wjo.v6.i9.719>

INTRODUCTION

It is often deemed that enhancing joint range of motion or flexibility with stretching routines will promote greater sporting ability by improving muscular performance and possibly reducing the risk of musculoskeletal injury^[1,2]. Dynamic, static, proprioceptive neuromuscular facilitation, and ballistic stretching are the usually performed techniques of stretching^[1]. Because of the safe and easy application, static stretching is the widely preferred method^[1]. Recently, however, some studies

have indicated temporary compromises in the ability of various muscles to generate isometric or isokinetic strength following pre-exercise static stretching^[3-8]. This is noteworthy for athletes participating in sport activities demanding on high force and strength production. Accordingly, some authors have recommended to exclude static stretching during warm-ups due to the probability of hindering performance during competition^[5,8]. On the other hand, there is little evidence about the role of static stretching as a preventive component to reduce the risk of musculoskeletal injury^[9-11].

It has been suggested that thigh muscle imbalance between the quadriceps and hamstring muscles is a potential mechanism for increased injury to the lower extremities^[12]. Although there are a variety of measurement techniques, the hamstring-to-quadriceps (H/Q) ratio has been used in both clinical and laboratory research as a balance of strength indicator about muscles around the knee joint, as it reflects the relationship between two contrary muscle groups, the agonist and antagonists, and provides a thorough description of reciprocal muscle function^[13,14]. Previous authors have suggested that the agonist-antagonist strength relationship may be better described by a functional knee flexion/knee extension (KF/KE) ratio of eccentric hamstring to concentric quadriceps muscle strength (ECC_{KF}/CON_{KE}) rather than the conventional ratios that are often used (CON_{KF}/CON_{KE})^[13,15]. It was shown that such reciprocal muscle group ratios provide information on knee function, injury risk and knee joint stability^[16]. Any imbalance in the functional ratio implicates a predisposing factor towards injury^[17,18]. Interestingly, when the ECC_{KF}/CON_{KE} ratio was less than 0.6 at 60°/s the probability of a hamstring muscle injury in elite soccer players was 77.5%^[19]. Similar results were demonstrated by Yeung *et al.*^[20]. If the pre-season hamstring to quadriceps ratio was lower than 0.6 at 180°/s angular velocity the risk of hamstring injury was 17 times higher in competitive sprinters^[20]. Studies have reported that injury, detraining or training might have impacts on the changes of normal reciprocal strength distribution around the knee joint^[21,22]. Few studies have investigated the impacts of static stretching during the pre-participation training routine on these strength ratios, and those data that are available are conflicting^[23,24]. Recently, Costa *et al.*^[24] showed that static stretching decreases functional H/Q muscle strength ratio. Besides, Ayala *et al.*^[23] could not demonstrate any adverse effects of static stretching on conventional and functional strength ratios. Strength ratios in both studies were calculated based on the peak moment obtained during the entire range of knee extension and flexion^[23,24]. However, since the antagonist muscles are more important during the end range of motion to decelerate limb movement and the functional dynamics of the knee are better approximated during end ranges, functional strength ratio in the end range of knee extension and/or flexion also seems to be functionally relevant.

The purpose of the present study was to investigate the effects of static stretching of both the quadriceps and

hamstring muscles on peak and end range functional H/Q strength ratios in elite women athletes.

MATERIALS AND METHODS

Subjects

Eleven healthy Caucasian females participated to this observational study. The mean value for age was 21 ± 2 years, for height was 166 ± 7 cm, and for weight was 59 ± 7 kg. All volunteers participated to sports activities in an elite competitive level and were members of National Athletic clubs. The sport activities the subjects were regularly involved were triple jump, hammer throw, high jump, heptathlon, 100 m hurdles, and middle- and long-distance track events. Team coaches and athletes declared that their training backgrounds they had regularly trained for were on average 11 ± 3 h per week for 8 ± 2 years. The test procedure assessed the dominant leg, which was the right leg for all subjects. The leg that the subjects used to kick a ball was determined as the dominant leg. Subjects were excluded from the study if they had a recent or current ankle-, knee-, hip-, or lower back-related injury, had previously complained of functional limitations, swelling, or pain in these joints or had previous apparent knee range of motion limitations. The subjects were informed about the study context and test procedures, and any likely risks and discomfort that might arise. Thereafter, all subjects read and signed the informed-consent form that had been approved by the University's Institutional Ethical Board for Protection of Human Subjects, which also approved the study.

Experimental procedure

Before initiating the experiments, the subjects were invited to the laboratory to give them information about the test procedure they need to know. Furthermore, to be familiar with the testing they participated to the isokinetic knee strength measurements in eccentric and concentric modes at the chosen angular velocities. To remind, when the tension on a muscle fiber increases as it shortens, it is called as concentric muscle contraction. On the other hand, when the tension on a muscle fiber increases as it lengthens, it is called as eccentric muscle contraction. When the subjects visited the laboratory for the second time, they performed the protocols for stretching intervention, non-stretching (control) and static stretching, in a randomized order on different days within one week. The isokinetic peak torque measurements for the hamstring and quadriceps muscles in eccentric and concentric modes and the calculations for the functional H/Q strength ratios were made before (pre) and immediately after (post) the stretching interventions. A five-minute warm-up at 50 W was performed by each subject using a stationary cycle ergometer before the first isokinetic testing. The static stretching procedure took approximately 6 ± 1 min. Therefore, to be similar, the subjects rested for five minutes in a supine or sitting position in the non-

stretching (control) period.

Static stretching exercises

The hamstring and quadriceps muscles of the dominant lower extremity were stretched with two unassisted static stretching exercises. Each unassisted static stretching routine, which comprised of two consecutive repetitions, was held for 20 s to the level the subject represented mild discomfort with no pain. The rest interval between the two repetitions and the static stretching exercises of the hamstring and quadriceps muscles was 15 s. Consequently, all the stretching routine took 6 ± 1 min totally. Although the common recommendation about performing stretching exercises for longer periods of time, we choose the given time because athletes actually carry this amount of stretching time before sport activities. The hamstring and quadriceps muscles were stretched statically in sitting and standing positions. A detailed description of the same quadriceps (Figure 1) and hamstring (Figure 2) static stretching exercises in standing and sitting positions used in this study has been published previously by Sekir *et al.*^[7].

Isokinetic testing

The hamstring and quadriceps isokinetic peak torque (PT) in eccentric and concentric modes were measured with the Cybex NORM isokinetic dynamometer (Lumex, Inc., Ronkonkoma, New York, United States) The calibration of the dynamometer was executed according to the regular equipment maintenance schedule for this testing device^[25].

After positioning the tested knee on the extension-flexion plate of the Cybex NORM system, Velcro straps were used to secure the knee key to the instructions of the manufacturer for isolating knee extension and flexion^[25]. The dynamometer was adjusted temper to the length of the knee joint of each subject. The chest and lower part of the thigh was stabilized by placing strapping across them, and placements were limited to grasping the waist stabilization strap. Range of motion was set between 10° and 90° knee range of motion angles (0° indicating full knee extension). In order to be familiar with the testing device, subjects were advised to execute three active repetitions of knee movement ranging from 90° to 10° knee range of motion before the testing session began. All the tests were performed by the same investigator for standardization. The investigator advised the subjects to exert 100% effort and gave them favourable feed-back during testing. Peak torque measurements for the eccentric and concentric modes were performed one by one; the concentric measurement was performed firstly. In order to familiarize the subjects with the test conditions, they conducted three submaximal contractions of the hamstring and quadriceps muscles before the test condition. Thereafter, they were then instructed to perform four maximal contractions at the test speeds of $60^\circ/\text{s}$ and $180^\circ/\text{s}$ angular velocities. Same angular velocities were valid for the eccentric strength measurement as in the concentric

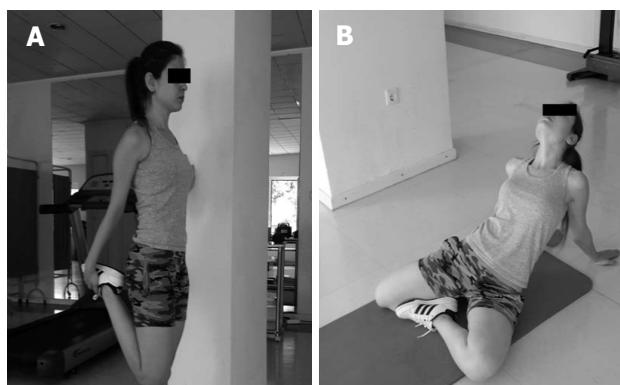


Figure 1 The two types of static stretching exercise for the quadriceps muscle (A in standing and B in sitting position).

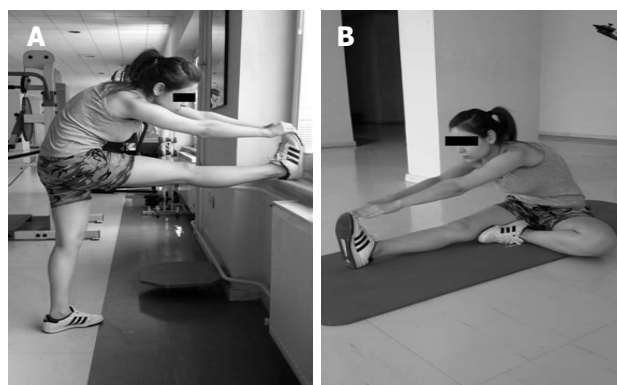


Figure 2 The two types of static stretching exercise for the hamstring muscle (A in standing and B in sitting position).

measurement. Each of the tests (60°/s and 180°/s) were separated with a one-minute rest, and the concentric and eccentric measurements were separated with a minimum of a three-minute rest to hinder the build-up of fatigue. The best PT of the four maximal contractions for each test condition during the entire range of motion and end range of knee extension and flexion (see below) was collected and used in the functional H/Q muscle strength ratio analysis.

Functional hamstring/quadriceps muscle strength ratio

Hamstring to quadriceps muscle functional strength ratio was calculated based on the peak moment obtained during the entire range of knee extension and flexion (90° to 10° and 10° to 90°, respectively). In addition, since the antagonist muscles are more important during the end range of motion to decelerate limb movement, we also calculated the functional ratio in the end range of knee extension (30° to 10°). This was also done to better approximate the functional dynamics of the knee. The maximal eccentric hamstring peak torque was divided by the maximal concentric quadriceps peak torque to determine the functional H/Q strength ratio (ECC_{KF}/CON_{KE}).

Statistical analysis

SPSS version 10.0 software (SPSS Inc., Chicago, IL, United States) was used for the statistical analysis. All variables were described with means and standard deviations. All tests were two-tailed and the level of significance was set at $P < 0.05$. The statistical review of the study was performed by associate professor Deniz Sigirli from Department of Biostatistics, Uludag University Faculty of Medicine.

Non-parametric statistical testing was chosen because of the limited number of subjects included in this study and non-normally distributed data. Normality was tested with Shapiro-Wilks test. A power analysis was performed based on the reported values of the study. According to the analysis, group sample sizes of $n_1 = n_2 = 11$ achieved 98% power to detect a mean difference = 0.07 and standard deviations of both

groups = 0.04 with a significance level (alpha) of 0.05.

Statistical differences between the groups [non-stretching (control) and static stretching] pre-intervention test scores and percent change values of the variables following the intervention were investigated using Mann-Whitney U test. Percent change values for each variable were calculated as: $[(\text{post-intervention} - \text{pre-intervention}) / \text{pre-intervention}] \times 100$. In addition, the statistical differences within the groups between pre- and post-stretching were investigated using Wilcoxon's signed rank test.

RESULTS

Strength

The mean peak torque values and the mean values during the end range of knee extension for the eccentric and concentric strength of the hamstring and quadriceps muscle in the static stretching and control group are represented in Tables 1 and 2. The quadriceps and hamstring peak torque and end range values were not significantly different between the groups before the stretching intervention ($P > 0.05$). As shown in Figure 3A and Table 1, static stretching significantly decreased quadriceps muscle strength in eccentric and concentric modes at 60°/s and 180°/s test speeds ($P < 0.01$), whereas the values showed no change following the control condition ($P > 0.05$). Similar to the changes in the quadriceps muscle strength, static stretching also induced a significant reduction ($P < 0.01$) in the hamstring muscle strength (Figure 3B and Table 2), with no changes seen after the non-stretching control condition ($P > 0.05$).

Functional ratio

Table 3 present the functional H/Q strength ratios during the entire and end range of knee extension in the two groups. As presented in the Table, no significant pre-intervention group differences were existent, both for the entire and end-range knee extension ($P > 0.05$). There were also no significant stretching intervention effects on the functional H/Q strength ratios for either

Table 1 Peak and end range muscle strength of the quadriceps before and after stretching intervention (mean \pm SD)

	Control		Static	
	Before	After	Before	After
ConPT60 (Nm)	226 \pm 49	223 \pm 51	229 \pm 49	210 \pm 52 ^b
ConPT60-ERE (Nm)	145 \pm 46	148 \pm 46	160 \pm 43	136 \pm 36 ^b
ConPT180 (Nm)	134 \pm 29	133 \pm 28	131 \pm 29	119 \pm 28 ^b
ConPT180-ERE (Nm)	103 \pm 26	102 \pm 26	104 \pm 27	89 \pm 24 ^b
EccPT60 (Nm)	266 \pm 79	269 \pm 76	273 \pm 76	246 \pm 70 ^b
EccPT180 (Nm)	234 \pm 66	236 \pm 63	246 \pm 56	224 \pm 51 ^b

^b $P < 0.01$ (following stretching). Ecc: Eccentric; Con: Concentric; PT: Peak torque; ERE: End-range of knee extension; Nm: Newton-meter; 60: 60°/s angular velocity; 180: 180°/s angular velocity.

Table 3 Functional hamstring-to-quadriceps muscle strength ratios for knee extension during the entire and end range before and after stretching intervention in the two groups (mean \pm SD)

	Control		Static	
	Before	After	Before	After
ER-Ext-60	1.10 \pm 0.28	1.09 \pm 0.26	1.00 \pm 0.32	1.07 \pm 0.41
ER-Ext-180	1.51 \pm 0.40	1.54 \pm 0.38	1.54 \pm 0.61	1.51 \pm 0.60
Ext-60	0.70 \pm 0.17	0.72 \pm 0.14	0.72 \pm 0.16	0.71 \pm 0.18
Ext-180	1.21 \pm 0.27	1.21 \pm 0.24	1.25 \pm 0.39	1.20 \pm 0.36

ER: End range; Ext: Extension; 60: 60°/s angular velocity; 180: 180°/s angular velocity.

group ($P > 0.05$, Figure 4 and Table 3).

DISCUSSION

Despite the well-known effects of static stretching on muscle strength^[3-8], its effects about the characteristics of injury risk have not been investigated thoroughly. Given that static stretching results in acute strength decrements of a specific musculature, only 2 studies^[23,24] to date (to our knowledge) have examined the relationship between static stretching and injury risk characteristics through the measurement of an imbalance in thigh muscle strength (deducted from functional H/Q strength ratio). However, both studies exhibited contradictory results; Costa *et al.*^[24] displayed decreases in functional H/Q ratios, whereas Ayala *et al.*^[23] stated that static stretching routines have no adverse effects on functional hamstring to quadriceps ratios. Hereby, the aim of the current study was to evaluate the acute influence of static stretching on functional H/Q ratios. Briefly, besides the significant individual decrements in hamstring and quadriceps muscle strength, static stretching exercises of the knee flexor and extensor muscles did not alter the functional hamstring to quadriceps strength ratios during the entire range of motion and end range of knee extension in elite women athletes.

Studies have reported that assessing the H/Q strength ratio and antagonist co-activation may contribute to identification of normal knee function and

Table 2 Peak and end range muscle strength of the hamstring before and after stretching intervention (mean \pm SD)

	Control		Static	
	Before	After	Before	After
ConPT60 (Nm)	150 \pm 34	152 \pm 34	157 \pm 32	145 \pm 29 ^b
ConPT180 (Nm)	105 \pm 22	106 \pm 23	110 \pm 26	101 \pm 23 ^b
EccPT60 (Nm)	161 \pm 52	160 \pm 47	162 \pm 44	144 \pm 42 ^b
EccPT60-ERE (Nm)	156 \pm 53	157 \pm 48	155 \pm 50	139 \pm 48 ^b
EccPT180 (Nm)	161 \pm 44	161 \pm 43	162 \pm 49	139 \pm 44 ^b
EccPT180-ERE (Nm)	154 \pm 47	155 \pm 46	156 \pm 56	132 \pm 50 ^b

^b $P < 0.01$ (following stretching). Ecc: Eccentric; Con: Concentric; PT: Peak torque; ERE: End-range of knee extension; Nm: Newton-meter; 60: 60°/s angular velocity; 180: 180°/s angular velocity.

muscle balance with which pathological states can be compared^[26]. By this way, the causes of hamstring and knee injuries might be explained, and *via* correcting training and rehabilitation athletic trainers might develop a preventive approach^[14]. Aagaard *et al.*^[13,15] suggested that a more functional ratio calculated by dividing eccentric strength of the hamstrings by the concentric strength of the quadriceps may better describe the capacity for muscular knee/joint stabilization compared with the traditional conventional (CON_{KF}/CON_{KE}) ratio. In fact, an eccentric contraction of the hamstring muscle (the stabilizer) combines the concentric action of the quadriceps muscle (the prime mover) during knee extension. When the knee joint approaches maximum knee extension, the shear and rotation of the tibia is counteracted by this co-activation of knee flexor muscles^[13,15]. The reason for this co-activation is the increase of the posterior pull and joint stiffness and reduction of anterior laxity force in order to oppose the force of the quadriceps loading^[27]. This helps to prevent overextension, decelerating the leg before knee reaches full extension and stabilizing the knee joint throughout the range of motion^[27]. In other words, a strain may occur if the hamstring does not lengthen sufficiently during extension of the knee and/or is relatively weaker than the quadriceps. Therefore, useful information is provided by the assessment of eccentric strength of the antagonist muscles relative to the concentric strength of the agonist muscles to describe the maximal capacity of the antagonist muscles. This could be more practical in detection an injury risk in comparison to the conventional H/Q strength ratio. Conversely, it is possible that the antagonist co-activation is more important at the end range of motion in order to control limb movement. To control for this, we calculated the functional H/Q strength ratio at the end ranges of knee extension (30°-10°), as well as during the entire range.

When the functional H/Q strength ratio for knee extension was taken into consideration, the ratio obtained from the peak torque values during the entire range of motion before the intervention was 0.70 and 0.72 at low angular velocity (60°/s) and 1.21 and 1.25 at high angular velocity (180°/s) for the control and static stretching groups, respectively. These ratios did not

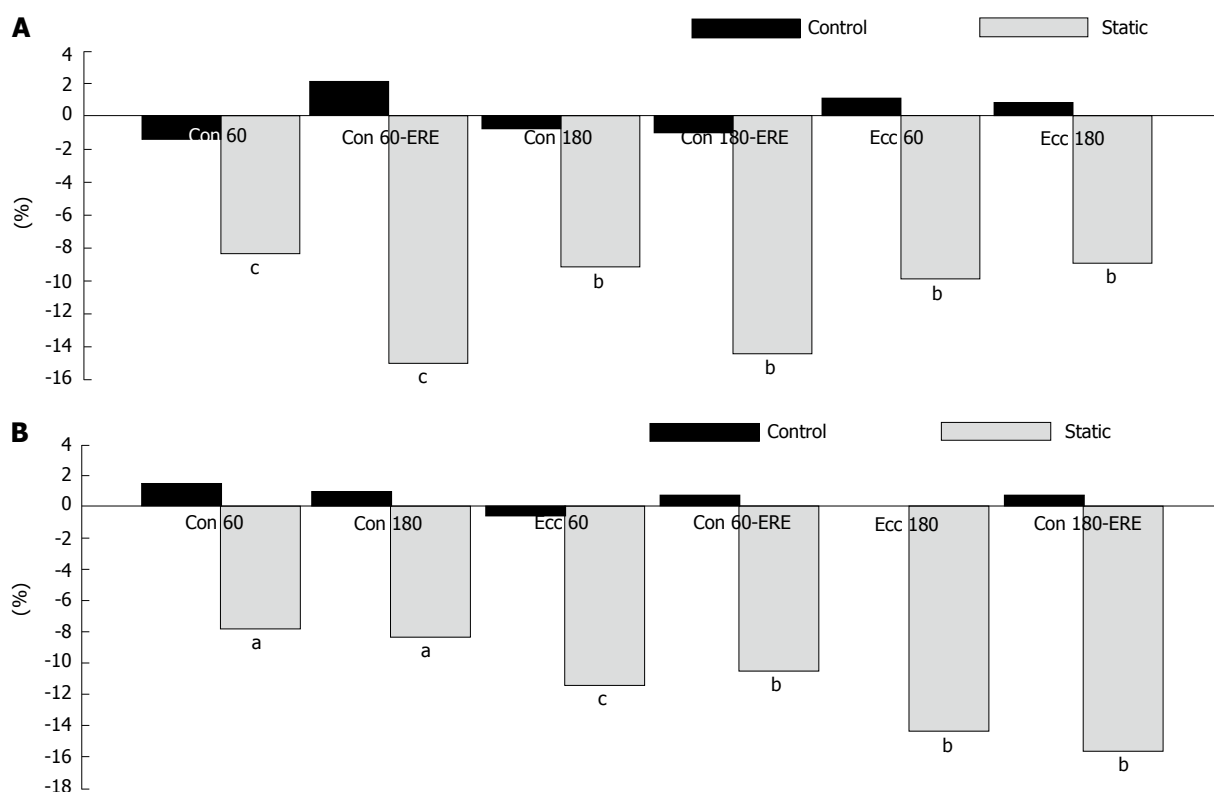


Figure 3 Changes in percentage (%) following stretching intervention for peak and end range torque measurements of the quadriceps muscle (A) and the hamstring muscle (B). Ecc: Eccentric; Con: Concentric; ERE: End-range of knee extension; 60: 60°/s angular velocity; 180: 180°/s angular velocity. (^a $P < 0.05$, ^b $P < 0.01$, ^c $P < 0.001$).

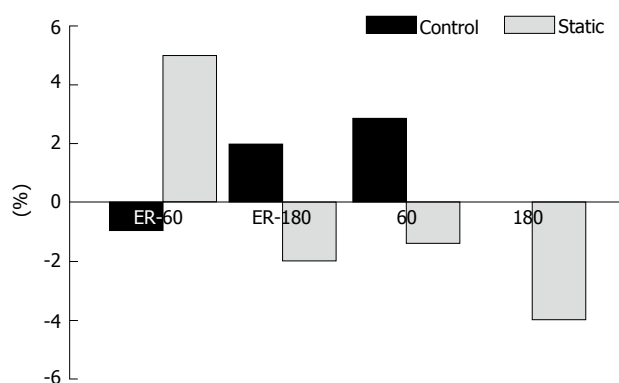


Figure 4 Changes in percentage (%) following stretching intervention for functional hamstring-to-quadriceps muscle strength ratios for knee extension during entire and end range of motion. ER: End range; 60: 60°/s angular velocity; 180: 180°/s angular velocity.

significantly change after the intervention (values were 0.72 and 0.71 at 60°/s and 1.21 and 1.20 at 180°/s for control and static stretching groups, respectively). Static stretching, therefore, did not alter the functional H/Q strength ratios, in contrast to observations reported in previous studies for individual muscle strength performance. Our results suggest that static stretching performed in a pre-participation warm-up routine does not increase injury risk characteristics. Similarly, Ayala *et al.*^[23] indicated also that static lower-limb stretching routines do not alter the relative risk of hamstring strains by reducing the functional H/Q ratio. Following

static stretching the ratio at 60°/s (stretching = 0.69 and control = 0.70) and 180°/s (stretching = 0.88 and control = 0.89) angular velocities displayed same values as the no-stretching control session. In contrast, Costa *et al.*^[24] reported a significant reduction of 7%-11.5% in the functional H/Q ratio at angular velocities of 60°/s and 180°/s following a session of quadriceps and hamstring static stretching. A possible explanation could be that Costa *et al.*^[24] used an extensive overall stretch duration of 36.5 min, whereas the current study stretched the hamstrings and quadriceps muscles for approximately 6 min, which represents more the typical warm-up preferred by athletes and recreationally active people before competition or exercise. Nevertheless, further research in this area is still necessary to address the injury risk features that follow static stretching.

The functional H/Q strength ratios in our study are consistent with those reported in previous studies that calculated the functional ratio for knee extension during the entire range^[15,22,28-33]. Besides, the functional H/Q strength ratios reported in our study were higher for the end ranges of knee extension (1.0-1.10 for 60°/s and 1.51-1.54 for 180°/s) than during the entire range of knee extension. Similar results were obtained from the few studies that calculated this ratio at the end ranges of extension^[15,34]. Aagaard *et al.*^[15] signified that the functional H/Q strength ratio increases at more extended knee joint positions. Their results displayed an increase from 0.6 to 1.0 for 30°/s and from 1.0 to

1.4 at the end ranges of knee extension. The functional H/Q strength ratios from the study of Kellis *et al.*^[34] were also higher (2.2 for 60°/s and 2.7 for 180°/s) for corresponding end ranges (30°-10°). Based on the measurements of peak moments from the entire and end ranges of knee extension, the functional H/Q ratios of 1.20 to 1.25 presently observed for fast knee extension (180°/s) suggests an equal or greater magnitude of capacity of the hamstring muscle to brake the action of the maximal quadriceps knee extension moment. Additionally, knee joint stabilization effect by the muscles was progressively increased when knee joint positions were gradually more extended, as indicated by the values of 1.51 to 1.54 observed at the end ranges of knee extension (30° to 10°). This was also valid for the slow angular test velocity (60°/s). The functional H/Q ratio for the entire range was 0.70-0.72, and increased to approximately 1.0-1.1 as the end ranges were approached. It is possible that this trend may help prevent hyperextension of the knee and reduce anterior displacement of the tibia on the femur when necessary. Our higher ratios obtained at the end range supports the idea that, in a typical movement, the agonist muscles produce the main force for the movement and the antagonist activity is higher at the initial and final phases of the movement to decelerate the limb and control the joint^[35]. Osternig *et al.*^[36] represented a sharp increase in eccentric hamstring activation during the last 25° of a concentric knee extension. The values reported for the functional H/Q ratios appeared to be consistent with the contractile force to length properties of the agonist-antagonist muscle synergies about the knee joint. It has been shown that the knee extensors peak moments occur at knee angles of approximately 60°-70°, whereas 20°-30° was the ranges where knee flexors generated peak moments^[13]. Furthermore, concentric quadriceps moment decreases from 90° of knee flexion to 0° (full extension) throughout the range of motion and the eccentric hamstring moment displays a relative constant behaviour, yielding an increase in the ratio as a full knee extension is approached^[15]. The high functional hamstring to quadriceps strength ratios observed for knee extension at end ranges are the result of the relationships of contractile force to muscle length and thus peak moment. At the end range of knee extension, the hamstring muscles approach their optimal length and peak moment, whereas the length to tension conditions of the quadriceps muscles are increasingly compromised.

It is generally thought that static stretching decreases individual muscle strength. Therefore, suggestions were made to omit static stretching during pre-participation routines in order to prevent a negative influence on performance. Our study shows that functional hamstring to quadriceps strength ratios do not change following a static stretching routine. Hereby, our findings also show that static stretching does not increase the imbalance between the quadriceps and hamstring muscles. The take home message for the practitioner is that elite women athletes not involved in sports mainly based

on sheer power like wrestling, weightlifting or power lifting can confidently perform static stretching during warm-up. Eventually, these results should be considered by women athletes who perform static stretching exercises for both the hamstring and quadriceps muscles before athletic events.

COMMENTS

Background

Despite the well-known effects of static stretching on muscle strength its effects on injury risk characteristics have not been investigated in depth. There are few studies in the literature investigating the relationship between static stretching and injury risk characteristics through the measurement of an imbalance in thigh muscle strength [deducted from functional hamstring-to-quadriceps (H/Q) strength ratio].

Research frontiers

Those data that are available about the effects of static stretching on functional H/Q strength ratio are conflicting. Additionally, strength ratios in the previous studies were calculated based on the peak moment obtained during the entire range of knee extension. However, since the antagonist muscles are more important during the end range of motion to decelerate limb movement and the functional dynamics of the knee are better approximated during end ranges, functional strength ratio in the end range of knee extension and/or flexion also seems to be functionally relevant.

Innovations and breakthroughs

To evaluate the functional H/Q strength ratio before (pre) and after (post) the intervention, the maximal eccentric hamstring moment was divided by the maximal concentric quadriceps moment. Finally, the authors could not find any differences in functional H/Q strength ratios following the static stretching routine.

Applications

These results demonstrate that the functional H/Q ratio does not change following a static stretching routine. Hereby, the findings show that static stretching does not increase the imbalance between the quadriceps and hamstring muscles.

Terminology

Static stretching means a stretch is held in a challenging but comfortable position for a period of time, usually somewhere between 20 to 30 s. Concentric muscle contraction is a type of muscle activation that increases tension on a muscle fiber as it shortens. Eccentric muscle contraction is a type of muscle activation that increases muscle tension on a muscle fiber as it lengthens. Functional H/Q strength ratio is the maximal eccentric hamstring moment divided by the maximal concentric quadriceps moment.

Peer-review

This is an interesting pilot type study with a lot of potential for future research.

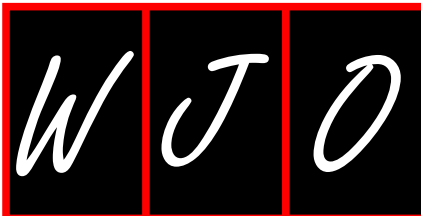
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Prospective Study

Volume and fat infiltration of spino-pelvic musculature in adults with spinal deformity

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Clinical trial registration statement: This study is registered at New York University of Medicine's Institutional Review Board. The registration identification number is 11-01647.

Informed consent statement: All study participants, or their legal guardian, provided informed written consent prior to study enrollment.

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musculoskeletal modelling. Virginie Lafage received a grant for research purpose by SRS and ISSG. She is giving lectures for Globus, Depuy Spine, Medtronic, Nuvasive and MDT. She is a shareholder of Nemaris.

Data sharing statement: Technical appendix, statistical code, and dataset available from the corresponding author at Virginie.lafage@gmail.com. Consent from participants was not obtained but the presented data are anonymized and risk of identification is low.

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Abstract

AIM: To investigate fat infiltration and volume of spino-pelvic muscles in adults spinal deformity (ASD) with magnetic resonance imaging (MRI) and 3D

reconstructions.

METHODS: Nineteen female ASD patients (mean age 60 ± 13) were included prospectively and consecutively and had T1-weighted Turbo Spin Echo sequence MRIs with Dixon method from the proximal tibia up to T12 vertebra. The Dixon method permitted to evaluate the proportion of fat inside each muscle (fat-water ratio). In order to investigate the accuracy of the Dixon method for estimating fat *vs* water, the same MRI acquisition was performed on phantoms of four vials composed of different proportion of fat *vs* water. With MuscIX software, 3D reconstructions of 17 muscles or group of muscles were obtained identifying the muscle's contour on a limited number of axial images [Deformation of parametric specific objects (DPSO) Method]. Muscular volume (V_{muscle}), infiltrated fat volume (V_{fat}) and percentage of fat infiltration [P_{fat} , calculated as follow: $P_{\text{fat}} = 100 \times (V_{\text{fat}}/V_{\text{muscle}})$] were characterized by extensor or flexor function respectively for the spine, hip and knee and their relationship with demographic data were investigated.

RESULTS: Phantom acquisition demonstrated a non linear relation between Dixon fat-water ratio and the real fat-water ratio. In order to correct the Dixon fat-water ratio, the non linear relation was approximated with a polynomial function of degree three using the phantom acquisition. On average, P_{fat} was $13.3\% \pm 5.3\%$. Muscles from the spinal extensor group had a P_{fat} significantly greater than the other muscles groups, and the largest variability ($P_{\text{fat}} = 31.9\% \pm 13.8\%$, $P < 0.001$). Muscles from the hip extensor group ranked 2nd in terms of P_{fat} ($14\% \pm 8\%$), and were significantly greater than those of the knee extensor ($P = 0.030$). Muscles from the knee extensor group demonstrated the least P_{fat} ($12\% \pm 8\%$). They were also the only group with a significant correlation between V_{muscle} and P_{fat} ($r = -0.741$, $P < 0.001$), however this correlation was lacking in the other groups. No correlation was found between the V_{muscle} total and age or body mass index. Except for the spine flexors, P_{fat} was correlated with age. V_{muscle} and V_{fat} distributions demonstrated that muscular degeneration impacted the spinal extensors most.

CONCLUSION: Mechanisms of fat infiltration are not similar among the muscle groups. Degeneration impacted the spinal and hip extensors most, key muscles of the sagittal alignment.

Key words: Spino-pelvic musculature; Adults with spinal deformity; Muscular degeneration; Muscular volume; Fat infiltration; Dixon method

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Core tip: Volume and fat infiltration of spine, hip, and knee extensor and flexor muscles of 19 patients with spinal deformity were evaluated with an innovative

method combining dedicated magnetic resonance imaging acquisition (Dixon method) and 3D reconstructions. The results demonstrated that mechanisms of fat infiltration are not similar among the muscle groups. Degeneration impacted the spinal and hip extensors most, key muscles of the sagittal alignment, highlighting the need for considering muscular factors beyond skeletal parameters.

Moal B, Bronsard N, Raya JG, Vital JM, Schwab F, Skalli W, Lafage V. Volume and fat infiltration of spino-pelvic musculature in adults with spinal deformity. *World J Orthop* 2015; 6(9): 727-737 Available from: URL: <http://www.wjgnet.com/2218-5836/full/v6/i9/727.htm> DOI: <http://dx.doi.org/10.5312/wjo.v6.i9.727>

INTRODUCTION

The muscular system plays an essential role in the maintenance of postural balance, however, there has only been limited investigation into the relationship between the muscular system and structural alignment pathologies.

In adult spinal deformity (ASD), recent research has highlighted the critical role of sagittal spino-pelvic alignment in patient-reported pain and function^[1-4]. Therefore, key muscles involved in pelvic-positioning and lumbar-stabilization are at the forefront of research needs.

Preliminary efforts have been directed towards understanding spine or thigh muscles using histological analyses^[5-8], muscular strength^[9-12], electromyographical signals^[13-15], muscle cross-sectional areas [via ultrasound, computed tomography (CT)-scan or magnetic resonance imaging (MRI)]^[11,15-26], measurement of muscular density with CT-scan^[15-18,27], or muscular intensity with MRI^[10,11,22,23,25,26,28]. However, difficulties arise in representing inter-muscle and inter-subject variability^[29].

To overcome these limitations, Jolivet *et al*^[30-32] developed a method of three-dimensional muscle reconstruction *via* segmentation of a few axial images (MRI or CT-scan). This method has been successfully implemented with CT scans for analysis of muscles involved in knee motion^[33] and hip muscles^[34]. Nevertheless, the radiation exposure from CT scans makes it unacceptable as a tool for studies involving ASD patients, frequently subjected to radiographic examination. Notably, the method has also been performed using MRI sequences^[33]. However, contrary to CT scans, MRI cannot be interpreted in terms of tissue composition, so quantification of fat and muscle requires the use of dedicated MRI pulse sequences.

Dixon *et al*^[35-40] developed a MRI method for fat quantification which exploits the slight difference in the Larmor frequency of fat and water protons (chemical shift). By acquiring the signal at different echo times,

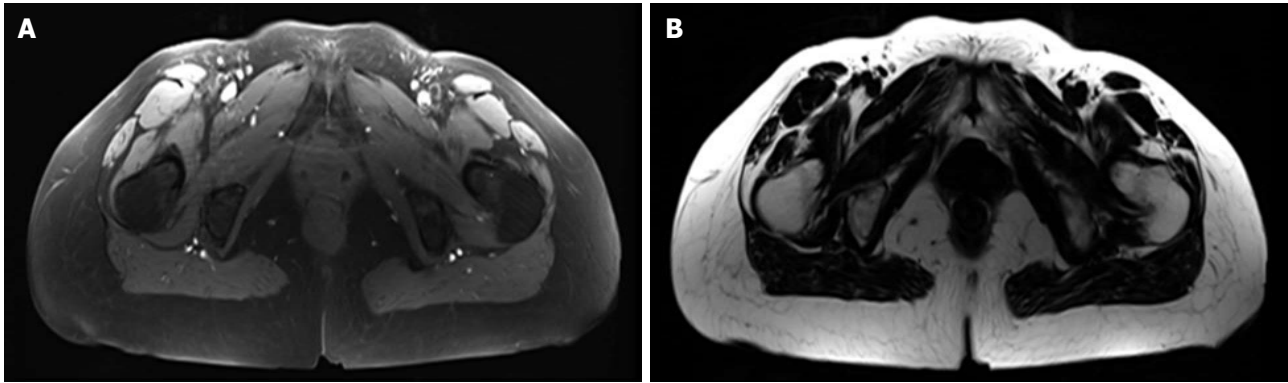


Figure 1 Example of water (A) and fat (B) images with Dixon methods on a 64-year-old female adult spinal deformity patient.

the modulation of the signal intensity can be fitted and the fat and water content can be separated.

Thus, by utilizing Dixon acquisitions and 3D muscular reconstructions, muscular volume and fat infiltration has been obtained and used to investigate the main functional groups of muscles associated with sagittal posture. The hypothesis is that volume loss and fat infiltration, previously demonstrated as factors of skeletal muscle degeneration due to aging^[41,42], do not equally affect the different muscles.

MATERIALS AND METHODS

Inclusion/exclusion criteria

This study is a prospective consecutive pilot series of ASD patients, recruited following international review board approval and written informed consent. Inclusion criteria were female patients over 35 years old and at least one of the following radiographic parameters: Thoraco-lumbar or lumbar coronal Cobb angle greater than 30°, sagittal vertical axis (SVA) greater than 4 cm, or pelvic tilt (PT) greater than 20°. Patients with existing instrumentation, history of spine surgery, or presenting contraindication for MRI were excluded.

Radiographic acquisition and measurements

All patients underwent a full-length coronal and lateral X-ray in free standing position^[43]. Radiographs were measured using a validated spine software^[44,45] (SpineView, Laboratory of Biomechanics ENSAM ParisTech, France), which provided the following spino-pelvic parameters: Coronal plane: Cobb angle and apex location, coronal alignment; Sagittal plane: SVA, PT, pelvic incidence (PI), pelvic incidence minus lumbar lordosis (PI-LL), lumbar lordosis (L1S1), thoracic kyphosis (T4T12).

Patients MRI acquisition

MRI was performed on a 3T whole-body scanner (Magnetom Skyra, Siemens Healthcare, Erlangen, Germany) using a 24-channel spine matrix coil and three 16-channel flex coils from the same vendor. The imaging protocol included a T1-weighted Turbo Spin Echo

sequence for applying the two point Dixon method^[35-38] [Repetition time (TR)/Echo time = 820/11 ms, acquisition matrix = 448 × 308, phase oversampling = 100%, in plane resolution = 0.94 × 0.94 mm², 4 stages, 40 slices by stage, slice thickness = 5 mm, slice gap = 0 mm, flip angle = 157°, turbo factor = 3, echo trains = 107, parallel imaging acceleration factor (iPat) = 2, iPat references lines = 26, bandwidth = 319 Hz/pixel, echo spacing = 15.7, acquisition time per stage = 5:53 min, Total acquisition time = 25 min]. Water and fat images were automatically generated by the scanner from in and out of phase images (Figure 1). Imaging volume covered the proximal tibia to the lumbar spine (T12 vertebra) and was acquired in four stages.

Phantom MRI acquisition

In order to investigate the accuracy of the 2 points Dixon method for estimating fat vs water, the same MRI acquisition was performed on phantoms composed of four 10 mL plastic vials. One vial was filled with soybean oil (100% fat) and another full of water (0% fat). The remaining two vials contained an emulsion of 10% and 20% fat obtained from intralipid 20% fat emulsion (Sigma-Aldrich, St. Louis, MO, United States). For the acquisition, the phantoms were submerged in a phosphate buffered saline solution.

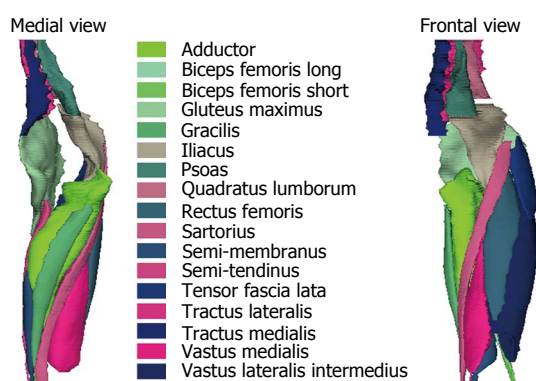
3D muscle reconstruction

The 3D reconstruction of individual muscles, listed Table 1, was performed using Muscl'X software (ENSAM, Laboratory of Biomechanics, Paris, France)^[26,30,32,33]. The reconstruction technique is based on the deformation of parametric specific objects (DPSO algorithm) as described by Jolivet *et al.*^[30-32] and briefly summarized hereafter.

For each muscle, a subset of MRI axial slices (MSS: manually segmented slices) were manually segmented. These contours were then approximated by ellipses, and cubic spline interpolation was used to interpolate ellipses on each intermediate MRI slice. These interpolated ellipses were deformed non-linearly using the manual segmentations of MSS. All segmentations were then verified by the operator.

Table 1 Muscles analyzed in this study, and grouping by function and joint

	Spine extensor	Spine flexor	Hip extensor	Hip flexor	Knee extensor	Knee flexor	Total muscle
Quadratus lumborum	x						x
Tractus medialis	x						x
Tractus lateralis	x						x
Psoas		x		x			x
Iliacus		x		x			x
Biceps femoris short			x			x	x
Biceps femoris long			x			x	x
Semi-membranosus			x			x	x
Semi-tendinosus			x			x	x
Gluteus maximus			x				x
Rectus femoris				x	x		x
Gracilis				x		x	x
Sartorius				x		x	x
Adductor				x			x
Tensor fascia lata				x			x
Vastus lateralis intermedius					x		x
Vastus medialis					x		x

**Figure 2** Medial and frontal view of all the left muscles reconstructed for one patient.

Some muscles were combined, since the low contrast made an accurate separation of the individual muscles difficult. The lumbar part of the psoas was reconstructed separately, but at a point where the distinction with the iliacus was not possible, it was then integrated into the iliacus. The external obturator, adductor longus, brevis and magnus and pectineus were reconstructed into a single group named "Adductor". The vastus lateralis and intermedius were reconstructed together. The muscle reconstructions were done on the fat images. Figure 2 presents the 3D reconstruction of the left muscles for one patient. The femurs were also reconstructed on the water images, the contrast between the cortical and cancellous bone was greater on water images.

Right and left muscles were grouped according to the joint (spine, hip, and knee) and by mechanical action (extensor/flexor) (Table 1). The entire set of muscles were also grouped and named total muscles.

Real fat water ratio: Correction from fat-water ratio with Dixon method

From the fat and water images, the fat-water ratio by voxel was calculated using equation 1 where SI_{fat} represents the signal intensity of the fat signal and SI_{water} the signal intensity of the water image:

$$\text{Dixon Dixon fat-water ratio} = 100 \times \frac{SI_{fat}}{SI_{fat} + SI_{water}} \quad (1)$$

From the Phantom acquisition, an 8-by-10 region of interest (ROI) was drawn in the center of each vial and the mean and the standard deviation of the Dixon fat-water ratio in each ROI were then calculated. Those results demonstrated a non linear relation between Dixon fat-water ratio and the real fat-water ratio. In order to correct the Dixon fat-water ratio, the non linear relation was approximated with a polynomial function of degree three (F) using the phantom acquisition. Then for each patients, the real fat-water ratio was calculated for each voxel for with equation 2.

$$\begin{aligned} \text{Real fat-water ratio} &= F(\text{Dixon fat-water ratio}) \\ &= 0.0002 \times (\text{Dixon fat-water ratio})^3 - 0.0071 \\ &\quad \times (\text{Dixon fat-water ratio})^2 + 0.5607 \times \\ &\quad (\text{Dixon fat-water ratio}) - 0.7714 \end{aligned} \quad (2)$$

If $F(\text{Dixon fat-water ratio})$ was less than 0%, real fat-water ratio was evaluated at 0 and if $F(\text{Dixon fat-water ratio})$ was greater than 100, real fat-water ratio was evaluated at 100.

Quantification of fat components and muscle parameters

From the 3D reconstructions, muscular volumes were calculated (V_{muscle}). The volume of infiltrated fat inside each muscles (V_{fat}) was calculated with the real fat-water ratio. The volumes were then normalized based upon the volume of the right femur, in an effort to limit the impact of the patient morphology. For each joint, the ratio of V_{muscle} and V_{fat} between flexors and extensors were calculated. The percentage of fat infiltration (P_{fat}) was also expressed and was calculated as follow: $P_{fat} = 100 \times (V_{fat}/V_{muscle})$.

Statistical analysis

Muscular volumes and fat infiltration distribution were characterized as well as P_{fat} . Paired *t*-test was used

Table 2 Demographic information

	Min	Max	Mean	SD	95%CI	
					Lower	Upper
Age	37	80	60	13	54	66
BMI	17.4	31.2	22.9	3.52	21.1	24.6

BMI: Body mass index.

Table 3 Mean and standard deviation of Dixon fat-water ratio for the phantom with the different concentrations of fat

Vials	Real fat concentration (%)	Dixon fat-water ratio (%)
Only soybean oil	100	85.4 ± 0.3
Intralipid 20% fat emulsion	20	38.7 ± 1.7
Intralipid 10% fat emulsion	10	22.2 ± 1.0
Only water	0	1.4 ± 0.6

to compare muscular volumes and fat infiltration distribution and Anova *t*-tests were used to compare muscular groups. For the Anova test, an analysis of the homogeneity of variance was performed, followed by Bonferonni or Games-Howell tests. Pearson's correlation coefficient was used to investigate the relationship between muscle parameters and demographic data. For each statistical analysis, the level of significance was set at 0.05.

RESULTS

Demographics

19 consecutive ASD patients with a mean age of 60 years old (range: 37-80) and a mean body mass index (BMI) of 22.9 kg/m² (range 17.4-31.2) were included (Table 2). There was no significant correlation between age and BMI ($r = 0.375$, $P = 0.114$).

Radiographic analysis

In the coronal plane, the mean coronal alignment was 23 mm (range: 0-119 mm, 16% of the patients reached a threshold of 40 mm). The mean maximal Cobb angle was 40° (range: 0°-60°, 79% of the patients reached the threshold of 30°). Forty-seven percent of the patients had a double curve, 32% a single curve, and 21% did not exhibit any coronal curve.

Thoracic kyphosis ranged between -91° and -8° with average of -51° ± 22°. The mean L1S1 was 54° (range: 15°-75°) for a mean PI of 55° (range: 30°-77°). The analysis of PI-LL (mean = 1°, range = -35°-55°) revealed that 21% of the patients were above the threshold defined by the SRS-Schwab classification^[3,46]. SVA ranged from -66 to 118 mm. The analysis of the PT revealed that 38% of the patients reached a threshold of 20°^[3].

Phantom analysis and correction of the Dixon fat-water ratio

The Table 3 presented the mean and standard deviation

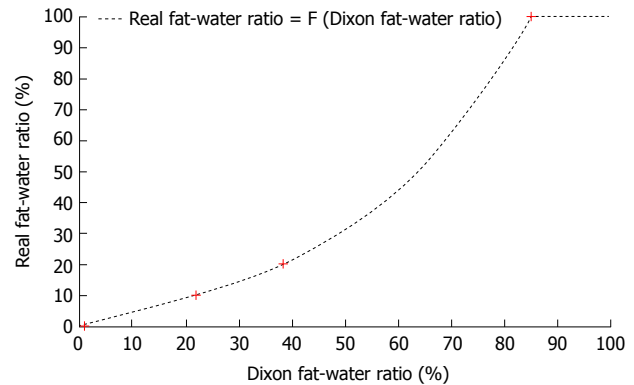


Figure 3 Average fat-water ratio for the phantom with different concentration of fat (0%, 10%, 20% and 100%) and the approximated function real fat-water ratio = F (Dixon fat-water ratio).

of Dixon fat-water ratio for the phantom with the different concentrations of fat. As previously mentioned, the function *F*, presented in equation 2, was used to approximated this non linear relation between the Dixon fat-water ratio and the real fat-water ratio (Figure 3).

Muscle analysis

Femoral volume normalization: The average femoral volume was 414 ± 71 cm³. A larger femoral volume was associated with a larger muscular volume when considering the Total Muscle (Pearson $r^2 = 0.837$, P -value < 0.001).

Muscle and fat infiltration repartition by functional groups:

"Hip group" *V*_{muscle} was significantly bigger than the "Knee group" *V*_{muscle} which in turn was significantly bigger than those of the "Spine Group" (Figure 4 and Table 4). The Spine extensor group represented on average 9% ± 2% of the total muscular volume but a greater proportion (21% ± 7%) of the total infiltrated fat volume ($P < 0.001$). The hip extensor group represents 29% ± 2% of the total muscular volume and 32% ± 5% of the total infiltrated fat volume ($P < 0.001$). For the Spine extensor group and the knee extensor group, the distribution of muscular volume and infiltrated fat was similar (respectively 7% and 17% with standard deviation less than 2%). For the hip flexor and knee extensor groups the distribution of infiltrated fat was significantly smaller than the distribution of muscular volume ($P < 0.001$).

Percentage of fat infiltration: P_{fat}: The analysis of P_{fat} (Table 5) within each group of muscles revealed not only a large variability among patients (range: 6.1%-28.8%, Figures 5 and 6), but also highlighted the difference of P_{fat} between muscle groups. Muscles from the spinal extensor group had a P_{fat} significantly greater than the other muscles groups, and the largest variability (P_{fat} = 31.9% ± 13.8%, $P < 0.001$). Muscles from the hip extensor group ranked 2nd in terms of P_{fat} (14% ± 8%), and were significantly greater than those of the knee extensor ($P = 0.030$). Muscles from the knee extensor group demonstrated the least P_{fat} (12%

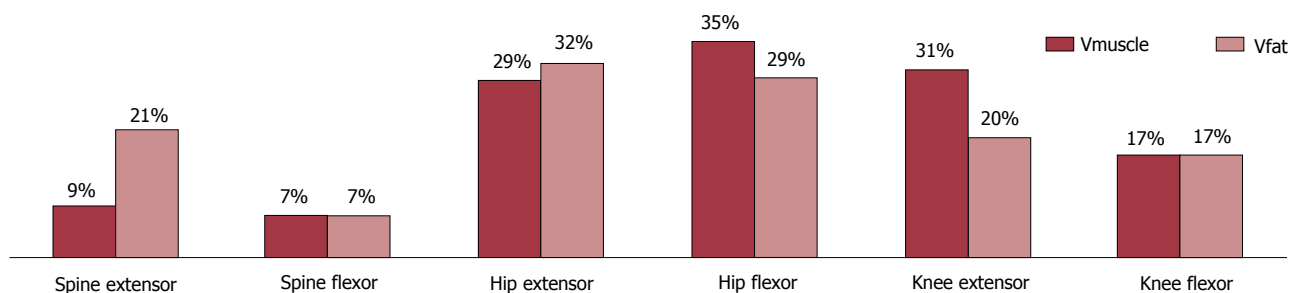


Figure 4 Distribution of Muscular volume and infiltrated fat volume expressed in percentage of the total muscle muscular volume and of the total infiltrated fat volume respectively. Vmuscle: Muscular volume; Vfat: Infiltrated fat volume.

Table 4 Muscular Volumes of each muscle group

	Muscular volume					
	Min	Max	Mean	SD	95%CI	
					Lower	Upper
Spine extensor	0.92	1.89	1.46	0.27	1.33	1.59
Spine flexor	0.85	1.67	1.24	0.22	1.13	1.34
Hip extensor	3.42	6.00	4.83	0.63	4.52	5.13
Hip flexor	4.79	7.13	5.91	0.71	5.57	6.25
Knee extensor	3.70	6.95	5.15	0.86	4.73	5.57
Knee flexor	2.18	3.41	2.88	0.33	2.72	3.04
Total muscles	12.87	19.44	16.67	1.87	15.77	17.57

Reported values are normalized based upon the volume of the right femur of each patient (for example, the mean "Total Muscles" volume = 16.67 femurs volume).

Table 5 Percentage of infiltrated fat expressed by functional groups

	Percentage of fat component					
	Min	Max	Mean	SD	95%CI	
					Lower	Upper
Spine extensor	12.72	71.15	31.90	13.83	25.24	38.57
Spine flexor	5.67	20.39	11.92	3.63	10.17	13.66
Hip extensor	6.39	38.09	14.81	7.01	11.43	18.19
Hip flexor	6.10	20.22	10.76	3.16	9.24	12.29
Knee extensor	3.84	20.02	8.66	4.03	6.72	10.60
Knee flexor	6.93	25.44	12.81	4.20	10.78	14.83
Total muscles	6.12	28.84	13.34	5.33	10.77	15.91

$\pm 8\%$). They were also the only group with a significant correlation between Vmuscle and Pfat ($r = -0.741$, $P < 0.001$), however this correlation was lacking in the other groups.

Flexors vs extensor: The comparison of flexor vs extensors revealed a larger flexor contribution with regards to Vmuscle for the hip. For the spine, the ratio flex/ext highlight the greater fat infiltration of the extensor (Table 6).

Age vs muscle parameters (Table 7): No correlation was found between Vmuscle and age except for the knee extensors (Pearson's $r = -0.701$, $P = 0.001$). For Vfat, all groups were significantly and positively correlated with age (Pearson's r between 0.555 and 0.645) except the Spine groups. Except the spine extensor, Pfat was positively and significantly correlated with age.

BMI vs muscle parameters (Table 8): For the Spine groups, no correlation was found between Vmuscle, Vfat or Pfat and BMI. Vmuscle of the hip extensors and the knee flexors was significantly and positively correlated with BMI (respectively, Pearson's $r = 0.642$, $P = 0.003$ and Pearson's $r = 0.470$, $P = 0.042$). BMI was correlated with Vfat and Pfat in the hip and knee flexor and extensor.

DISCUSSION

While the radiographic presentation of ASD patients commonly demonstrates coronal and sagittal components of malalignment, sagittal spino-pelvic parameters have been identified as the main radiographic drivers of disability^[2,47-49]. The objective of the current study was to investigate the volume and fat infiltration of the main functional groups of muscles associated with sagittal posture.

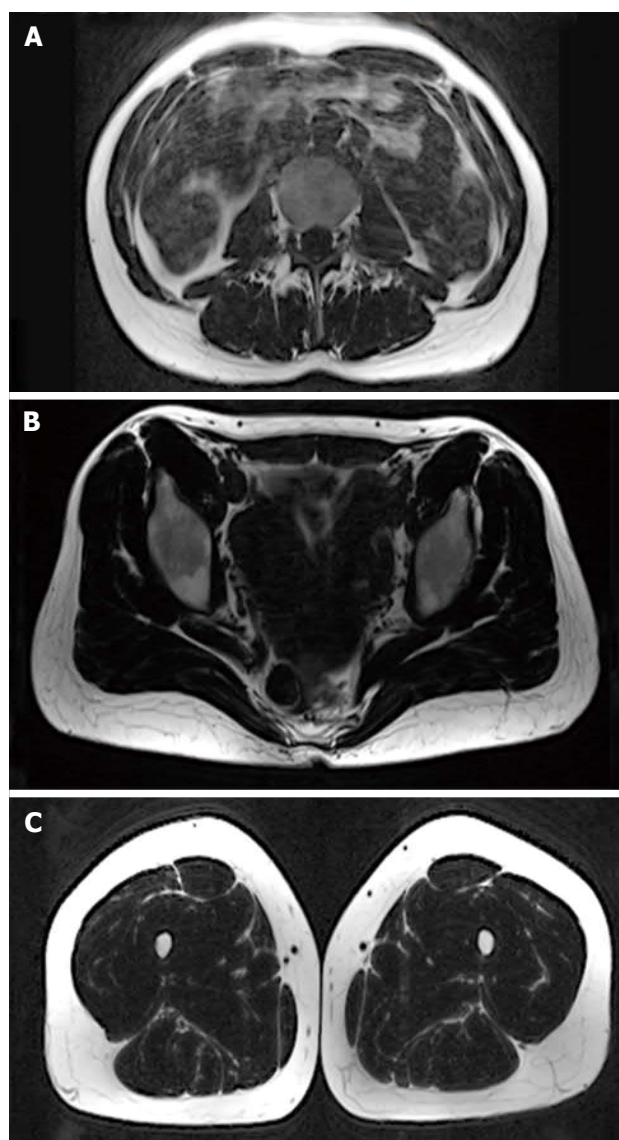


Figure 5 Magnetic resonance imaging samples (A: Lumbar area; B: Pelvis area; C: Limb area) of a 37-year-old female adult spinal deformity patient with a body mass index of 22 kg/m². This patient presents a sagittal deformity with hyperlordosis of the lumbar spine (pelvic incidence minus lumbar lordosis = -29°) and a thoraco-lumbar kyphosis of 45°. The analysis of the muscle quality revealed an 6.1% of fat infiltration on average.

Relationship with posture

Fat infiltration within muscle groups ranged from 8.7% and 31.9% on average-the least affected being the knee extensors. This suggests that muscular degeneration, evaluated with fat infiltration, does not impact the groups of muscles to the same extent. The lumbar spine extensors had the greatest percentage of fat component (31.9%). This is particularly interesting in regard to the loss of lumbar lordosis present in most ASD patients^[4] because lumbar spine extensors are highly involved in the maintain of lumbar lordosis. Furthermore, correlations between fat infiltration and age for the spine were smaller than for the other groups and no correlation was found with the BMI. These results suggest that the greater degeneration of those muscles is probably not solely attributed to age and

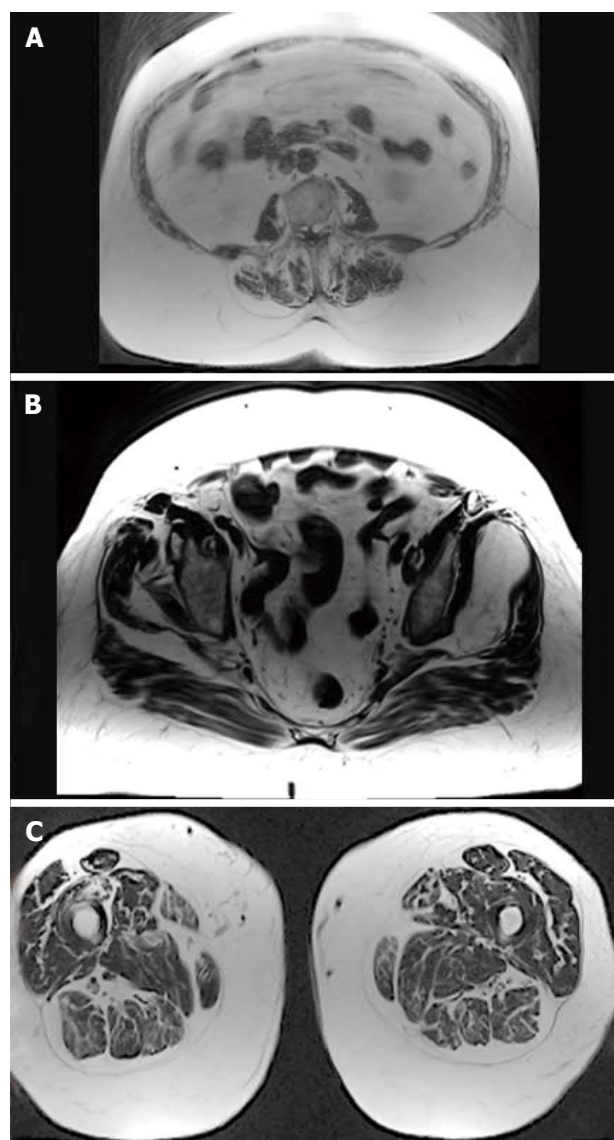


Figure 6 Magnetic resonance imaging samples (A: Lumbar area; B: Pelvis area; C: Limb area) of an 80-year-old female with a body mass index of 31 kg/m². This patient presents a degenerative scoliosis with a thoraco-lumbar Cobb angle of 32°, a hyperkyphosis of the thoracic spine (thoracic kyphosis = 63°) and a global sagittal malalignment (sagittal vertical axis = 11 cm). The analysis of the muscle quality revealed an 28.8% of fat infiltration on average.

BMI. However the study cannot conclude whether this observation is a cause or a consequence of the spinal deformity.

Moreover, in the ASD population, sagittal malalignment is highly associated with pelvic retroversion, described by PT^[1] and the agonist of this retroversion, the hip extensor, has the second greatest percentage of fat infiltration.

Flexor and extensor fat infiltration ratios were found to be smaller for the spine groups. This finding in the ASD population studied may reflect the unfavorable balance of forces leading to sagittal plane deformity across the trunk. Coupled with the findings of hip extensors and loss of contractile component with ageing, components of sagittal spino-pelvic misalignment from a perspective of soft tissue imbalance are emerging.

Table 6 Ratio between flexors and extensors for each group of muscles (muscular volume and infiltrated fat volume)

	Ratio flex/ext: Vmuscle						Ratio flex/ext: Vfat					
	Min	Max	Mean	SD	95%CI		Min	Max	Mean	SD	95%CI	
					Lower	Upper					Lower	Upper
Spine	0.61	1.21	0.87	0.17	0.79	0.95	0.10	0.68	0.36	0.14	0.29	0.42
Hip	1.02	1.43	1.23	0.13	1.17	1.29	0.54	1.31	0.95	0.19	0.86	1.04
Knee	0.42	0.72	0.57	0.08	0.53	0.61	0.66	1.10	0.87	0.12	0.81	0.93

Vmuscle: Muscular volume; Vfat: Infiltrated fat volume.

Table 7 Correlation between age and muscular volume, infiltrated fat volume and percentage of fat component

		Vmuscle		Vfat		Pfat	
		<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>
Age	Spine extensor	-0.208	0.393	0.420	0.073	0.480 ^a	0.038
	Spine flexor	-0.417	0.076	0.208	0.393	0.427	0.068
	Hip extensor	0.018	0.943	0.564 ^a	0.012	0.633 ^b	0.004
	Hip flexor	-0.309	0.198	0.555 ^a	0.014	0.658 ^b	0.002
	Knee extensor	-0.701 ^b	0.001	0.645 ^b	0.003	0.680 ^b	0.001
	Knee flexor	-0.319	0.183	0.589 ^b	0.008	0.679 ^b	0.001
	All muscles	-0.433	0.064	0.614 ^b	0.005	0.676 ^b	0.001

Statistically significant difference with ^a*P*-value < 0.05; Statistically significant difference with ^b*P*-value < 0.01.

Vmuscle: Muscular volume; Vfat: Infiltrated fat volume; Pfat: Percentage of fat component.

Table 8 Correlation between age and muscular volume, infiltrated fat volume and percentage of fat component

		Vmuscle		Vfat		Pfat	
		<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>
BMI	Spine extensor	0.127	0.606	0.017	0.944	-0.038	0.876
	Spine flexor	-0.027	0.913	0.443	0.057	0.450	0.053
	Hip extensor	0.642 ^b	0.003	0.693 ^b	0.001	0.587 ^b	0.008
	Kip flexor	0.159	0.515	0.657 ^b	0.002	0.587 ^b	0.008
	Knee extensor	-0.236	0.330	0.596 ^b	0.007	0.518 ^a	0.023
	Knee flexor	0.470 ^a	0.042	0.761 ^b	< 0.001	0.570 ^a	0.011
	All muscles	0.207	0.394	0.592 ^b	0.008	0.458 ^a	0.049

Statistically significant difference with ^a*P*-value < 0.05; Statistically significant difference with ^b*P*-value < 0.01.

Vmuscle: Muscular volume; Vfat: Fat volume; Pfat: Percentage of fat component.

Fat infiltration, age and BMI

The difference between muscular volume and infiltrated fat volume demonstrated that muscle degeneration is not similar among the different functional groups. Those differences were highlighted by the difference of correlation between age and BMI. Only knee extensor muscular volume loss was correlated with age, however, infiltrated fat was correlated with age for each muscle group (except Spine Flexor *P* = 0.068), reflecting that age-related muscular degeneration is in general more associated with an increase of fat infiltration than an absolute muscular volume loss.

Greater BMI was associated with a greater percentage of infiltrated fat for hip and knee groups, but also associated for the hip extensor and the knee flexor groups with an increase of the muscular volume.

In light of the wide range of age and BMI values observed in this pilot study, the current findings will have to be confirmed in a larger population.

Fat and contractile component evaluation

The evaluation of the fat infiltration using the two points Dixon method has already been applied to investigate different organs (liver^[38,40], bones^[39] and muscles^[36,50]). The decay in signal intensity between the in-phase and opposed phase images due to T2* was not taken into account^[38]. The measurement of T2* would have required additional measurements or the use of sequences (e.g., multi echo gradient echo sequences) that were not available at our scanner. Even more, the limited ability of patients with spinal deformities to hold still in the magnet forced us to reduce the scan time, so we could not measure T2* on these patients. Recent studies have shown that the two point Dixon without T2* has excellent concordance with spectroscopy measured in the spine, bones^[39], liver^[40], or spine muscles^[50].

With the 3 points Dixon method applied onto phantoms filled with different proportions of fat and water, Kovanlikaya *et al*^[51], demonstrated a linear

correlation between the fat-water ratio and the proportion of fat. However in our phantom study, this relationship was not linear, explaining why we corrected the fat water ratio evaluated with the two Dixon method with a polynomial function.

This disagreement observed between the nominal and the measured fat fraction in phantoms can be caused partially because of the T1 weighting of the images. Fat have much shorter T1 values (300 ms) than water in muscle (900 ms) at 3T^[52]. With a TR of 820 ms the magnetization from fat was almost completely relaxed [TR/T1fat approximately 2.73, $(1-e^{-TR/T1fat}) = 0.94$, *i.e.*, 94% of the signal available for the next excitation], while the magnetization for water did not have enough time to recover [TR/T1water approximately 0.91, $(1-e^{-TR/T1water}) = 0.60$, *i.e.*, 60% of the signal available for the next excitation]. Therefore in our measurements the signal from water was underestimated and this resulted in overestimation of the fat fraction. Additional errors with the two-point Dixon included sensitivity to B0 inhomogeneity, which could explain why the differences between the in phase and out of phase in the 100% phantom lead to an underestimation of the fat fraction for large values of the fat fraction.

While investigations of the muscles of the thigh^[36] or extensor of the spine^[50] exist, they are based on a limited number of MRI slices and none of them report results on the entire muscular volume. To our knowledge, there is no study combining 3D reconstruction of muscles and fat component calculated with the two points Dixon method.

Limitations

Due to our experimental design and the limited sample size, we cannot draw any definitive conclusions correlating ASD and muscular factors. The various deformities presented in this population limited the ability to associate changes in a specific muscle groups with deformation type. Given the fact that the prevalence of adult spinal deformity is greater in female than in male patients, only female subjects were included in this study in an effort to limit confounding factors related to gender's difference in muscular system. Female subjects were considered due to the higher incidence of spinal deformity in the female population^[6,20]. Data for a larger gender mixed population and an asymptomatic population are important next steps to evaluate more clearly the contractile component and correlation between muscle groups of the spino-pelvic complex and spino-pelvic alignment.

The applied MRI protocol permits a quantitative and qualitative characterization of the main muscles involved in the spino-pelvic complex. Regarding the differences between distribution of muscular and contractile components only, this study demonstrated the necessity of a complete characterization of the muscular system (including the quantification of the fat infiltration) and stress the limitations of considering only geometric parameters. Muscle degeneration seems more related to

fat infiltration than volume loss but muscle degeneration does not affect all the muscles equally. In the studied ASD population, lumbar spine and hip extensor were the groups most affected by muscular degeneration, and muscle volume ratios between flexors and extensors were greatest in the spine group.

ACKNOWLEDGMENTS

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COMMENTS

Background

In adult spinal deformity, recent research has highlighted the critical role of sagittal spino-pelvic alignment in patient-reported pain and function. However these patients are mostly analyzed by skeletal parameters obtained with radiographies, with only a minor consideration on the muscular system which limits the understanding of the pathology.

Research frontiers

Numerous methods have been directed towards analyzing muscular system. However difficulties arise in representing inter-muscle and inter-subject variability as well as obtaining a reliable evaluation of muscular volume and fat infiltration.

Innovations and breakthroughs

Combining Dixon magnetic resonance imaging (MRI) acquisitions and 3D muscular reconstructions, muscular volume and fat infiltration have been obtained for the main functional groups of muscles associated with sagittal posture in the setting of adult spinal deformity. The results have demonstrated that mechanisms of fat infiltration are not similar among the muscle groups for this population. Moreover degeneration mostly impacted the spinal and hip extensors, key muscles in opposition with the anterior sagittal malalignment.

Applications

The results suggest the interest of a complete characterization of the muscular system (including the quantification of the fat infiltration) in the evaluation of patients with spinal deformities.

Terminology

Adult spinal deformity refers to abnormal curvatures of the spine in patients who have completed their growth. Dixon MRI allows the separation of fat and water content and so the calculation of fat infiltration within each muscle.

Peer-review

This manuscript describes an observational study of volume loss and fat infiltration of muscles associated with sagittal posture in patients with adult spinal deformity.

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Subtrochanteric fractures after retrograde femoral nailing

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Abstract

Secondary fractures around femoral nails placed for the management of hip fractures are well known. We report, two cases of a fracture of the femur at the interlocking screw site in the subtrochanteric area after retrograde femoral nailing of a femoral shaft fracture. Only a few reports in the existing literature have described these fractures. Two young men after sustaining a fall presented to us with pain, swelling and deformity in the upper thigh region. On enquiring, examining and radiographing them, peri-implant fractures of subtrochanteric nature through the distal interlocking screws were revealed in both patients who also had histories of previous falls for which retrograde intramedullary nailing was performed for their respective femora. Both patients were managed with similar surgical routines including removal of the existing hardware, open reduction and ace cephalomedullary antegrade nailing. The second case did show evidence of delayed healing and was additionally stabilized with cerclage wires. Both patients had uneventful postoperative outcomes and union was evident at the end of 6 mo postoperatively with a good range of motion at the hip and knee. Our report suggests that though seldom reported, peri-implant fractures around the subtrochanteric region can occur and pose a challenge to the treating orthopaedic surgeon. We suggest these be managed, after initial stabilization and resuscitation, by implant removal, open reduction and interlocking intramedullary antegrade nailing. Good results and progression to union can be expected in these patients by adhering to basic principles of osteosynthesis.

Key words: Peri-implant fracture; Retrograde femoral nail; Antegrade femoral nailing; Interlocking screw; Subtrochanteric fractures

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Core tip: The occurrence of peri-implant subtrochanteric

fractures in patients operated previously by retrograde nailing for femoral diaphyseal fractures has been rarely reported. This case report provides the description of two such cases with subtrochanteric peri-implant fractures. These challenges are best met, according to our experience, by implant removal, open reduction and interlocking antegrade nailing.

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INTRODUCTION

Intramedullary nailing is the surgical treatment of choice in displaced diaphyseal femur fractures with excellent results reported in literature. Antegrade nailing either through the trochanter or the piriform fossa is the usual standard of treatment^[1]. Retrograde intramedullary nailing of the femur was first reported by Green^[2] in 1970. In the last two decades, a significant increase in the use of this technique has been witnessed in patients with difficult access to the proximal femur (obesity, bilateral femur fractures, ipsilateral pelvic fracture, hip fracture, tibia fracture and associated contralateral tibial plateau fractures which need internal fixation or staged external fixation). While knee pain and delay in union requiring dynamization have been reported with retrograde nailing, proclaimed benefits have included decreased blood loss and operative time and improved alignment when fixing distal femoral fractures^[3-9].

Complications associated with nailing include implant failure, angulation, shortening, malunion and nonunion of the fracture with associated migration of the nail. While fractures at the distal end of a short intramedullary nail used to fix hip fractures are well known, peri-implant fractures of the proximal femur at the far end of a retrograde nail placed for a femoral shaft fracture as in our report have been infrequently reported^[10-13]. We present a report of two patients sustaining a subtrochanteric fracture after retrograde femoral nailing.

CASE REPORT

Case 1

A 33-year-old male presented to the emergency room with history of pain in his back and the left hip after sustaining a fall during skydiving. In a similar skydiving accident in the past, he had sustained bilateral femur fractures in addition to a burst fracture of the third lumbar vertebra. He had been operated for the same with bilateral retrograde femoral nails, cannulated screw fixation in the right femur and internal fixation of the L3 burst fracture.

In the current episode, he had sustained a peri-implant fracture of the left femur in the subtrochanteric

region at the far end of the retrograde nail placed through the knee to manage his previous injury (Figure 1).

A computed tomography (CT) scan confirmed the fracture at the locking screw site. The fracture was through the distal of the two interlocking screw-containing holes at the subtrochanteric area. The patient elected operative intervention (Figure 2).

With the patient in a floppy lateral position on a bean bag under general anesthesia, we approached the knee through his previous midline incision and performed a medial parapatellar arthrotomy. The nail was identified and the interlocking screws at the lateral aspect of the femur were removed after connecting the jig to prevent rotation. The proximal screws were then removed through an anterior incision and the nail was extracted. The implants were intact on retrieval. The knee arthrotomy was closed in a routine manner after irrigation. The fracture site was exposed and reduced through a lateral incision over the proximal femur and a trochanteric entry Ace cephalomedullary nail was placed with two screws in the femoral neck and two distally at the knee in appropriate rotation.

He was advised toe-touch weight for 6 wk and then progressed to bear weight as tolerated with interval healing of the fracture. His fracture showed full union at six months postoperatively (Figure 3) and he had full range of movement of the hip and knee.

Case 2

A 45-year-old male alcoholic presented to the emergency room with history of pain in his right hip after a fall. He had a history of internal fixation of right femur with a retrograde nail and internal fixation of a left tibial plateau 4 mo prior to this fall after being involved in a motor vehicle accident.

He sustained, similar to the previous patient, a peri-implant fracture of the right femur in the subtrochanteric region at the far end of the retrograde nail placed through the knee to manage his previous injury (Figure 4). The implants appeared intact on imaging.

A CT scan confirmed the fracture at the locking screw site and delayed union of the previously treated femoral shaft fracture (Figure 5).

The patient opted for operative intervention. The fracture was found to extend through the distal of the two interlocking screw holes at the subtrochanteric area. The patient was positioned and under general anesthesia, the right knee was approached through the previous incision. After a medial parapatellar arthrotomy, the nail was identified and the distal and proximal interlocking screws removed. The implants were intact on retrieval. After the extraction of the nail, the wound was closed as per routine.

Through a lateral incision over the proximal femur, the fracture site was exposed, reduced and held with two cerclage wires. A trochanteric entry Ace cephalomedullary nail was placed with two screws in the femoral neck and two distally at the knee in a manner similar to the first case (Figure 6).

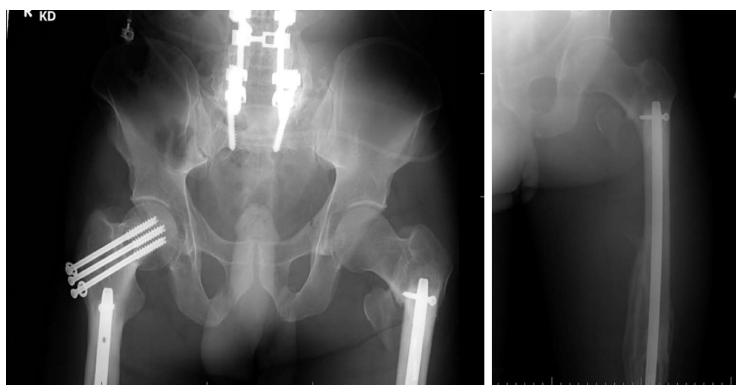


Figure 1 Anteroposterior and lateral radiographs of left femur showing peri-implant fracture involving the interlocking screw site in the subtrochanteric area.

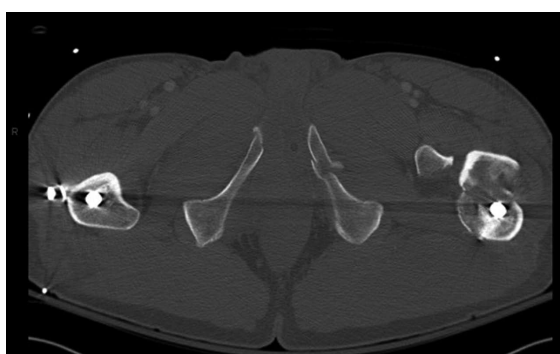


Figure 2 Axial computed tomography scan image showing the fracture at the screw insertion site.



Figure 3 Anteroposterior and lateral radiographs six months after internal fixation of the peri-implant fracture.

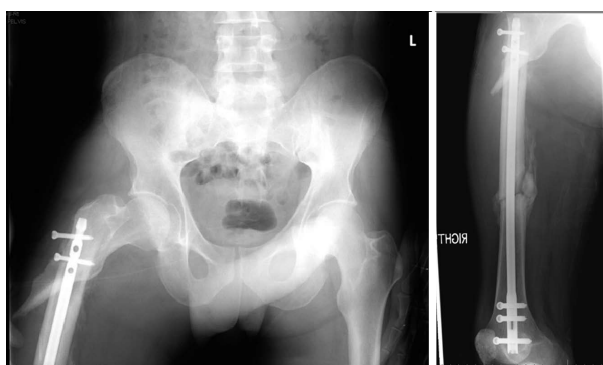


Figure 4 Anteroposterior and lateral radiographs of right femur showing peri-implant fracture involving the Interlocking screw site in the subtrochanteric area. Also seen is the femoral shaft fracture with interval healing.

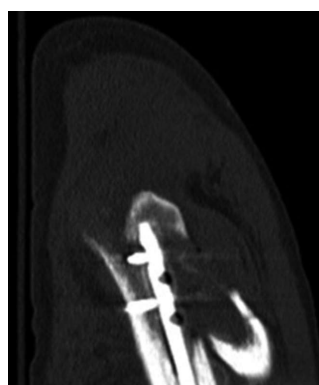


Figure 5 Sagittal computed tomography scan image showing the fracture at the screw insertion site.

Postoperative management was identical to the previous patient. During the last office visit at six months postoperatively, he was full weight bearing on his right lower extremity and had near full range of motion at the hip and knee. Radiographs showed a healed subtrochanteric as well as the shaft fracture with no loss of alignment (Figures 7 and 8).

DISCUSSION

After its first description nearly four and a half decades back, retrograde intramedullary nailing has been often

employed for femoral diaphyseal or supracondylar fractures associated with ipsilateral tibia and/or patella fractures. It is also a useful modality in diaphyseal fractures of femur associated with ipsilateral femoral neck fracture as well as acetabular fractures. In pregnancy, it proves advantageous over the antegrade nail by limiting radiation exposure to abdomen. In a polytrauma patient with multiple fractures and obese patients with bilateral femoral diaphyseal fractures, the retrograde nail negates the necessity of a fracture table or any special positions^[3-9]. At our center, we perform around 75 retrograde femoral nails per year.



Figure 6 Anteroposterior radiograph of the pelvis post revision fixation.

In a prospective randomized controlled trial, Ostrum *et al*^[3] compared the results, function, and complications of antegrade and retrograde femoral nailing for femoral shaft fractures in one hundred consecutive patients and concluded that both groups yielded high union rates. Knee pain was common in both the groups while antegrade nailing patients complained of thigh pain. They also noted that antegrade nailed femurs healed faster and a few retrograde nailed patients needed dynamization to achieve union.

In a paper on proximal femoral fractures associated with ipsilateral shaft fractures managed by hip screws and reamed retrograde intramedullary nails, Ostrum *et al*^[4] reported union rates of 98% and 91.3% for the femoral neck and shaft fractures respectively. In a systematic review of literature, Papadokostakis *et al*^[14] analyzed retrograde nailing of 544 femoral shaft fractures and observed an overall union rate of 94.6% and a mean time to union of 3.2 mo. They reported that 24.5% patients had knee pain and 17.7% of patients needed reoperations for screw related issues or to achieve union. Though none of them had proximal implant related fractures, 7.4% patients had malunion and the infection rate was 1.1%.

Our second case did show evidence of delayed union following both surgeries. In a case-control study by Taitzman *et al*^[15], identified risk factors for nonunion after femoral nailing of diaphyseal femur fractures were open fractures, tobacco use and delayed weight bearing. Modalities of managing femoral nonunions following nailing have included exchange nailing, plating and augmentative locking plating. All of these have shown excellent results^[16-18]. In a recent retrospective cohort study, Swanson *et al*^[16] described various strategies of exchange nailing for femur nonunions with nail *in-situ* including larger nails (at least 2 mm larger in diameter), nails from a different manufacturer, static interlocking, correction of metabolic and endocrine disorders and secondary dynamization.

Koval *et al*^[19] reported that any drill hole that occupies 20% of the diameter weakens the bone by 40% and that 90% of fractures around fixation implants occur through a drill hole. Proximal-end fractures after retrograde femoral nailing have been reported in the

Table 1 Comparison with previous case reports

Study	No. of cases	Index implant	Revision implant	Outcome
Leibner <i>et al</i> ^[12]	1	Supracondylar nail		
O'Mara <i>et al</i> ^[13]	1	Retrograde nail	95° blade plate	Good
Present	2	Retrograde nail	Antegrade nail	Good

past^[12,13] (Table 1). Leibner *et al*^[12] reported one case of a femoral fracture at the proximal end of an intramedullary supracondylar nail and concluded that it may be due to the proximal end acting as a stress riser and cortical holes drilled for the interlocking screw placement increasing the risk for failure. In their case report, the patient had a supracondylar nail placed for a distal third femur fracture and secondary fracture occurred in the diaphysis of the femur^[12]. In another case report by O'Mara *et al*^[13], a 61-year-old lady presented a month after sustaining a peritrochanteric fracture at the tip of a retrograde femoral nail 4 mo postoperatively with evidence of incomplete bridging callus at the index fracture shaft of the femur. She was managed by fracture reduction with traction and fixation with a 95° angled blade plate. The retrograde nail was left in situ. The authors reported a good outcome 1.5 years postoperatively.

Norris *et al*^[10] reported secondary fracture around femoral nails used to treat hip fractures and noted a slight decrease in the same when longer nails were used in comparison to short nails. The overall incidence was around 1.7%. Biaxial fixation compared to uniaxial fixation had a significantly lower risk of fracture. Further, emerging design changes have decreased the incidence of secondary fractures.

Iatrogenic femoral neck fractures during insertion of antegrade nails have been reported. These may be due to wrong insertion site, forceful insertion, multiple entry points, excessive lateral entry point and oblique insertion of the nail^[20,21]. Parker *et al*^[22] identified several factors responsible for peri-implant fractures including traumatic, stress, iatrogenic, avascular necrosis, implant failure and pathologic causes. These fractures were common in the elderly, osteopenic population. To avoid fatigue failure, multiple and larger diameter screws were added^[23].

Mounasamy *et al*^[24] reported two cases of a peri-implant fracture through distal interlocking screw site after fresh trauma, in patients who had previous intramedullary implant.

We are unsure why these fractures occurred in our patients. Metabolic and osteoporotic parameters of both patients were within normal limits. A probable explanation could be the presence of stress risers at the proximal end of the nail and screw holes. We preferred antegrade nailing with cephalomedullary screw fixation to manage both these secondary fractures in view of the location of both these fractures at the subtrochanteric level. Additionally, the second patient had delayed union



Figure 7 Anteroposterior and lateral radiographs six months after internal fixation of the peri-implant fracture.



Figure 8 Anteroposterior and lateral radiographs showing healed diaphyseal femur fracture.

of his previously treated femur fracture, which was addressed with reaming and a larger diameter nail.

Other treatment options to manage these fractures would be the use of proximal femoral locking plates, angled blade plates or the dynamic condylar screw plate device. Antegrade intramedullary nailing is the treatment of choice for subtrochanteric femur fractures^[25]. The proximal fragment in a subtrochanteric fracture is displaced in flexion, abduction and external rotation. Afsari *et al*^[26] have reported a high rate of union of subtrochanteric femur fractures treated with open clamp reduction and intramedullary nailing. They also reported that the subtrochanteric region has cortical bone with less vascularity and healing potential as compared to the intertrochanteric region.

To our knowledge, there is no consensus in the current literature regarding fracture at the far end of the retrograde nail placed to treat a femoral shaft fracture. We suggest the removal of the retrograde nail, if the fracture has healed anatomic reduction of subtrochanteric fracture and fixation with antegrade intramedullary nail.

COMMENTS

Case characteristics

Two patients presented with pain, swelling and deformity of the upper thigh following an injury.

Clinical diagnosis

Fracture proximal one third of the femur.

Differential diagnosis

Subtrochanteric fracture, fracture shaft of femur, fracture neck of femur, intertrochanteric fracture femur.

Imaging diagnosis

Case 1: Peri-implant fracture of the left femur in the subtrochanteric region at the far end of the retrograde nail confirmed by a computed tomography (CT) scan; Case 2: Peri-implant fracture of the right femur in the subtrochanteric region at the far end of the retrograde nail and delayed union of the previously treated femoral shaft fracture confirmed by a CT scan.

Treatment

Case 1: Implant removal, open reduction and interlocking antegrade femoral nailing; Case 2: Implant removal, open reduction, cerclage wiring and interlocking antegrade femoral nailing.

Experiences and lessons

This case report of two patients not only represents an unusual pattern of peri-implant femoral shaft fracture, but also confirms the excellent outcome following the management of these cases by antegrade nailing.

Peer-review

The authors have performed a good study, the manuscript is interesting.

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Ewings sarcoma of patella: A rare entity treated with a novel technique of extensor mechanism reconstruction using tendoachilles auto graft

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Abstract

We report a case of Ewings sarcoma (ES) involving the

patella in a young female. ES of patella is a rare entity. The patient was presented with anterior knee pain and swelling arising from the patella. She was treated with neoadjuvant chemotherapy followed by wide excision of the patella and reconstruction of the extensor mechanism using split tendoachilles auto graft. The patella is an uncommon site for primary or metastatic tumors of the bone. ES, though rare, should be included in the differential diagnosis of swellings arising from the patella. Auto graft from the tendoachilles is a good alternative for reconstructing the extensor mechanism of the knee.

Key words: Patellar tumor; Tendoachilles auto graft; Extensor mechanism repair; Ewing sarcoma; CD99

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Core tip: We are presenting an article of Ewings sarcoma (ES) of the patella-a rare entity treated by a novel technique. The common reported tumors of the patella include chondroblastoma, giantcell tumor, osteosarcoma, metastasis, *etc.* We could not find any report on a single case of ES/PNET in the patella treated with patellectomy and extensor mechanism reconstruction using tendoachilles auto graft in the whole of English bio-medical literature. We present here a case of ES of the right patella in a 26 years old female. All reported extensor mechanism reconstructions after patellectomy were by tendoachilles allografts. We resorted to a novel technique of reconstruction of the extensor mechanism using tendoachilles auto graft.

Valsalan RM, Zacharia B. Ewings sarcoma of patella: A rare entity treated with a novel technique of extensor mechanism reconstruction using tendoachilles auto graft. *World J Orthop* 2015; 6(9): 744-749 Available from: URL: <http://www.wjgnet.com/2218-5836/full/v6/i9/744.htm> DOI: <http://dx.doi.org/10.5312/wjo.v6.i9.744>

INTRODUCTION

Ewings sarcoma (ES) was first described by Ewing^[1] in 1921 as a "diffuse endothelioma of bone". The origin of these tumors is not definitively known. The two theories which support its origin suggest that these tumors arise from a primitive cell derived either from an embryologic tissue called the neural crest, or from resident cells in the body-mesenchymal stem cells. But it is not clear if this tumor is of mesenchymal or neuroectodermal origin. Now it has become clear that these entities comprise the same spectrum of neoplastic diseases known as the Ewing sarcoma family of tumors (EFT), which also includes malignant small-cell tumor of the chest wall (Askin tumor) and atypical ES^[2,3]. The incidence of Ewing sarcoma is approximately three cases per 1 million per year^[4]. EFT usually arises from the diaphysis or metadiaphyseal region of long bones. It also arises from the pelvic bones and ribs^[2]. The patella is an uncommon site for primary or metastatic tumors of the bone. The fact that the patella is a sesamoid bone, developing from an endochondral centre with a relatively short period of growth, plays a role in making patella a least preferred site for primary tumors^[5,6]. Primary tumors account for less than 0.06% of all bone tumors while metastatic lesions are even rarer^[7]. We report a case of ES involving the patella in a young female. ES is a relatively uncommon tumour accounting for 6%-8% of primary malignant bone tumors^[8]. Tumors of the patella are a rare cause of knee pain. Information available in the literature is largely in the form of isolated case reports and small case studies because of the rarity of patellar tumors^[9,10]. Epiphyseal tumors such as giant cell tumors and chondroblastomas are more common in the patella^[11]. Christensen hypothesized that the immunity of patella to bone tumors is due to the absence of loss of growth restraint incident to active diaphyseal growth and pressure epiphysis^[5,6]. We were unable to find any documentation of ES of the patella treated with wide excision and extensor mechanism reconstruction using tendoachilles auto graft in the English medical literature. We discuss a case of ES of the patella in a 26 years old female.

CASE REPORT

A 26 years old woman complained of anterior knee pain and swelling arising from the anterior aspect of right knee joint for the past two months. A private physician diagnosed prepatellar bursitis and treated with anti-inflammatory medications and rest that gave symptomatic relief for few days. At three months duration, patient noticed progressive increase in the size of the swelling and was referred to our institution. Initial examination showed a 19 cm × 16 cm × 10

cm firm, tender and warm swelling in the anterior aspect of right knee. Swelling was found to be arising from the right patella. There was no fixity to the skin. The movements of right knee were painful and the pain was worse while going up or downstairs and in squatting positions. The patient walked with a limp and preferred keeping the leg in an extended position. There was painful restriction of passive flexion beyond 90 degrees. Active movements showed a flexion of 70 degrees restricted by pain. There was no effusion, joint line tenderness or synovial thickening. Regional lymph nodes were not involved clinically and there was no distal neurovascular deficit. Routine hematological investigations were within normal limits. Radiographs showed multiple lytic and sclerotic lesions with ill-defined margins involving the anterior two-thirds of the patella (Figure 1). Computer tomography (CT) of the right knee joint showed destruction of patella with sclerotic and lytic lesions with intact posterior cortex. Magnetic resonance imaging showed the tumor mass involving the patella with an anterior soft tissue extension. There were no skip or satellite lesions. The possibility of either a primary malignancy of patella or metastatic lesion was considered. Clinical examination failed to reveal any primary for a metastatic lesion in the patella. CT of abdomen and chest were negative. As fine needle aspiration cytology gave inconclusive results, an incision biopsy was performed under lumbar subarachnoid block through anterior midline approach. Histopathology reports were suggestive of small round cell tumor possibly ES (Figure 2A). The tumour was classified as stage IIA as per the tumour staging by Enneking^[10]. After four cycles of neoadjuvant chemotherapy with Vincristin, Adriamycin and Cyclophosphamide, wide excision of the tumor was done. Preoperative injection of 1 g cefazolin was given 30 min prior to surgery. Surgery was done under lumbar subarachnoid block. Patient was in supine position with a pillow underneath the right buttock. A longitudinal midline incision extending 15 cm above to 10 cm below the right patella was made and a wide excision of the tumor mass including the whole patella, anterior soft tissue mass, 5 cm of quadriceps tendon beyond tumor margin and patellar tendon was done.

Intraoperatively, we found a 14 cm × 12 cm × 8 cm mass arising from the anterior aspect of right patella. The articular surface of the patella was grossly uninvolved (Figure 3). The whole patella appeared thickened with a soft tissue mass adherent to it. There was no involvement of the overlying skin. Intra operative frozen section showed that margins of resected specimen are free of tumor. This wide excision has created a 20 cm defect in the extensor mechanism of the knee. Then we opened the right tendoachilles tendon through a posterolateral 20 cm long incision. We took a 15 cm long lateral half of tendoachilles tendon as a graft. Extensor mechanism reconstruction was done with a V-Y quadriceps lengthening at musculo-tendinous junction and repair of defect using split graft taken from ipsilateral



Figure 1 Radiograph of the right patella shows multiple lytic and sclerotic lesions involving the anterior two-thirds of the patella.

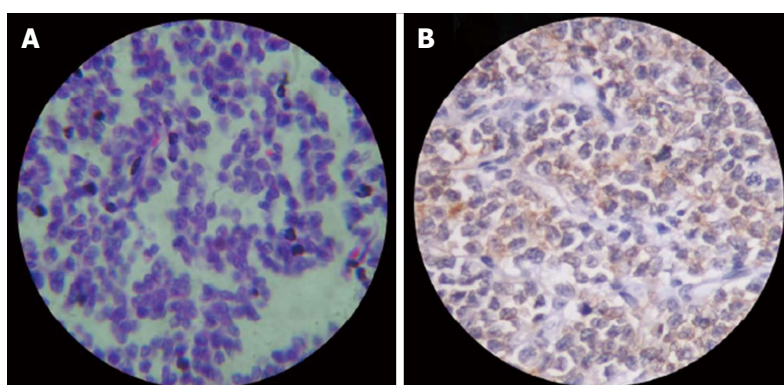


Figure 2 Haematoxylin and Eosin staining shows uniform, small, polygonal cells with scanty cytoplasm and indistinct cell borders (HE \times 400) and Immunohistochemical staining shows CD99 diffuse positivity (A and B).

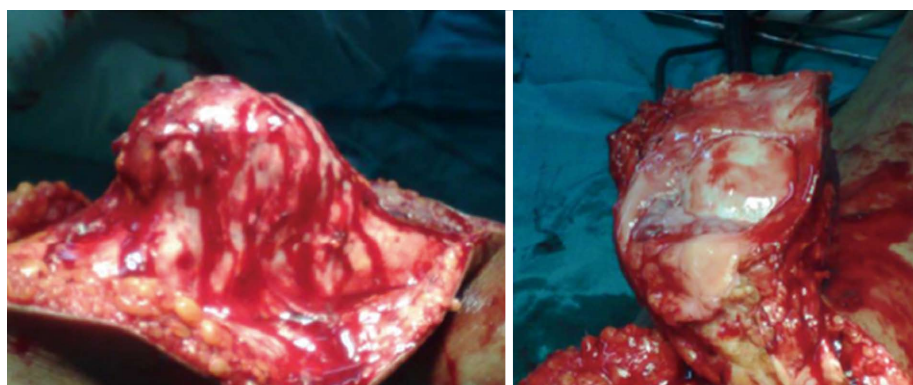


Figure 3 Intraoperative picture shows thickened patella with uninvolved articular surface.

tendoachilles (Figure 4). The whole procedure took about two hours and a half and no tourniquet was used.

Postoperatively, right leg was immobilized in a long leg cast for six weeks followed by physiotherapy to regain the quadriceps power. She regained about 80 degrees of knee flexion and walked with support of a cane. She had 10 degrees of extension lag with no donor site morbidity. Postoperatively, adjuvant chemotherapy was started on with alternating regimen of vincristin, adriamycin, cyclophosphamide and ifosfamide, etoposide. After 12 mo she complained of recurrent backache. A Bone scan showed multiple

metastatic lesions at different skeletal sites like cervical and thoracic vertebrae, scapula, pelvis and base of skull. Bone pain was treated symptomatically in consultation with the radiotherapy department. At two years follow-up, the patient is walking with cane support. There are no clinical or radiological evidences of local recurrence. CT thorax did not show any evidence of lung metastasis. Grossly, the resected specimen showed firm grey-white lesion arising from the patella with areas of hemorrhage and cystic degeneration. The extra osseous soft tissue component was soft and friable. Microscopy showed broad sheets and large nests of uniform, small,

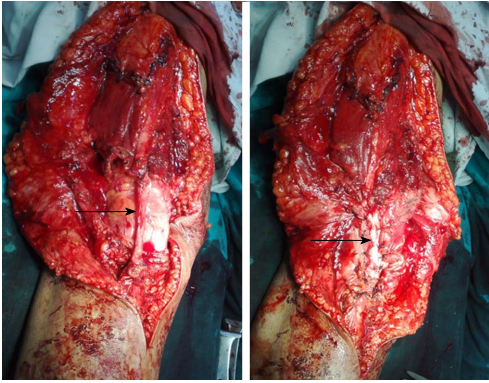


Figure 4 Peroperative picture shows repair of the extensor mechanism using V-Y plasty and split tendoachilles autograft.

polygonal cells with scanty pale cytoplasm and indistinct cell borders (Figure 2A). There were also areas of rosette formation. The specimen margins were free of tumor tissue. Immunohistochemical examination of the specimen showed CD99 diffuse positivity that favored the diagnosis of ES (Figures 2B and 4).

DISCUSSION

Primary malignant tumors of patella are rare entity^[12]. The fact that the patella is a sesamoid bone, developing from an endochondral centre with a relatively short period of growth plays a role in making patella a least preferred site for primary tumors^[13,14]. Chondroblastomas and giant cell tumors form the most common tumors of the patella^[12-14]. This is probably due to the similarity in the ossification of the patella with that of the epiphysis of long bones^[11]. There are reports of tumors like osteoid osteoma, osteoblastoma, spindle cell sarcoma, osteitis fibrosa cystica, aneurysmal bone cyst and myelomatous infiltration arising from the patella^[15-20]. Osteosarcoma is the most frequent primary malignant tumor of patella^[9]. Other reported primary malignant neoplasms are hemangioendothelioma, malignant fibrous histiocytoma and angiosarcoma^[21]. Systemic lesions such as lymphoma and plasmacytoma may also involve patella^[9]. There are several reports of metastasis to the patella from sites like kidney, lung, eye, prostate, breast and uterus^[9,22-24]. However, documentation of ES of patella in the English medical literature is lacking. Chronic anterior knee pain is the most common presenting feature in patients with patellar tumors^[11]. The prognosis for patellar tumors is good even though most of the cases appear late, as majority of the tumors are benign^[11]. The outcome following a malignant tumor of the patella and the need of an immediate surgical intervention remain unanswered due to lack of adequate literature. ES is the third most common primary sarcoma of the bone after osteosarcoma and chondrosarcoma^[25]. Approximately 80% of patients afflicted are younger than 20 years of age^[26]. ES is now thought to be least differentiated of a group of small cell neoplasms with varying degrees of neuroectodermal differentiation. ES

typically affects diaphysis of long bones. Epiphyseal ES is a rare entity^[27]. Usual clinical features include pain and swelling associated with fever, anemia and leukocytosis. Radiological picture of ES consists of mixed sclerotic and lytic lesions. An ill-defined osteolytic lesion involving the diaphysis of a long bone or flat bone is the most common feature. ES is characterized by a recurrent (11:22) (q24:12) chromosomal translocation, which is detectable in 85% of cases^[28]. ES has a strong potential to metastasize mostly to the lungs and bone. More than 10% of patients present with multiple bone metastases at initial diagnosis. While metastases in the lungs, bone, bone marrow, or a combination thereof are detectable in approximately 25% of patients, metastases to lymph nodes are rare^[26]. Microscopically, classic ES consist of broad sheets and nests of uniform, small, polygonal cells with scanty pale cytoplasm and indistinct cell borders. About 10% of cases contain rosette-like structures that in reality represent necrotic cell "dropout" of a central mass. CD99 is one of the most sensitive markers for the diagnosis of ES^[29,30]. It is expressed in almost all cases. They have also shown to express neural markers such as neuron specific enolase^[8]. But these markers are less sensitive. The tumour can be staged according to the tumour staging by Enneking^[31]. Extensive patellectomy with removal of the distal part of the quadriceps tendon, the proximal part of the patellar tendon, and the overlying patellar fascia is necessary in patients with Stage IIA tumors because these neoplasms might have satellites in the peripheral, reactive zone^[9]. Surgical excision of the patellar tumor is justified in view of its location in an expendable bone^[32]. Patella is an important part of the extensor mechanism. It seems logical to combine patellectomy with extensor mechanism reconstruction or reinforcements^[33]. Whenever patellectomy is indicated. Several methods of extensor mechanism reconstruction like Z-plasty or cruciate plasty or fascia lata graft or vastus medialis obliquus advancement have been described. Repair of the extensor mechanism using Achilles tendon allografts has produced good results^[34,35]. We repaired the gap in the extensor mechanism following tumor excision using V-Y quadriceps plasty and ipsilateral split tendoachilles auto graft. Split tendoachilles auto graft is good option for reconstructing the extensor mechanism in places where allograft is not available. It has got advantages like ease of harvesting, free availability, good strength, low graft site morbidity and no issues related to disease transmission and graft rejection. Here we have a young lady with ES of the patella, which has not been reported earlier. The tumor being localized to the patella was excised along with a part of quadriceps and patellar tendon followed by extensor mechanism reconstruction using quadriceps lengthening and split tendoachilles auto graft after neoadjuvant chemotherapy. Two years after surgery, patient is able to carry out her activities of daily life. She is on regular follow up. There are only two cases of ES of patella reported previously of which one is a case associated with nail patella syndrome^[36,37].

Primary malignant tumors of the patella are very rare. ES of the patella is a rare entity. Extensor mechanism reconstruction using split tendoachilles auto graft following excision of the patellar tumor is an effective technique. ES, though rare, should be included in the differential diagnosis of swellings arising from the patella.

COMMENTS

Case characteristics

A 26 years old woman presented with pain and swelling in the right knee for the past two months.

Clinical diagnosis

On examination there was a 19 cm × 16 cm × 10 cm warm tender swelling in the anterior aspect of the right knee.

Differential diagnosis

Her radiograph and computer tomography showed multiple lytic and sclerotic lesions in the patella. Also, magnetic resonance imaging showed tumor in the patella with anterior soft tissue extension. Histopathology confirmed small round cell tumor - Ewings sarcoma with CD99 positivity in immunohistochemistry.

Treatment

She was treated by a wide excision of tumor along with patella and resulted gap was repaired using tendoachilles auto graft taken from the ipsilateral side and a V-Y quadriceps lengthening.

Experiences and lessons

This report is presented due to the rarity of patellar tumors and highlights the usefulness of tendoachilles auto graft in treating extensor mechanism defects of knee, especially after wide excision of tumors of patella.

Peer-review

The paper gives detail as to the biopsy results and method to treat plus basic follow up information.

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