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ANATOMO-PATOLOGIA DA REGIÃO ANTERO-SUPERIOR DO OMBRO.

MARIA JOÃO LEITE CABRAL MONTEIRO DE ALMEIDA

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Autor: Maria João Leite

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Exma. Senhora

Mestre Maria João Leite Cabral Monteiro de Almeida

mjlcma@gmail.com

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PREFÁCIO

Há vários anos, no início do meu percurso na Ortopedia a Traumatologia, apercebi-me que na medicina nada acontece por acaso. Na Ortopedia e no caso da patologia do ombro em especifico, o papel das estruturas anatómicas na fisiopatologia das roturas da coifa é fonte de discussões acesas em reuniões científicas um pouco por todo o mundo. Por outro lado, desde o início dos meus primeiros passos nesta especialidade, que nos ensinam o papel da anatomia e da biomecânica tanto para a compreensão das patologias que tratamos bem como para planearmos o tratamento adequado a cada um destes síndromes.

Foi numa quinta feira à tarde, entre o final da primeira cirurgia e a anestesia do segundo doente, que em conversa com o Professor João Torres surgiu o desafio de estudarmos a fisiopatologia das roturas do subescapular, um tendão cuja fisiopatologia era até recentemente negligenciada.

Seguiram-se vários meses de planeamento e finalmente anos de trabalho conjunto com os desafios e recompensas comuns a muitos Doutoramentos. Um caminho longo e trabalhoso, cheio de contratempos que eventualmente resultaram em avanços, mas que revejo com nostalgia e carinho. Deste percurso resultou esta Tese, que não procura ser definitiva, mas antes um ponto de partida para continuação da procura das respostas a tantas perguntas novas que me surgiram durante este Doutoramento.

Esta tese contou, de uma forma ou outra, com o apoio de um extenso número de participantes, aos quais devo os meus agradecimentos.

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À minha mãe por me ensinar a querer sempre mais e melhor, e me fazer acreditar que sou capaz de tudo. À minha irmã, tios e primos pelos momentos de partilha e entreajuda. Às minhas amigas, pilares essenciais neste percurso, sempre presentes na celebração de vitórias e sobretudo na ajuda para enfrentar e ultrapassar os desafios.

A ti, João, pela compreensão e por me fazeres descer à realidade quando precisei.

RESUMO

Introdução

A fisiopatologia das roturas da coifa dos rotadores foi já extensamente estudada, no entanto, a fisiopatologia das lesões do subescapular é ainda pouco compreendida. Sabe-se que a maioria das roturas do subescapular decorre da progressão de uma rotura antero-superior da coifa, contudo podem também correlacionar-se com a presença de conflito subcoracoide.

Adicionalmente o diagnóstico de lesões do subescapular continua a ser desafiante, uma vez que a sensibilidade dos testes diagnósticos e dos meios complementares de diagnóstico é reduzida, quando comparada com a restante coifa dos rotadores.

Materiais e métodos

Neste contexto torna-se imprescindível uma melhor compreensão da fisiopatologia associada às roturas da coifa anterior, a definição de fatores de risco que possam predispor a este tipo de lesões, bem como a identificação de fatores anatómicos responsáveis por este grupo de patologias. Para atingirmos os objetivos proposto, foram realizados 4 estudos que procuraram estabelecer fatores de risco para roturas do subescapular, determinar o papel do conflito subcoracoide nas suas roturas, elucidar o mecanismo de progressão das roturas antero-superiores da coifa e correlacionar estes achados num modelo humano.

Resultados

Os estudos imagiológicos permitiram estabelecer o papel de fatores de risco previamente descritos e descrever novos possíveis preditores de lesões do subescapular. A distância coraco-umeral foi o melhor preditor de roturas do subescapular, seguida do ângulo coracoide, sendo que ambos os índices mostraram um papel mais importante na fisiopatologia destas

roturas do que a dimensão da coracoide. Adicionalmente, a versão umeral também parece influenciar o risco de desenvolver patologia do subescapular. Demonstramos ainda que roturas completas do supraespinhoso resultam num conflito subcoracoide secundário, e consequentemente um maior risco de lesões do subescapular.

O estudo anatómico permitiu confirmar uma possível base anatómica para o conflito subcoracoide, bem como definir pela primeira vez o papel de um ligamento coraco-acromial (LCA) duplo na fisiopatologia das roturas do subescapular

Discussão e Conclusão

Pela melhor compreensão da fisiopatologia das lesões do subescapular esperamos poder contribuir para um melhor tratamento dos doentes com patologia da região anterior do ombro, através do aumento do índice de suspeição clínica e identificação de doentes com maior risco de desenvolver estas patologias.

ABSTRACT

Introduction

The pathophysiology of rotator cuff tears has been extensively studied, however, subscapularis injuries are still poorly understood. Although, most subscapularis tears result from the progression of an anterosuperior cuff tears, they can also be correlated with the presence of subcoracoid conflict. Additionally, the diagnosis of lesions of the subscapularis remains challenging, since the sensitivity of clinical tests and imaging exams is reduced, when compared to the rest of the rotator cuff tears.

Materials and methods

In this context it is essential to understand the pathophysiology associated with anterior cuff tears, define risk factors that may predict this type of injury, and define anatomical factors that may play a role in this group of pathologies. In order to achieve these objectives, four studies were carried out that sought to establish risk factors for subscapularis tears, determine the role of subcoracoid conflict in these lesions, elucidate the mechanism of progression of anterior-superior cuff tears, and finally, correlate these findings in a human model .

Results

Imaging studies allowed us to establish the role of previously described risk factors and to describe new possible predictors of subscapularis lesions. The coracohumeral distance was the best predictor of subscapularis tears, followed by the coracoid angle, with both indices playing a more important role in the pathophysiology of these tears than the dimension of the coracoid.

Additionally, the humeral version also appears to influence the risk of developing subscapularis pathology. We further demonstrate that complete ruptures of the supraspinatus result in secondary subcoracoid conflict, and consequently an increased risk of subscapularis lesions.

The anatomical study confirmed a possible anatomical basis for the subcoracoid conflict, as well as defining for the first time the role of a double coracoacromial ligament (ACL) in the pathophysiology of subscapularis tears.

Discussion and Conclusion

While contributing to a deeper understanding of the pathophysiology of subscapularis lesions, we hope that this work will be able lead to a better treatment of patients with pathology in the anterior region of the shoulder, by increasing the index of clinical suspicion and identifying patients at greater risk of developing these injuries.

ÍNDICE

LISTA DE ABREVIATURAS

AUC	*Area under the ROC curve*
AC	Ângulo Coracoide
CCD	Comprimento coracoide distal
CCP	Comprimento coracoide proximal
CCR	Ratio dos comprimentos coracoides
CCT	Comprimento coracoide total
CHUSJ	Centro Hospitalar Universitário de São João
DCU	Distância coraco-umeral
LCA	Ligamento coracoacromial
LPB	Tendão da longa porção (cabeça longa) do bicípite
OC	Overlap Coracoide
RE	Rotação externa (lateral)
RI	Rotação Interna (medial)
RMN	Ressonância eletromagnética
ROC	*Receiver Operating Characteristic Curve*
SE	Supraespinhoso
SS	Subescapular
TC	Tomografia compoturizada

1. INTRODUÇÃO

A fisiopatologia das roturas da coifa dos rotadores foi já extensamente estudada, com alguns autores a defenderem mecanismos condicionados por *overuse* e hipóxia, outros a postularem processos degenerativos e grupos de estudo a salientarem a importância da anatomia da cintura escapular nesta patologia. [1,2] Contudo, contrariamente ao que sucede com as roturas do supraespinhoso, a fisiopatologia das lesões do subescapular é ainda pouco compreendida.

Sabe-se também que as roturas isoladas do subescapular são raras, e que a maioria decorre da progressão de uma rotura antero-superior da coifa, progredindo antero-inferiormente. [3]

Para além disso, o conflito subcoracoide, associado a uma diminuição da distância coraco-umeral, é uma entidade que tem sido reconhecida de forma crescente e pode também ser responsável por quadros de omalgia anterior recorrente. [1,4] Contudo, a influência da dimensão e da anatomia da apófise coracoide ainda não foi completamente compreendida, e não obstante a influência da morfologia da glenoide na patologia da coifa já ter sido definida, não existiam ainda estudos relativos à influência da versão umeral nestas patologias. [2,5]

Apesar do crescente reconhecimento, o diagnóstico de lesões do subescapular continua a ser desafiante, uma vez que a sensibilidade dos testes diagnósticos e dos meios complementares de diagnóstico é reduzida, quando comparada com a do diagnóstico de patologia da restante coifa dos rotadores. [6-10]

Assim torna-se imprescindível uma melhor compreensão da fisiopatologia associada às roturas da coifa anterior, a definição de fatores de risco que possam predispor a este tipo de lesões, bem como a identificação de fatores anatómicos responsáveis por este grupo de patologias.

I. Anatomia da região antero-superior do ombro

Recentemente um interesse crescente tem existido no estudo da anatomia da região anterior do ombro, na esperança de compreender melhor a patologia do espaço subcoracoide e do tendão subescapular. Este interesse foi fomentado pela acumulação de evidência do papel de fatores anatómicos na fisiopatologia das roturas da coifa, nomeadamente da morfologia da apófise coracoide e do acrómio, anatomia do ligamento coraco-acromial e distância coraco-umeral (DCU). A coracoide é fundamental na anatomia cirúrgica do ombro, sendo apelidada do "farol do ombro" na comunidade ortopédica, sendo que um dos princípios de segurança durante a abordagem da região anterior do ombro é manter a disseção lateral à coracoide, evitando as estruturas neurovasculares, como o plexo braquial e a artéria axilar. [11] Para além de representar o limite da disseção segura, a coracoide serve ainda como uma referência anatómica palpável útil no planeamento da incisão cirurgica e serve como inserção de várias massas musculares e ligamentos. [12]

Assim, a coracoide funciona como inserção proximal do peitoral menor, coracobraquial e da curta porção do bicípite braquial, bem como dos ligamentos coracoclavicular, coraco-umeral, coracoacromial e supraescapular. Desta forma, é natural que a região da coracoide seja uma fonte de patologia desta zona, e abordada frequentemente. [12]

A apófise coracoide é uma apófise com formato em gancho, que se projeta antero-lateralmente a partir da região superior do colo da omoplata, servindo como inserção muscular e ligamentar medial e lateralmente. O peitoral menor insere-se medialmente na superfície superior da coracoide. O coracobraquial e a cabeça curta do bicípite apresentam uma origem comum na extremidade da apófise coracoide. [12]

A relação da coracoide com a coifa subjacente e restantes estruturas do ombro é crucial para a realização de procedimentos e interpretação de imagens de meios complementares de diagnóstico. A anatomia óssea da coracoide divide-se na sua porção proximal ou pilar inferior, e a porção distal ou pilar superior. [13-15] O segmento proximal estende-se do colo da omoplata dirigindo-se superomedialmente, mudando de direção no segmento distal que se dirige antero-lateralmente. [13-15]

A coracoide faz ainda parte do arco coraco-acromial, constituído também pelo acrómio e ligamento coracoacromial, e cuja função é limitar a migração superior da cabeça umeral (Figura 1). [16] Este arco situa-se imediatamente superior à bursa subacromial e tendão do supraespinhoso, podendo estar envolvido no *impingment* subacromial, o tipo de conflito mais frequente no ombro.[17]

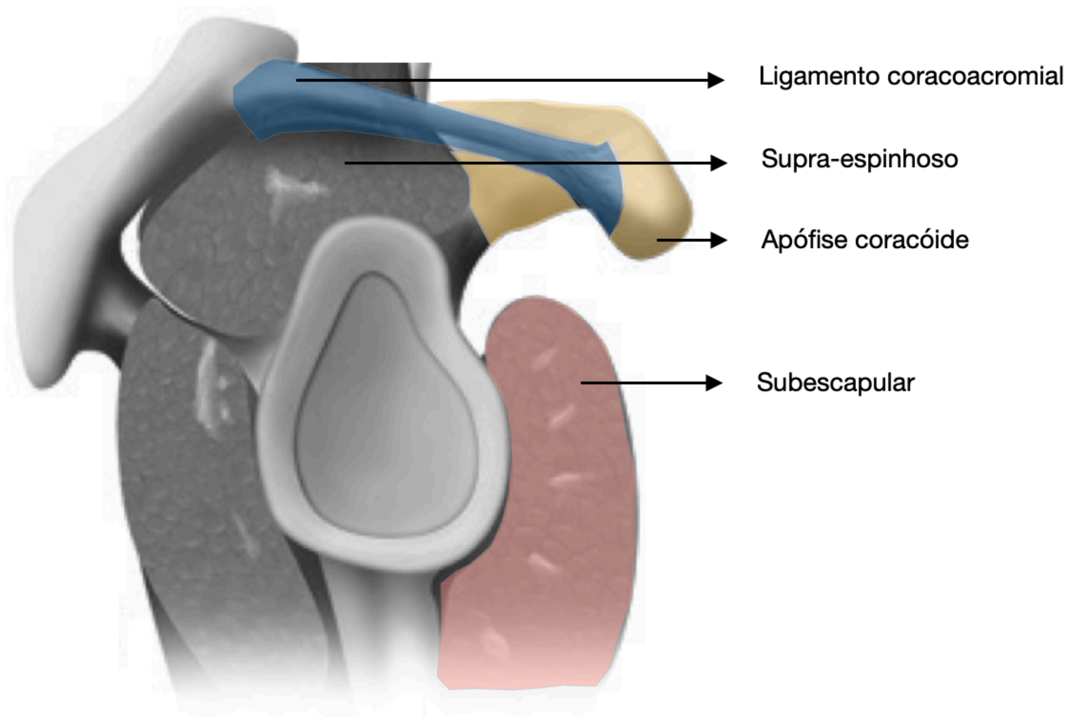

Fig. 1: Arco coracoco-acromial, constituído pelo acrómio, ligamento coraco-acromial e apófise coracoide. Tendão do subescapular em íntima relação com a apófise coracoide e ligamento coraco-acromial.

Este *impingment* foi descrito pela primeira vez por Neer [18] em 1972 e pode estar associado a alterações da anatomia do acrómio ou ligamento coraco-acromial (LCA). Estudos demonstraram também que LCA mais extensos e com alteração das suas propriedades intrínsecas se associaram a *impingement* subacromial. [19] Relativamente à morfologia do LCA, este era tradicionalmente descrito como um ligamento com forma triangular que se estendia da coracoide em direção ao acrómio, contudo estudos descreveram 5 principais variantes: (1) um ligamento com uma banda, (2) um ligamento em forma de Y, (3) um ligamento mais extenso e de formato quadrangular, (4) um ligamento duplo e (5) um ligamento com múltiplas bandas. Todavia, a frequência relativa de cada variante difere entre estudos. [19]

O *impingement* subcoracoide é um tipo de conflito do ombro menos frequentemente diagnosticado, sendo definido pelo conflito do espaço do tendão do subescapular entre a pequena tuberosidade (tubérculo menor do úmero) e apófise coracoide. [6,20] Assim, a definição da margem de segurança para procedimentos cirúrgicos da apófise coracoide é essencial para a realização segura coracoplastia em casos de conflito subcoracoide. [21,22] Apesar de o *impingement* subcoracoide ser um processo dinâmico, a maioria dos estudos do espaço subcoracoide são radiológicos e portanto baseiam-se em avaliações estáticas. Neste contexto, modelos humanos, como os estudos em cadáver, apresentam a vantagem adicional de permitir uma avaliação dinâmica deste espaço. [21,23,24]

A longa porção do bicípite origina-se do tubérculo supraglenoideu e porção superior do labrum, dirigindo-se lateral e inferiormente em direção à sua goteira. A bainha da LPB é uma estrutura capsulo-ligamentar estabilizadora deste tendão, sendo formada pelo ligamento coraco-umeral, ligamento gleno-umeral superior e com contribuição do subescapular, que formará o teto da goteira. É importante conhecer a anatomia normal da LPB e da sua polia para que possam ser reconhecidas lesões desta estrutura. [25]

Assim, a LPB encontra-se em íntima relação com o tendão do subescapular, e qualquer evidência de lesão ou instabilidade da LPB deve levantar a suspeita de lesão do tendão do subescapular. [26]

As lesões da LPB incluem um espetro de patologias, desde tendinopatia a instabilidade e rotura e podem ser classificadas segundo diferentes critérios. Existem diversas classificações que classificam a patologia do LPB de acordo com a topografia da lesão, segundo o processo subjacente ao quadro patológico, com base em alterações histológicas do tendão e ainda tendo em conta a presença de outras lesões da coifa dos rotadores e de outras estruturas intra-articulares. [27-29]

De particular interesse no caso da associação com patologia do subescapular, é a classificação de Habermeyer e Walch para lesões do LPB. [27] Este sistema classificativo inclui a divisão das lesões do LPB em lesões da sua origem (tipo I), lesões no intervalo dos rotadores (tipo II) e lesões associadas a roturas da coifa (tipo III). [27]

Segundo esta classificação, as subluxações do LPB podem decorrer de lesões do intervalo (tipo II) dos rotadores associadas a rotura das fibras superiores do subescapular (subtipo C.II), resultando numa subluxação medial do LPB. [27]

De acordo com estes autores, subluxações e luxações do LPB podem também ocorrer no contexto de roturas da coifa (tipo III). Segundo Habermeyer e Walch a luxação da LPB associada a lesões do subescapular, pode ocorrer quer na presença de rotura parcial da sua porção mais cefálica e superficial, quer na presença de rotura completa deste tendão com luxação infero-medialmente e intra-articular da LPB. [27]

Posteriormente em 2004 Habermeyer *et al* descreveu uma nova classificação que estratificava em detalhe as lesões da polia do LPB, percursoras de instabilidade deste tendão (Figura 2). Assim, as lesões da polia seriam divididas em quatro tipos, sendo que no tipo 3 e 4 lesões do tendão do subescapular estariam na base da instabilidade do LPB. [28]

Em 2007, Lafosse *et al* procurou estabelecer a relação entre diferentes tipos de instabilidade do LPB e lesões concomitantes da coifa. Neste estudo, os autores determinaram que 45% dos doentes submetidos a sutura da coifa apresentavam instabilidade do LPB, sendo que a instabilidade anterior se associou a lesões do tendão do subescapular. Neste trabalho, os autores demonstraram ainda que o tamanho da rotura da coifa se correlacionava com o grau de instabilidade do LPB. Através destas observações Lafosse *et al*, criou uma classificação artroscópica da instabilidade do LPB em doentes com roturas da coifa, em que a instabilidade é classificada segundo a aparência macroscópica do LPB (normal, lesão minor ou lesão major), grau (normal, subluxação ou luxação) e direção da instabilidade (anterior, posterior ou combinada), assim como presença de rotura da coifa adjacente (intacta, rotura parcial ou rotura total).[29]

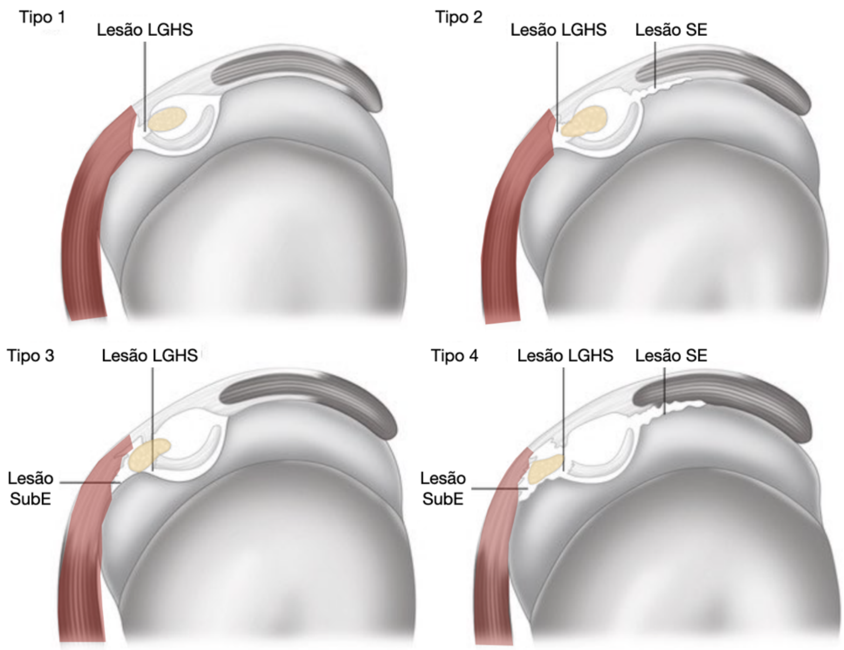

Fig. 2: Tipo de lesões da polia do LPB segundo Habermeyer *et al*. Tipo 1 – lesões isoladas do ligamento gleno-umeral superior (LGHS). Tipo 2 – lesões do LGHS e lesão parcial articular do supraespinhoso (SE). Tipo 3 – lesão do LGHS e da camada profunda do subescapular (SubE). Tipo 4 – lesão combinada do LGHS, SE e SubE. Circulo amarelo – longa porção do bicípite (LPB).

Parece consensual entre autores a relação entre roturas da coifa, particularmente do subescapular, e lesões da LPB, possivelmente ditada pela contribuição do subescapular para a constituição da polia estabilizadora deste tendão. Assim, a capacidade de identificação e avaliação das lesões do LPB e da sua polia nos meios de imagem e intra-operatoriamente são pistas importantes na deteção de lesões do subescapular, bem como uma causa importante de morbilidade nos doentes com patologia da coifa antero-superior.[27-29]

Para além da caraterização da anatomia óssea e musculo-tendinosa, o conhecimento das relações anatómicas com as estruturas neurovasculares é essencial para o tratamento seguro das patologias da região anterior do ombro. [22,30]

As complicações neurológicas não são raras na cirurgia do ombro, com uma incidência que pode ir até 8%, possivelmente associada a uma tendência crescente de realização de procedimentos cada vez mais complexos. Apesar destas lesões poderem afetar várias estruturas neurovasculares, as complicações afetam na sua maioria os nervos axilar e músculo-cutâneo. [31,32]

Medial e inferiormente à apófise coracoide, encontra-se o eixo neurovascular, incluindo o plexo braquial e artéria e veia axilar (Figura 3). Distalmente à individualização do nervo dorsal da omoplata e supraescapular, o plexo braquial inicia a divisão dos cordões medial, lateral e posterior nos seus ramos. [12] O cordão posterior dá origem ao nervo axilar, subescapular superior e inferior, e toracodorsal, antes de originar o nervo radial. [25]

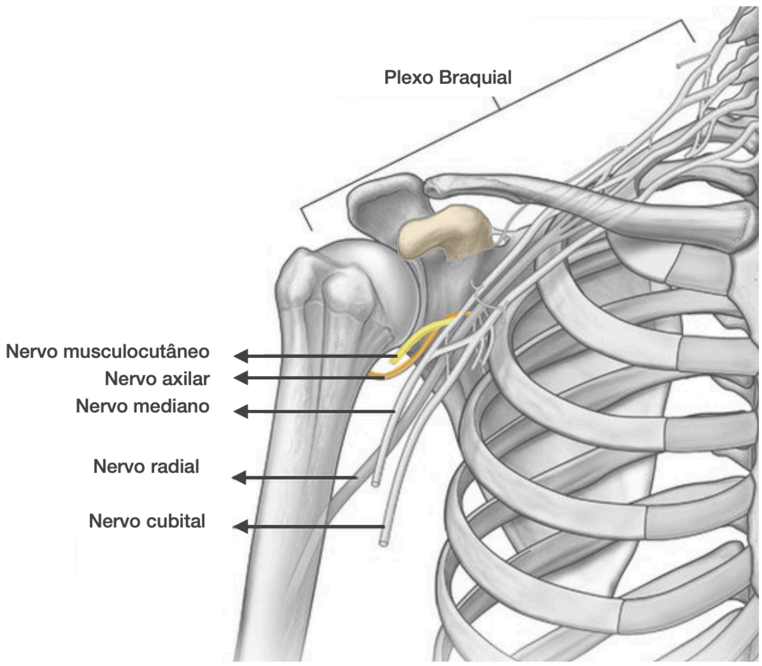

Fig. 3: Plexo braquial ao nível da articulação gleno-umeral, verificando-se uma estreita relação de proximidade entre a coracoide, e os nervos axilar e musculocutâneo.

O nervo axilar é um importante nervo periférico, frequentemente em risco de lesão iatrogénica durante procedimentos artroscópicos e abertos. Este representa um dos principais ramos do cordão posterior, sendo constituído por fibras de C5 e C6. O nervo axilar encontra-se na proximidade do eixo vascular, situando-se posteriormente à artéria e veia axilares, bem como na proximidade de estruturas neurológicas, situando-se superiormente ao nervo radial e lateralmente ao nervo mediano e cubital. [33-35] Após a divisão do nervo axilar a partir do cordão posterior, este dirige-se inferolateralmente em direção ao tendão subescapular. Posteriormente divide-se nos seus ramos anterior e posterior, ao atravessar o espaço quadrangular ao nível do bordo inferior do subescapular. Finalmente origina vários ramos responsáveis por suprir o deltóide, redondo menor e articulação gleno-umeral, originando ainda o nervo cutâneo lateral superior do braço. [33-35]

A cordão lateral vai dar origem ao nervo peitoral lateral, nervo musculocutâneo, contribuindo ainda para a formação do nervo mediano juntamente com o cordão medial. O nervo musculocutâneo conta com a participação de fibras de C5 a C7, surgindo posteriormente ao pequeno peitoral, superior e lateralmente ao nervo mediano e artéria axilar. Este dirige-se inferolateralmente cruzando o subescapular, até penetrar no músculo coracobraquial. Distalmente ao ponto onde abandona o coracobraquial, o nervo musculocutâneo vai fornecer enervação para o bicípite e braquial, cruzando a face anterior do braço e dirigindo-se distalmente até se tornar subcutâneo, ao nível do cotovelo. [25,37]

Vários procedimentos envolvem a disseção e manipulação do tendão conjunto e do músculo corado-braquial, colocando potencialmente em risco o nervo musculocutâneo. [25]

Finalmente, o cordão medial vai originar o nervo cutâneo medial do braço e antebraço, o nervo peitoral medial e o nervo cubital. [25]

II. Fisiopatologia das roturas do Subescapular

As roturas da coifa apresentam uma fisiopatologia multifatorial, com componentes traumáticos, degenerativos, condicionados por fatores intrínsecos ou extrínsecas. As causas extrínsecas incluem síndromes de conflito, como o *impingement* subacromial ou subcoracoide.[1]

O subescapular é o músculo mais forte e com maior massa da coifa dos rotadores, contudo as suas lesões são frequentemente subdiagnosticadas. [38] Roturas do subescapular foram descritas pela primeira vez em 1834 por Smith, sendo que a reparação deste tendão foi conseguida pela primeira vez em 1954 por Hauser. [38,39] Posteriormente Gerber, Burkhart e Lafosse publicaram trabalhos focados em series de doentes tratados a roturas do subescapular de forma aberta e artroscópica. [40-42]

Assim, nos últimos anos, o aumento do índice de suspeição aliado ao desenvolvimento dos métodos de imagem e à generalização de técnicas artroscópicas de sutura da coifa têm identificado um número crescente de doentes com estas roturas. [38] À medida que se expandiu o conhecimento relativo à patologia do subescapular, este tendão foi reconhecido como uma importante fonte de patologia na cintura escapular. [38]

Contudo, contrariamente ao que acontece com o supraespinhoso, roturas isoladas do subescapular são raras. Assim, a maioria das roturas do subescapular ocorrem no contexto de roturas antero-superiores da coifa, sendo que estas roturas progridem caudalmente, desde roturas do terço superior até roturas de todo o *footprint* nas lesões mais complexas. [6-9]

A massa muscular do subescapular origina-se da fossa subescapular da face anterior da omoplata, representando mais de metade da massa muscular da coifa dos rotadores. [38] Lateralmente quatro a seis feixes formam a inserção tendinosa do subescapular ao nível da pequena tuberosidade, que distalmente se continua como uma inserção muscular correspondendo a 1/3 do seu *footprint*. [38] Estudos reportam *footprints* do subescapular que variam entre 25 e 52mm de comprimento e 11 a 18 mm de largura, dependendo da inclusão ou exclusão da inserção muscular. [43-45]

Biomecanicamente o subescapular funciona como um rotador interno do ombro, trabalhando sinergicamente com o grande peitoral, grande dorsal e redondo maior, sendo adicionalmente um estabilizador dinâmico desta articulação, e contribuindo para a normal biomecânica do ombro no seu arco de mobilidade. [38]

O diagnóstico deste tipo de roturas exige um alto índice de suspeição, sendo que frequentemente os doentes apresentam dificuldade nas atividades que envolvam rotação interna. Contudo a clínica de lesão do subescapular pode ser mascarada pela mais evidente rotura do supraespinhoso que frequentemente também está presente. [38]

A avaliação clínica deve incluir testes específicos para o subescapular como o *Lift-Off*, *Belly-Press* e o *Bear-Hug*, que em conjunto apresentam uma sensibilidade de aproximadamente 80%. [46]

Relativamente ao diagnóstico, a sensibilidade dos meios complementares de imagem para lesões do subescapular é inferior quando comparada com a restante coifa dos rotadores. [38] Estudos por ecografia apresentam uma sensibilidade de 39,5% e especificidade de 93,1%, sendo estes valores inferiores para roturas pequenas. [47] A ressonância eletromagnética (RMN) é o meio complementar de diagnóstico mais frequentemente utilizado para o diagnóstico das lesões deste tendão, contudo continua a ser menos sensível do que para o diagnóstico de lesões da restante coifa. [38]

Assim, o diagnóstico de lesões do subescapular apresenta vários desafios, fazendo com que estas lesões devam ser ativamente pesquisadas durante o procedimento artroscópico, mesmo na ausência de lesão descrita nos meios complementares de diagnóstico. Para além da presença de rotura do tendão, existem sinais indiretos que devem ser procurados, como instabilidade da LPB, rotura parcial da LPB no ponto de saída da articulação (*sentinel sign*) e ainda a presença do *comma sign*. [38,48,49] Mesmo na ausência destes sinais, perante a alta suspeição clínica ou na presença de um doente de risco para patologia da coifa anterior, roturas do subescapular devem ser ativamente procuradas com recurso a desbridamento do intervalo dos rotadores ou mobilização do tendão. [38]

Existem diversas classificações utilizadas para descrever as roturas do subescapular, incluindo a classificação de Pfirrmann *et al* e de Voo and Rhee, contudo a Classificação de Lafosse continua a ser particularmente útil na descrição da lesão e subsequente decisão terapêutica. [38]

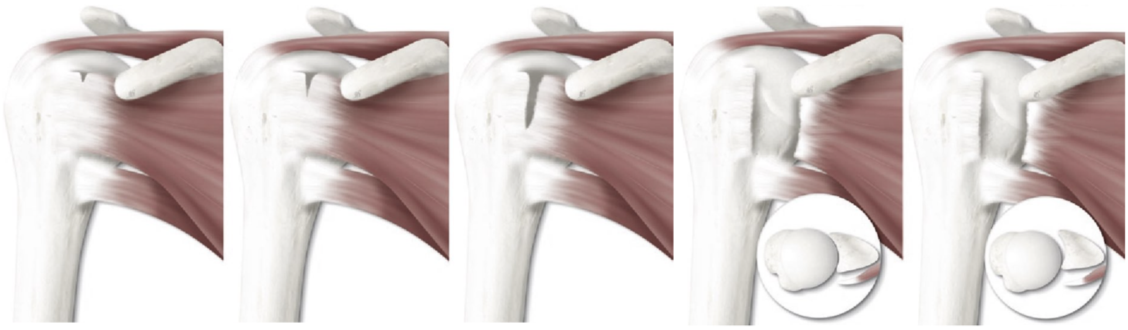

Fig. 4: Classificação das lesões do tendão do subescapular de acordo com Lafosse, com 5 graus de gravidade crescente.

Segundo a Classificação de Lafosse, (Figura 4) o tipo I representa uma rotura parcial do terço superior. O tipo II traduz uma desinserção completa do terço superior do subescapular do *footprint*, o tipo III uma rotura completa dos 2/3 superiores e o tipo IV uma rotura completa do subescapular com retração do tendão mas com a cabeça umeral centrada e um *Goutalier* grau 3 ou inferior. O tipo V representa uma rotura completa do subescapular já com um grau de *Goutalier* superior a 3 ou posição excêntrica da cabeça umeral. [38,42]

Os princípios do tratamento das restantes roturas da coifa aplicam-se ao tratamento das roturas do subescapular. Doentes com roturas parciais podem beneficiar do tratamento conservador, enquanto que doentes com roturas agudas traumáticas beneficiam de reparação cirúrgica precoce. [38] Porém nem todas as roturas completas são reparáveis, dependendo a sua reparabilidade da qualidade do tendão, retração, atrofia e infiltração gorda da massa muscular. Em roturas reparáveis a sutura pode ser feita de forma artroscópica ou aberta, por outro lado em roturas irreparáveis procedimentos como transferências tendinosas por técnicas abertas ou artroscópicas, ou artroplastias podem ser as únicas opções. [38]

As reparações abertas foram amplamente substituídas por procedimentos artroscópicos. Estas são realizadas através de uma abordagem deltopeitoral na maioria dos casos, sendo que após preparação da tuberosidade e libertação de aderências do tendão do subescapular, este é reinserido com suturas transósseas ou ancoras. [38] A reparação aberta oferece a possibilidade de aumentar a reparação com auto ou aloenxerto ou membranas comercializadas. [38]

A sutura artroscópica do subescapular depende em grande parte da capacidade de acesso e mobilização do tendão do subescapular, permitindo a classificação da rotura e a sua redução anatómica. No desbridamento do espaço subcoracoide, deve ser tida em atenção a proximidade ao plexo braquial, incluindo o nervo axilar, e a artéria axilar. [50] O *comma sign*, quando presente, é constituído pela bainha da LPB, ligamento coraco-umeral e ligamento gleno-umeral superior, está inserido no canto supero-lateral do tendão do subescapular e serve como referência anatómica para a reparação deste tendão. [49] Roturas do tipo Lafosse I e II, podem ser reparadas utilizando uma ancora, enquanto que roturas tipo III e IV exigem uma reparação com duas ou três ancoras e por vezes técnicas em dupla fileira. [51]

Nas roturas Lafosse tipo V e outras roturas irreparáveis ou doentes com artrose gleno-umeral, o nível de atividade do doente vai ditar o tratamento. Em doentes mais novos, ativos e sem alterações degenerativas, procedimentos de reconstrução com aumento ou transferências tendinosas podem estar indicados. [38,52] Em doentes com alterações degenerativas ou com menor grau de atividade, a artroplastia invertida pode ser uma boa opção [38] , podendo também ser associada a transferências tendinosas.

Fatores de risco anatómicos para roturas do subescapular

As roturas da coifa apresentam frequentemente causas multifatoriais, incluindo fatores anatómicos. Neer mostrou que uma parte importante das roturas do supraespinhoso poderiam ser decorrentes de *impingement* subacromial, com Bigliani a estabelecer uma relação entre a morfologia do acrómio e o risco de roturas deste tendão. [53,54]

Posteriormente foi reconhecida a importância do arco coraco-acromial, quando Gerber descreveu pela primeira vez o espaço subcoracoide e o *impingement* subcoracoideu. [3,19]

A influência da inclinação da glenoide nas roturas da coifa também já foi definida, sendo que glenoides com inclinação cefálica se associaram a maior risco de patologia da coifa dos rotadores. [2]Para além disso, uma retroversão mais marcada da glenoide, mostrou ser preditora de lesões da coifa anterior, enquanto que uma glenoide antevertida se associa a lesões da coifa posterior. [5]

Contudo, no caso concreto do tendão do subescapular, a fisiopatologia das suas roturas e eventuais fatores de risco são ainda pouco conhecidos.

O *Impingement* Subcoracoide é uma entidade relativamente infrequente e que raramente é considerada como potencial causa de omalgia, [1] podendo ter várias etiologias entre elas iatrogénicas, traumáticas, degenerativas ou ainda outras como variações da anatomia da apófise coracoide ou da pequena tuberosidade, quistos ou calcificações. [3,6,20]

Muitas vezes carateriza-se por omalgia anterior inespecífica, agravada pela flexão anterior, adução e rotação interna do úmero; [56] o seu diagnóstico é clinico, contudo estudos por imagem como RMN ou tomografia computorizada (TC) podem fornecer informações valiosas pela avaliação da anatomia da coracoide, da presença de lesões do subescapular e da distância coraco-umeral. [57] O conflito subcoracoide pode também ser responsável por omalgia anterior resistente ou com meios complementares de diagnóstico normais. Nestes doentes, sem alterações imagiológicas diagnósticas, a presença deste conflito pode contudo ser inferida quando existe uma diminuição da Distância Coraco-umeral (DCU), definida como a distância mínima entre a coracoide e a cabeça umeral, e cujos valores normais oscilam entre 8,7mm e 11mm (Figura 5a). [1,6,55] O *Overlap Coracoide* (OC) é usado para descrever a projeção da coracoide, representando a distância da fossa glenoideia até ao ponto mais lateral da apófise coracoide (Figura 5b).

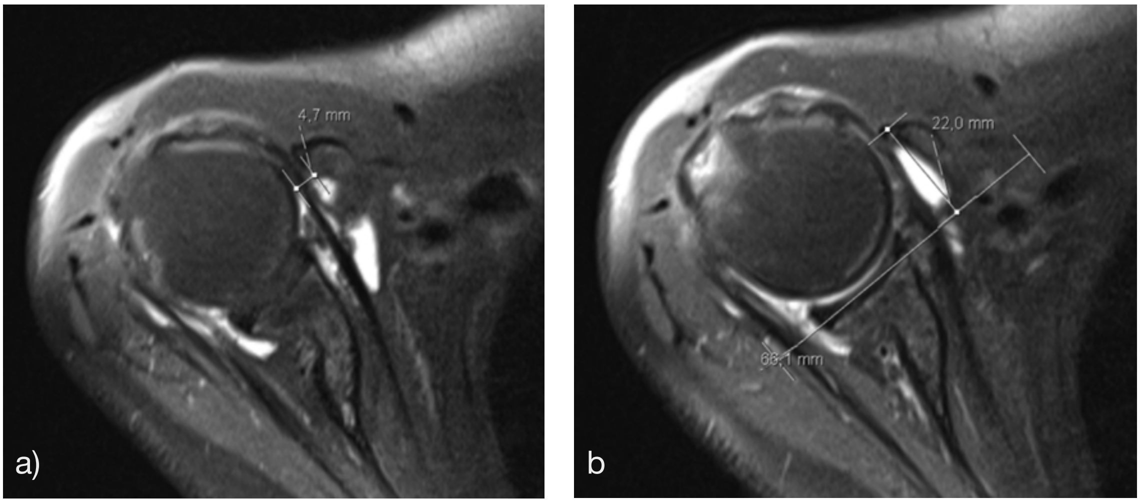

Fig. 5: a) Distância coraco-umeral (DCU), neste caso com 4,7mm, representando a menor distância entre a cortical medial da coracoide e a cortical umeral. b) *Overlap coracoide* (OC), medindo 22mm, que representa a projeção medio-lateral da coracoide, desde a fossa da glenoide.

O tratamento deste síndrome é, na maioria dos casos, conservador com repouso, crioterapia, anti-inflamatórios não esteróides e tratamento fisiátrico. Na falência do tratamento conservador ou presença de uma rotura da coifa, o tratamento cirúrgico está indicado, recorrendo à sutura da coifa e coracoplastia. [56,57]

Apesar do estudo do papel fisiopatológico destas estruturas, existe apenas um número modesto de trabalhos relativamente ao papel da apófise coracoide na fisiopatologia de roturas do subescapular e ainda nenhum estudo tinha avaliado o papel da versão umeral no risco de roturas da coifa.

III. Progressão das roturas Antero-Superiores da Coifa

A compreensão da patofisiologia das roturas degenerativas da coifa tem-se expandido nos últimos anos focando-se contudo, nas mais frequentes - roturas postero-superiores envolvendo o supraespinhoso e infraespinhoso. [59] Apesar da maioria das roturas do subescapular ocorrerem como consequência da progressão de roturas do supraespinhoso, existem relativamente poucos estudos focados na progressão das roturas antero-superiores da coifa, como descrito por Warner *el al*. [60]

Estudos mostraram que roturas do supraespinhoso são fatores de risco e podem progredir para roturas do subescapular, sendo isto particularmente evidente no caso de roturas completas que incluam o cabo anterior. [3,59] Para além disso, estudos recentes re-estabeleceram o conceito de que este tipo de roturas poderiam levar a uma ascensão da cabeça umeral, devido à ação do deltóide sem o antagonismo da coifa dos rotadores, responsável pelas forças que concentravam a cabeça umeral na glenoide. [3,61,62]

Pelo contrário, outros estudos mostraram que roturas do subescapular isoladas, ou a adição de uma rotura do subescapular a uma coifa com o supraespinhoso previamente roto, não resultam na ascensão da cabeça umeral, parecendo assim ser um fenómeno exclusivo das roturas superiores da coifa. [61,63]

Estudos concordam que esta ascensão da cabeça umeral irá colocar uma porção de maior diâmetro da cabeça do úmero posteriormente à coracoide. [3,61,62] Esta ascensão da cabeça irá então resultar numa redução secundária da distância coraco-umeral (DCU) e consequente conflito subcoracoide (Figura 6). [1,9,62,64]

A diminuição secundária da DCU, poderá levar ao *impingement* subcoracoide com lesão das estruturas contidas neste espaço, como o subescapular e a longa porção do bicípite (LPB).

Assim, roturas do supraespinhoso, poderão progredir antero-inferiormente, estendendo-se até ao subescapular, através da diminuição da DCU e resultando num conflito subcoracoide secundário.

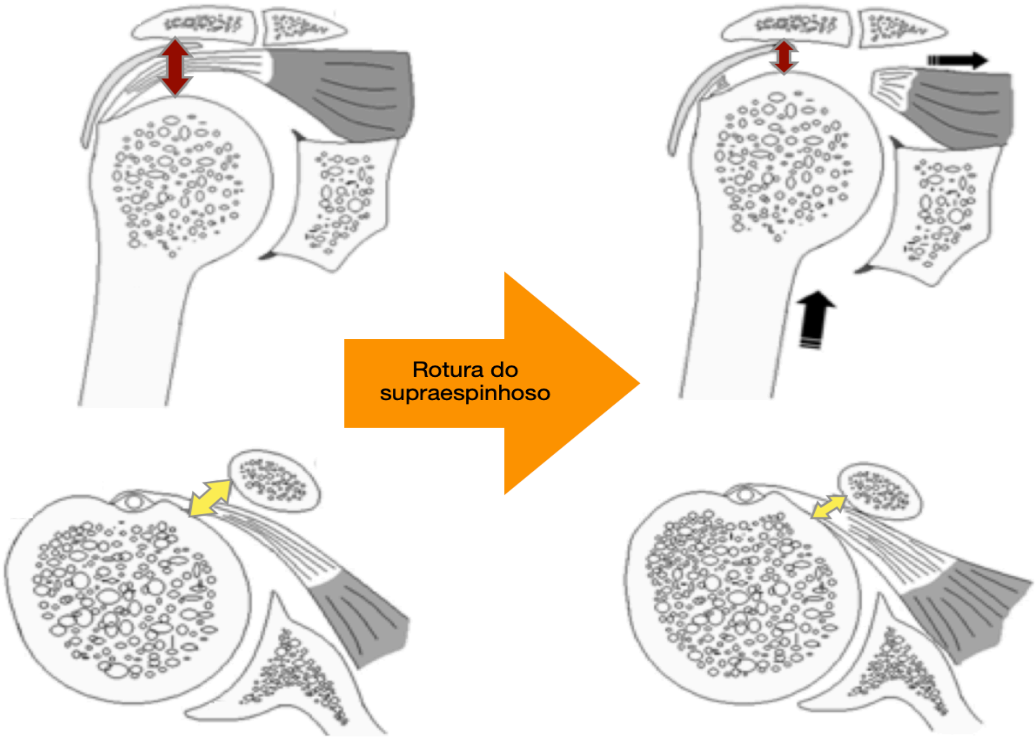

Fig. 6: Processo pelo qual uma rotura completa do supraespinhoso resulta num possível conflito subcoracoide. A ascensão da cabeça umeral associada à rotura rotura do supraespinhoso (setas pretas) resulta numa diminuição da distância acromio-umeral (setas vermelhas). Ao mesmo tempo, esta ascensão coloca uma porção da cabeça umeral com maior diâmetro posteriormente à coracoide, resultando numa diminuição secundária da distância coraco-umeral (setas amarelas).

2. OBJETIVOS E ESTRUTURA DA TESE

I. Objetivos e estrutura

Mais do que apenas a realização académica, o objetivo desta Tese de Doutoramento é influenciar a nossa futura prática clínica. Assim o principal objetivo é permitir a maior compreensão da patologia do subescapular e das roturas antero-superiores da coifa, bem como do conflito subcoracoide. Indiretamente espera-se poder contribuir para um melhor tratamento dos doentes com patologia da região anterior do ombro através da identificação de doentes com maior risco de desenvolver estas patologias.

Neste contexto definimos os seguintes objetivos específicos:

- Confirmação da relação entre patologia da longa porção do bicípite e do subescapular e a distância coraco-umeral e *overlap* coracoide.
- Estudo da influência entre diferentes parâmetros da morfologia da coracoide e patologia do subescapular.
- Avaliação do papel da versão umeral na patologia do subescapular.
- Estudo da patofisiologia da progressão das roturas antero-superiores da coifa e sua relação com o conflito subcoracoide secundário.
- Confirmação das estreitas relações anatómicas entre as estruturas ósseas, neurológicas, tendinosas e ligamentares da região anterior do ombro, bem como confirmação da existência de uma base anatómica para o conflito subcoracoide.

II. Estudos Imagiológicos

O projeto de investigação foi iniciado pelo ramo do estudo baseado em dados imagiológicos. O Centro Hospitalar Universitário de São João no Porto presta cuidados de saúde a uma população que representa 20% da região Norte e 7% dos doentes a nível Nacional. Isto resulta no atendimento de um número considerável de doentes na consulta externa de

Ortopedia, o que permitiu a obtenção de uma amostra extensa de doentes com patologia da coifa dos rotadores.

A parte inicial deste projeto de investigação usou dados imagiológicos de RMN para a avaliação de vários fatores de risco possivelmente implicados na fisiopatologia das roturas do tendão do subescapular e longa porção do bicípite. Para além disso tentamos também compreender o processo de progressão das roturas antero-superiores da coifa.

Para atingir os objetivos propostos foram definidos três estudos individuais:

1. **Coracohumeral distance and Coracoid Overlap as Preditors of Subscapularis and Long Head of the Biceps Injuries.**

Este estudo teve como principal objetivo estudar a correlação entre a DCU e o OC e a presença de lesões do subescapular e da longa porção do bicípite. Procurávamos ainda definir valores que permitissem identificar doentes com risco superior destas lesões.

2. **Coracoid Morphology and Humeral Version as risk factors for Subscapularis Tears.**

Este trabalho teve como principal objetivo determinar a influência da morfologia coracoide na incidência de roturas do subescapular. Procuramos ainda como determinar o papel da versão umeral nas lesões do subescapular.

3. **Can supraspinatus tears contribute to acquired subcoracoid impingement? A radiological study of anterosuperior cuff tears.**

O principal objetivo deste trabalho foi avaliar a influência de roturas do supraespinhoso na distância coraco-umeral e no *overlap* coracoide. Postulamos que roturas completas do supraespinhoso poderão resultar em conflito subcoracoide secundário, explicando pelo menos em parte a patofisiologia da progressão das roturas antero-superiores da coifa dos rotadores.

III. Estudo em Modelos de Cadáver

O objetivo do estudo em modelos de cadáver foi transferir os achados dos estudos radiológicos para um modelo humano. Adicionalmente, os modelos de cadáver permitiram a avaliação dinâmica dos vários parâmetros. Esta conversão de achados estáticos dos métodos de imagem, para modelos humanos dinâmicos é essencial para a confirmação da sua importância clínica.

1. Anterior Shoulder Anatomy and Subcoracoid Impingement: An anatomical study.

Este trabalho teve como propósito re-examinar a anatomia da região anterior do ombro para responder aos novos desafios cirúrgicos desta região. O nosso principal objetivo foi descrever a anatomia da região anterior do ombro, incluindo o subescapular, apófise coracoide, ligamento coraco-acromial e estruturas neurológicas desta região. O nosso objetivo secundário foi definir as relações entre estruturas possivelmente envolvidas na patologia do subescapular, como o *footprint* e as caraterísticas deste tendão, processo coracoide e ligamento coraco-acromial.

Postulamos que o espaço subcoracoide seria exíguo para acomodar o tendão do subescapular, predispondo ao desenvolvimento de conflito subcoracoide.

3.RESULTADOS

Coracohumeral distance and Coracoid Overlap as Predictors of Subscapularis and Long Head of the Biceps Injuries

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Coracohumeral distance and coracoid overlap as predictors of subscapularis and long head of the biceps injuries

Maria J. Leite, MD[a,*], Márcia C. Sá, MD[b], Miguel J. Lopes, MD[a], Rui M. Matos, MD[a], António N. Sousa, MD, PhD[a], João M. Torres, MD, FEBOT, PhD[a,c]

[a]*São João University Hospital, Porto, Portugal*
[b]*Primary Health Care Unit Saúde em Família, Porto, Portugal*
[c]*Porto Medical School, Porto University, Porto, Portugal*

Background: Subscapularis (SS) lesions are often underdiagnosed because of an incomplete understanding of contributing factors but also because of a greater difficulty in SS tear diagnosis with magnetic resonance imaging or physical examination. In this setting, predicting factors can be useful tools in these injuries' management. The goal of this study was to determine the influence of the coracohumeral distance (CHD) and coracoid overlap (CO) in anterior rotator cuff lesions, as well as to determine the CHD and CO values that can accurately predict SS and long head of the biceps (LHB) injuries.
Methods: We performed a retrospective, controlled, single-blinded study. We analyzed 301 patients with rotator cuff pathology and magnetic resonance imaging studies; patients with SS lesions represented the study group. The CHD and CO were measured.
Results: We found that lower CHD and higher CO values were progressively related to more serious injuries of the SS and LHB. The CHD was a very strong predictor of SS injury and tear and a good predictor of LHB injuries. A CHD of 7.6 mm had a sensitivity of 84.4% and specificity of 88.6% for SS tears. The CO was also a very strong predictor of SS tears and a good predictor of LHB injury, with a CO of 16.6 mm reaching a sensitivity of 77.8% and specificity of 68.3% for SS tears.
Conclusions: The CHD is an excellent predictor of SS tears and a good predictor of LHB lesions, with the CO also being a very strong predictor of SS tears and a good model for LHB injuries.
Level of evidence: Level IV; Case Series; Prognosis Study

Keywords: Subscapularis; long head of biceps; rotator cuff tears; coracohumeral distance; coracoid overlap; shoulder; subcoracoid impingement

Rotator cuff injuries have multifactorial causes. When their etiology is traumatic, it may be due to either extrinsic or intrinsic causes. Extrinsic causes include impingement syndromes, such as subacromial and subcoracoid impingement.[2]

Institutional review board approval was not required for this retrospective prognosis study.

*Reprint requests: Maria J. Leite, MD, Alameda Professor Hernani Monteiro, Centro Hospitalar Universitário de São João, Serviço de Ortopedia e Traumatologia, 4200-319, Porto, Portugal.
E-mail address: mjlcma@gmail.com (M.J. Leite).

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As knowledge about the subscapularis (SS) has expanded, it has been recognized as a major participant in shoulder pathology. Unlike the supraspinatus, isolated SS tears are uncommon and most often a part of an anterior-superior rotator cuff injury.[8] SS injuries usually start within the superior third of the tendon, and the inferior portion is injured only in more complex lesions. The diagnosis of SS lesions remains a challenge as the sensitivity of the physical examination findings and imaging modalities is low; magnetic resonance imaging (MRI) remains the gold-standard test for diagnosis of suspected SS tears, despite studies showing that its accuracy is lower for SS tears than for other rotator cuff tears.[1,3,6,10,12] In this setting, tools to predict SS injury would be useful in diagnosing subcoracoid impingement as the cause of shoulder pain, as well as knowing when there is a need to perform a thorough examination of the SS during arthroscopic inspection.

Subcoracoid impingement is a relatively infrequent entity and rarely considered as a potential cause of pain.[2] It is defined by an entrapment of the SS between the lesser tuberosity of the humerus and coracoid process and is related to a decreased coracohumeral distance (CHD) and narrowing of the subcoracoid space. This narrowing can be either iatrogenic, traumatic, or due to numerous other causes such as abnormal coracoid anatomy, a calcified SS tendon, cysts, or anomalies of the lesser tuberosity. A traumatic event or previous surgical procedure can also predispose to this syndrome.[1,2,7] Subcoracoid impingement can be a cause of residual pain after rotator cuff repair or a cause of shoulder pain in patients with normal imaging studies.

The subcoracoid space includes key structures such as the SS tendon, the long head of the biceps (LHB), and the middle glenohumeral ligament, which can all undergo impingement when the CHD is compromised.[1,7] The CHD is defined as the minimal distance between the coracoid and the humeral head and is reported as normal when between 8.7 and 11 mm in MRI studies.[1,2,4] The coracoid overlap (CO) is used to describe the coracoid shape: It measures the distance from the glenoid fossa to the most prominent aspect of the coracoid process.

The main goal of our study was to confirm the correlation between the CO and CHD and the presence of an SS lesion, defining values that signal a higher risk that this pathology may actually be present when in question on MRI and eventually recommend a subcoracoid space release. We also aimed to relate these variables to LHB injuries.

Materials and methods

We performed a retrospective, controlled, single-blinded study, including the period between 2009 and 2018. Patient data were collected retrospectively from the outpatient orthopedics clinical files and included all patients with degenerative rotator cuff pathology diagnosed in this period. Patients without an MRI study or with inflammatory arthropathy, rotator cuff arthropathy, or congenital deformities were excluded.

A standard MRI shoulder protocol was applied, including T1- and T2-weighted fat-saturated images, with the arm in a neutral position. All MRI scans were performed in our institution's radiology department, using similar MRI models with equivalent gantries. The CHD and CO were measured on transverse sections of T1-weighted images to take advantage of their better definition of the cortical margins. The CHD consists of the minimal distance between the humeral cortex and the coracoid cortex. The CO represents the distance from the glenoid to the tip of the coracoid process (Figs. 1 and 2). The axial images were acquired where the subcoracoid space was at its minimum, and the values correspond to the average of 3 measurements.[10]

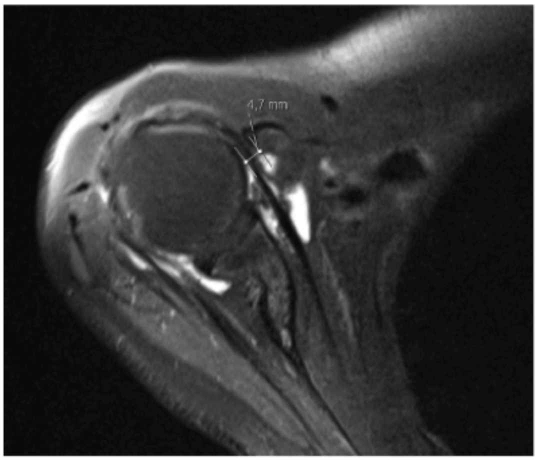

Figure 1 Transversal section of T1-weighted magnetic resonance image showing coracohumeral distance—minimal distance between humeral and coracoid cortices.

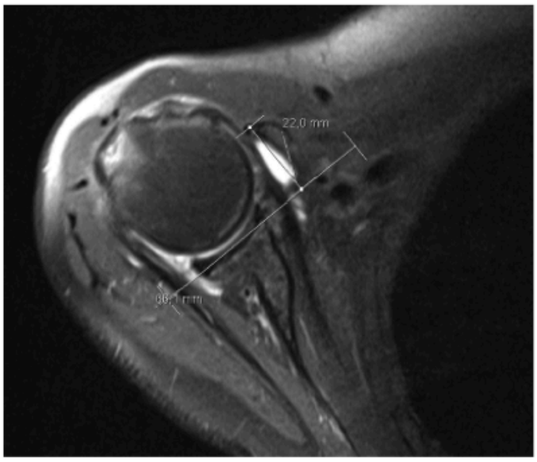

Figure 2 Transverse section of T1-weighted magnetic resonance image showing coracoid overlap—distance from glenoid to tip of coracoid process.

The measurements were recorded by an orthopedic surgeon, blinded to the MRI report. The presence and type of injury to the SS, supraspinatus, and LHB, as well as its laterality, were also recorded.

Statistical analysis

Statistical analysis was performed using SPSS software (version 24; IBM, Armonk, NY, USA). Categorical variables are presented as absolute and relative frequencies, whereas continuous variables are characterized by the mean and standard deviation. The statistical tests used were the χ^2 test to evaluate the association between categorical variables and 1-way analysis of variance test to compare means of continuous variables. To determine the best cutoff points, receiver operating characteristic (ROC) curves were designed for each studied variable and the Youden index was applied. The value with the highest Youden index was considered the cutoff with the best precision. Statistical significance was considered at $P < .05$.

Results

The sample comprised 301 shoulders, including 143 female (47.5%) and 158 male (52.5%) shoulders. The study group included 145 shoulders, representing shoulders with SS injuries (tendinopathy or tear), corresponding to 48.2% of the sample. The control group (without an SS injury) included 156 shoulders, corresponding to 51.8% of the sample. The sample comprised 158 right (52.5%) and 143 left (47.5%) shoulders.

In every patient, we evaluated the presence of supraspinatus, SS, and LHB injuries. In our sample, 90.4% of shoulders had a supraspinatus tear, 145 shoulders presented with an SS injury (48.2%), and 99 shoulders (32.9%) presented with an SS tear (complete or partial). Regarding the LHB, 93 shoulders showed lesion of this tendon (Table I). Comparing types of rotator cuff injuries in both sexes, we found a statistically significant relationship between the presence of an SS lesion and male sex ($P = .04$). Comparing the presence of simultaneous lesions of the SS and supraspinatus or the SS and LHB, we found a significant association between SS lesions and lesions of the supraspinatus or LHB ($P = .04$). We also found a significant association between more serious SS lesions (complete vs. partial tears) and more serious LHB injuries (tear and subluxation vs. tendinopathy) ($P = .01$).

The CHD and CO were measured in 301 shoulders; the average CHD value was 8.6 ± 3.0 mm, and the average CO value was 16.4 ± 4.8 mm. No significant differences between sexes were found in the CHD or CO variable. Regarding joint laterality, the CHD was significantly higher in right-sided shoulder ($P = .04$); no statistical significance was obtained in the comparison between CO and joint laterality ($P = .34$).

Comparing the CHD and CO with the presence of an SS lesion, we found that both the CHD and CO had a statistically significant association with the presence of an SS lesion or SS tear ($P < .001$). The mean CHD in the presence of an SS lesion and SS tear was 6.7 ± 2.7 mm and 5.7 ± 1.7 mm, respectively, and the mean CO was 18.6 ± 4.6 mm and 19.7 ± 3.9 mm, respectively. In the control group, the CHD and CO were 10.3 ± 2.2 mm and 14.3 ± 3.9 mm, respectively.

In our sample, as the values of CHD decreased, a progression to more serious injuries of the SS occurred (Table II). In the partial SS tear subgroup, the average CHD was 6.2 ± 1.6 mm, and in the complete SS tear subgroup, the mean CHD was 5.0 ± 1.7 mm, with this difference being statistically significant ($P < .001$).

This was also true for LHB lesions, with the CHD and CO being significantly different between patients with and without LHB lesions ($P < .001$). In the control group, the average CHD and CO were 9.2 ± 2.9 mm and 15.6 ± 4.6 mm, respectively, and in the group with LHB injuries, the mean CHD and CO were 7.1 ± 2.7 mm and 18.2 ± 4.6 mm, respectively. A statistically significant correlation ($P < .001$) between the CHD and CO was shown, with a coefficient of –52.1% ($P < .001$).

ROC curves were designed to evaluate the ability of the CHD and CO to predict SS and LHB lesions. The accuracy of the model was measured by the area under the ROC curve (AUC); an AUC of 1 would represent a perfect test. The CHD was a very strong predictor of SS injury (AUC, 87.9%) and an excellent predictor of SS tears (AUC,

Table I Tendon lesion types and frequencies

Tendon	Condition	Frequency	%
Supraspinatus	Normal	29	9.6
	Rupture	272	90.4
Subscapularis	Normal	156	51.8
	Tendinopathy	46	15.3
	Partial tear	63	20.9
	Complete tear	36	12.0
Long head of biceps	Normal	208	69.1
	Tendinopathy	46	15.3
	Dislocation	19	6.3
	Rupture	28	9.3

Table II CHD and CO for subscapularis lesions

Subscapularis condition	CHD	CO
Normal		
n	156	156
Mean, mm	10.3 ± 2.2	14.3 ± 3.9
Tendinopathy		
n	46	46
Mean, mm	8.9 ± 3.0	16.2 ± 5.0
Partial tear		
n	63	63
Mean, mm	6.2 ± 1.6	19.7 ± 3.9
Complete tear		
n	36	36
Mean, mm	5.0 ± 1.7	19.9 ± 3.9

CHD, coracohumeral distance; *CO*, coracoid overlap.

93.8%) (Fig. 3). CHD was also a good predictor of LHB tears, with an AUC of 79.0%. By use of the CHD–SS tear ROC curve, a cutoff value of 8.0 mm had a sensitivity of 89.9% and specificity of 84.2% for SS tears. The CHD partial vs. total SS tear ROC curve was a good predictor of partial vs. total SS tears, with an AUC of 0.73 and with a sensitivity and specificity of 73.0% and 66.7%, respectively, for a CHD of 5.3 mm.

The CO was a very strong predictor of SS tears and a good predictor of SS injury, with AUCs of 0.81 and 0.76, respectively. Applying the CO–SS tear ROC curve, we found that the value of 16.6 mm had a sensitivity of 78.8% and specificity of 68.3% (Fig. 4). The CO was also a good predictor of LHB ruptures, with an AUC of 0.73. However, for LHB lesions and ruptures, we achieved a better ROC curve with the CO/CHD ratio (AUCs of 71.0% and 79.0%, respectively). For a CO/CHD ratio of 2.3, we could predict an LHB rupture with a sensitivity of 82.1% and specificity of 68.9%.

Regarding the SS lesions, none of the ratios were superior to the CHD alone in predicting these injuries. To differentiate between the risk of partial SS tears and the risk of total SS tears, we created a CHD ROC curve, which was a good predictor of partial vs. total SS tears, with an AUC of 72.7%. For a CHD value of 5.3 mm, we could differentiate between a partial tear and complete tear with a sensitivity of 73.0% and specificity of 66.7%.

Discussion

The search for subcoracoid impingement risk factors and SS and LHB lesion predictors is increasing. We chose to assess the CHD and CO, as the first measurement translates the available space for these structures and the second measurement represents the distance by which the coracoid process overlaps the glenoid toward the humeral head.

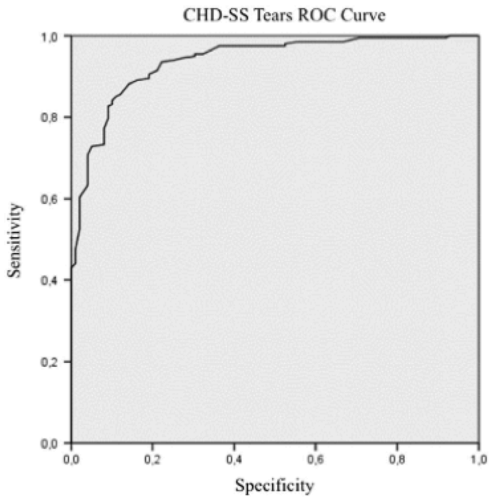

Figure 3 Coracohumeral distance (*CHD*)–subscapularis (*SS*) tear receiver operating characteristic (*ROC*) curve, with an area under the ROC curve of 93.8%; a cutoff value of 7.95 mm had a sensitivity of 89.9% and specificity of 84.2% for SS tears.

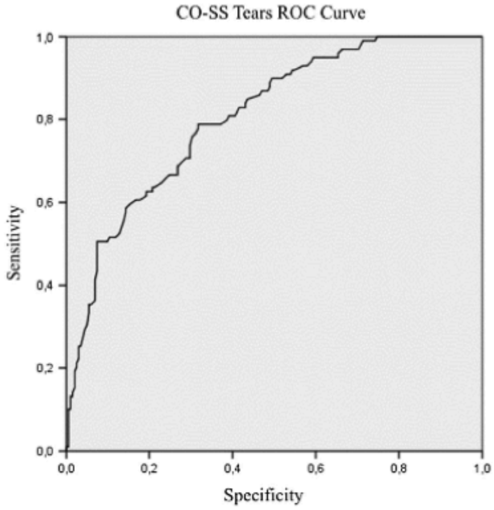

Figure 4 Coracoid overlap (*CO*)–subscapularis (*SS*) tear receiver operating characteristic (*ROC*) curve, with an area under the ROC curve of 80.6%; a value of 16.6 mm had a sensitivity of 78.8% and specificity of 68.3%.

To our knowledge, our study has the largest sample on this topic, including 301 patients, fairly evenly distributed between the study and control groups. In addition, this study is the first to use both the CHD and CO as injury predictors.

The average CHD in the control group (10.3 $\pm$ 2.2 mm) is within the sparse values presented in the literature.[1,7,9] Our sample achieved a significant difference between the control and study groups, with the CHD being significantly smaller and the CO being significantly higher in the presence of SS and LHB lesions. In the presence of SS lesions (including tendinopathy), the CHD and CO were 6.7 mm and 18.6 mm, respectively; and when only the SS tear subgroup was considered, the CHD and CO were 5.7 mm and 19.7 mm, respectively.

To our knowledge, only 1 other study has focused on the CO as an important parameter in subcoracoid impingement: In the study by Çetinkaya et al,[2] the CO was statistically the most important test in predicting SS tears, with an AUC of 65.6% and with a sensitivity of 62.0% and specificity of 64.0% for a value of 22.9 mm. In our study, the CO–SS tear ROC curve had an AUC of 80.6%, and for a value of 16.8 mm, it had a sensitivity of 77.8% and specificity of 68.3%. Our study found a CO value with superior diagnostic accuracy (AUC of 80.6%) and higher sensitivity (77.8%) and specificity (68.3%).

The close relationship between the SS and LHB has been well established, often with simultaneous injuries owing to their anatomic proximity. So, it is crucial to determine whether the SS pathologic factors have the same effect on the LHB tendon.[5,11]

Our study is also the first to explore the impact of the CHD and CO on LHB lesions, with both variables being good predictors of LHB pathology with AUCs of 79.0% and 72.6%, respectively. We achieved an even better predictor curve for LHB lesions or ruptures with the CO/CHD ratio (AUCs of 76.0% and 79.3%, respectively). For LHB rupture, there was a sensitivity of 64.3% and specificity of 68.9% for a CO of 18.9 mm and a sensitivity of 78.6% and specificity of 68.1% for a CHD of 7.7 mm.

However, there are some limitations to our study. Although our MRI protocol stated that the arm should be in a neutral position, variation in patient positioning was a possibility and may have influenced the measurements. In addition, our study was designed as a retrospective study with its inherent limitations.

This study is, to our knowledge, the first study to compare both the CHD and CO with the presence of SS and LHB tears. This study also had the largest sample, including 301 patients. Moreover, this study is the only one focusing on LHB injuries, as well as on the differences in the CHD and CO according to different types of SS lesions. Finally, our study is the first to postulate values for the CHD and CO with a high specificity and sensitivity for SS and LHB tears, as well as cutoff values to determine the risk of partial and complete SS tears.

Conclusion

This study shows that the CHD is an excellent predictor of SS tears and a good predictor of LHB lesions, with the CO also being a very strong predictor of SS tears and a good model for LHB injuries.

Disclaimer

The authors, their immediate families, and any research foundations with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

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Coracoid Morphology and Humeral Version as risk factors for Subscapularis Tears

Maria João Leite, André Pinho, Márcia Sá, Miguel Silva,

Antonio Sousa, João Torres.

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Coracoid morphology and humeral version as risk factors for subscapularis tears

Maria J. Leite, MD[a,*], André R. Pinho, MD[a,b,c], Márcia C. Sá, MD[d], Miguel R. Silva, MD[a], António N. Sousa, MD, PhD[a], João M. Torres, MD, FEBOT, PhD[a,c]

[a]*São João University Hospital, Porto, Portugal*
[b]*Unit of Anatomy, Department of Biomedicine, Porto Medical School, Porto University, Center for Health Technology and Services Research (CINTESIS), Porto, Portugal*
[c]*Porto Medical School, Porto University, Porto, Portugal*
[d]*Primary Health Care Unit Saúde em Família, Porto, Portugal*

Background: The pathophysiology of subscapularis (SS) lesions is still relatively unknown despite recent interest in predictive factors for SS tears. Our goal was to determine the influence of the coracoid morphology and humeral version on SS tears.
Methods: This was a retrospective, controlled, single-blinded study. We analyzed 232 shoulders with SS lesions confirmed by magnetic resonance imaging. The coracoid proximal length, coracoid distal length (CLD), and coracoid total length were measured. The coracoid length ratio, coracoid angle (CA), and humeral version were also evaluated.
Results: We found that greater humeral retroversion was progressively related to more serious SS injuries, with values of –28.6° ± 19.5° and –51.0° ± 11.1° in the normal SS group and tear group, respectively ($P < .001$). The same tendency was shown for the CA, with values of 123.8° ± 11.1° in the control group vs. 97.4° ± 10.1° in the tear group ($P < .001$). Greater CLD, coracoid total length, and coracoid length ratio were also associated with an increased risk of SS tears ($P < .001$). The CA and CLD represented the best predictors of SS tears, presenting areas under the receiver operating characteristic curve of 90.0% and 89.0%, respectively.
Conclusions: This article is the first to study the influence of different parameters of the coracoid process morphology and humeral version on SS tears. We proved that humeral version and coracoid morphology were important risk factors for SS pathology and could accurately predict these lesions. Finally, our study was the first to create a classification system to divide coracoids according to their morphology and relative risk of associated SS tears.
Level of evidence: Level III; Cross-Sectional Design; Epidemiology Study

Keywords: Subscapularis; rotator cuff tears; coracoid morphology; coracoid length; coracoid angle; humeral version; subcoracoid impingement

The pathophysiology of rotator cuff tears remains controversial, with some authors advocating a degenerative process driven by hypoxia and overuse but other authors arguing that shoulder girdle morphology plays a predominant role.[5] Rotator cuff injuries have multifactorial causes, and many anatomic factors are implied. Neer[13] showed that most rotator cuff injuries, namely supraspinatus tears, result from impingement under the anterior acromion. A few years later, Bigliani et al.[2] proved that acromial morphology also influences the risk of rotator cuff tears.

Institutional review board approval was not required for this study.

*Reprint requests: Maria J. Leite, MD, Centro Hospitalar Universitário de São João, Serviço de Ortopedia e Traumatologia, Alameda Professor Hernani Monteiro, 4200-319 Porto, Portugal.
E-mail address: mjlcma@gmail.com (M.J. Leite).

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The coracoacromial arch and the coracoid are being recognized as major players in rotator cuff tears, with Gerber et al[8] describing the subcoracoid space and, later the coracoid overlap index.[9] However, studies focusing exclusively on the coracoid morphology and its influence on this pathology are lacking. Other authors, such as Tetreault et al[15] and Chalmers et al,[5] described the influence of glenoid inclination and version on rotator cuff tears, with superior inclination being regarded as a risk factor for rotator cuff pathology, and greater retroversion being predictive of anterior cuff injury and greater anteversion of posterior cuff lesions.[5,15]

Although the influence of the glenoid and coracoacromial arch on rotator cuff pathology is well established, no studies have focused on the influence of humeral version on rotator cuff pathology. Moreover, only a modest number of studies have been performed regarding the influence between coracoid morphology and rotator cuff injuries.[8,9,11] This is particularly true regarding subscapularis (SS) tears, of which the pathophysiology and risk factors are still very much unknown.

We know from our previous study that subcoracoid impingement can lead to SS tears and that smaller coracohumeral distances and greater coracoid overlaps are associated with a greater risk of anterior cuff pathology.[11] However, there is still uncertainty regarding the influence of the coracoid morphology on SS tears.

Humeral version, on the other side, is a well-established factor in shoulder instability; however, its influence on rotator cuff tears has never been studied. Studies evaluating humeral version initially used cadaveric models and radiographs,[14] later evolving to imaging studies with computed tomography (CT) that nowadays is widely used.[4,12] However, several authors have recognized that evaluating humeral version with CT has several disadvantages, such as exposure to ionizing radiation, as well as difficulty in defining the true limits of the articular cartilage and, as a consequence, low accuracy defining the central axis of the humeral head.[4,7] As a result, recent studies have preferred magnetic resonance imaging (MRI) to evaluate the shoulder girdle anatomy, particularly humeral version.[4,5] Most studies regarding humeral version have also used the transepicondylar axis as a reference, demanding images of the whole arm and consequently implying greater economic costs and radiation exposure. However, as most of the humeral head version is the result of torsion occurring in the proximal growth plate, this can be dismissed, and humeral version can be assessed using only images of the proximal humerus.[1,6]

The main goal of this study was to evaluate the influence of coracoid morphology on the incidence of SS tears, as well as determine the relationship between humeral version and SS injuries. We hypothesized that longer coracoids and inferior coracoid angles (CAs) would translate into an increased risk of SS lesions and that greater humeral retroversion would also be a risk factor for SS tears.

Materials and methods

We performed a retrospective, controlled, single-blinded study. Patient data were collected retrospectively from our institution's outpatient orthopedic clinical files and included all patients with SS pathology confirmed by MRI between 2009 and 2019. We excluded patients without an MRI study; obese patients (body mass index > 30); and patients with inflammatory arthropathy, rotator cuff arthropathy, shoulder instability, or congenital deformities.

The control group included patients observed at the orthopedic outpatient clinic for shoulder pain without rotator cuff pathology on the MRI study. The same exclusion criteria defined for the study group were applied.

Our institution's standard MRI shoulder protocol was applied, including T1- and T2-weighted fat-saturated images, with the patient in the supine position with the arm alongside the body, elbow extended, and forearm supinated. All MRI scans were performed in our institution's radiology department, using similar MRI models with equivalent gantries.

Coracoid morphology was evaluated, including (1) proximal segment length, (2) distal segment length, and (3) CA. Before measurement of the coracoid length was performed, the coracoid knee was defined by the intersection of the proximal and distal coracoid segments' long axes. The proximal coracoid segment was then defined between the coracoid base and its knee, and the distal segment, distal to it. Both lengths were evaluated on MRI axial sections (Fig. 1). The CA was measured using MRI sagittal cuts at the section corresponding to the greatest coracoid cross-sectional length. The proximal and distal coracoid segments' long

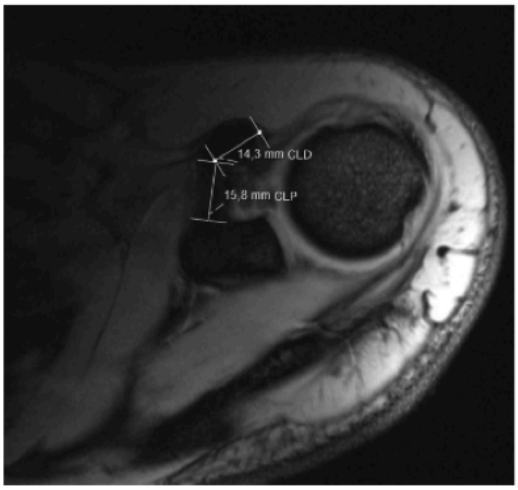

Figure 1 Evaluation of coracoid length including proximal and distal segment lengths. In this case, the coracoid proximal length *(CLP)* measured 15.8 mm and the coracoid distal length *(CLD)* measured 14.3 mm.

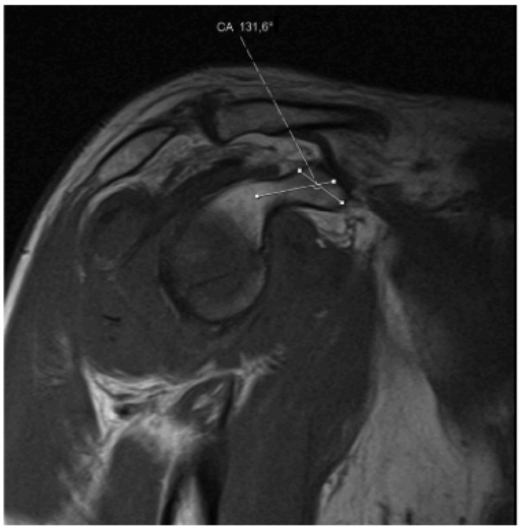

Figure 2 The coracoid angle *(CA)* was measured determining the angle between 2 lines passing at the axis of its proximal and distal segments.

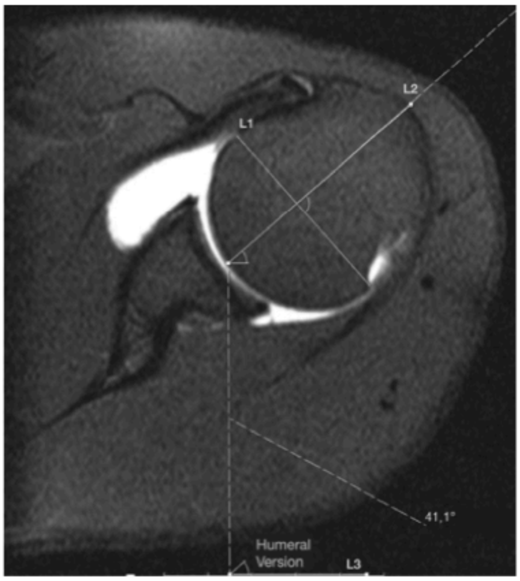

Figure 3 Humeral version, measured according to technique validated by Athwal et al,[1] using magnetic resonance imaging axial sections. The determined humeral version in this case was 41.1°. *L1*, line drawn between anterior and posterior limits of humeral head cartilage; *L2*, humeral head central axis, perpendicular to L1; *L3*, line parallel to magnetic resonance imaging scanner.

axes were traced, and the angle formed under these represented the CA (Fig. 2).

Humeral version was measured according to the technique validated by Athwal et al.[1] It is determined using MRI axial sections, first drawing a line (L1) joining the anterior and posterior margins of the articular cartilage, at the point of maximal head diameter, previously measured and defined. Thereafter, a perpendicular line (L2) passing at the L1 line midpoint was drawn. As such, L2 represented the central axis of the humeral head. A third line (L3) parallel to the MRI scanner orientation was drawn. Then, the angle drawn between L2 and L3 corresponded to humeral version. Retroversion was expressed in negative values; anteversion, in positive values (Fig. 3).

Both humeral version and coracoid morphology were measured using sections of T1-weighted images, taking advantage of the better definition of the cortical margins, and T2-weighted fat-saturated cuts, allowing the articular cartilage to be effectively evaluated. A standardized measurement technique was developed to determine humeral version, coracoid length, and CA. These measurements were recorded by the same orthopedic surgeon, blinded to the MRI report. The final recorded value represents the average of 3 separate and consecutive evaluations of each index. The presence of SS rupture, presence of long head of the biceps brachii (LHB) injuries, sex, and laterality were also recorded.

Statistical analysis

Statistical analysis was performed using SPSS software (version 24; IBM, Armonk, NY, USA). Categorical variables are presented as absolute and relative frequencies, whereas continuous variables are characterized by mean and standard deviations. The statistical tests used were the χ^2 test to evaluate the association between categorical variables and 1-way analysis of variance test to compare means of continuous variables. To determine the best cutoff points, receiver operating characteristic (ROC) curves were designed for each studied variable and the Youden index was applied. The value with the highest Youden index was considered the cutoff value with the best precision. $P < .05$ was considered statistically significant.

Results

The sample comprised 330 shoulders, including 129 female shoulders (39.1%) and 201 male shoulders (60.9%). The study group included 188 shoulders with SS tears and 44 shoulders with SS tendinopathy, corresponding to 70.3% of the sample. The control group included 98 shoulders without SS pathology, corresponding to 29.7% of the sample. Our series comprised 150 right (45.5%) and 180 left (54.5%) shoulders. Regarding the LHB, 29.1% of shoulders presented an LHB lesion (tear or subluxation).

No statistically significant relationship was found between the presence of an SS lesion and sex or laterality. Regarding simultaneous lesions, we found a significant association between SS lesions and LHB lesions ($P < .001$).

Table I Relationship between humeral version and SS lesions

SS status	n	Mean humeral version, °*
Normal SS	98	−28.6 ± 19.5
SS tendinopathy	44	−48.7 ± 9.1
SS tear	188	−51 ± 11.1

SS, subscapularis.
* $P < .001$.

The CA, coracoid proximal length (CLP), coracoid distal length (CLD), and humeral version were obtained from the 330-shoulder sample. Average humeral version was –44.1° ± 17.2° of retroversion. Regarding coracoid morphology, the average CA was 106.2° ± 15.4°. The coracoid length was divided into proximal (CLP) and distal (CLD) segments, with average values of 22.3 ± 3.7 mm and 10.2 ± 3.3 mm, respectively; the average coracoid total length (CLT) was 33.5 ± 5.2 mm. We postulated that a newly created coracoid length ratio (CLR), the ratio between the distal and proximal coracoid lengths, would help evaluate which of the coracoid segments had a greater influence on SS pathology; its average value was 0.43 ± 0.2.

Associating humeral version and the presence of an SS lesion, we found that greater retroversion had a statistically significant association with the presence of an SS tear ($P < .001$). Mean humeral version was –28.6° ± 19.5° in the control group, contrasting with –48.7° ± 9.1° in the SS tendinopathy group and –51.0° ± 11.1° in the SS tear group, with this difference being statistically significant between all groups ($P < .001$). In our series, as we reached greater humeral retroversion, a progression to more serious injuries of the SS occurred (Table I), with this difference being statistically significant ($P < .001$).

In addition, we found a significant relationship between greater humeral retroversion and increased frequency of LHB injuries, with mean humeral version of –39.4° ± 19.2° and –49.3° ± 12.3° in the group with normal LHB tendons and the injured LHB group, respectively ($P < .001$).

We also reached a statistically significant association between the measured coracoid indices and the presence of SS tears ($P < .001$). A greater CLD was associated with SS pathology, with average values of 6.8 ± 1.5 mm, 10 ± 2 mm, and 12.1 ± 2.7 mm for normal SS tendons, tendinopathy, and SS tears, respectively ($P < .001$). Similarly, the CLT was correlated with the presence of SS lesions: Healthy SS tendons were associated with a mean total length of 29.6 ± 3.9 mm; SS tendinopathy, 32.3 ± 4.6 mm; and SS tears, 35.8 ± 4.6 mm ($P < .001$). Furthermore, the CLR showed a significant association with SS tears, with average values of 0.3 ± 0.1 for normal shoulders and 0.5 ± 0.1 for the SS tear group ($P < .001$) (Table II).

However, with the CLP, we did not achieve a linear association with SS lesions. In our sample, the CLP was, on average, 22.8 ± 3.2 mm in shoulders without SS pathology, 22.3 ± 3.5 mm in those with tendinopathy, and 23.7 ± 3.9 mm in those with SS tears. In contrast, the CA reached a statistically significant relationship with the presence of SS tears ($P < .001$), with average values of 123.8° ± 11.1°, 104.6° ± 6.8°, and 97.4° ± 10.1° for normal tendons, SS tendinopathy, and SS tears, respectively.

ROC curves were designed to evaluate the ability of humeral version and coracoid ratios to predict SS lesions. The accuracy of the model was measured by the area under the ROC curve (AUC), with an AUC of 100% representing a perfect test.

Humeral version was a good predictor of SS injury (AUC, 79.0%) (Fig. 4), with the cutoff value of –44.5° having a sensitivity of 76.6% and specificity of 70.4% for SS tears. The CLD was a very strong predictor of SS tears, with an AUC of 89.0%. Applying the CLD–SS tear ROC curve, we found that the value of 9.3 mm had a sensitivity of 81.0% and specificity of 85.6% for SS tears. In addition, the CLR was an extremely good predictor of SS tears, showing an AUC of 87.0%, with the cutoff value of 0.4 reaching a sensitivity of 81.7% and specificity of 83.0% for SS lesions. Furthermore, the CLT represented a good model for predicting SS tears, with an AUC of 81.0%.

The CA was the best predictor of SS tears, with an AUC of 90.0% (Fig. 5), making it excellent in predicting these lesions. On the basis of analysis of the CA ROC curve, it is possible to define the cutoff value of 105.5° with a sensitivity of 82.4% and specificity of 78.9% for SS tears.

Table II Relationships between coracoid indices and SS lesions

SS status	Mean coracoid index, mm*			
	CLP	CLD	CLT	CLR
Normal SS tendon	22.8 ± 3.2	6.8 ± 1.5	29.6 ± 3.9	0.3 ± 0.1
SS tendinopathy	22.3 ± 3.5	10.0 ± 2.0	32.3 ± 4.6	0.5 ± 0.1
SS tear	23.7 ± 3.9	12.1 ± 2.7	35.8 ± 4.6	0.5 ± 0.1

SS, subscapularis; *CLP*, coracoid proximal length; *CLD*, coracoid distal length; *CLT*, coracoid total length; *CLR*, coracoid length ratio.
* $P < .001$.

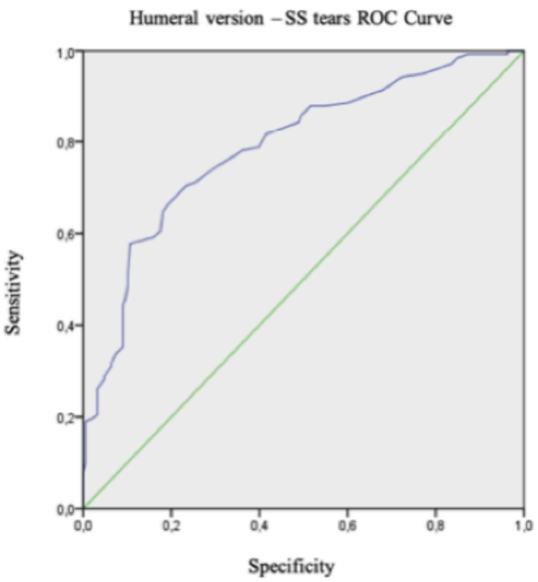

Figure 4 The humeral version receiver operating characteristic *(ROC)* curve showed it was a fair predictor of subscapularis *(SS)* injury (area under ROC curve, 79.0%).

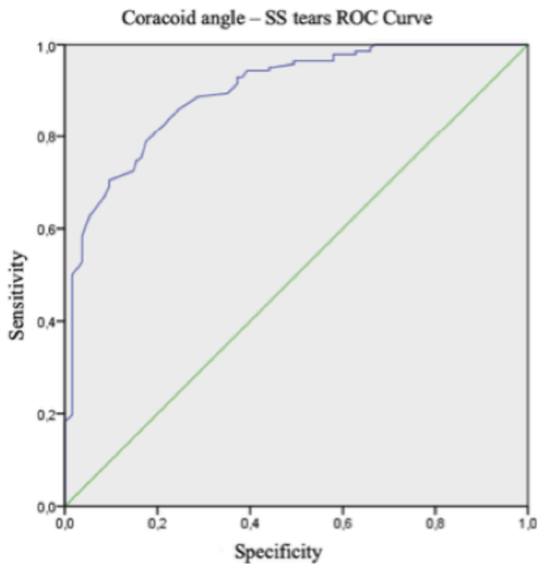

Figure 5 The coracoid angle receiver operating characteristic *(ROC)* curve showed it was an excellent predictor of subscapularis *(SS)* tears (area under ROC curve, 90.0%).

Discussion

The search for anatomic risk factors in rotator cuff pathology and possible SS tear predictors has been increasing in recent years. Many structures of the shoulder girdle have been implicated in these injuries, including the glenoid and acromion and, in the particular case of SS tears, the coracoid.

However, most studies evaluating the influence of the coracoid on SS tears have focused on the coracoacromial arch and coracohumeral distance, ignoring the influence of the coracoid shape and length. We chose to assess the coracoid lengths and CA to define which of these were most implicated in SS tears. Our results showed that both the coracoid length and the CA influence the risk of SS lesions but in different proportions. The CA was the index with the most predictive value for SS lesions (AUC, 90.0%), closely followed by the CLD (AUC, 89.0%) and CLR (AUC, 87.0%).

Even in comparison with other known SS risk factors, such as the coracohumeral distance or coracoid overlap, the CA proved to be a better predictor of SS lesions than coracoid overlap, with an AUC of 90.0% vs. 80.6%, and performed equivalently to the coracohumeral distance, with an AUC of 93% in some studies.[11] As the CA is an excellent predictor of SS tears, we used the CA ROC curve to define different risk categories in SS lesion development, according to the CA. These data allowed us to determine 3 types of coracoid morphology with an increasing risk of SS tears (Fig. 6): flat coracoid with CA superior to 120°, curved coracoid with CA between 95° and 120°, and hooked coracoid with CA inferior to 95°.

Using this coracoid morphologic classification system within our sample, we can see that the type I, or flat, coracoid presents a low risk of SS lesions, with only 4.5% of shoulders presenting SS tears. Regarding type II, or curved, coracoids, we can conclude that these are associated with an intermediate risk of SS lesions, with SS tears in 60.0% of these shoulders. Furthermore, type III, or hooked, coracoids are associated with a higher risk of SS injuries, with 97.2% of this group showing an SS tear (Table III).

To our knowledge, our study presents the largest sample on this topic, including 330 patients, being also the first to evaluate the differing influence of the CLP, CLD, and CLT length, as well as the CLR, on SS tears.

Our study showed that the distal coracoid length (AUC, 89.0%) is a more important determinant factor in SS tears than the proximal coracoid length (AUC, 57.0%) or total coracoid length (AUC, 81.0%). This finding can be explained by the coracoid anatomy, as the segment distal to the coracoid knee is directed inferiorly and laterally and therefore is in a closer relationship with the SS tendon compared with the proximal coracoid segment. In contrast, the CLP, with an AUC of 57.2%, is of no use in predicting SS lesions.

Our study is also the first to evaluate and prove that the CA is an excellent predictor of SS tears (AUC, 90.0%), showing that the angulation and shape of the coracoid

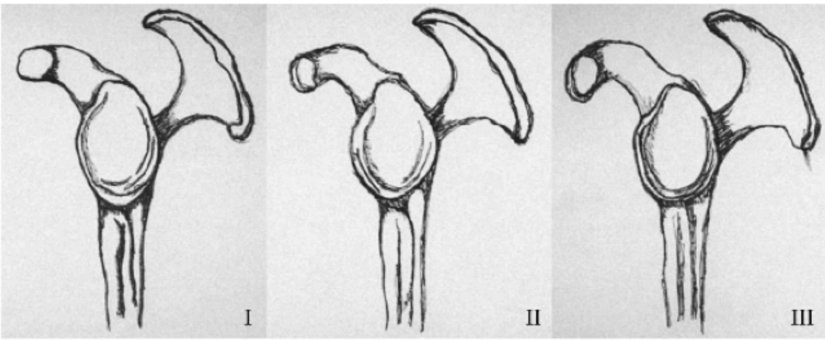

Figure 6 Leite-Torres classification of coracoid morphology: I, flat coracoid; II, curved coracoid; and III, hooked coracoid.

process are even more important than its size regarding SS tear pathology. In addition, our work was inaugural in using this parameter to create a classification system that allows us to divide coracoids by shape according to the relative risk of SS tears.

After it is determined that a patient is at higher risk of an SS lesion, on the basis of MRI measurements or our proposed classification, our results can translate into different approaches in the clinical setting. During arthroscopy, the surgeon should probably look for underdiagnosed SS lesions on preoperative MRI. If not found, he or she could eventually consider the choice of a "preventive" coracoplasty. In addition, during SS repair, in high-risk patients, the realization of performing a "protective" coracoplasty could also be considered to eventually diminish the chances of failure of the repair or rerupture. All these clinical repercussions need further studies with solid data that can back up eventual changes in clinical practice.

This study is the first to relate humeral version with SS tears. Analyzing the control group, we can see that average humeral version (–28.6° ± 19.5°) is within the range of values presented in the literature.[3,6,7,10,12] Furthermore, looking at the humeral version ROC curve, we can conclude that humeral version influences the incidence of SS tears and that greater humeral retroversion is linked to a greater risk of SS injury (AUC, 79.0%). This can be explained by the impingement of the articular surface of the SS tendon between the glenoid and more retroverted humerus, as theorized by Tétreault et al[15] regarding glenoid retroversion and its influence on rotator cuff tears. Nevertheless, as proved by the AUC of the different ROC curves, the coracoid indices (CLD, CLT, CLR, and CA) are superior to humeral version in predicting SS lesions.

Another strong point in our study is the use of MRI to evaluate humeral version instead of the more common CT scan. MRI's superiority in evaluating the humeral head cartilage allows a more accurate definition of the humeral head central axis and, therefore, of humeral version. This scenario is complemented by its ability to simultaneously assess rotator cuff integrity and characteristics, defining it as our preferred method when evaluating humeral and coracoid morphology.

However, there are some limitations to our study. Although our MRI protocol stated that the arm should be in a predefined position, variation in patient positioning is always a possibility and may influence the measurements. In addition, despite the implementation of a standardized protocol and implementation of 3 separate and consecutive measures, all measurements were performed by the same observer. Finally, our study was designed as a retrospective study, with its inherent limitations.

Table III Leite-Torres classification of coracoid morphology

Type	Morphology	Angle	Risk of SS tear
I	Flat coracoid	CA > 120°	Coracoid with lowest risk of SS tear development
II	Curved coracoid	CA between 95° and 120°	Coracoid with intermediate risk of SS tear development
III	Hooked coracoid	CA < 95°	Coracoid with highest risk of development of SS tear

SS, subscapularis; *CA*, coracoid angle.

Conclusion

This article is, to our knowledge, the first to study the influence of different parameters of the coracoid process morphology on SS tears. It is also the first study to evaluate the role of humeral version in SS injury pathology, proving that this parameter is also a risk factor in anterior rotator cuff injuries. The largest published sample, including 330 patients, also contributes to the strength of this study. Finally, our study was the first to create a classification system according to the coracoid morphology and its relative risk of associated SS tears.

Disclaimer

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Can supraspinatus tears contribute to acquired subcoracoid impingement? A radiological study of anterosuperior cuff tears

Maria João Leite, André Pinho, Márcia Sá, Miguel Relvas,
Joana Almeida, António Sousa, João Torres

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REVIEW

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Can Supraspinatus Tears Contribute to Acquired Subcoracoid Impingement? A Radiological Study of Anterosuperior Cuff Tears

M. J. Leite[1], A. R. Pinho[1,2,4], M. C. Sá[3], M. R. Silva[1], J. M. Almeida[1], A. N. Sousa[1], J. M. Torres[1,4]

[1] *Orthopedics and Traumatology Service, São João University Hospital, Porto, Portugal*
[2] *Department of Biomedicine, Unit of Anatomy, Porto Medical School, Porto University, Center for Health Technology and Services Research (CINTESIS), Porto, Portugal*
[3] *Primary Health Care Unit Saúde em Família, Porto, Portugal*
[4] *Porto Medical School, Porto University, Portugal*

CORRESPONDING AUTHOR:
Maria J. Leite
Serviço de Ortopedia e Traumatologia
Centro Hospitalar Universitário de São João
Alameda Professor Hernani Monteiro
4200-319 Porto, Portugal
E-mail: mjlcma@gmail.com

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SUMMARY

Backgroud. Many subscapularis (SubS) lesions represent the result of the progression of anterosuperior cuff tears, although their pathophysiology is still relatively unknown. The goal of this paper was to determine the influence of supraspinatus tears in the development of subcoracoid impingement and therefore SubS tears.

Methods. This is a retrospective, controlled and single-blinded study. We analyzed 301 patients with rotator cuff pathology and an MRI study. The coraco-humeral distance and coracoid overlap were measured. The presence of supraspinatus and subscapularis lesions were also evaluated.

Results. Supraspinatus tears were found to be associated with the presence of subscapularis tears ($p = 0.003$). A significant relationship ($p = 0.002$) was achieved between supraspinatus tears and inferior coraco-humeral distance, with average values of 8.4 ± 2.9 mm and 10.2 ± 3.2 mm in shoulders with and without supraspinatus tears respectively. On the opposite side, there wasn't a significant association between supraspinatus tears and the coracoid overlap.

Conclusions. This paper is, to our knowledge, the first to study the influence of supraspinatus tears in different parameters implied in subscapularis tears pathology, representing also the largest published sample on this theme, including 301 patients. Finally, this study offers an explanation for anterosuperior cuff progression pathophysiology, confirming that supraspinatus full thickness tears can lead to a secondary subcoracoid impingement and thus subscapularis tears.

KEY WORDS

Coracoid-humeral distance; coracoid overlap; rotator cuff tears; subscapularis; subcoracoid impingement; supraspinatus.

BACKGROUND

Rotator cuff tears pathophysiology remains controversial, with both probable contributions from degenerative processes, traumatic events and variants in shoulder anatomy (1-3). This is particularly true regarding subscapularis (SubS) tears, which pathophysiology and risk factors are still very much unknown (1, 2).

Although the understanding of degenerative rotator cuff pathology has evolved over the past decades, most of these studies focused on the more frequent posterosuperior cuff tears, including the infraspinatus and supraspinatus (SS) (3, 4). However, in recent years, there has been an increasing interest regarding anatomical risk factors for SubS tears, with the coracoacromial arch and the coracoid process being recognized as major players in anterior cuff tears (2, 5-7). Many

papers have recently showed that subcoracoid impingement can lead to SubS tears, and that smaller coraco-humeral distances (CHD) and greater coracoid overlaps (CO) are associated with greater risk of anterior cuff pathology (2, 7).
Despite the fact that many of SubS tears occur in the context of progression of a previous SS tear, there are relatively few studies focusing on the progression of anterosuperior tears, as described by Warner *et al.* (8), affecting the SS and SubS (4, 9).
Some studies have showed that SS tears are risk factors, and could progress to a SubS tear. This progression was particularly evident with full thickness SS tears, larger SS tears, and SS tears that included the anterior cable (4, 10).
Recently a few papers also re-established the previous notion that a rotator cuff tear would lead to the superior escape of the humeral head, because of the unopposed pull from the deltoid (10-12). Studies also agree that a superior cuff tear will lead to failing to compress the humeral head in the glenoid cavity, resulting in its superior migration (10, 12). On the other hand, papers have also showed that SubS tears do not cause a superior migration of the humeral head, more so, the addition of a SubS tear to a shoulder with previous SS tear didn't result in aggravated superior humeral head escape (11, 13).
However there is still a sparse number of papers focusing in the process behind the progression of anterosuperior tears, although studies agree that a superior cuff tear will result in superior humeral head migration which will result in a decreased coraco-humeral distance (CHD) (10, 12). This association between superior cuff complete tears and smaller CHD, is explained by the superior migration of the humeral head, placing a part of the humeral head with greater cross section posteriorly to the coracoid, leading to a secondary subcoracoid impingement, defined by entrapment of the SubS between the coracoid process and the humerus (10, 12, 14). In a study conducted by Nove-Josserand *et al.* (15), the authors reported an association between patients with SS, SubS and infraspinatus tears and diminished CHD (15).
In a previous paper by MacMahon *et al.* (10), the authors compared the effect of complete SS tears in CHD and the association of these with SubS tears (10). They concluded that SS tears were associated with increased risk of SubS tears ($p < 0.05$). They also found that patients with SS tendentially showed narrowing of the CHD, however without significant differences between the study and control group (10).
Similarly, to the subacromial impingement role in posterosuperior cuff tears, decreased CHD could be an etiologic factor in progression of SS tears anteriorly into the SubS (7, 12, 16-18).
Besides the CHD, studies also showed that the CO is also a very strong predictor of SubS tears (2). The CO is used to describe the coracoid shape as it measures the distance from the glenoid fossa to the most prominent aspect of the coracoid process (2). However, none of the previously published papers established if the presence of SS tears would influence the CO.
The main goal of this study was to evaluate the influence of SS full thickness tears in the CHD and CO. We postulated that a full thickness SS tear would result in a secondary subcoracoid impingement and help explain the pathophysiology of anterosuperior cuff tears.

MATERIALS AND METHODS

We performed a retrospective, controlled, single-blinded study. Patient data were collected retrospectively from our instituition's outpatient orthopedics clinical files, and included all patients with suspected rotator cuff pathology evaluated between 2009 and 2019. The study group included patients with full thickness SS tears, while the control group included patients with normal MRIs. Patients without an MRI study, with inflammatory arthropathy, rotator cuff tears other than full thickness SS tears, rotator cuff arthropathy, shoulder instability, or congenital deformities were excluded.
Our institution's standard MRI shoulder protocol was applied, including T1- and T2-weighted fat-saturated images, with the patient in supine position with the arm alongside the body, elbow extended, and forearm supinated. All MRI scans were performed in our institution's radiology department, using similar MRI models with equivalent gantries.
The CHD and CO were measured in transversal sections of T1 weighted images to take advantage of its better definition of the cortical margins. The CHD consists in the minimal distance between the humeral cortex and the coracoid cortex. The CO represents the distance from the glenoid to the tip of the coracoid process (**figures 1, 2**). The axial images were acquired where the subcoracoid space was at its minimum (5).
The presence of SS tears, the presence and type of injury to the SubS and long head of the biceps (LHB), gender and laterality were also recorded.
A standardized measurement technique was developed, these measurements were recorded by the same orthopedic surgeon, blinded to the MRI report. The final recorded value was the average of three separated evaluations of each index.

Statistical analysis

Statistical analysis was performed using SPSS software (version 24; IBM, Armonk, NY, USA). Categorical variables are presented as absolute and relative frequencies, whereas continuous variables are characterized by the mean and

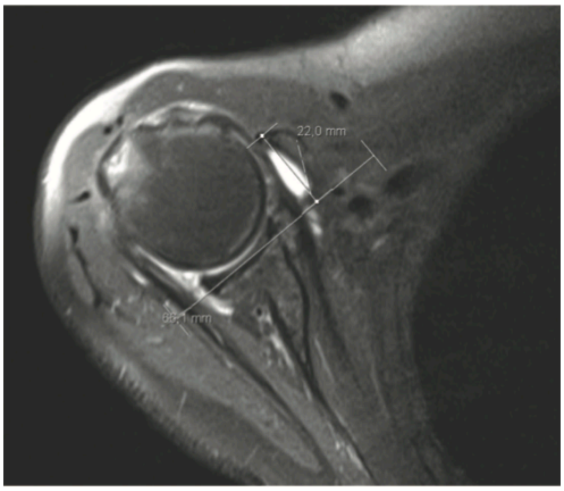

Figure 1. Coracohumeral distance measurement using T1-weighted MRI transversal sections.

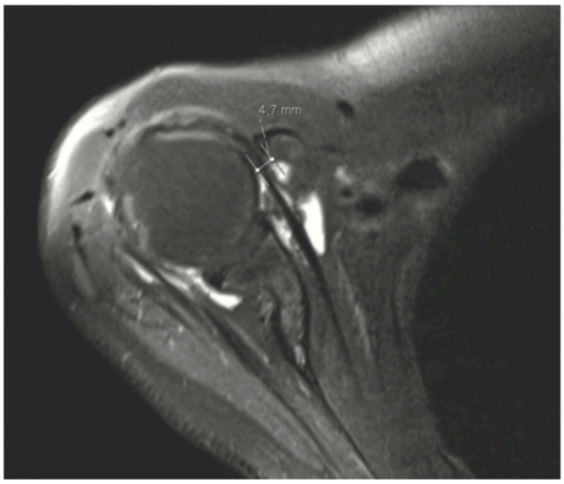

Figure 2. Coracoid overlap measurement using T1-weighted MRI transversal cuts.

standard deviation. The statistical tests used were the $\chi 2$ test to evaluate the association between categorical variables and 1-way analysis of variance test to compare means of continuous variables. The value with the highest Youden index was considered the cutoff with the best precision. Statistical significance was considered at $P < .05$.
Ethical commission approval was obtained regarding this paper.

RESULTS

The sample was comprised of 301 shoulders, including 143 female (47.5%) and 158 male (52.5%). The study group included 272 shoulders with complete SS tears, and corresponded to 90.4% of the sample.
The sample included 145 shoulders with SubS injuries (tendinopathy or tear), corresponding to 48.2% of the sample, with 99 (32.9%) presenting a SubS tear (complete or partial). Regarding the LHB, 93 shoulders presented a lesion of this tendon, including tendinopathy, rupture or instability.
The sample included 158 right (52.5%) and 143 left shoulders (47.5%). The left shoulder was associated with more SS tears (p = 0.008).
Comparing the type of rotator cuff injuries in both genders, we didn't find any statistically significant relationship between the presence of a SS lesion and gender.
Analyzing the presence of simultaneous lesions of the SS, SubS or LHB, we found a significant association between SS lesions and lesions of the SubS (p = 0.003) or LHB (p = 0.045).
The CHD and CO were measured in 301 shoulders, with an average CHD of 8.6 ± 3 mm and an average CO of 16.4 ± 4.8 mm. There were no significant differences in CHD or CO variables according to gender. Regarding joint laterality, the CHD was significantly smaller in the left shoulder (p = 0.04); no statistical significance was obtained in the comparison between CO and joint laterality (p = 0.34).
Comparing the CHD and CO with the presence of a SS lesion, we found that only the CHD showed a statistically significant association with the presence of a SS tear (p = 0.002). The mean CHD in the presence of a SS tear was 8.4 ± 2.9 mm, contrasting with an average CHD value of 10.2 ± 3.2 mm in the control group.
Regarding the CO, the average values were 16.5 ± 4.7 mm and 15.1 ± 4.7 mm in the shoulders with and without SS tears respectively. This difference didn't achieve statistical significance (p = 0.12).

DISCUSSION

The role of subacromial and subcoracoid impingement in SS and SubS tears is extensively studied, however there are no published studies able to establish the exact pathophysiology of these two entities, that often are present simultaneously.
In this paper we confirmed the relationship between the presence of SS full thickness tears and SubS tears, and even LHB injuries, with a statistical significant association between these lesions. Comparing both groups, we can see that the control group presents a healthy SubS in 82.8% of shoulders, and

that only 48.5% of shoulders in the study group present a normal SubS. Besides that, 34.9% of the study group presented a SubS tear, contrasting with 13.7% in the control group. Regarding the CHD, we found a significant relationship between SS tears and decreased CHD, with average values of 10.2 ± 3.2 mm and 8.4 ± 2.9 mm, for the control and study group respectively ($p = 0.002$).

On the other hand, no statistical significant relationship was established between the CO and the presence of SS tears.

To our knowledge, our paper presents the largest sample on this topic, including 301 patients, being also the first to evaluate the different influence of the CHD as well as the CO in shoulders with SS tears and their roles in SubS tears pathology. However, there are some limitations to our study. Although our MRI protocol stated that the arm should be in a predefined position, variation in patient positioning is always a possibility and may influence the measurements. Also, our control group was relatively small when compared to the study group, due to the strict inclusion criteria for this group, which only included patients with completely normal MRI. In addition, our study was designed as a retrospective study, with its inherent limitations, and a prospective longitudinal study would be of value to confirm our preliminary conclusions.

It is known that many SubS tears originate from the anterior extension of SS tears, and many authors have already proved that SS tears are risk factors for SubS pathology (3, 9, 10). More so, numerous papers have showed that SS tears result in superior migration of the humeral head with decreased acromio-humeral distance (10-12).

Differently, only a few study groups were able to establish the effect of SS tears in CHD, with complete SS tears associated with inferior CHD, and none of these searched the effect on other known SubS predictors, such us CO (10, 12). Our results allow us to extrapolate that the humeral head superior migration results in a secondary subcoracoid impingement, resulting in increased risk of SubS tears in the context of SS full thickness tear.

As it is also known, both the CO and CHD are very strong predictors of SubS tears, with studies showing ROC Curves with areas under the curve of 93.8% and 80.6% (2). Both these parameters demonstrated being excellent SubS lesion predictors in several studies, however they translate different anatomic particularities of the shoulder gridle. The CHD corresponds to the smaller distance between the humerus lesser tuberosity and the coracoid, and represents the space available for de SubS (2, 7, 19-21). This space can be altered by pathologies affecting the humerus lesser tuberosity or the coracoid, such as fracture mal union, osteophytes, cysts or anomalies of the lesser tuberosity, SS tendon calcifications or even abnormal coracoid anatomy (2, 7, 19-21). As stated previously, other papers have also showed that the CHD can also be influenced by the presence of SS tears, and the phenom is explained by superior subluxation of the humeral head in these patients, that results in a greater humeral cross-section posteriorly to the coracoid process, and secondary subcoracoid impingement (10).

On the other hand, the CO represents the medial to lateral projection of the coracoid process, in regard to the glenoid fossa (2). This measurement is less susceptible to alterations caused by traumatic, iatrogenic or degenerative processes as it only depends on the coracoid projection, and the superior migration of the humeral head should not influence this measurement, as proved by our study.

The fact that the study group, with increased risk of SubS tears, was associated with inferior CHD but not with greater CO, suggests that this subcoracoid impingement is secondary to subluxation of the humeral head and not a result of coracoid process morphology. This can represent one more clue in explaining the physiopathology of SubS tears as a progression of SS tears, in the context of anterosuperior rotator cuff tears.

Our results shed a light in anterior superior cuff progression pathophysiology, confirming the hypothesis that SS full thickness tears lead to a secondary subcoracoid impingement and consequently SubS tears. However future prospective longitudinal studies are needed to further explain this complex relationship. The study meets the ethical standards of the journal (22).

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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Anterior Shoulder Anatomy and Subcoracoid Impingement: An anatomical study

Maria João Leite, André Pinho, Márcia Sá, Miguel Relvas,
João Torres, Dulce Madeira, Pedro Pereira

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MORPHOLOGIE

ORIGINAL ARTICLE

Anterior shoulder anatomy and subcoracoid impingement: An anatomical study

Anatomie antérieure de l'épaule et conflit sous-coracoïde : une étude anatomique

M. Leite[a,*], A. Pinho[a,b,d], M. Sá[c], M. Relvas[a], J. Torres[a,d], M. Madeira[b,d], P. Pereira[b,d]

[a] *Serviço de Ortopedia e Traumatologia, São João University Hospital, Centro Hospitalar Universitário de São João, Alameda Prof. Hernâni Monteiro, 4200-319 Porto, Portugal*
[b] *Unit of Anatomy, Department of Biomedicine, Porto Medical School, Porto University, Center for Health Technology and Services Research (CINTESIS), Alameda Prof. Hernâni Monteiro, Porto, Portugal*
[c] *Primary Health Care Unit Saúde em Família, R. Angola 172, Pedrouços, Portugal*
[d] *Porto Medical School, Porto University, Alameda Prof. Hernâni Monteiro, Porto, Portugal*

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Subscapularis;
Subcoracoid impingement;
Coraco-humeral distance;
Coracoid;
Musculocutaneous nerve;
Axillar nerve;
Coracoacromial ligament

Summary

Objective. — The aim of our study was to describe the anatomy of the anterior shoulder, specifically structures potentially involved in subscapularis tears pathophysiology and also to identify structures at risk during surgical approaches of this area.

Materials and methods. — We designed an observational, experimental study based on cadaveric models. Dissection was performed and several structures of the anterior shoulder were characterized including the subscapularis, coracoid morphology, the coracoacromial ligament, coraco-humeral distance, and the axillary and musculocutaneous nerves.

Results. — Our sample included 16 shoulders. The coracoacromial ligament presented two bands in 37.5%, and these variants were significantly wider and thinner, and were associated with inferior coraco-humeral distance in internal rotation. The subscapularis footprint was longer and the coracoid process was bigger in male specimens, and the median coracoid angle was 122°, corresponding to a Leite-Torres type I. The Subscapularis showed a median thickness of 0.7 cm, while the coraco-humeral distance in our sample ranged from 0.30 cm in internal rotation to 0.85 cm in external rotation. Neurologic relevant structures were at least more than 2.55 cm from the coracoid tip.

* Corresponding author.
E-mail address: mjlcma@gmail.com (M. Leite).

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Conclusions. — This is the first paper to explore the eventual relationship between the presence of a double band coracoacromial ligament variant and subcoracoid impingement. Also, to our knowledge, this is the first cadaveric model study to postulate a possible anatomic base for subcoracoid impingement, as the SS myotendinous junction thickness was found to be greater than the coraco-humeral distance in neutral position and in IR.

Résumé
Objectif. — Le but de notre étude était de décrire l'anatomie de la partie antérieure de l'épaule, en particulier les structures potentiellement impliquées dans la physiopathologie des ruptures du sous-scapulaire et également d'identifier les structures à risque lors des approches chirurgicales de cette zone.
Matériel et méthodes. — Il s'agit d'une étude observationnelle et expérimentale basée sur des modèles cadavériques. Des dissections ont été pratiquées et plusieurs structures de l'épaule antérieure ont été décrites.
Résultats. — Notre échantillon comprenait 16 épaules. Le ligament coraco-acromial présentait deux bandes dans 37,5 %, et ces variantes étaient significativement plus larges et plus minces, et étaient associées à une distance coraco-humérale inférieure en rotation interne. L'empreinte sub-scapulaire était plus longue et le processus coracoïde était plus grand chez les spécimens mâles, et l'angle coracoïde médian était de 122°, correspondant à un Leite-Torres type I. Le sub-scapulaire avait une épaisseur médiane de 0,7 cm, tandis que la distance coraco-humérale dans notre échantillon variait de 0,30 cm en rotation interne à 0,85 cm en rotation externe. Les structures neurologiques pertinentes étaient au minimumà plus de 2,55 cm de la pointe de la coracoïde.
Conclusions. — C'est le premier article qui analyse la relation éventuelle entre la présence d'une variante de ligament coracoacromial à double bande et un impact sous-coracoïde. De plus, à notre connaissance, c'est la première étude de modèle cadavérique à supposer une base anatomique possible pour un impact sous-coracoïde, car l'épaisseur de la jonction myotendineuse SS s'est avérée supérieure à la distance coraco-humérale en position neutre et en IR.

Introduction

Recently increasing interest in anterior shoulder pathology has been seen, regarding mainly the subscapularis tendon (SS) pathology and its repair, and subcoracoid impingement and coracoplasty.

Subcoracoid impingement is an uncommon condition, that is characterized by anterior shoulder pain worsened by forward elevation and internal rotation and caused by the impingement of the SS between the lesser tuberosity and the coracoid process [1,2].

Also, there is growing evidence that several anatomic factors, such as humeral version, coracoacromial ligament, coracoid morphology and coraco-humeral distance, influence the risk of anterior cuff tears [3—5]. In addition, extensive knowledge of the SS footprint will make it easier to diagnosis and allow more accurate anatomic repair of SS tear [6].

Subcoracoid impingement is a dynamic process, however most of the studies regarding this condition are based on radiological measurements, and therefore represent static evaluations. In this setting human models, such as cadaver studies, are lacking and have the additional advantage of allowing a dynamic evaluation [5,7,8].

Besides the importance of anatomy in anterior shoulder pathology, the knowledge of the bony and neurovascular anatomy are essential in defining the safety margins for surgical procedures in this area [9,10]. Regarding the coracoid in particular, there have been limited data defining the distance until the major neurovascular structures in proximity and the safety margin for coracoid decompression procedures [7,9].

Neurologic complications are not uncommon in shoulder surgery, with an incidence between 1% and 8%, and although arthroscopic procedures are considered safe, the incidence of neurologic complications described in the literature is rising reflecting the increasingly complex procedures done, and affecting in most cases the axillar (AN) and musculocutaneous nerve (MCN) [11—13].

The aim of our study was to re-examine the anatomy of the anterior shoulder to meet the demands of the new challenges in this area and the constant development of surgical procedures to address them.

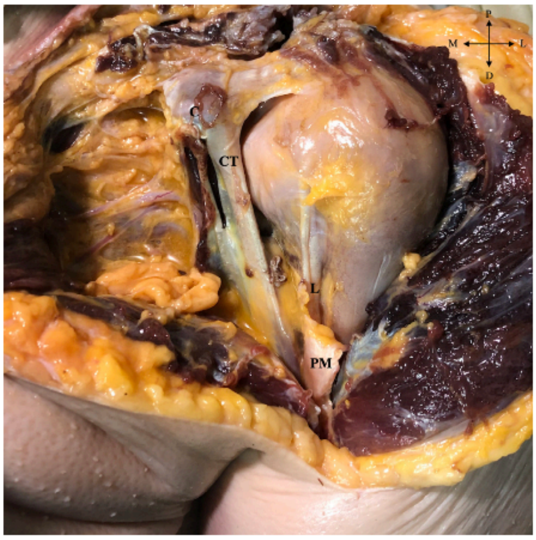

Figure 1 Dissection showing the coracoid (C), the long head of the biceps (L), the conjoint tendon (CT) and the *pectoralis major* tendon (PM).

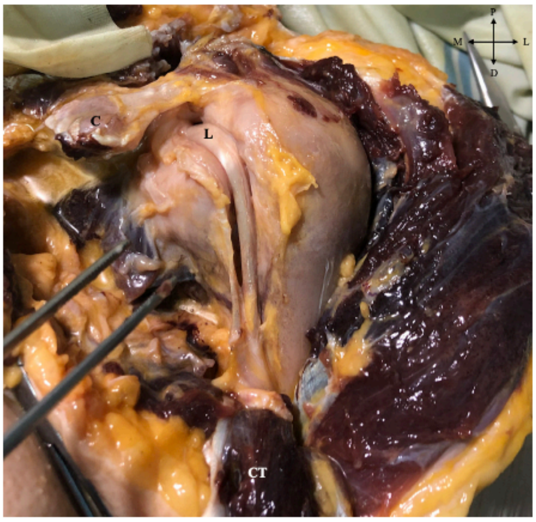

Figure 2 Dissection showing the conjoint tendon (CT) reflected distally, the coracoid (C) and the long head of the biceps onits groove (L).

Our main objective was to describe the anterior shoulder surgical anatomy, including the SS, coracoid process, coracoacromial ligament and neurologic structures. Our secondary goal was to describe the anatomic relationship between structures possibly involved in SS pathophysiology such as the SS footprint, the coracoid process and the coraco-acromial ligament (CAL).

We hypothesized that the space available under the coracoid for the SS tendon would be sparse, predisposing to subcoracoid impingement.

Material and methods

We design an observational, experimental study based on cadaveric models. Eight embalmed full body cadaveric models, resulting in 16 shoulder girdles, were used. All the cadavers derived from body donation with informed consent, written and signed by the donator himself, according to the Country's legislation. All work was performed at the Anatomy Department of the Faculty of Medicine to which the authors are affiliated.

The cadavers were in supine position with the arm extended and supinated along the body. Dissection begun with a skin incision using a deltopectoral approach extended medially and posteriorly to expose the full clavicle and acromion, and carried out until the level of the SS.

The deltoid was dissected of the clavicle and acromion and mobilized, the *pectoralis major* was released from its proximal and distal insertions and the *pectoralis minor* removed from the coracoid and both reflected, exposing the brachial plexus (Figs. 1—3).

First the distances from the coracoid to the MCN were evaluated, regarding the minimal Coracoid-MCD distance and the coracoid-MCN distance at the point of penetration of the most proximal branch of the MCN in the *coracobrachialis*

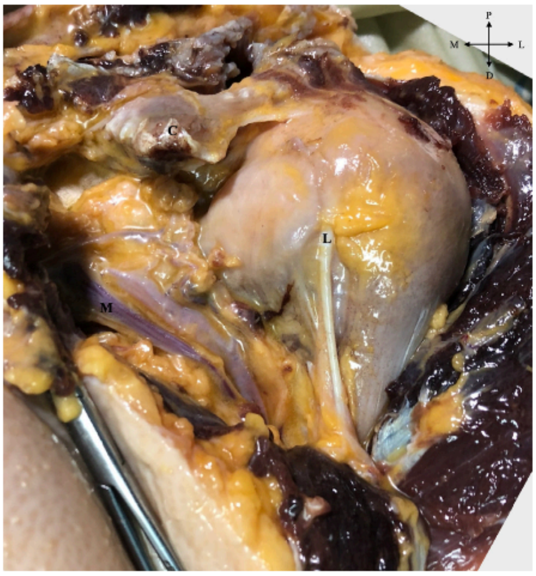

Figure 3 Further dissection showing part of the brachial plexus, namely the musculocutaneous nerve (M). Also visible is the coracoid (C) and the long head of the biceps (L).

muscle (Fig. 4). The distance from the AN, anteriorly to the SS, to the coracoid was also recorded (Fig. 5).

The coracoacromial ligament (CAL) was also evaluated, including its wide and thickness at the middle point, and the presence of a single band or two distinct bands. The distance from the CAL to the supraspinatus and SS were also recorded.

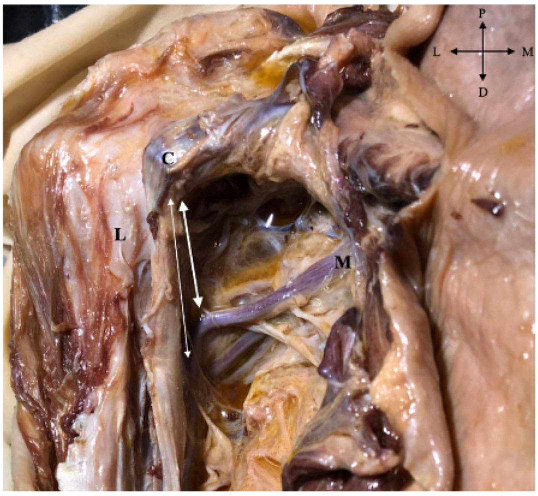

Figure 4 Evaluating the minimal distance (wider arrow) from the musculocutaneous nerve (M) to the coracoid (C) and the distance from the musculocutaneous nerve to the coracoid at the point where it enters the conjoint tendon (thinner arrow). Laterally can be seen the long head of the biceps (L) for reference.

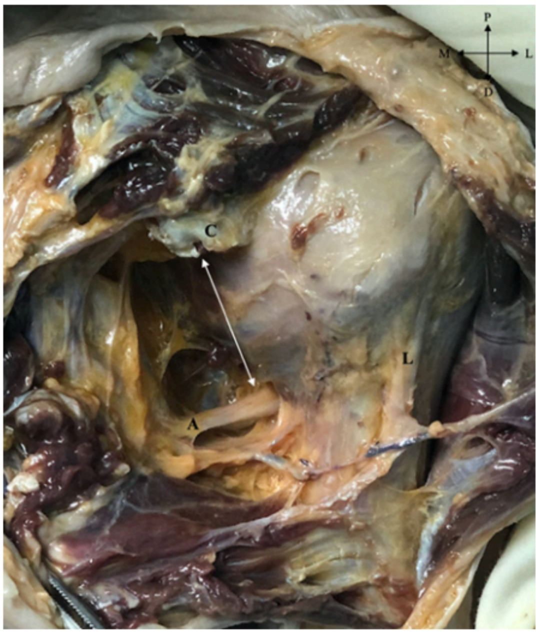

Figure 5 Measurement of the minimal distance from the coracoid (C) to the axillary nerve (A). Laterally can be identified the long head of the biceps (L) for reference.

To ensure accurate evaluations, at this point all soft tissues were sharply dissected from the coracoid process. Coracoid morphology was evaluated, including:

- proximal (CLP);
- distal (CLD) segments length;
- the base to tip distance and;
- coracoid angle (CA).

The proximal coracoid segment was defined between the coracoid base and its knee, and the distal segment, distal to it. [3] The base to tip distance was measured according to the axial plane and corresponds to the smallest distance from the base to do tip of the coracoid process. The CA represents the angle between the long axis of the proximal and distal coracoid segments [3].

The SS was dissected, and elevated subperiosteally from the lesser tuberosity, revealing its footprint. The SS footprint was measured superior to inferior (height) and medial to lateral (wide) at the middle point. The SS tendon was inspected to exclude any partial thickness tears, and afterwards, its thickness at the myotendinous junction was recorded. The long head of the biceps (LHB) was identified and evaluated, looking for LHB pathology.

To study the influence of the humeral position in subcoracoid impingement, the smallest distance between the lesser tuberosity and the coracoid process tip was evaluated in neutral position (CHD), 45° of internal rotation (CHD-IR) and 45° of external rotation (CHD-ER). At this point the elbow was kept at 90° of flexion, to help with mobilization and to serve as an indicator of rotation. A standardized measurement technique was developed using a standard paper ruler (millimeter scale) and goniometer, evaluating the distance or angle between two points previously marked with needles. These measurements were recorded by two of the authors, and resulted from the average of two consecutive measures. Gender and laterality were also recorded. Exclusion criteria included shoulders scars, shoulder deformity, supraspinatus, SS or LHB tears, and limitations in passive range of motion (ROM).

To analyze the collected data, we used the software IBM SPSS Statistics 24®. We presented continuous variables as median, minimum, maximum and interquartile interval (IQI) while categorical variables were described as absolute and relative frequencies. As we only analyzed 16 shoulders, we used non-parametric tests to evaluate association between variables.

As so, we used Mann—Whitney test to compare continuous and categorical variables, and Spearman correlation to compare continuous variables between each other. The *P*-value was defined to provide a statistically significant association when < 0.05.

This anatomic study did not require investigational review board or ethics committee approval.

Results

The sample was comprised of 8 full body cadaveric models, representing 16 shoulders, including 4 female and 4 male models, all Caucasian with a median age of 74.5 years. All cadavers included in this study presented normal rotator cuffs and normal bony anatomy.

Regarding the proximity between the coracoid and neurologic structures, our sample showed a median minimal distance from the coracoid to the MCN of 2.55 cm and interquartile interval (IQI) of 0.95. The median distance from the coracoid to the MCN at the point of penetration of

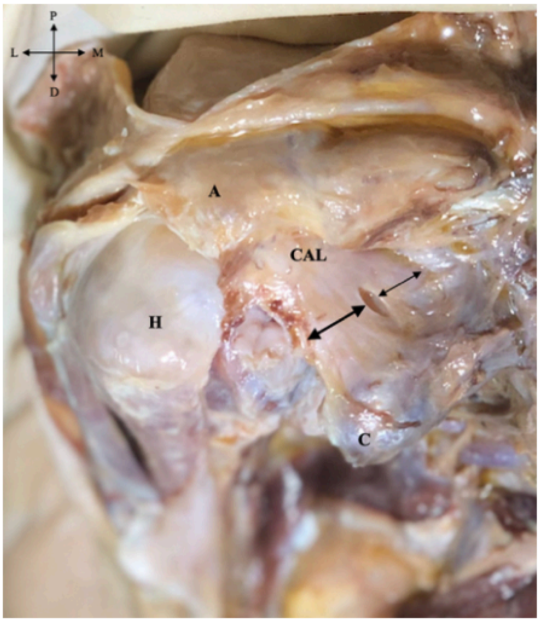

Figure 6 The coracoacromial ligament (CAL), extending from the acromion (A) to the coracoid (C), showing the width of the two distinct bands, the medial band (thinner arrow) and the lateral band (thicker arrow). Laterally can be identified the humerus (H) for reference.

the most proximal branch of the MCN in the coracobrachialis muscle was 2.65 cm (IQI = 0.88). The axillary nerve was identified when crossing perpendicular to the humeral shaft and within the deep fascia of the deltoid. Its distance to the coracoid was evaluated at the point where it lays anterior and inferior to the SS tendon, and showed a median interval of 3.20 cm to the coracoid process (IQI = 1.10). The coracoacromial ligament (CAL) presented a median width and thickness of 2.15 cm (IQI = 0.55) and 0.30 cm (IQI = 0.13) respectively, with males presenting a significantly wider CAL ($P = 0.01$) with median width of 2.5 cm and 1.95 in males and females respectively. We also evaluated the relationship of the CAL to the rotator cuff, founding a distance of 0.20 cm (IQI = 0.03) from the supraspinatus and 1.20 cm (IQI = 0.70) from the SS. The CAL showed a significant closer relationship with the supraspinatus, when compared with the SS ($P = 0.03$).

Regarding our sample, 37.5% of shoulders presented a CAL with two distinct bands, a smaller medial band (median width of 0.80 cm and IQI = 0.10) and a lateral band (median width of 1.60 cm and IQI = 0.90) almost double in size (Fig. 6). The shoulders with double CAL showed significantly wider ligaments ($P = 0.01$) with a median width of 2.40 cm (versus 1.95 cm in the single band group), despite being thinner with a median thickness of 0.20 cm versus 0.3 cm in the single band CAL group ($P = 0.04$).

Coracoid morphology was studied including proximal (CLP) and distal (CLD) segments length, the base to tip distance and the coracoid angle (CA). The coracoid process presented a median CLP of 2.20 cm (IQI = 0.33), median CLD of 3.35 cm (IQI = 0.30) and a median base to tip distance of 3.75 cm (IQI = 0.73). These measurements were all significantly greater in males, with a median CLP of 2.35 cm in males and 2.05 cm in females ($P = 0.02$), a median CLD of 3.40 cm in males and 3.15 in females ($P = 0.03$), and a median base to tip distance of 4.20 cm and 3.45 in males and females respectively ($P < 0.001$). The median CA was 122° (IQI = 10.50), and did not show significant divergences between gender.

The SS footprint was evaluated disregarding the extension to LHB groove and the muscular insertion at the humerus, and presented an oval form with a height and width of 2.70 cm (IQI = 0.65) and 1.55 cm (IQI = 0.40) respectively. The SS footprint was significantly longer ($P = 0.01$) in men, with a median length of 2.95 cm versus 2.35 cm in women. The SS tendon had a median thickness of 0.70 cm (IQI = 0.30) in the musculotendinous junction.

Regarding the coraco-humeral distance, this parameter was evaluated in neutral position (CHD), 45° of internal rotation (CHD-IR) and 45° of external rotation (CHD-ER). Although the coraco-humeral distance showed a tendency to reach inferior values in internal rotation, these differences were not statistically significant, with a median CHD-N of 0,75 cm (IQI = 0.15), CHD-IR of 0,3 cm (IQI = 0.23) and CHD-ER of 0.85 cm (IQI = 0.35). A power analysis was performed, revealing that at least 385 shoulders would need to be dissected for a statistically difference to potentially be found.

The coraco-humeral distance seemed to be influenced by the morphology of the CAL, with cadavers which presented a doubled band CAL showing significantly lower ($P = 0.005$) distances in internal rotation, with a median CHD-IR of 0.25 cm versus 0.35 cm (single band CAL).

Discussion

After evaluation of all collected parameters, we did not find any lateral dominance. From this, we can infer that, at least in our sample, there was no effect of hand dominancy in subcoracoid impingement, and that no adaptative mechanisms occurred regarding the *subscapularis* tendon.

The most important factor in decreasing iatrogenic lesions in surgical procedures involving the coracoid is a thorough understanding of the anatomy of the area.

In our sample the MCN is at a minimal distance of 2.55 cm from the coracoid tip, and distances 2.65 cm from the coracoid at the point where enters the conjoint tendon, which is similar to the distances reported in the literature [7,11,14].

The AN is close to the surgical field during a routine deltopectoral approach to the shoulder, the most commonly used during procedures around this joint, and forceful retraction or aggressive dissection can result in AN damage and impaired shoulder function. We evaluated the relationship between the coracoid process and the AN, and found a mean distance of 3.20 cm from the coracoid tip to the AN, which is in accordance with the literature [7,15].

The fact that the aforementioned measurements are in line with what has been previously published, contributes to the validation of our sample, despite its small size.

According to these data, surgery near the coracoid base, such as Latarjet procedures or acromioclavicular joint dislocation reductions, should be considered relatively safe, as the median base to tip distance is 3.75 cm, and the neurologic structures distance more than 2.50 cm from the coracoid process tip. However, the surgeon should be cautious when approaching the distal and medial aspect of the coracoid tip.

The CAL is traditionally described as a triangular shaped ligament included in the coraco-acromial arch. This ligament is involved in humeral head stabilization and subacromial impingement, and although increasing interest has been seen lately in its function, limited literature exists regarding the CAL anatomy and its relationship with the rotator cuff. In our sample, despite being within an inferior distance from the supraspinatus, the CAL also showed a close relationship with the SS tendon, distancing only 1.2 cm from this structure.

Chahala et al., [9], described in their study the presence of two distinct bands in the CAL, one posterior (more medial) and smaller, and another anterior (more lateral) and with greater areas. In our study, 37.5% of shoulders presented this double band CAL, also with a smaller medial band and a greater lateral band, and these CALs were significantly wider and thinner than the single band CALs.

Additionally to Chahala et al., [9], our study also evaluated the relationship between the CAL and the underlying rotator cuff, and searched for the influence of its variants in a possible impingement. We found that the CAL has a closer relationship with the *supraspinatus* tendon (0.2 cm), but is still in close proximity with the SS tendon (1.20 cm). We found that subjects with the double band CALs variant presented an inferior CHD-IR; we believe this to be a very relevant result, since it could possibly make these subjects more prone to subcoracoid impingement. We hypothesized that the CAL could function as a spacer, between the coracoid process tip and the SS in internal rotation, and therefore the presence of a thinner double band CAL would be a risk factor for subcoracoid impingement. However more studies are needed to confirm our hypothesis.

The coracoid process was evaluated regarding its proximal (CLP) and distal length (CLD), base to tip distance and coracoid angle (CA). The coracoid process presented a median CLP of 2.20 cm, CLD of 3.35 cm and a base to tip distance of 3.75 cm, with these values being slightly superior to those described in the literature. [10,15,16] These measurements were all significantly greater in males, probably traducing the typical differences in body size between men and women. The median CA was 122°, corresponding to a Flat Coracoid according to the Leite-Torres Classification [3], which was to be expected given that none of the models had a SS lesion.

The *subscapularis* footprint, excluding the distal muscular insertion showed comparable measurements to those found in the literature, with a median width and length of 1.55 cm and 2.70 cm respectively, again contributing to the validation of our sample, despite its size. The fact that the SS footprint varies with gender is also in according to the available literature [6,17,18].

Knowledge of the SS footprint dimensions is essential for the correct diagnosis and evaluation of SS tears, allowing the surgeon to better identify the extent of these tears and decide the most appropriate treatment, and proceed, if necessary, with a more accurate anatomic repair.

This is, to our knowledge, the first study to report the SS myotendinous junction thickness and comparing it with the available space in the subcoracoid region. This is important in the actual clinical setting, where subcoracoid impingement is increasingly recognized as a major player in SS pathology [3,4]. The SS myotendinous junction thickness showed a median of 0.7 cm, while the coraco-humeral distance in our sample ranged from 0.30 cm in internal rotation to 0.85 cm in external rotation. This allows us to infer an anatomical background to the subcoracoid impingement, and a possible anatomic relation between repetitive professional or sports related shoulder activities, in IR vs ER, and the development of *subscapularis* and long head of the biceps pathological changes.

The assessment of the distance between the SS and the coracoid in different arm positions is required to provide a comprehensive and accurate assessment of the potential risk of impingement during shoulder ROM.

Our study revealed that although the SS footprint got closer to the coracoid in IR, the coraco-humeral distance did not vary in a significant manner according to arm position. According to the power analysis performed, at least 385 shoulders would need to be dissected for a statistically difference to potentially be found, what would render this study impracticable. On the other hand, this can contribute to the validation of the measurement of the coraco-humeral distance using static imaging modalities, such as MRI or CT.

Our values of coraco-humeral distance were inferior to the majority described in the literature, [2,8,15]; this can eventually be explained by the fact that we evaluated this interval after removing the SS tendon, which may serve as a soft tissue spacer between the lesser tuberosity and the coracoid process, and also due to the larger freedom of movement of the humeral head resulting from resection of soft tissues.

The morphology of the CAL also appears to influence the CHD-IR, as we found that cadavers with a double band CAL presented an inferior CHD-IR. Analyzing the morphologic differences between the single and double band CAL, we can conclude that the double band CAL is thinner, allowing an inferior CHD-IR and resulting in an inferior protection for the SS tendon from the coracoid process bony impingement.

Our study has showed important findings with potential clinical relevance that can ultimately influence our clinical practice and explain part of the rotator cuff tears pathophysiology; however our research also presents some important limitations.

One is inherent to cadaveric experimental studies and is related to the changes in volume and trophicity of muscle and tendon masses after death and fixation techniques. We tried to minimize this limitation by using mainly bony references. In addition, although a detailed dissection was performed, distances were calculated using vector norms, which do not provide directional information.

The relatively limited number of cadaveric models may have led to a underpower of this study results, and although higher-power anatomic studies are required to further define the surgical and functional anatomy of the anterior shoulder, this paper provides meaningful data in understanding the local relationships in our surgical workspace at the anterior shoulder. Also, several previous published works validates the anatomical characteristics our sample.

On the other hand, our study was optimized by using full-body cadavers in which the neurologic structures were intact and fully connected to the neck and shoulder. Also, dissection was minimized as much as possible, as to maintain the in vivo relationships between these structures.

Conclusion

Our study provides important data in understanding surgical and functional anatomy of the anterior shoulder.

This is the first paper to fully describe the eventual relationship between the presence of a double band CAL variant and subcoracoid impingement, with a double band CAL being associated with lower CHD-IR.

Also this is, to our knowledge, the first cadaveric model study to postulate a possible anatomic base for subcoracoid impingement, as the SS myotendinous junction thickness was found to be greater than the coraco-humeral distance in neutral position and in IR.

Disclosure of interest

The authors declare that they have no competing interest.

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4. DISCUSSÃO

As roturas do subescapular continuam a ser desafiantes. Quer seja pela necessidade de elevado índice de suspeição, quer seja pela baixa sensibilidade dos métodos de imagem, estas lesões foram durante vários anos subdiagnosticadas e subtratadas.

Contudo, recentemente tem-se verificado um aumento crescente do interesse em compreender melhor a fisiopatologia do subescapular, resultando num diagnóstico mais eficaz destas lesões e melhor tratamento destes doentes.

O conceito de conflito subcoracoide, descrito por Gerber, tem também ganho nova popularidade recentemente, como um possível processo responsável por roturas da coifa anterior, incluindo o subescapular e a longa porção do bicípite.

Assim um dos objetivos deste projeto foi definir quais os fatores anatómicos que poderiam ter um papel patológico nas roturas anteriores da coifa. Após revisão bibliográfica optamos inicialmente por confirmar o papel de possíveis determinantes já conhecidos, seguido da procura de novos parâmetros ainda não descritos como possíveis fatores de risco para patologia do subescapular.

Após a colheita e análise de dados, propusemo-nos a avaliar qual destes parâmetros seria um melhor preditor destas lesões. Assim, para avaliarmos a capacidade preditiva de cada parâmetro foram desenhadas curvas ROC (*Receiver Operating Characteristic Curve*) e calculadas as AUC (*Area Under the Curve*) para cada uma delas, sendo que uma AUC de 100% representaria o teste perfeito, enquanto uma AUC<50% representa um teste sem utilidade.

Coracohumeral distance and Coracoid Overlap as Predictors of Subscapularis and Long Head of the Biceps Injuries.

De forma a identificarmos quais os possíveis fatores da região anterior do ombro envolvidos na fisiopatologia da coifa anterior, iniciamos este projeto de investigação por uma série de estudos imagiológicos. Neste primeiro trabalho começamos por confirmar a influência de dois parâmetros, a Distância coraco-umeral (CDU) e o Overlap coracoide (OC), já previamente conhecidos mas cujo papel ainda não estava bem definido. Adicionalmente, a utilização destes dois parâmetros permitem caraterizar o espaço subcoracoide de duas formas distintas, descrevendo o espaço disponível no intervalo subcoracoide e a projeção medio-lateral da apófise coracoide em direção à cabeça umeral.

Obtivemos a maior amostra publicada até à data sobre o tópico, com uma distribuição equilibrada entre grupo de estudo e de controlo, o que contribui para a validade dos nossos resultados.

Verificámos uma associação estatisticamente significativa entre a presença de lesões do subescapular e da longa porção do bicípite, uma vez que provavelmente pela sua proximidade anatómica estarão sujeitos aos mesmos fatores patológicos.

Relativamente aos fatores de risco avaliados, o valor médio da DCU do grupo de controlo foi de acordo com o descrito na restante literatura validando a nossa amostra. [6,8,9] Atingimos também diferenças estatisticamente significativas entre menor DCU, maior OC e maior incidência de lesões do subescapular e da LPB.

Verificou-se ainda que valores progressivamente inferiores de DCU e progressivamente superiores de OC se associaram a lesões progressivamente mais graves da coifa anterior, desde tendinopatia, a roturas parciais e roturas totais.

Na presença de lesão (rotura ou tendinopatia) do subescapular a DCU e o OC foram 6,7 e 18,6mm respetivamente, sendo que quando consideramos apenas o subgrupo de doentes com roturas, os valores médios de DCU e OC foram 5,7mm e 19,7mm respetivamente.

Foram desenhadas curvas ROC e calculada a respetiva *Area under the curve* (AUC) para avaliar a capacidade preditiva de cada um destes fatores. Utilizando as curvas ROC foi possível definir valores de cut-off do DCU e OC que permitem determinar o risco de roturas do subescapular.

A DCU foi o melhor preditor de roturas do subescapular, com uma AUC de 93,8%, tornando-o um excelente preditor, sendo que uma DCU de 7,95mm apresenta uma sensibilidade de 89,9% e especificidade de 84,2% para a presença de roturas do subescapular.

Uma vez que a DCU foi o melhor preditor de lesões do subescapular, desenhamos uma curva ROC para determinar a probabilidade de um doente ter uma rotura parcial ou total do subescapular. Assim na curva DCU - rotura parcial vs total, que apresentou uma AUC de 72,7%, um valor de DCU de 5,3mm permite diferenciar uma rotura completa de parcial com uma sensibilidade de 73% e especificidade de 66,7%.

O OC representa também um bom preditor com uma AUC de 80,6%, sendo que um OC de 16,6mm se associa a uma sensibilidade de 78.8% e especificidade de 68,3% para a presença de roturas do subescapular. Assim foi possível definir valores de cut-off do DCU e OC que permitem determinar o risco de roturas parciais ou totais do subescapular.

Apesar da frequente associação entre patologia do subescapular e LPB, este foi o primeiro estudo a explorar a relação entre a DCU e o OC e lesões do bicípite. No nosso estudo, tanto a DCU como o OC foram bons preditores destas lesões, com AUC de 79% e 72,6% respetivamente. Contudo, ao contrário do que aconteceu com o subescapular, no caso da presença de roturas da LPB, o *ratio OC*/DCU apresentou um valor preditivo superior ao OC. Obtivemos uma curva ROC OC/DCU - roturas da LPB com uma AUC de 79%, sendo que um *ratio* de 2,3 se associava a uma sensibilidade de 82,1% e especificidade de 68,9% para roturas da LPB.

Este estudo teve a particularidade de apresentar à data de publicação a maior amostra da temática, ser o único que se focava também nas lesões da LPB e na distinção das roturas parciais e totais do subescapular.

Coracoid morphology and humeral version as risk factors for subscapularis tears.

Após confirmação da influência da distância coraco-umeral e overlap coracoide, propusemo-nos procurar e descrever novos fatores de risco anatómicos para as roturas do subescapular. Assim, após uma extensa revisão bibliográfica verificamos a existência de uma lacuna na descrição da influência dos diferentes parâmetros da morfologia coracoide nestas roturas.

Por consequência, propusemo-nos definir qual o papel do comprimento dos segmentos proximal (CCP) e distal (CCD) da coracoide, bem como o seu comprimento total (CCT). Procuramos também a existência de alguma associação entre a razão entre o comprimento do segmento proximal e distal da apófise coracoide e roturas do subescapular. Recorrendo às curvas ROC e respetivas AUC, verificamos que o comprimento do segmento distal da coracoide foi o que mais influenciou o risco de roturas do subescapular, com uma AUC de 89%. Apesar de apresentarem poder preditivo inferior, tanto o ratio entre o comprimento proximal e total da coracoide (CCR) e o comprimento coracoide total (CCT) foram bons preditores destas lesões com AUC de respetivamente 87%, e 81%. O CCP tendo apresentado uma AUC de 57,2% não tem nenhuma utilidade como preditor de lesões do subescapular.

O fato do CCD apresentar um valor predicativo superior, pode ser explicado pela anatomia da coracoide, uma vez que o segmento distal se dirige inferior e lateralmente e portanto se encontra em maior proximidade do tendão do subescapular, quando comparado com o segmento proximal, que se projeta anterosuperiormente.

Definimos também pela primeira vez o ângulo coracoide (AC) e estudamos o seu papel nestas roturas. O ângulo coracoide apresentou uma AUC de 90%, representado o melhor preditor de roturas do subescapular neste estudo. Assim a forma, mais do que o tamanho da apófise coracoide, parece ser um fator determinante nas roturas do subescapular.

Sendo que o AC se mostrou um excelente preditor de roturas do subescapular, utilizamos este parâmetro para criar a Classificação Leite-Torres para a morfologia da coracoide. Esta classificação permite a estratificação dos doentes em 3 classes de acordo com o tipo de coracoide e o consequente risco crescente de desenvolvimento de roturas do subescapular. As coracoides tipo I, ou coracoides planas, têm um AC>120º, associando-se a baixo risco de lesão do subescapular. Coracoides tipo II, ou curvas, com um AC entre 95 e 120º, associam-se a um risco intermédio de rotura do subescapular. E coracoides tipo III, ou coracoides em gancho, apresentam um AC<95º, e associam-se a risco elevado de roturas do subescapular. Relativamente à nossa amostra, apenas 4,5% dos doentes com coracoides tipo I apresentavam roturas do subescapular, contrastando com 60% dos doentes com coracoides tipo II e 97,2% dos doentes com coracoides tipo III.

Esta classificação poderá ter um papel importante na identificação de doentes de risco para o desenvolvimento de roturas do subescapular, uma vez que a identificação do subgrupo de doentes de risco com base na análise das imagens pré-operatórias pode condicionar a nossa prática clínica de várias formas. Durante o procedimento artroscópico neste subgrupo de doentes o cirurgião deve procurar ativamente a presença ou ausência de roturas do subescapular, lesão frequentemente subdiagnosticada na RMN. [10] Em doentes com coracoides tipo II ou III, após a reparação de uma rotura do subescapular ou mesmo na ausência de rotura evidente deste tendão, a realização de uma coracoplastia protetora da sutura ou profilática deve ser considerada.

Não existia também nenhuma referência ao papel da versão umeral nas roturas da coifa anterior, sendo o nosso estudo o primeiro a estudar esta associação. A versão umeral média do grupo controlo, correspondendo a 28,6º de retroversão, encontra-se dentro dos valores descritos na literatura, contribuindo para a validação da nossa amostra. [54,65-68] Verificamos que a versão umeral era um bom preditor de roturas do subescapular, com uma AUC de 79%, apresentando contudo com uma capacidade preditiva inferior quando comparada com os parâmetros da morfologia coracoide. Obtivemos uma correlação entre maior retroversão umeral e maior risco de lesão do subescapular. Isto pode ser explicado pelo *impingement* do tendão do subescapular entre a glenoide e a cabeça umeral mais retrovertida, analogamente ao descrito por Tretrault [62] relativamente à influência da retroversão da glenoide. Verificamos ainda que graus progressivamente superiores de retroversão se associaram a lesões progressivamente mais complexas do subescapular, desde tendinopatia até rotura.

Este estudo apresentou à data de publicação a maior amostra na matéria, sendo ainda o primeiro trabalho a estudar o papel de diversos parâmetros da morfologia coracoide, como o ângulo coracoide e comprimentos distal, proximal e total da coracoide, nas roturas do subescapular. Foi ainda o primeiro trabalho a estudar a relação entre a versão umeral e roturas do subescapular.

Can supraspinatus tears contribute to acquired subcoracoid impingement? A radiological study of anterosuperior cuff tears.

Apesar de existir bibliografia extensa relativamente à influência do conflito subacromial e subcoracoide nas roturas do supraespinhoso e subescapular respetivamente, a fisiopatologia da progressão das roturas antero-superiores da coifa ainda não é completamente compreendida.

Neste trabalho começamos por confirmar a já descrita associação entre roturas completas do supraespinhoso, roturas do subescapular e também e lesões da LPB. Na nossa amostra, 82,8% do grupo de controlo (sem rotura do supraespinhoso) apresenta um subescapular saudável, ao contrário do grupo de estudo (doentes com rotura completa do supraespinhoso) em que apenas 48,5% apresentava subescapular sem lesão. A presença de rotura do subescapular também foi significativamente diferente entre o grupo de controlo e de estudo, sendo que estes subgrupos apresentavam roturas do subescapular em 13,7% e 34,9% dos doentes respetivamente.

Verificámos também a existência de uma relação entre roturas do supraespinhoso e menor Distância coraco-umeral (DCU), com valores médios de DCU de 10,2 e 8,4 mm respetivamente para o grupo de controlo e estudo. Isto vai de encontro ao descrito na literatura, com vários estudos a descreverem a relação entre roturas do supraespinhoso e ascensão da cabeça umeral pela ação do deltóide sem o antagonismo do supraespinhoso.[3,61,62]

Tem surgido um renovado interesse na explicação da progressão das roturas antero-superiores e fatores de risco para roturas anteriores da coifa. No primeiro trabalho deste projeto de investigação já determinamos que a distância coraco-umeral e o *overlap* coracoide são ótimos preditores de lesões do subescapular, com AUC de 93,8% e 80,6%. [69] Apesar de ambos serem fatores de risco para o subescapular, traduzem diferentes parâmetros anatómicos da articulação gleno-umeral. A DCU corresponde à menor distância entre o úmero e a coracoide, representando o espaço disponível para o subescapular. Esta distância pode ser alterada por várias patologias que afetem o úmero ou a coracoide, como pseudartroses, osteófitos, quistos, calcificações do tendão do subescapular ou variações anatómicas da pequena tuberosidade ou coracoide. [1,6,2,69] Por outro lado o OC representa a projeção medio-lateral da coracoide em relação à fossa glenoideia. Esta medida é assim menos suscetível a alterações traumáticas, iatrogénicas ou degenerativas, uma vez que apenas depende da projeção da coracoide, não sendo influenciada pela ascensão da cabeça umeral decorrente da rotura do supraespinhoso.

Recentemente alguns estudos procuraram estabelecer o efeito de roturas do supraespinhoso na distância coraco-umeral. Estes trabalhos demonstraram que roturas completas do supraespinhoso se associam a menor distância coraco-umeral, podendo assim contribuir para um eventual conflito subcoracoide. [3,62] Através da análise dos nossos resultados, podemos inferir que a ascensão da cabeça umeral que existe na presença de roturas do supraespinhoso,[3,61,62] resulta numa diminuição secundária da distância coraco-umeral. Este fenómeno será condicionado pelo fato de uma área de maior circunferência da cabeça umeral se passar a situar posteriormente à coracoide, resultando num conflito subcoracoide secundário e consequente aumento do risco de desenvolver roturas do subescapular.

Pelo contrário, o *overlap* coracoide, outro fator já descrito como associado a lesões do subescapular, [1,69] não foi influenciado pela presença de roturas do supraespinhoso, uma vez que este parâmetro traduz a anatomia e projeção medio-lateral da apófise coracoide, e não o espaço subcoracoide.

Assim, em doentes com roturas completas do supraespinhoso o conflito subcoracoide parece ser causado por uma diminuição do espaço subcoracoide como consequência da ascensão da cabeça. Este *impingement* secundário não parece ser consequência da morfologia da coracoide, uma vez que o OC não atingiu nenhuma relação estatisticamente significativa com a presença de roturas do supraespinhoso. Este mecanismo de conflito subcoracoide secundário pode representar mais uma pista na explicação da progressão das roturas antero-superiores da coifa

Os três primeiros trabalhos deste projeto de investigação permitiram-nos confirmar o papel de determinadas estruturas na fisiopatologia das roturas anteriores da coifa e identificar novos fatores de risco, contudo estes trabalhos apresentam também as suas limitações. Apesar de termos um protocolo de RMN bem definido, poderão ter ocorrido variações na posição do membro, com consequente influência nas imagens adquiridas. Adicionalmente, apesar de todas as medidas serem a média de 3 medições separadas, estas foram todas realizadas pela mesma investigadora. Para além disso, estes foram estudos retrospetivos com as limitações inerentes a este tipo de estudo.

Assim para combater alguns dos pontos fracos inerentes aos estudos imagiológicos, o último trabalho deste projeto de investigação passou pela confirmação dos achados prévios em modelos de cadáver.

Anterior Shoulder anatomy and subcoracoid impingement: an anatomical study.

Um dos fatores mais importantes para a diminuição de lesões iatrogénicas nos procedimentos da região anterior é o conhecimento detalhado da anatomia desta região.

Avaliando a nossa amostra não se verificaram diferenças significativas com a lateralidade, sendo que não parecem existir mecanismos adaptativos de acordo com a dominância.

Relativamente a estruturas neurovasculares, o nervo musculocutâneo passou em média a uma distância mínima de 2,55cm da coracoide, situando-se a 2,65cm desta no ponto em que entra no tendão conjunto. Estes valores são sobreponíveis aos descritos na literatura, o que contribui para os achados do nosso estudo. [21,31,36]

O nervo axilar encontra-se na proximidade da abordagem deltopeitoral, podendo ser lesado durante esta abordagem ou afastamento. Avaliamos a relação entre o nervo axilar e a apófise coracoide, e verificamos que este nervo dista em média apenas 3,2cm da ponta da coracoide, indo de acordo ao previamente descrito. [21,70]

De acordo com estes dados, procedimentos cirúrgicos na região da base da apófise coracoide são relativamente seguros, uma vez que a distância medida da base à ponta da coracoide foi de 3,75cm, e as estruturas neurológicas se situam a mais de 2,5cm desta. Contudo, o cirurgião deve ter cautela durante procedimentos no bordo medial e região distal da coracoide.

O ligamento coraco-acromial (LCA) constitui parte do arco coraco-acromial e funciona como um estabilizador da cabeça umeral, podendo estar envolvido também no conflito subacromial. Recentemente tem-se verificado um interesse crescente na descrição desta estrutura, apesar disso, a literatura disponível ainda é escassa no que toca à sua anatomia e relação com a coifa dos rotadores.

O LCA é tradicionalmente descrito como de forma triangular, contudo Chahala *et al*., descreveu no seu estudo a presença de uma variante com duas bandas do LCA. [22] No nosso estudo, 37,5% dos ombros apresentavam esta variante, com o LCA constituído por duas bandas, uma menor medial e uma mais extensa lateral. Os LCA de banda dupla mostraram ser significativamente mais largos, contudo menos espessos, que os LCA de banda única.

Avaliamos também a relação entre o LCA e a coifa dos rotadores, procurando uma possível base para o conflito subcoracoide ou subacromial. Confirmamos que o LCA está numa relação de estreita proximidade com o supraespinhoso, distando dele apenas 0,2cm. Isto também se verifica em menor grau com o subescapular, que dista deste ligamento em média 1,2cm.

Relativamente à morfologia da coracoide, foi avaliado o comprimento proximal, distal, total e ângulo coracoide. A coracoide mediu 2,2cm e 3,35cm na sua porção proximal e distal e

3,75cm da base à ponta da coracoide. Estes valores foram significativamente superiores em indivíduos do sexo masculino, podendo traduzir as diferenças em tamanho corporal entre géneros.

A mediana do ângulo coracoide correspondeu a 122º, traduzindo uma coracoide plana, o que seria de esperar tendo em conta que nenhum dos modelos apresentava lesões do tendão do subescapular.

Um dos principais objetivos deste trabalho foi permitir a avaliação dinâmica e confirmar os achados dos estudos imagiológicos. Assim a distância coraco-umeral (DCU) foi avaliada na posição neutra, em rotação interna (RI) e rotação externa (RE). A mediana de valores da DCU foi inferior à descrita na literatura,[24,70,71] o que pode ser explicado pelo fato de a medição ter sido feita após disseção do tendão do subescapular, comprometendo o efeito tenodese do subescapular na cabeça umeral e o efeito de espaçador do próprio tendão. A DCU mostrou uma tendência decrescente com graus superiores de RI, com medianas de DCU de 0,85cm, 0,75cm e 0,3cm em RE, neutro e RI respetivamente. Apesar destas diferenças não terem atingido significância estatística devido possivelmente ao tamanho da amostra, não devem ser desprezadas.

A morfologia do LCA também parece influenciar o espaço subcoracoide, uma vez que cadáveres com LCA duplo apresentaram uma DCU em RI significativamente inferior. Uma vez que o LCA duplo apresenta uma espessura inferior, pode permitir uma maior aproximação da apófise coracoide do úmero em RI. Assim o LCA pode funcionar como uma estrutura protetora do subescapular, contudo a presença de um LCA duplo pode ser um fator de risco para lesões deste tendão.

As caraterísticas do tendão e inserção do subescapular também foram avaliadas. O *footprint* do tendão apresentou medidas sobreponíveis ao previamente descrito com 1,55cm e 2,7cm de largura e comprimento respetivamente. Da mesma forma que se verificou com o comprimento da coracoide, o *footprint* do subescapular também foi significativamente mais extenso nos modelos de sexo masculino. [72-74] O conhecimento detalhado das caraterísticas do *footprint* do subescapular é essencial para o correto diagnóstico das roturas deste tendão e reparação anatómica.

Este foi o primeiro estudo a comparar caraterísticas da junção miotendinosa do subescapular com o espaço disponível na região subcoracoide. Esta relação é importante no atual contexto em que o conflito subcoracoide está a ser reconhecido como um importante fator na fisiopatologia do subescapular. A junção miotendinosa apresentou uma espessura de 0,7cm, que quando comparada com a DCU aponta para uma possível base anatómica para o conflito subcoracoide, principalmente na posição de RI.

Este estudo revelou achados importantes com possíveis implicações clínicas e que podem ajudar na compreensão da fisiopatologia das roturas da coifa anterior.

5. CONCLUSÃO

Apesar da fisiopatologia das roturas da coifa dos rotadores já ter sido extensamente estudada, contrariamente ao que sucede com as roturas do supraespinhoso, a fisiopatologia das lesões do subescapular é ainda pouco compreendida.

As roturas do subescapular foram colocadas em segundo plano, até recentemente se ter verificado um interesse crescente no estudo dos mecanismos responsáveis por esta patologia. Sabemos que a maioria destas lesões ocorre na presença de uma rotura prévia do supraespinhoso, decorrente da progressão antero-inferior da rotura. Contudo, apesar de menos frequentes também podem estar presentes roturas do subescapular isoladas, associadas a um evento traumático ou a um síndrome crescentemente reconhecido, o conflito subcoracoide.

Mais do que apenas a realização académica, este projeto de investigação ambicionava influenciar a nossa prática clínica futura. Assim, o principal objetivo desta tese de Doutoramento foi permitir a melhor compreensão da fisiopatologia das lesões do subescapular e das roturas antero-superiores da coifa, bem como do conflito subcoracoide.

O primeiro braço deste projeto consistiu num conjunto de trabalhos imagiológicos que procuraram estabelecer o papel de fatores de risco previamente descritos e descrever novos possíveis preditores de lesões do subescapular.

A distância coraco-umeral foi o melhor preditor de roturas do subescapular, com uma AUC de 94%, seguida do ângulo coracoide com uma AUC de 90%. Ambos os índices mostraram um papel mais importante na fisiopatologia destas roturas do que a dimensão da coracoide, traduzida pelo *overlap* coracoide e comprimento dos segmentos e total da apófise coracoide. Isto parece salientar a importância da morfologia da apófise coracoide e da dimensão do espaço subcoracoideu na patologia do subescapular.

Contudo, a morfologia do úmero, mais propriamente a versão umeral também parece influenciar o risco de desenvolver patologia do subescapular, sendo um bom preditor destas lesões.

O nosso projeto também procurou explicar a presença de roturas do subescapular no contexto de progressão de roturas do supraespinhoso. Este trabalho mostrou que roturas completas do supraespinhoso resultam em ascensão da cabeça e consequentemente em diminuição da distância coraco-umeral. Isto vai condicionar um conflito subcoracoide secundário, e consequentemente um maior risco de lesões do subescapular.

Existe uma possível base anatómica para o conflito subcoracoide e o seu papel na fisiopatologia das roturas do subescapular, sendo que a DCU varia de forma dinâmica com as mobilidades do ombro, apresentando valores tendencialmente inferiores em RI, e que podem chegar aos 0,3cm. Nesta posição, a espessura da junção miotendinosa do tendão do subescapular é superior ao espaço disponível na região subcoracoide. A presença de um LCA duplo pode também ser um fator de risco para roturas da coifa anterior, uma vez que se associa a DCU inferiores em rotação interna.

Pela melhor compreensão da fisiopatologia das lesões do subescapular esperamos poder contribuir para um melhor tratamento dos doentes com patologia da região anterior do ombro, através do aumento do índice de suspeição clínica e identificação de doentes com maior risco de desenvolver estas patologias.

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