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SCIENTIFIC ARTICLE

Frequency, imaging findings, risk factors, and long-term sequelae of distal clavicular osteolysis in young patients

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Abstract
Objective Atraumatic distal clavicular osteolysis (DCO) has been described in adult male weightlifters. Our purpose was to investigate the frequency, magnetic resonance imaging (MRI) characteristics, risk factors, and long-term sequelae of DCO in young patients.
Materials and methods Individuals with atraumatic DCO were identified in a retrospective review of 1,432 consecutive MRI shoulder reports in patients between 13 and 19 years of age. MRI findings of DCO, association with athletic activity, short-term clinical outcome after 3–6 months, and long-term clinical and MRI outcome after 2 years were analyzed. A pre-MRI questionnaire assessed the patients' athletic history including overhead activity and weightlifting.
Results At a mean age of 15.9 years, 6.5 % (93/1432) of patients had atraumatic DCO, and 24 % were females. The combination of an overhead sport (basketball, volleyball, tennis, swimming) and supplemental weight training was a risk factor for DCO (odds ratio=38, p=0.01). Ninety-three percent of patients responded to conservative therapy. On follow-up imaging, 71 % of DCO patients had acromioclavicular (AC) joint osteoarthritis (vs. 35 % in controls, p=0.006); 79 % had flattening of the distal clavicle and interval widening of the AC joint to a mean of 5.0 mm (compared to 2.4 mm in controls, p<0.001). Severity of DCO edema was associated with pain (p<0.02) at initial presentation and with AC joint osteoarthritis (p=0.004) on follow-up.
Conclusion In athletic teenagers, the combination of weightlifting and overhead activity is a risk factor for atraumatic DCO, and females are affected in 24 %. Long-term sequelae include widening of the AC joint and AC joint osteoarthritis.

Keywords Distal clavicular osteolysis · Magnetic resonance imaging, MRI · MR imaging · Acromioclavicular joint · Osteoarthritis · Weightlifting · Young patients · Teenagers

Introduction

Distal clavicular osteolysis (DCO) is a well-known cause of shoulder pain in adults [1]. There are two forms of DCO: posttraumatic DCO, caused by a traumatic injury and first described in 1936 by Dupas et al. [2], and atraumatic DCO, caused by repetitive stress and first described in 1959 by Ehricht et al. [3]. Subsequent studies in adults have shown that the radiographic [4] and magnetic resonance imaging (MRI) [5] findings are the same in both forms of DCO. The MR characteristics include distal clavicular bone marrow edema out of proportion to edema at the acromion as well as a subchondral cystic change and in advanced cases periostitis at the distal clavicle [5–7]. The etiology may also be similar in both types of DCO (traumatic and atraumatic), as a subchondral fracture was found in most patients with atraumatic DCO, likely caused by repetitive stress [8]. In adults, the most common risk factor for stress-induced DCO has been shown to be weightlifting [1]. In a clinical study by

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Cahill et al. using radiographs for imaging, 45 of the 46 (98 %) patients with atraumatic DCO were found to be weightlifters [1]. Previous imaging and clinical studies on DCO have been performed on adults, with the two MRI studies to date investigating patients with an average age in the mid 30s [5, 8]. In children and adolescents, however, the characteristics of atraumatic DCO have not been previously reported. Furthermore, the long-term sequelae of DCO at the acromioclavicular joint are unknown. The purpose of this study was to investigate the appearance of atraumatic DCO in young patients, between 13 and 19 years of age. Additionally, the frequency, MRI characteristics, risk factors, short-term outcome, and long-term implications of DCO at the acromioclavicular joint are studied in this younger age population.

Materials and methods

Patients

A retrospective report review of 1,432 consecutive patients, between 13 and 19 years of age, who underwent shoulder MRIs for shoulder pain between July 2006 and July 2011 was performed. Institutional review board approval was obtained. The requirement for informed consent was waived.

Of the 1,432 consecutive MRI shoulder reports reviewed, 127 demonstrated MRI findings of DCO and no history of trauma. The inclusion criteria for DCO were the following, in part based on previous studies [8, 9]: (1) distal clavicular bone marrow edema without acromial edema; (2) subchondral fracture or subchondral cystic change at the distal clavicle. Two blinded fellowship-trained musculoskeletal radiologists (15 and 5 years of experience) assessed the imaging inclusion criteria for DCO and the degree of edema. Fourteen out of the 127 patients were excluded since concurrent shoulder pathology was seen on MRI. Exclusion criteria were concurrent labral or rotator cuff tears and edema at the distal acromion. All of the remaining 113 patients had distal clavicular edema without acromial edema. However, only 93 patients had a concurrent subchondral fracture or subchondral cystic change at the distal clavicle. These 93 subjects comprised the DCO study group and were divided into three age categories (age group I: 13–14.9; age group II: 15–16.9; age group III: 17–18.9). Then, an age- and sex-matched control group was created by dividing the remaining 1,305 subjects in two sex and three age groups. Subsequently, the SPSS random case generator was applied, and 93 control patients were selected (SPSS Inc., version 21.0, Chicago, IL).

Image analysis

Due to a lack of DCO grading systems in the literature, we agreed on our own grading categories based on observations in our musculoskeletal division. Grading of DCO was dependent on the degree of bone marrow edema and periostitis at the distal clavicle. Grade I represents mild edema not spanning the entire anteroposterior (ap) dimension on axial imaging (Fig. 1) and/or the entire craniocaudal (cc) dimension on coronal imaging (Fig. 2). In grade II, edema spans the clavicle entirely in both the ap and cc dimensions. In grade III, periostitis along the distal clavicle is seen in addition to bone marrow edema. A training session for the two readers with 12 cases preceded the study interpretation. These 12 cases were not included in the investigation. Bone marrow edema was defined as hyperintense signal on both the short-tau inversion recovery (STIR) and proton density (PD) weighted fat-saturated (FS) sequences and as hypointense signal on the T1-weighted images. The normal bone marrow signal at the adjacent acromion was used as a reference, and the T2 signal at the distal clavicle had to be higher than the signal at the distal acromion. The two blinded, fellowship-trained musculoskeletal radiologists determined the grade of DCO in each patient. In case of disagreement, a third musculoskeletal radiologist made a final decision.

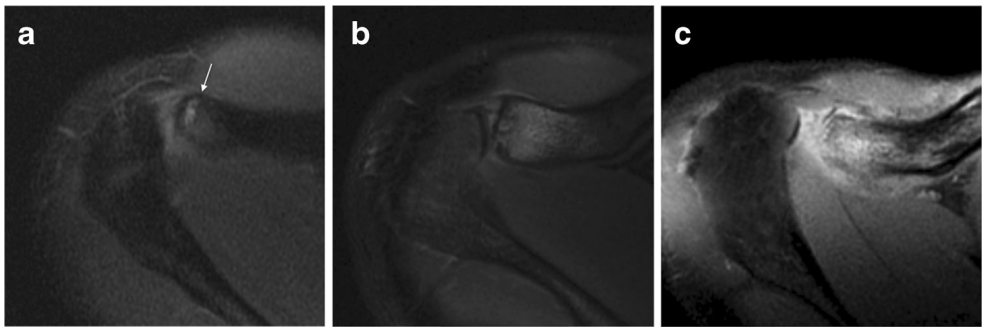

Fig. 1 Grading of atraumatic distal clavicular osteolysis (DCO). Three axial PD FS images were obtained through the acromioclavicular joint in three different patients. **a** A 14-year-old male tennis player who is not weightlifting presents with a small subchondral fracture (*arrow*) and mild distal clavicular edema (grade I DCO). **b** Moderate distal clavicular edema (grade II DCO) with subchondral cystic change in a 16-year-old female volleyball player participating in a weight-training program twice a week. **c** Severe edema with severe periostitis (grade III DCO) in an 18-year-old competitive male swimmer who is not weightlifting

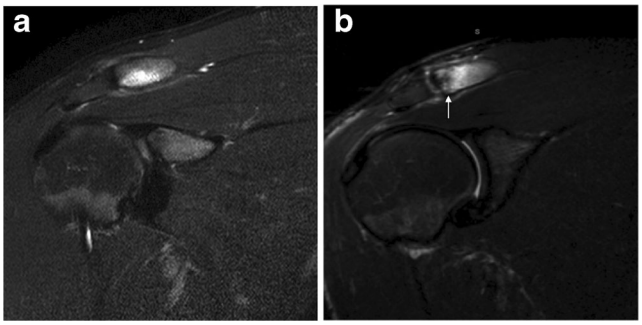

Fig. 2 Coronal imaging of distal clavicular osteolysis (DCO). **a** Coronal STIR images in an 18-year-old female volleyball player without supplemental weightlifting presenting with mild distal clavicular edema involving only the inferior aspect of the distal clavicle (grade I DCO). **b** Coronal STIR images in a 17-year-old male tennis player who is weightlifting twice a week and presents with moderate distal clavicular edema involving the entire inferior to superior dimension of the distal clavicle (grade II DCO) and a subchondral fracture line (*arrow*)

Clinical data

Acromioclavicular (AC) joint and/or distal clavicular tenderness to palpation and/or a positive cross-body adduction test were considered the corresponding clinical findings of DCO. Findings from the physical examination at the time of initial MRI and on follow-up office visits were available from the electronic medial records. Additional clinical data were retrieved from a pre-MRI clinical questionnaire regarding the location of pain (anterior, superior, posterior, lateral), type of pain (sharp, dull, aching, tender to palpation), pain with overhead and/or behind the back movements, pain severity (on a pain scale from 0 to 10), impingement symptoms, and time of symptom onset. Information about overhead athletic activity was retrieved from a pre-MRI questionnaire investigating the type of athletic activity the subject has participated in with a specific question asking about the participation in overhead sports, involvement since which age, and the side of the dominant arm (right/left). Additionally, participation in a weightlifting program was inquired about by the questionnaire.

Follow-up imaging

Follow-up MR images acquired at least 2 years after the initial MRI were reviewed (when available) by the two readers. On both the initial MRIs and follow-up MRIs, the AC joint was evaluated for the presence of AC joint osteoarthritis. Grading of AC joint osteoarthritis was based on a modified, previously published staging system [10]: grade 0 represents no osteoarthritis; grade I represents mild AC joint osteoarthritis with capsular distention, but no osteophytes. Grade II represents moderate osteoarthritis with capsular distention, reciprocal subchondral bone marrow edema, and small osteophytes. Grade III represents findings of grade II, but additionally large osteophytes, cortical irregularity, and a joint effusion. A training session for the two readers in grading AC joint osteoarthritis with 12 cases preceded the study interpretation. These 12 cases were not included in the investigation. Additionally, the distal clavicle was assessed for flattening of its articular surface (yes/no) secondary to subchondral resorption. The AC joint distance/width was measured (in mm) on both the initial and follow-up MRI on the axial PD FS sequence. The interval joint widening between both studies was calculated.

MRI paramaters

MRI studies were performed over a 5-year period on 1.5-T MRI scanners (Optima and Signa, General Electric Medical Systems, Milwaukee, WI, USA) with dedicated shoulder coils. The MRI parameters are shown in Table 1.

Statistical analyses

Differences between the study and control group (Tables 2 and 3) were assessed with the Mann-Whitney *U* test for age and time (time between initial and follow-up studies) and either chi-square (Table 2) or Fisher's exact tests (Table 3) for the other variables. Since the variable counts were lower on follow-up imaging, Fisher's exact tests were used for the variables in Table 3. Predictors of DCO were determined using a multivariate binary logistic regression analysis with DCO as the dependent variable and with the covariates listed in Table 2. Kappa values and Spearman's rho correlation coefficients were calculated to assess interreader variability. Associations between the DCO grade (grades I, II, and III) and distal clavicular pain (pain scale from 0 to 10) and between the DCO grade and the interval change in the acromioclavicular (AC) joint width were calculated with Kruskal-Wallis tests. Statistical software (SPSS inc, version 21.0, Chicago, IL) was used for the analyses.

Results

Frequency, imaging findings and risk factors of DCO

Among the 1,432 patients between 13 and 19 years of age (mean age 15.9) who presented with shoulder pain, 93 (6.5 %) were found to have atraumatic DCO (Table 2). About one quarter of the DCO patients were female (24 %). There was no significant difference in age and gender between the DCO patients and the control group (Table 2). All 93 patients with DCO had distal clavicular edema on MRI; 74 % (69/93) had a subchondral fracture, 45 % (31/69) of which had additional subchondral cystic change. The remaining 26 % (24/93) had subchondral cystic change at the distal clavicle, but no fracture.

Table 1 Parameters of MR imaging

Parameters	Coronal T1 SE, non-FS	Coronal STIR	Axial PD FSE, FS	Sagittal T2 FSE, non-FS
TR (in ms)	400–800	2,000–6,000	2,000–3,000	2,000–6,000
TE (in ms)	10–20	20–40	25–30	90–110
TI (in ms)		120		
Flip (in degrees)		90°		
FOV (in mm)	160×160	160×160	100×100	160×160
Matrix	256×256	256×192	512×256	256×256
Thickness (in mm)	3	4	4	3
ETL		8	8	8
NEX	1	3	2	2
Gap (in mm)	0.5	0.5	0.5	0.5
BW (in MHz)	16	16	16	16

SE spin echo; *FS* fat saturated; *STIR* short-tau inversion recovery; *PD* proton density; *FSE* fast spin echo; *ms* milliseconds; *TR* time to repeat; *TE* time to echo; *TI* inversion time; *Flip* flip angle; *FOV* field of view; *Thickness* slice thickness; *ETL* echo train length; *NEX* number of excitations; *Gap* gap between slices; *BW* band width; *MHz* megahertz

The complete clinical information and athletic history were available in 147 of the 186 patients (79 of the study group and 68 of the controls, see Table 2). All patients were involved in some type of athletic activity. The vast majority of the 147 patients (74 %, 108/147) participated in upper body athletic activity (overhead sports and/or weight training). The remainder (26 %, 29/147) were predominantly involved in lower body sports, such as soccer. Patients with DCO were more commonly involved in overhead sports (60 % vs. 43 %, $p=0.04$) and in weight training (63 % vs. 34 %, $p<0.001$, see Table 2) compared to the control group. The most substantial difference between both groups was in patients who performed a combination of both an overhead sport and a supplemental weight-training program (43 % of patients in the DCO vs. 10 % of patients in the control group, $p<0.001$, see Table 2). This combination of both weight-training and overhead activity was the only risk factor of DCO that remained significant in a multivariate binary logistic regression analysis (OR=38, $p=0.01$, see Table 2). The only other significant predictor of DCO was a clinical presentation with pain at the AC joint/distal clavicle (OR 224, $p<0.001$, see Table 2).

Treatment and outcome after 3–6 months

All 93 DCO patients were initially treated conservatively for 3 months including the avoidance of provocative maneuvers and overhead sports, modification of weight-training techniques, nonsteroidal antiinflammatory drugs (NSAIDs), and cooling with ice. Clinical short-term follow-up after an average of 4.4 months (range 3–6 months) was available in 46 of the 93 DCO patients. Among the 46 patients, 43 (93 %) had either resolution or significant improvement in their pain symptoms after conservative therapy. However, 7 % of the DCO patients (3/46) did not respond to conservative treatment and were not willing to give up or modify weight training or manual labor for more than 3 months. These three patients had grade III findings of DCO on the initial MRI. They underwent arthroscopic surgery with resection of 5 to 10 mm of the distal clavicle. All three patients responded well to surgery with resolution of their symptoms.

Long-term MRI follow-up

Furthermore, long-term imaging and clinical follow-up after an average of 4.3 years were available in 28 of the 93 DCO patients and in 34 of the 93 controls (see Table 3). The mean age at follow-up was 20.1 years in the DCO group (Table 3). In all patients, the initial MRI findings of DCO had resolved on the follow-up imaging. As a long-term sequela of DCO, we observed flattening of the distal clavicle (Figs. 3 and 4) from subchondral resorption in 79 % of patients (22/28) and significant interval widening of the AC joint (Figs. 3 and 4) between the initial and the follow-up MR study (widening by 2.6 mm from a mean of 2.4 mm on the initial MRI to a mean of

Table 2 Patient characteristics, univariate and multivariate analyses. In the univariate analysis, differences between patients with distal clavicular osteolysis (DCO) and the control group (No DCO) were calculated with the Mann-Whitney *U* test for age and chi-square tests for the other variables. Predictors of DCO were determined using a multivariate binary logistic regression analysis with DCO as the dependent variable and with the covariates listed below under the multivariate column. Odds ratios (OR) and 95 % confidence intervals (CI) are listed

	DCO n=93	No DCO n=93	Univariate	Multivariate
Age; in years, mean±SD; range	15.9±1.7; 13.0–18.9	15.6±1.6; 13.0–18.9	p=0.4	p=1.0
Gender; in numbers (male; female)	71; 22	70; 23	p=0.9	p=0.8
DCO[1] grade; in numbers (grades I; II; III)	23; 42; 28	N/A	N/A	N/A
Pain[2] at AC joint and/or distal clavicle (in percent)	89 % (70/79)	9 % (6/68)	p<0.001	p<0.001 OR=224 CI=43–1171
Overhead sport[2] (in percent)	60 % (47/79)	43 % (29/68)	p=0.04	p=0.6
Type of overhead sport[2]; in numbers (bask, vol, ten, swi, base)	10; 11; 9; 11; 6	4; 2; 3; 4; 16	p=0.001	N/A
Weight training[2] (in percent)	63 % (50/79)	34 % (23/68)	p=0.01	p=0.8
Overhead sport AND supplemental weight training[2] (in percent)	43 % (34/79)	10 % (7/68)	p<0.001	p=0.01 OR=38 CI=2–656

[1] Grade I=mild DCO

Grade II=moderate DCO

Grade III=severe DCO

[2] Complete history of pain and overhead/upper body athletic activity including basketball (bask), volleyball (vol), tennis (ten), swimming (swi), baseball/softball (base), and weightlifting was available in 147 (79 DCO patients, 68 controls) of the 186 patients

5.0 mm on the follow-up) compared to the control group (widening by 0.2 mm from 2.2 to 2.4 mm). A normal AC joint width is considered to be less than 6 mm, and 50 % of patient with DCO (14/28) had an AC joint width of more than 6 mm on follow-up imaging (Figs. 3 and 4) compared to the control group where only one patient (1/34, 7 %, p<0.001, Fisher's exact) had AC joint widening to more than 6 mm. Secondary AC joint osteoarthritis was present in 71 % (20/28) of DCO patients (Figs. 3 and 4) on follow-up imaging compared to 35 % (12/34) in the control group (p=0.006, Table 3). However, only patients with moderate or severe AC joint osteoarthritis (13 of the 20 patients, 39 %) were clinically symptomatic at the AC joint.

The DCO grade (grade I to III) on the initial MR study was significantly associated with the pain scale at the initial office presentation (pain scale 0 to 10, p<0.02, Kruskal-Wallis). The DCO grade was also associated with both the AC osteoarthritis grade (grade 0 to III, p<0.001, chi-square) and with the interval widening of the AC joint width (p=0.012, Kruskal-Wallis) on the follow-up MRI.

Contralateral shoulder

In 2 of the 11 tennis players with DCO, the contralateral, nondominant arm was imaged at the same time. In both patients, the contralateral shoulders showed a normal distal clavicle without DCO or AC joint osteoarthritis.

Interreader reliability

Interreader reliability was excellent (kappa >0.8) for all variables. The kappa values between both readers were 0.83 for grading DCO and 0.82 for grading AC joint osteoarthritis. The Spearman correlation between both readers was 0.94 (p<0.001) for the AC joint width on the initial MR examination and 0.88 for the AC joint width on the follow-up MRI (p<0.001).

Discussion

Frequency and imaging findings

Previous investigations in the radiology and orthopedic literature studied DCO in the adult population, with the two MRI studies to date reporting an average patient age in the mid 30s [5, 8]. We discovered that atraumatic DCO also exists in a younger age group (less than 20 years of age) and that about 6.5 % of teenage patients (between 13 and 19 years of age) who present with shoulder pain are affected by atraumatic DCO. The imaging findings in our younger study population including distal clavicular edema with a subchondral fracture and/or subchondral cystic change are identical to the findings described in adults [8]. We graded DCO using a novel system based on the degree of edema and presence of periostitis. The grading system was significantly associated with the degree of pain and subsequent development of AC joint osteoarthritis.

Females and overhead athletic activity in younger patients

In the adult population, DCO has typically been associated with weightlifters [1]. To the best of our knowledge, no other athletic activity has been found to be a risk factor for DCO. In the younger population of our study, we found that overhead sports (including basketball, volleyball, tennis, and swimming) were associated with an increased incidence of DCO. The combination of supplemental weight training and

Table 3 Association between distal clavicular osteolysis and AC joint osteoarthritis on follow-up imaging. "Time since initial study" was the time between the initial MR imaging (with the findings of distal clavicular osteolysis, DCO) and the follow-up study at least 2 years after the initial MR. Differences between both groups in "Time since initial study" and "Age" were calculated with Mann-Whitney tests. Differences in the other variables were calculated with Fisher's exact tests. The odds ratio (OR) for DCO as a predictor for "AC joint osteoarthritis" was calculated using a binary logistic regression analysis with age, gender, and DCO as covariates and with "AC joint osteoarthritis" as the dependent variable

	DCO n=28	No DCO n=34	P	Odds ratio
Time since initial study in years, mean±SD	3.9±1.2	4.6±1.7	0.11	
Follow-up age in years, mean±SD; range	20.1±2.2; 17.1–23.8	19.2±2.0; 15.6–23.4	0.16	
Gender; in numbers (male; female)	23; 5	27; 7	1.0	
Overhead sport[1] AND supplemental weight training (in percent)	46 % (13/28)	6 % (2/34)	<0.001	
AC joint osteoarthritis[1] in percent	71 % (20/28)	35 % (12/34)	0.006	OR=4.5 CI=1.5–13.4 p=0.008
Grades of AC OA[2]; in numbers (Grades 0; I; II; III)	8; 7; 10; 3	22; 11; 1; 0	0.001	
AC joint width in mm, mean±SD				
On initial MR	2.4 mm±0.8	2.2 mm±1.1	0.2	
On follow-up	5.0 mm±2.2	2.4 mm±1.1	<0.001	
Interval widening	2.6 mm±1.9	0.2 mm±0.2	<0.001	

OR odds ratio; *CI* 95 % confidence interval; *SD* standard deviation; *AC* acromioclavicular; *OA* osteoarthritis

[1] Overhead athletic activity included basketball, volleyball, tennis, swimming, and baseball/softball

[2] Grade 0=no AC joint osteoarthritis

Grade I=mild AC joint osteoarthritis

Grade II=moderate AC joint osteoarthritis

Grade III=severe AC joint osteoarthritis

overhead athletic activity was the strongest risk factor for DCO in our young study population. It is unclear and beyond the scope of this article to explain why repetitive overhead activity contributes to DCO in younger patients. In children, the thick periosteal sleeve surrounding the epiphysis and weak physis of the distal clavicle provide the attachment for the strong acromioclavicular and coracoclavicular ligaments [11, 12]. Therefore, severe tension and traction from these ligaments caused by overhead activity and weightlifting are constantly put on a weak distal clavicle. We hypothesize that this combination predisposes young patients to a Salter-Harris type microfracture at the skeletally immature distal clavicle,

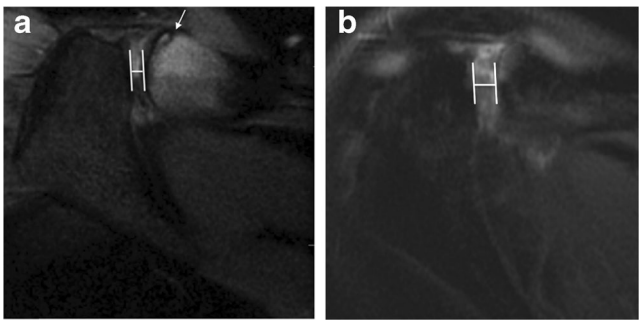

Fig. 3 Interval widening of the acromioclavicular (AC) joint on follow-up imaging of a patient with distal clavicular osteolysis (DCO). Two axial PD FS images through the AC joint were performed on the same patient. **a** An 18-year-old female short-distance freestyle swimmer participating in a weight-training program twice a week presented with grade II DCO (with a small subchondral fracture, arrow) and an AC width of 3.3 mm. **b** The same patient (as in **a**) presented 4 years 9 months later with AC joint pain. MR imaging revealed flattening of the distal clavicle, widening of the AC joint now to 6.7 mm (interval widening: 3.4 mm), and early (grade I) osteoarthritis with small marginal osteophytes at the AC joint

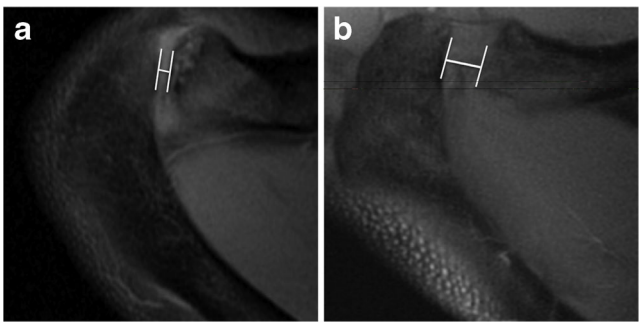

Fig. 4 Interval widening of the acromioclavicular (AC) joint on follow-up imaging of a patient with distal clavicular osteolysis (DCO). Two axial PD FS images through the AC joint were performed on the same patient. **a** A 14-year-old female competitive basketball player with supplemental strength training twice a week who presented with grade II DCO and an AC width of 2.9 mm. **b** Same patient (as in **a**) presented 4 years 6 months later with superior shoulder pain. MR imaging revealed flattening of the distal clavicle, widening of the AC joint now to 9.1 mm (interval widening: 6.2 mm), and early (grade I) osteoarthritis with small marginal osteophytes at the AC joint

which then leads to osteolysis. We found subchondral fractures at the distal clavicle in 74 % of our DCO subjects, which is concordant with a previous study in adults where fractures were found in 86 % of patients with DCO [8]. These fractures are thought to be secondary to repetitive stress [8] and in our younger study population are likely related to a combination of an overhead sport (such as basketball, volleyball, tennis, and swimming) and weight training. A prior investigation showed that the shoulder is the most frequently injured body part in swimmers and 38 % of injuries were not related to swimming practice or swimming competition, but to supplemental strength training [13]. Among volleyball players, about 10 % were found to suffer from overuse injuries of the shoulder [14], and since chronic repetitive trauma to the shoulder is common in high-level tennis players, the United States Tennis Association (USTA) recommends no more than 70 matches per year for 14-year-old and no more than 90 matches per year for 16-year-old tennis players to prevent shoulder overuse injuries [15]. Our study supports this caution in overtraining young overhead athletes to avoid both short- and long-term, potentially irreversible shoulder injuries [16, 17]. Furthermore, in our younger population, females are relatively more often affected by DCO than in the adult population. There is a substantial gender difference between younger patients and adults regarding DCO. Females compromised 24 % of the DCO cases in our study. This is in contrast to previous investigations in the adult population where atraumatic DCO has been exclusively found in male patients in two studies [1, 5]. In a third study, 89 % (32/36) of patients with DCO were male [8]. There is a case report of DCO in a female patient, a professional bodybuilder (weightlifter) [18]. Our finding that overhead activity added to the risk of DCO in the younger population might possibly explain why females are relatively often affected: In the younger population, sports such as basketball, tennis, volleyball, and swimming are associated with DCO. These overhead activities are popular with both genders, which might explain why both male and female patients are affected by DCO in the younger population. In adults, only weightlifting has been associated with DCO. Weightlifting is a male-dominant sport, which might explain why DCO in adults almost exclusively affects men.

Treatment and outcome

Ninety-three percent of our patients were successfully treated with conservative therapy and only 7 % underwent arthroscopic surgery. Multiple studies have investigated surgical outcomes for DCO in adults including one arthroscopic study where seven of the ten patients returned to athletic activity after 12 weeks [19] and another study where 37 of 40 patients returned to weight training after surgery [1]. However, to our knowledge, there has been no study to date examining the outcome of conservative therapy for DCO and no study investigating the surgical outcome in young patients (<20 years of age). Our study shows that the vast majority of young patients (93 %) can be successfully treated with conservative strategies. The three patients who underwent surgery had complete resolution of symptoms and returned to full athletic activity after 12 weeks. Further studies with larger patient numbers are warranted to investigate surgical outcome in young patients with DCO.

Aside from the short-term follow-up between 3 and 6 months, we studied the long-term imaging and clinical findings in DCO patients. After an average of 4.3 years, the initial MRI findings of DCO had resolved in all patients. We observed widening of the AC joint with flattening of the distal clavicle from subchondral resorption and early mild AC joint osteoarthritis as long-term sequelae from DCO. The imaging findings of AC joint osteoarthritis were only symptomatic in 39 % of patients, which is consistent with the known high frequency of asymptomatic AC joint osteoarthritis [20]. To our knowledge, no other studies have examined the long-term sequelae of DCO, and further investigations are warranted with longer follow-up times beyond 5 years to study the significance of post-DCO acromioclavicular joint osteoarthritis.

Limitations

Our investigation has several limitations including the retrospective study design and the long-term clinical and imaging follow-up data only being available in 28 of 93 DCO patients. Furthermore, the frequency of DCO might be biased and overestimated in our patient population since the frequency of competitive teenage overhead athletes is high in our daily clinical practice. This might make it difficult to apply our results to patient populations at other institutions or in other countries.

Conclusion

In conclusion, atraumatic distal clavicular osteolysis (DCO) is common in athletic patients between 13 and 19 years of age, with a frequency of 6.5 %. Females are affected in 24 % of cases, and the combination of a repetitive overhead athletic activity and supplemental weightlifting is the strongest risk factor for DCO. Ninety-three percent of patients responded to conservative therapy. Long-term sequelae on MRI included widening of the AC joint and AC joint osteoarthritis.

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