

Pathological Findings of Osteoarthritis in Sternoclavicular Joint

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Abstract

Background: The sternoclavicular joint (SCJ) is the only synovial articulation between the upper extremity and the trunk. This joint is one of the most frequently used joints, so osteoarthritis (OA) should be very common. However, there are few studies about OA in this joint.

Methods: In this study, 48 sternoclavicular joints from the left and right joints of 23 cases and two left joints from two further cases were studied. Right and left sternoclavicular joints were removed together in an unselected sequential autopsy series. Ninety two blocks were prepared by cutting every SCJ to superior and inferior parts. Using histological staining, the articular surfaces of the SCJs were assessed microscopically. Contact radiography was done to help assessing the presence or absence of osteoarthritis.

Results: The features of normal joints were found in 18 blocks. Osteoarthritis changes were seen in 82 of the 92 blocks. There was no significant correlation between age and osteoarthritis. No differences in the degenerative changes were found between the sexes. Severe osteoarthritis changes were more common in the right SCJ and inferior part of the joint than in the left and superior parts respectively. The osteoarthritis changes were severe in 36.6% of cases and mild to moderate in 48.8%.

Conclusion: OA was very common in these SCJs, which is not related to age and sex of the cases. There are clear changes in structure and glycan expression in the articular cartilage of the osteoarthritic sternoclavicular joint, which allow a distinction to be made between mild, moderate, and severe osteoarthritis and normal cartilage. Histochemical staining of the joints can lead to accurate diagnosis of this disease.

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Keywords • Sternoclavicular joint • osteoarthritis • histological

Introduction

The sternoclavicular joint (SCJ) is a true diarthrodial joint.¹ It is formed by the inferior portion of the medial end of the clavicle, which articulates with the clavicular facet of the manubrium of sternum and the cartilage of the first rib.² Because of the small area of contact between the two articulating surfaces and their congruity, the joint is potentially unstable. However, an intra-articular disc partly compensates for this instability.³

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The intra-articular disc typically is thick, strong, and nearly circular. It usually divides the joint cavity into two separate joint spaces.³ The attachment of disc permits to act as a hinge, which supplies the total range of joint movement and enables the bones to move freely.⁴ This method of disc attachment also stabilises the joint against forces from the shoulder, transmitted through the clavicle to the axial skeleton. Without this attachment, these forces would tend to cause medial dislocation of the clavicle. This ability to resist forces is augmented by its thickness, which also contributes to its function as a shock absorber.^{4,5} This complex articulation shows that the SCJ bearing with different forces in upper extremity movement. In addition, the SCJ is the only synovial articulation between the upper extremity and the trunk.¹ Although the movement occurring at the SCJ somewhat resembles that of a ball-and-socket joint,⁵ it is a gliding diarthrodial joint. The amount of movement is relatively small and is magnified at the lateral end of each clavicle. This is essential for normal mobility of the shoulder complex,⁴ which causes higher risk to progress osteoarthritis (OA).

The clavicle can be elevated, depressed, moved anteriorly (protracted), moved posteriorly (retracted), and rotated.^{4,5} Motion at the SCJ accompanies every movement of the arm. Therefore this joint is one of the most frequently used joints.²

All mentioned factors show that OA can happen in the SCJ especially because of the movement of the upper extremity. OA can progress according to age and sex. Despite this fact, there are few available studies on the prevalence and morphological data of OA of this important joint. The present study was performed to address this deficiency.

Materials and Methods

This descriptive study examined 48 SCJs from autopsy material (23 pairs of rights and lefts, and 2 further lefts). SCJs were removed together with the upper sternum *en bloc* with consent in an unselected sequential autopsy series. Specimens were fixed for 24-48 hours in 10% (v/v) formaldehyde. Contact radiographs were made to help assess the presence or absence of osteoarthritis and to provide a baseline for decalcification.

Twenty three rights and lefts SCJs were separated to 46 SCJs and then 44 SCJs were cut to superior and inferior parts (88 blocks), by parallel sagittal cut, 4 blocks only contain inferior part. The cuts were orientated so that each block was composed of parts of the sternum

and clavicle, their two articular surfaces, the intra-articular disc and the anterior end of the first rib. Decalcification was done with EDTA (0.19M pH 7.4-7.6) at room temperature under radiographic control. After decalcification all blocks were processed for histological examination, embedded in Ralwax (RA Lamb Ltd., Eastbourne, UK) and 7 μ m thick sections were cut and mounted on glass slides for staining by hematoxylin and eosin (H&E), alcoholic toluidine blue, picro Sirius red or alcian blue in three concentrations (0.05M, 0.5M and 0.9M) of magnesium chloride.

Using histochemical stained sections, the articular surfaces of the SCJs were assessed microscopically and categorised as normal, or having mild/moderate, or severe osteoarthritis using the grading system proposed by Mankin et al,⁶ which was according to age and sex. This method is the best method to diagnose OA, but it could be used only in autopsy materials or removed joints.

SPSS software (version 11) was used for the statistical analysis and two-tailed Spearman's test was used to evaluate the correlation between age and osteoarthritis and Chi-square test was used to assess the correlation between degenerative changes and sexes.

Results

In this project 48 complete sternoclavicular joints were available for study from the left and right joints of 23 cases and two other left joints from two further cases. These cases were made up of 14 males, and 11 females with an age range of 47-92 years, mean 70.4 years (SD= \pm 12.9).

Radiographs of whole bilateral SCJs were made as initial assessments. This was done to obtain initial information about the degree and extent of articular damage and to provide a baseline for the decalcification process. The reports of radiographs were confirmed by H&E staining. All studied samples showed that both the sternal and clavicular components were covered by a hyaline articular cartilage, with a fibrocartilaginous intra-articular disc. The features of normal joints were found in 12 blocks. These normal features were a smooth surface, and uniform matrix, which was pale eosinophilic in zones I-III, more eosinophilic in zone IV, and strongly eosinophilic in zone V. The tidemark was intact in 52 cases.

Osteoarthritic changes were seen in 82 of the 92 blocks. Fibrillation was seen in 80 clavicular cartilages and intra-articular discs and in 50 sternal cartilages. Clefs were seen in 45 blocks including 40 clavicular cartilages, 42 intra-articular discs and 26 sternal cartilages.

Thirty-one blocks showed complete disorganisation of some component of the joint, which include 29 clavicular cartilages, 27 intra-articular discs and 13 sternal cartilages (one block had more than one disorganised part). There was no significant correlation between age and osteoarthritis (two-tailed, Spearman's test, $P < 0.05$) (table 1).

No differences in the degenerative changes were found between the sexes (Chi-square test, $P > 0.05$). The clavicular articular cartilage showed more severe changes than sternal articular cartilage. Changes in the intra-articular disc were slightly more common than in the articular cartilages. Severe osteoarthritic changes were more common in the right SCJ than in the left because 33 of the blocks showing these changes were from the right SCJs and only 3 of the 12 normal blocks were from the right SCJs. The inferior part of the joints were more affected than the superior parts because 35 blocks showing severe osteoarthritic changes were from the inferior parts of the SCJs and 3 of the 12 normal blocks were from the inferior parts of the SCJs. The osteoarthritic changes of the infromedial facet were more severe than superposterior. There were significant differences of the severity of OA between right and left SCJs (Chi-square test, $P < 0.05$) and between superior and inferior parts of the joints (Chi-square test, $P < 0.05$) (table 2).

Clonal proliferation of chondrocytes with new cartilage matrix formation (a feature of an attempted repair process) was observed in 64 blocks (figure1). Subchondral bone cysts were observed in 54 blocks. Bone hyperplasia was found in 33 blocks and osteophytosis was observed in a few. In 20 blocks cartilage damage was seen without any related bone changes.

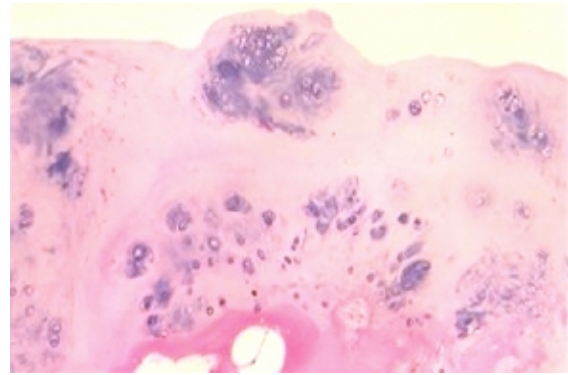


Figure 1: Clones of chondrocytes are present mostly in the superficial zone (H&E $\times 10$).

H&E staining showed the microanatomical changes in SCJs affected by osteoarthritis. The tidemark in osteoarthritic cartilage was duplicated or occasionally triplicated, and was crossed by blood vessels. Osteophytosis was found at the joint margins of severe osteoarthritic disease (figure 2).

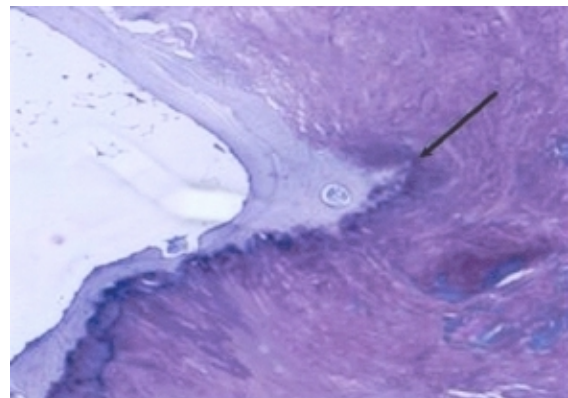


Figure2: Severe osteoarthritic changes in articular cartilage (Toluidine blue $\times 20$). Osteophytosis can be seen in severe OA (arrow).

Irregularity of the surface, clefts and clones of chondrocytes were taken to represent os-

Table 1: Evaluation of OA severity according to the age of cases

Age	OA severity		Mild to Moderate		Severe		Normal		Sum
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	
40-59	5	19.2	20	77	1	3.8			26
60-79	7	18.4	25	65.8	6	15.8			38
80-100	8	32.1	15	50	5	17.9			28
Sum	20	21.7	60	65.2	12	13.1			92

Two tailed Spearman's test ($P > 0.05$)

There is no significant relation between age and severity of OA, which means age did not affect the OA in SCJ.

Table 2: Evaluation of OA severity in both sides of SCJ

Joint	OA severity	Mild to Moderate		Severe		Normal		Sum
		Number	Percent	Number	Percent	Number	Percent	
Right	Superior	5	23.8	14	66.7	2	9.5	21
	Inferior	3	13	19	82.6	1	4.4	23
Left	Superior	5	21.7	11	47.8	7	30.5	23
	Inferior	7	28	16	64	2	8	25
Sum		20	21.7	60	65.2	12	13.1	92

Chi-square test between right and left ($P < 0.05$) and superior and inferior parts of the joints ($P < 0.05$)

Right SCJs showed more severe OA changes than left SCJs, and inferior part of the joints showed more severe changes than superior parts.

teoarthritic changes in the fibrocartilage. The matrix of osteoarthritic cartilage showed a general reduction in the staining by toluidine blue but the new matrix around the chondrocytes in clones stained strongly. Forty-six cases showed moderate reduction of toluidine blue staining, 32 cases showed severe reduction, and in nine cases 90% of the cartilages were not stained with toluidine blue (figure 3).

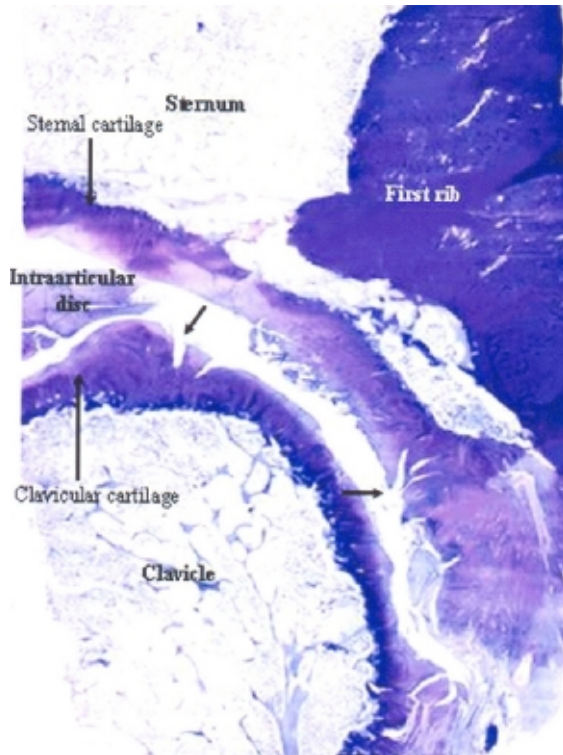


Figure 3: Inferior part of the right sternoclavicular joint showing mild to moderate osteoarthritic changes in the articular cartilage (arrows) and splits in the intra-articular disc (H&E $\times 10$).

Using polarised light, areas of superficial fibrillation gave a specific appearance described as 'tiger tail'. This showed as alternating light and dark bands due to changes in the orientation of collagen fibre bundles (figure 4).

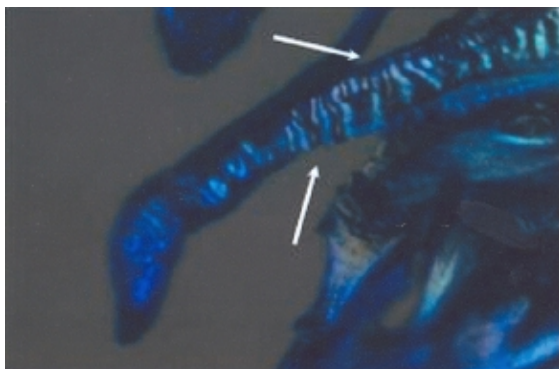


Figure 4: "Tiger till" feature in the fibrillated area (arrows) of the articular cartilage viewed in polarizing light (Toluidine blue $\times 40$).

In osteoarthritic cartilage the alcian blue staining of the matrix, at all concentrations of electrolyte, was decreased especially in the middle zone. The matrices of the clones of chondrocytes were stained strongly in the higher electrolyte concentrations of 0.5M and 0.9M.

The Picro Sirius red staining pattern changed in osteoarthritic cartilage. A mixed pattern of pale and intense staining was found in 73 cases with osteoarthritic cartilage. Twenty-seven cases with severe osteoarthritis showed very pale staining matrices, 18 severe cases showed irregular staining, and three cases showed normal staining. Twenty-nine cases of mild/moderate osteoarthritis showed pale staining matrices, 15 cases showed irregular staining, seven cases showed irregular staining, and seven cases showed normal staining. In osteoarthritic fibrocartilage there was irregularity of picro Sirius red staining.

Discussion

Osteoarthritis, which is the most common diseases of all joints, is one of the multifactorial genetic disorders. The exact definition of osteoarthritis is still debated in large part because of the disorder's heterogeneity.⁷ Because of the absence of a single diagnostic test, sets of criteria are relied upon to enhance the probability of making the correct diagnosis.

Osteoarthritis of the SCJ will not be unusual in autopsy material and in diagnostic biopsy material if it is looked for.² In the present study, osteoarthritic changes were seen in 82% of the blocks and 85% of the individual sternoclavicular joints. The patients from whom the specimens were obtained did not have any evidence of joint disease in their medical records although only one case from the 26 had no evidence of osteoarthritis in any part of the SCJ.

Six of the individual joints in the present study had osteoarthritic changes in one of the blocks but not in the other. This confirms the observation of Lafeber et al. who recommended that whole joints needed to be studied in the diagnosis and grading of osteoarthritis because the location and degree of severity of OA might be focal.⁸

Le Loet and Vittecoq in their review article on the SCJ stated that there was a high frequency of degenerative changes in this joint.⁹ In the present study, osteoarthritic changes were seen in 85% of the sternoclavicular joints, which is higher than the incidence reported by Kopp et al. (80%).¹⁰ There is no record of how often osteoarthritic changes of the SCJ are symptomatic because such symptoms may be confused with the symptoms arisen from shoulder disorders.⁹

In the present study, the osteoarthritic changes were severe in 36.6% of cases and were mild to moderate in 48.4%. De Palma stated that degenerative changes in the SCJ were not observed until the third decade of life and these changes would become progressively more severe and frequent after the fifth decade.¹¹ Similar results have been reported by Kier et al.¹²

The present study showed that osteoarthritic changes, including subchondral bone changes, were more severe in the right SCJ than in the left. Because most of the people are right-handed this finding suggests that the greater use of the dominant limb may play an important role in localising the degenerative processes. There are no published histological studies comparing osteoarthritis in the right and left SCJs. Studies using computed tomography found no differences in the incidence of osteoarticular diseases in the right and left SCJs but the severity of degenerative disease was greater on the dominant side.^{13,14} Lane et al found similar results in a study comparing right and left hands.¹⁵

Osteoarthritic changes were more severe in clavicular than in sternal articular cartilage. The fibrocartilaginous disc is closer to the sternal cartilage and, hence, it could be protecting the sternal cartilage from external forces.¹⁶ Berteretche et al believed that displacement of the disc in temporomandibular joints always resulted in degenerative changes in the cartilage.¹⁷ In addition, malposition of the disc causes degenerative changes.¹⁸ The costoclavicular and interclavicular ligament attachments could also help to stabilise the joint.¹⁶ De Palma claimed that the disc was able to protect both clavicular and sternal articular surfaces from osteoarthritic changes before the seventh decade of life.³ Berteretche et al believed that condylar fibrocartilage absorbed considerable stress in joints.¹⁷ In addition, meniscectomy in ovine knee joints induced osteoarthritis in both articular surfaces.¹⁹ None of these studies discussed the severity of degenerative changes in the articular surfaces of the SCJ.

The current study also showed that the inferior parts of the joints were more affected than the superior parts. These findings were confirmed in a previous study.²⁰ Osteoarthritis has been shown to affect some parts more severely than the others in joints such as hip and knee.¹⁹

Osteoarthritic changes in the SCJ consisted of fibrillation, clefts, and disorganisation of the clavicular and sternal articular cartilage and fibrocartilage, hyperplasia and cyst formation in subchondral bone, and osteophytosis. These changes have been reported in previous investigations of the SCJ, and in other joints.^{2,11,20-22}

Various degenerative changes were seen in the present study using both microanatomical and histochemical criteria. The fibrillated areas of the matrix showed loss of staining for glycosaminoglycans using toluidine blue and alcian blue stains, especially in the severely osteoarthritic cartilage. This has been found in other joints affected by osteoarthritis and is caused by the breakdown of aggrecan by proteinases.^{23,24} However, the rate of proteoglycan synthesis is increased in mild to moderate osteoarthritis.²⁵ The superficial matrix in fibrillated areas appeared striped, like a "tiger tail", because of degeneration of collagen fibrils. Collagenases (matrix metalloproteinase 1 and 13) cleave and denature type II collagen in osteoarthritic cartilage, especially in the superficial zone.²⁶ Thinning and cracking are other reactions, which change the matrix components. Fibrillation and thinning of the superficial zone were usually present without subchondral changes. However, in a few cases, subchondral bone changes (hyperplasia, cysts or osteophytosis) happened before fibrillation. This suggests that changes in the subchondral bone might antedate cartilage changes or both might occur over a fairly narrow period of time, rather than sequentially, as had been suggested by Pritzker.²⁷ Bone hyperplasia was seen in most cases with high-grade osteoarthritic changes in articular cartilage and fibrocartilage.

The risk of degenerative changes increases with age.²⁸ The results of the present study agree with that of Kopp et al. who found an exact relationship between age and osteoarthritic changes.¹⁰ These investigations showed that osteoarthritic changes probably were due mostly to the factors within the individual joints, but the influence of age could not be excluded.

Conclusion

The SCJ is superficial, easily accessed and, therefore, a valuable object for study. It is the only connection between the upper extremity and the trunk. Every movement of the arm results in the transmission of forces across the SCJ. Although it is a non-weight-bearing joint the osteoarthritis can be a common disorder in this joint. Osteoarthritis can possibly change not only the overall structure of cartilage, but also its molecular composition. Histological staining demonstrates these changes; therefore it is a suitable method for OA evaluation in autopsy and even biopsy materials.

Overall, there are clear changes in structure and glycan expression in the articular cartilage of the osteoarthritic sternoclavicular joint, which allow a distinction to be made between mild, moderate and severe osteoarthritis and normal

cartilage. The superficial location and accessibility of this joint would make it a possible cartilage for biopsy.

Suggestions for future studies

1- The incidence and prevalence of OA in SCJ should be determined.

2- Sternoclavicular joints should be examined in people who have clinical problems that might affect their sternoclavicular joints (SCJs). These problems include fractured clavicle, malformed clavicle or malformed sternum i.e. pectus carinatum (pigeon chest) and pectus excavatum (funnel chest).

3- SCJs could be examined in quadruped animals, because in these animals they are weight bearing joints.

4- SCJs could be examined in people who have used their hands extensively or have hung by their hands, such as swimmers or gymnasts, and compared with those with average use of the SCJ.

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