Faculty of Medicine and Health Science

Symptomatic degenerative osteoarthritis of the sternoclavicular joint

Alexander VAN TONGEL

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Promotor: Prof. dr. L. De Wilde
Co-promotor: Prof. dr. P. Debeer
Advisory Committee: Prof. dr. N. Pouliart

Prof. dr. F. Van Glabbeek

Jury members

Dr. J. Willems

Prof. dr. A. Cools

Prof. dr. K. D’Herde

Prof. dr. N. Hollevoet

Dr. B. Poffyn

Prof. dr. F. Vermassen

Prof. dr. J. Victor
If we knew what it was we were doing, it would not be called research, would it.

(A. Einstein)
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Chapter I: Introduction
The shoulder is one of the most sophisticated and complicated joints of the body. It has the greatest range of motion of any joint in the body allowing to position the hand anywhere in space.

The shoulder constitutes a complex mechanism in which no less than three joints participate, the sternoclavicular, the acromioclavicular, and glenohumeral, as well as the accessory motion of the scapula on the thoracic cage.

Two of these three joints (sternoclavicular and acromioclavicular joint) can only be seen in a small percentage of mammals. During evolution all seamammals and those adapted for running lost their clavicle because their movement only occurs in antero-posterior plane and there is no need for lateral swinging. In contrast, prehensile forelimbs (primates) and bats have a clavicle. In these animals, the clavicle allows the scapula and humerus to be held away from the body. Thanks to this lever arm, the muscles of the shoulder girdle can provide a better strength to perform the task as hanging on a tree, flying, heavy lifting or throwing (1).

Symptomatic degenerative osteoarthritis of the acromioclavicular joint is a common pathology and its treatment option has been studied extensively (2-6). In contrast symptomatic degenerative osteoarthritis of the sternoclavicular joint is uncommon and relatively little attention is paid to this joint.

**Anatomy of the sternoclavicular joint**

The sternoclavicular articulation is a double arthrodial joint (clavicle/manubrium, clavicle/first rib) composed of two portions separated by an articular disc. It is comprised of the sternal end of the clavicle, the upper and lateral part of the manubrium sterni, and the cartilage of the first rib (7-9).
Derived from the Latin clavis (key), the s-shaped clavicle has an anterior convexity medially and a posterior convexity laterally that provide a bony roof over the contents of the thoracic outlet (subclavian and brachial vessels) (10). The medial end of the clavicle, is larger than the opposing sternum in both the vertical and anteroposterior dimensions and extends superiorly and posteriorly relative to the sternum. It is also invested with a layer of cartilage, which is considerably thicker than that on the latter bone (11). To my knowledge, it has not been described which part of sternal end of the clavicle is covered by cartilage.

The articular capsule surrounds the articulation and varies in thickness and strength (9, 11). In front and behind, it is of considerable thickness, and forms the anterior and posterior sternoclavicular ligaments; but above, and especially below, it is thin and appears more consistent with areolar than true fibrous tissue.

The anterior sternoclavicular ligament (ASL) is a broad band of fibers, covering the anterior surface of the articulation (Fig 1); it is attached above to the upper and front part of the sternal end of the clavicle, and, passing obliquely downward and medial-ward, is attached below to the front of the upper part of the manubrium sterni (7-9, 11, 12).

Fig 1: anterior sternoclavicular ligament (ASL)
The posterior sternoclavicular ligament has been described as a similar band of fibers, covering the posterior surface of the articulation (11, 12). The sternohyoid and sternothyroid muscles separate the sternoclavicular joint from the innominate veins and the aortic arch branches more posteriorly (13).

The costoclavicular ligament (CCL) is short, flat, strong, and rhomboid in form (Fig 2). It consists of two parts or fascicles, similar to the coracoclavicular ligaments supporting the acromioclavicular joint. These fascicles are short and strong, and provide stability to the sternoclavicular joint during elevation and rotation of the clavicle, as the fibers from each cross over each other synchronously. The anterior fascicle arises from the anteromedial surface of the first rib, and is directed superiorly and laterally. The posterior fascicle is even shorter than the anterior, and arises lateral to the anterior fibers, directed superiorly and medially (11, 14). The articular disk is flat and circular, interposed between the articulating surfaces of the sternum and clavicle (Fig 3) (7, 9). It is attached, above, to the

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Fig 2: Costoclavicular ligament (CCL)

Fig 3: Discus intra-articularis
upper and posterior border of the articular surface of the clavicle and below, to the
cartilage of the first rib, near its junction with the sternum. It divides the joint into two
cavities, each of which is furnished with a synovial membrane. It acts to reduce the
incongruities between the articulating joint.

The sternoclavicular joint lies immediately above and medial to the thoracic outlet, which
is bounded by the first thoracic vertebra, first rib and upper border of the manubrium. The
sternoclavicular joint pathology may therefore interfere with important local structures,
including the trachea and oesophagus posteromedially and the subclavian vessels and
supraclavicular brachial plexus posterolaterally, causing serious symptoms (15).

**Embryology of the sternoclavicular joint**

The clavicle is classified mainly as a membranous bone and the sternum and ribs are
formed by endochondral ossification. The clavicle is the first long bone to start to ossify
(fifth embryonal week). However, the epiphysis at the medial end of clavicle is the last to
appear (age 18–20 years) and to close (age 23–25 years) (16, 17).

The sternum develops from a pair of vertical mesenchymal bands, sternal bands that are
located ventrolaterally in the body wall (18-20) (Fig 4). As these bands become converted
into precartilage they converge toward the midline and start to fuse with each other,
beginning cephalically. Following its establishment in the midline, there are curious
secondary transverse divisions of the sternum into a series of separate cartilages called

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**Fig 4: embryology sternum (20)**
sternebrae (6).

These centres of ossification appear first craniocaudally in the sternum in the sixth month. Most of the time there is one point of ossification in the manubrium, a variable number of points (4 until 13) in the body and sometimes another point for the xiphoid. The ossification centres of the body unite in 3 or 4 bigger segments in the first year. The segments are together at the age of 4 years (20).

In 1971 Olah and Ludwig described the development of the sternoclavicular joint. Unlike most synovial joints, the sternoclavicular joint does not develop from a blastema. The sternoclavicular joint anlage consists of loosely packed tissue with scanty cell content. From the earliest developmental stages, the clavicular perichondrium also sheathes the medial end of the clavicle, its fibre layer providing the tissue for the discus articularis and the covering of the articular surface. The inner layer of perichondrium, corresponding to the stratum germinativum, acts as the end of the clavicle as a medial proliferation zone for the clavicle. In comparison with other joints, the articular hollow of the sternoclavicular joint appears relatively late. During their examination, which only covered the developmental period, they were unable to observe any fibrous cartilage in the sternoclavicular joint. Thus the fibrocartilaginous transformation of the discus anlage and the fibrous surface layers of the articular surface must occur in the course of later development (21).

Biomechanics of the sternoclavicular joint

The sternoclavicular joint is likely the most frequently moved joint of the long bones in the body because almost any motion of the upper extremity is transferred proximally to the sternoclavicular joint (22-24). Anatomically, it is a saddle joint but it seems to function like a ball and socket joint. This seems to be confirmed by preliminary results of a
cadaver study in our department. The sternoclavicular joint has the distinction of having the least amount of bony stability of the major joints of the body because less than half of the medial clavicle articulates with the upper angle of the sternum (inferior pole of medial clavicle) (25).

Motion of the clavicle relative to the sternum is defined as protraction-retraction about the vertical axis, elevation-depression about the horizontal axis and anterior-posterior rotation about the lateral axis (Fig 5) (22, 24, 26, 27).

Since no muscle group exists that crosses the sternoclavicular joint to produce an active posterior axial rotation, the clavicle moves like an intercalated segment, being pulled into posterior rotation by means of the linkage of the coracoclavicular and acromioclavicular joint ligaments by the scapulothoracic muscles. This results in motion of the scapula relative to the thorax only occurring through simultaneous motion at the acromioclavicular and sternoclavicular joints.

I would like to make a comparison between the sternoclavicular joint and the mast base of a surfboard. The sail of the surfboard can be compared with the scapula and the surfer can
be compared with the thoracoscapular muscles (Fig 6). During surging, the surfer (thoracoscapular muscle) is positioning the sail (scapula) adequately in the wind (in space). Without a fixation point it is probably still possible to surf but the surfer (muscles) will need to work much harder to get the sail (scapula) under control and in heavy wind it will not be possible to hold the sail. This is comparable with persons without a clavicle (cleidocranial dysplasia) who describe that they can do almost anything but no heavy lifting and they are quickly getting tired. Thanks to the fixation point less strength of the surfer is necessary to control the sail.

Fig 6: surfboard – sternoclavicular joint

**Degenerative osteoarthritis sternoclavicular joint**

*Background*

Degenerative osteoarthritis of a joint is a common finding on technical investigations. Degenerative osteoarthritis is characterized by narrowing of the joint space, osteophytes, subchondral sclerosis, and cysts on both sides of the joint (28). This condition is strongly age-related, being less common before 40 years, but rising in frequency with age, such that most people older than 70 years have radiological evidence of osteoarthritis in some joints.
(29). Trauma and weight bearing are also generally considered important contributors to this degenerative process. But degenerative osteoarthritis is also commonly seen in the non-weightbearing joint (DIP, PIP, sternoclavicular joint) (30). Regional joint pain in older people is common, and osteoarthritis is thought to be the biggest cause. However, the correlation between radiographic evidence of osteoarthritis and the symptomatic disease is rather weak. (31, 32)

**Epidemiology**

In 1934 Langen was the first to describe degenerative osteoarthritis in the sternoclavicular joint. He stated that this degenerative process already starts at the age of 25 years (33). At the age of 49 years, 50% of the cadavers he examined showed signs of severe osteoarthritis. Other authors confirmed these findings (34-38). Silderberg described age alterations as early as the third decade of life. He described that on an examination of 200 human sternoclavicular joints over 90% of the joints were affected (36). Kier and colleagues described that moderate or severe radiographic changes of osteoarthritis were uncommon in specimens younger than age 40, but present in 53% of specimens older than age 60 (38). In spite of the high incidence of sternoclavicular joint degeneration on technical investigations, it seems this degeneration is frequently well tolerated without clinical symptoms (36).

To my knowledge, no epidemiological studies has been performed to evaluate the prevalence of symptomatic degenerative sternoclavicular osteoarthritis

**Clinical examination**

In 1942, Westermann was the first to describe symptomatic degenerative osteoarthritis of the sternoclavicular joint (39). He mentioned patients with pain during active motion of the shoulder girdle and prominences in the sternoclavicular region with radiological signs of
degenerative sternoclavicular osteoarthritis (39). These symptoms were later on confirmed by other colleagues (40-44). Pain during palpation and during elevation is described frequently, but in contrast to the acromioclavicular joint (45), these clinical tests have not been validated.

*Technical investigation*

The most commonly used technical investigation to evaluate the sternoclavicular joint is CT-scan (Fig 7). CT imaging have been described to be superior to other imaging techniques when evaluating narrowing of the joint space, osteophytes, subchondral sclerosis, and cysts at both sides of the joint (40-44). Another advantage is the fact that CT imaging also enables to create 3D bony reconstructions. These reconstructions can be used to evaluate the relationships between the bones of a joint (46). Conventional plain x-rays of the joint may be suboptimal to evaluate abnormalities because the overlying ribs, spinal column, and soft-tissue obscure joint detail (28). MRI should be the first modality of choice when suspecting malignancies or infection in the sternoclavicular region but not for the diagnosis of degenerative osteoarthritis (20). Scintigraphy is a sensitive method for detecting disorders with increased bone turnover, but is in general not specific for disorders in the sternoclavicular region except for the “bullhead-like” sign in sternocostoclavicular hyperostosis (20).

As described, a common complaint in patients with symptomatic degenerative arthritis is a prominence of the clavicle (40-44). To our knowledge, it has not been evaluated if this prominence is caused by bony enlargement and osteophytes or by a subluxation of the clavicle. 3D CT reconstructed images can help with this research.
**Fig 7: degenerative sternoclavicular osteoarthritis**

*Treatment*

The primary treatment of symptomatic degenerative sternoclavicular osteoarthritis is conservative, including rest, analgetics and modification of behavior on lifting and reaching out. (40-44). Similar to other degenerative joints, also intra-articular injection of corticosteroids can be given. But it has been described that intra-articular injection at the sternoclavicular joint is a challenging procedure and even a highly experienced physician cannot guarantee success (31). In difficult or doubtful cases, ultrasound guidance of the intra-articular puncture is recommended as a means of preventing unintended peri-articular injection and subsequent complications (47).

In instances where conservative treatment fails, a medial claviculectomy has been proposed (35, 39, 42, 44). In 1942 Westermann was the first surgeon to describe this surgical treatment option in one patient with a good result four year postoperatively (39). Arlet and colleagues described good results in two patients (35). Bremer and colleagues described good results in six patients that were treated with a synovectomy and excision of the medial inch of the clavicle (42). Pingsmann and colleagues described the mid-term
clinical results of the surgical treatment of primary degenerative arthritis of the sternoclavicular joint in eight women. Four patients had an excellent result, three good, and one poor (44). In 2013, Tytherleigh-Strong and colleagues reported the results of a series of 10 patients who underwent an arthroscopic excision of the sternoclavicular joint for osteoarthritis. The clinical results were rated as excellent in seven patients, good in two, and fair in one (48). This means, in total, the results of only 27 cases have been described in the literature.

References
Chapter II: Aims of the thesis
As described in the introduction, in contrast to the common findings of osteoarthritis of the sternoclavicular joint on technical investigations, pain at the sternoclavicular joint is rare. The aim of this thesis is to obtain a better understanding of this pathology and to evaluate current treatment options. This is done on the basis of 5 topics: 1) anatomy, 2) frequency, 3) clinical manifestation, 4) radiological manifestation and 5) treatment.

1) Anatomy of the sternoclavicular joint.
In general, if conservative treatment of symptomatic degenerative osteoarthritis fails, all different kind of operative treatments have been proposed (debridement, arthrodes, interposition arthroplasty, prosthesis, resection arthroplasty) and the results of this surgical solutions have been studied extensively. In contrast, for the sternoclavicular joint, only a few studies are describing the result of operative treatment (1-3). A possible explanation is the fact that effective management is often hindered by a limited understanding of the anatomy (4). To our knowledge, no clear description of the anterior and posterior SC ligament can be found in the published literature. Also a macroscopic view of the articulating surfaces of the sternal end of the clavicle and clavicular notch of the manubrium has not described in the literature.

The first aim of the thesis was to confirm and clarify the structural anatomy of the soft-tissue structures and the cartilaginous surfaces of the sternoclavicular joint.
To obtain this goal, a macroscopic evaluation of the ligaments, the intra-articular disc and the articulating surfaces of 25 sternoclavicular joints was performed.

2) Frequency of symptomatic degenerative sternoclavicular arthritis.
Symptomatic degenerative sternoclavicular arthritis is rare and the frequency of this pathology in daily practice of a shoulder surgeon is not known.

The second aim of the thesis is to evaluate the frequency of this pathology in daily practice
of shoulder surgeons in different areas of the world.

To obtain this goal, a survey was circulated to members of six different national and international shoulder societies. Questions focused on the numbers of cases of degenerative symptomatic sternoclavicular osteoarthritis seen in the past year.

3) Clinical manifestation of symptomatic degenerative sternoclavicular arthritis.

Patients are consulting primarily because of localized swelling and/or mechanical pain at the level of the sternoclavicular joint (1, 5). Several clinical tests have been described, but no study have evaluated which tests are most helpful in diagnosing sternoclavicular joint pain (6-8).

The third aim of the thesis is to evaluate the diagnostic value of the current clinical tests and of two newly described tests.

To obtain this goal, all patients between June 2011 and October 2013 that visited our department with atraumatic pain in the area of the sternoclavicular joint were analysed. Prominence, pain at palpation and pain during arm elevation were evaluated. In addition two new clinical tests were evaluated: pain during active scapular protraction and retraction.

4) Radiological manifestation of symptomatic degenerative sternoclavicular arthritis.

In patients with symptomatic degenerative arthritis, clinical examination sometimes reveals a prominent clavicle (5). Two reasons may attribute to this prominent clavicle 1) the clavicle is anteriorly subluxated and/or 2) the clavicle is larger.

The fourth aim of the thesis is to describe a reproducible measurement technique to evaluate the relationship of the medial clavicular head and the manubrium in a normal population and patients with painful swelling caused by sternoclavicular arthritis and to evaluate if the prominent clavicle is caused by an enlarged clavicle or by anterior...
subluxation of the clavicle.

To obtain this goal, 100 normal sternoclavicular joints, 25 sternoclavicular joints with symptomatic degenerative arthritis, and 25 non-symptomatic sternoclavicular joints on the contra-lateral side were 3D reconstructed using computer modeling. The greatest width and height of the medial clavicle were measured. Also the position of the anterior border and superior border of the medial clavicle and the distance to respectively the frontal plane and axial plane respectively, were evaluated.

5) Treatment of symptomatic degenerative sternoclavicular arthritis.

The proposed primary treatment in literature is conservative and includes rest, modification of behavior with restriction of lifting and reaching out, analgesia, intra-articular injection of corticosteroids and medial clavicle excision (9). It is not known whether these treatments options are also common practice.

The fifth aim of the thesis is to evaluate if there is clinical agreement on the treatment of symptomatic degenerative arthritis between shoulder surgeons in different areas of the world on treatment options.

To obtain this goal, a survey was circulated to members of six different national and international shoulder societies. Questions focused on treatment preference, number of medial clavicle excisions performed in their career and evaluation of the risk of a medial clavicle excision.

Recently arthroscopic medial clavicle resection has also been proposed as a treatment for symptomatic degenerative arthritis. (10, 11). Because of the proximity of the neurovascular structure posterior to the sternoclavicular joint, it is necessary to evaluate if this procedure can be performed safely.

The sixth aim of the thesis was to examine the safety or accessibility of arthroscopy of the
sternoclavicular joint.

To obtain this goal, arthroscopic debridement was performed in 20 cadaveric specimens. After debridement, the specimens were dissected and the integrity of the posterior capsule was evaluated macroscopically. The distance to the neurovascular structures behind the sternoclavicular joint was also measured.

References
Chapter III: Research work
1. A Cadaveric Study of the Structural Anatomy of the Sternoclavicular Joint

A. Van Tongel M.D.¹, P. MacDonald M.D. F.R.C.S.C.², J. Leiter Ph.D. ², N. Pouliart M.D. Ph.D. ³, J. Peeler Ph.D. CAT(C) ⁴

¹ Department of Orthopaedic Surgery and Traumatology, Ghent University Hospital, De Pintelaan 185, B-9000 Gent, Belgium
² PanAm Clinic, University of Manitoba, 75 Poseidon Bay, Winnipeg, Manitoba, R3M 3E4, Canada
³ Department of Orthopaedics and Traumatology, Universitair Ziekenhuis Brussel, Laarbeeklaan, 101, 1090 Brussels, Belgium.
⁴ Department of Human Anatomy & Cell Science, University of Manitoba, Winnipeg, Manitoba, Canada


Abstract

Pathologies of the sternoclavicular (SC) joint are infrequent and effective management is often hindered by a limited understanding of the anatomy. In this study we did macroscopic evaluations of the ligaments, the intra-articular disc and the articulating surfaced of 25 SC joints. After removal of the joint capsule, the articulating surfaces of the sternal end of clavicle and the sternum were evaluated and the intra-articular disc was macroscopically examined. The anterior SC ligament covered the intra-articular disc, which divided the joint into a clavicular and a sternal part. A thin capsule, relatively lateral and medial from the anterior SC ligament, covered the two intra-articular parts. This means that the anterior SC ligament can be used as a landmark to enter into clavicular or sternal part of the SC joint. Posteriorly there was a thick capsule without soft-spot nor clear posterior SC ligament. Only the antero-inferior surface of the sternal end of every clavicle was covered by cartilage. Of the intra-articular discs 56% were incomplete. All of these incomplete discs displayed a central hole with signs of degeneration and fraying. This was associated with increased cartilage degeneration at the clavicular side. By experimental
design (past and present), it would seem reasonable to assume that the incomplete types are caused by degeneration and are not developmental.

**Keywords:** sternoclavicular joint - ligament - intra-articular disc - articulating surface

**Introduction**

The sternoclavicular (SC) joint is a point of articulation between the upper extremity and the axial skeleton. It is classified as a double arthrodial synovial joint, and is reported to have little intrinsic stability (1). The joint is formed by the sternal end of the clavicle, the clavicular notch of the manubrium and the cartilage of the first rib (2-4). The joint has an articular disc that interposes between the sternal end of the clavicle and the clavicular notch of the sternum. Ligamentous structures in this region include the anterior and posterior sternoclavicular ligaments, costoclavicular ligament, and interclavicular ligament (2-5). Pathologies of the SC joint are infrequently reported in the medical literature (6). As a consequence, relatively little attention is paid to this joint. Non-traumatic causes of sternoclavicular pain and swelling can be treated with intra-articular injection of corticosteroids (7, 8). With a suspected septic arthritis of the joint, intraarticular aspiration is warranted (7). To our knowledge there is no literature describing the technique and the accuracy of injections into the sternoclavicular joint.

Concerning the soft-tissues, several authors have proposed several types and variations of the disc (3, 4) but no clear description of the anterior and posterior SC ligament can be found in the published literature. Also a macroscopic view of the articulating surfaces of the sternal end of the clavicle and clavicular notch of the manubrium has not described in the literature. The purposes of this investigation were to confirm and clarify the structural anatomy of the soft-tissue structures and the cartilaginous surfaces of the SC joint.
Materials and Methods

This study was performed on 16 cadavers. Information on age, gender, and cause of death was obtained from the Department of Human Anatomy and Cell Science (within the Faculty of Medicine) at the University of Manitoba in accordance with the Personal Health Information Act (PHIA) of Manitoba. The handling of all cadaveric materials was in accordance with the “Human Tissue Act”, as outlined by government regulations in the Province of Manitoba, Canada. In total, 25 SC joints (12 left, 13 right) of 16 cadavers (7 men, 9 women) ranging in age from 43 to 103 years (mean ±SD: 80.75 years ± 14.66) were evaluated. (Table 1) All cadavers were fixed by perfusion of 10% formalin solution and stored in 50% alcohol. All but one specimen had been used for dissection in an undergraduate medical training program. The SC joint was intact on both sides in nine cadavers and on one side in seven. Twelve of these specimens were examined with the entire clavicle intact, while the remaining cadavers had the clavicle transected through the middle 1/3rd. Specimens that presented visible evidence of surgery, trauma or previous dissection through the SC joint region were excluded from the study. In total 25 SC joints were evaluated.

The dissection protocol for the study was adopted from a format described by Barbaix et al (3). Each dissection began with removal of the sternocleidomastoid and the pectoralis major muscles from their attachments on both the sternum and clavicle. The complete SC joint was removed by transecting the clavicle through its middle 1/3rd, cutting the manubrium portion between the first and the second ribs and cutting the first rib just anterior to the scalene tubercle.

Then, the anterior and posterior parts of the SC joint were examined and the capsule was inspected for the presence of soft spots and ligaments.

Through several pilot dissections, the technique of Barbaix et al was refined to facilitate evaluation of the articular surface of the clavicle and the intra-articular disc. The adaptation
consisted of completely incising the joint capsule from its attachment on the medial part of the clavicle as well as sacrificing the costoclavicular ligament to facilitate complete removal of the clavicle. Data collected during the pilot project were not used for the present report.

Subsequently, the articular surface of sternal end of the clavicle was assessed for damage to the articular cartilage according to the Outerbridge classification system (9) (Table 2).

Table 2 Outerbridge classification

<table>
<thead>
<tr>
<th>Grade 0 - normal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade I - cartilage with softening and swelling</td>
</tr>
<tr>
<td>Grade II - a partial-thickness defect with fissures on the surface that do not reach subchondral bone</td>
</tr>
<tr>
<td>Grade III - fissuring to the level of subchondral</td>
</tr>
<tr>
<td>Grade IV - exposed subchondral bone</td>
</tr>
</tbody>
</table>

The morphology of the intra-articular disc was macroscopically examined by unenhanced visual observation. Finally, the intra-articular disc was completely removed from its attachments to the sternum and the first rib, in order to be able to evaluate the articulating surfaces of the sternum and the degree of cartilage damage. Statistical analysis was performed using SPSS version 16.0. Independent t-test was used to compare values during the study. Pearson’s correlation coefficient was applied to the correlation of articular damage on the sternal side of the medial clavicle and the sternum and morphology of the intra-articular disc. P value of less than 0.05 was considered to be significant.

**Results**

When evaluating the anterior part, in every dissected SC joint, the anterior portion of the SC joint could be divided in three parts (Fig 1).
Fig 1: The anterior portion of the sternoclavicular capsule with the three distinctive parts

The borders of part one were the anterior SC ligament on the medial side, the medial clavicle on the cranial side, the first rib on the caudal side. It represented a soft-spot lateral to the anterior SC ligament. Part two was the anterior SC ligament. It was attached to the anterior portion of the medial clavicle and had an oblique configuration, which started cranial and lateral, and ended caudal and medial to the sternum. It was impossible to dissect the ligament of the capsule in this region. Part three was represented by a soft spot on the medial side. It was triangular in shape and its borders were the interclavicular ligament cranially; the anterior SC ligament on the lateral side; and the sternum on the medial side.

When evaluating the posterior part, unlike the anterior aspect of the joint, there was no soft spot or clear posterior SC ligament.

When progressively detaching the capsule from the clavicle, its anterolateral part appeared very thin. In the area of the anterior SC ligament, the capsule was thicker. Medial to the anterior SC ligament the capsule was again very thin. After excision of anterior capsule we could visualize that the anterior sternoclavicular ligament was covering the intra-articular
disc. This disc divides the joint in a lateral or clavicular part and medial or sternal part. The clavicular part was covered by part one (Fig 2) and the sternal part by part three (Fig 3).

Fig 2: View on the clavicular part of the SC joint after removal of covering capsule (part 1)
Fig 3: View on the sternal part of the SC joint after removal of covering capsule (part 3)

The articular surface of the clavicle was positioned anterior-inferiorly and a broad attachment of the capsule covered the superior and posterior aspects of the clavicle (Fig 4).

Fig 4: The medial clavicle with region of the attachment of the capsule in blue
Fig 5: A degenerated intra-articular disc after removal clavicle

The intra-articular disc was located in the centre of the joint and, if complete, it had a smooth surface (Fig 5).
No disc was observed between the clavicle and the first rib.

Of the 25 joints examined, 44% demonstrated complete discs, while 56% were incomplete (Table 2). All of these incomplete discs displayed a central hole with signs of degeneration and fraying. None of the incomplete discs demonstrated a sharp rim. 72% of all discs (8 complete, 10 incomplete) displayed signs of calcification. All incomplete discs were 75 years or older.

Table 1: list of dissected SC joints with evaluation of intra-articular disc and cartilage degeneration

<table>
<thead>
<tr>
<th>cadaver</th>
<th>side</th>
<th>age</th>
<th>intra-articular disc</th>
<th>cartilage sternum*</th>
<th>cartilage clavicula*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>right</td>
<td>43</td>
<td>complete/intact</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>2</td>
<td>right</td>
<td>60</td>
<td>complete/intact</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>3</td>
<td>right</td>
<td>69</td>
<td>complete/intact</td>
<td>I</td>
<td>III</td>
</tr>
<tr>
<td>4</td>
<td>left</td>
<td>75</td>
<td>incomplete/degenerative</td>
<td>II</td>
<td>III</td>
</tr>
<tr>
<td>5</td>
<td>right</td>
<td>76</td>
<td>complete/intact</td>
<td>II</td>
<td>IV</td>
</tr>
<tr>
<td>6</td>
<td>left</td>
<td>76</td>
<td>incomplete/degenerative</td>
<td>I</td>
<td>III</td>
</tr>
<tr>
<td>7</td>
<td>left</td>
<td>78</td>
<td>complete/intact</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>8</td>
<td>left</td>
<td>81</td>
<td>incomplete/degenerative</td>
<td>I</td>
<td>IV</td>
</tr>
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<td>right</td>
<td>82</td>
<td>complete/intact</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>10</td>
<td>right</td>
<td>83</td>
<td>incomplete/degenerative</td>
<td>I</td>
<td>III</td>
</tr>
<tr>
<td>11</td>
<td>left</td>
<td>83</td>
<td>complete/intact</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>12</td>
<td>left</td>
<td>87</td>
<td>incomplete/degenerative</td>
<td>II</td>
<td>IV</td>
</tr>
<tr>
<td>13</td>
<td>right</td>
<td>87</td>
<td>incomplete/degenerative</td>
<td>I</td>
<td>IV</td>
</tr>
<tr>
<td>14</td>
<td>right</td>
<td>89</td>
<td>incomplete/degenerative</td>
<td>III</td>
<td>IV</td>
</tr>
<tr>
<td>15</td>
<td>left</td>
<td>89</td>
<td>incomplete/degenerative</td>
<td>II</td>
<td>IV</td>
</tr>
<tr>
<td>16</td>
<td>left</td>
<td>94</td>
<td>complete/intact</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>17</td>
<td>right</td>
<td>95</td>
<td>incomplete/degenerative</td>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>18</td>
<td>right</td>
<td>103</td>
<td>incomplete/degenerative</td>
<td>III</td>
<td>IV</td>
</tr>
</tbody>
</table>

All clavicular articular surfaces demonstrated at least moderate cartilage damage (Table 3). The articular surface of the sternum almost completely covered the width of the sternum. The damage of the cartilage on the sternal side was less extensive than on the clavicular side (Table 3).
Table 3: difference of cartilage degeneration between sternal and clavicular side

<table>
<thead>
<tr>
<th></th>
<th>clavica</th>
<th>sternal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outerbridge I</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Outerbridge II</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Outerbridge III</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Outerbridge IV</td>
<td>9</td>
<td>0</td>
</tr>
</tbody>
</table>

When the disc was incomplete (14/25 joints) there was a high prevalence of cartilage damage on the both articular surfaces with severe damage noted on 71% (10/14) of clavicular surfaces. In contrast, when the disc was complete (11/25 joints), severe damage to the articular surface of the clavicle was only detected on 27% (3/11) (Table 1). The correlation between the morphology of the disc and articular damage on the sternal side of the medial clavicle was good (r=0.571, p=0.003). The correlation between the morphology of the disc and articular damage on the sternum was not as strong but still statistically significant (r=0.493, p=0.012).

**Discussion**

Pathologies of the SC joint are infrequent and injections in the joint are described as a treatment option. This study showed that the anterior SC ligament could be used as a landmark to enter either into the clavicular or the sternal part of the SC joint.

An intra-articular injection of the clavicular part of SC joint should be done through the thin anterior-inferior part of the capsule where it is only attached to a small rim on the anterior part of the clavicle. The soft spot medial from the anterior SC ligament can be used to gain access to the sternal part of the joint (fig 6).
If the disc is intact, the fluid will only reach one of both parts of the joint. In describing the effect of injections, until now this differentiation between the two parts has not been mentioned (8). As the disc frequently appears to be degenerated in patients with symptomatic degenerative SC joint arthritis, both parts of the joint would be connected. It that case, it would not matter into which part an injection is given.

Posteriorly, a thick capsule, without distinct ligament nor soft spot, is attached to the superior and posterior 2/3rds of the surface of the medial clavicle. It may offer some protection of the neurovascular structures posterior to the SC joint when doing an infiltration.

When resecting the acromioclavicular joint, it is important to preserve the capsular attachments to minimize instability (10). Likewise, it would be useful to minimize bony resection of the sternal end of the clavicle while preserving a maximum of the capsular insertion, especially posteriorly. Knowing that the articular surface of the clavicle can be found antero-inferiorly may help achieve this goal and reduce the amount of bone resection that has previously been suggested when dealing with osteoarthritis (11-13).

Currently within the literature, all soft-tissue structures located between the surfaces of the
clavicle and the sternum, are lumped together and labeled as an intra-articular disc (3, 4). Our results suggest, however, that a clear differentiation should be made between the disc and the capsule. Structurally, the disc and the capsule have very different configurations and are macroscopic distinct structures. In our study, the disc was always attached to the capsule and the capsule to the bone. This is contrast with the description by Barbaix et al and Emura et al where the falciform rough zone of the disc is directly attached to the medial region of the sternal end of the clavicle (3, 4).

In the anatomical literature, the disc has routinely been classified into two types: complete and incomplete (2, 3, 14). More recently, Emura et al proposed a sub-classification of incomplete articular discs into two subtypes: ring and meniscoid (4). We did not observe this subdivision. Concerning the prevalence of the two types of discs, Barbaix et al found in an incomplete disc 7 out of 22 dissections (31,8%) (aged cadavers – no specific data) (3). This is consistent with observations made by Brossman et al, who found 5 incomplete discs in 14 joints (35%) (age between 64 and 94 – mean age 84) (2) and by Emura et al who described an incomplete disc in 15 out of 51 cases (30%) (age between 68 to 94 years – mean age 84) (4). DePalma et al found perforations of the central portion of the disc in 8 of the 25 specimens (32%) in cadavers of the seventh decade. This incidence increased in subsequent decades (14). In the present study, we found incomplete types in 14 out of 25 dissections (56%) and all incomplete discs showed signs of degeneration. This higher incidence may be due to bias based upon limited sampling. In our study, incomplete discs also seemed to be associated with severe degenerative signs of the clavicular cartilage. These results contrast with the finding of Barbaix et al who did not see any particular sign of osteoarthritic degeneration (3). Our hypothesis is that the incomplete types are caused by degeneration and are not developmental. Therefore, older patients will have more incomplete (degenerative) types. This degeneration process, in our opinion, could be comparable to that observed in the meniscus of the knee. Since the inner part of the
meniscus of the knee is avascular, degenerative tears do not display a healing capacity (15). Degenerative meniscal tears in the knee are associated with an increased incidence and severity of cartilage degeneration compared with other types of meniscal tears (16). In our specimens, the presence of an incomplete type of disc was associated with an increased incidence of cartilage damage. This hypothesis is corroborated by two studies. Kier et al demonstrated that radiographic degenerative changes of the SC joint were minimal in young patients, increased in frequency and severity with advancing age, and were virtually ubiquitous in the elderly (17). Sick and Ring described the presence of an avascular centre within the intra-articular disc of the SC joint (18).

While the results of the current investigation contribute to the anatomical literature regarding the structure of SC joint, it has some limitations. The small number of specimens with a relatively high mean age certainly influences the observed incidences of disc type and degeneration. More specimens, including a younger sample population, would reduce bias. Furthermore, microscopic and histologic data would be useful to supplement the findings from our macroscopic observations. Corroboration with imaging, CT or MRI, would further help in clarifying the role that aging play in degeneration of the SC joint.

**Acknowledgments:**

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**References**

2. Frequency and management of symptomatic degenerative sternoclavicular arthritis: A survey of orthopaedic surgeons

A. Van Tongel M.D.¹, S. McRae M.Sc², A. Gilhen M.Sc², J Leiter Ph.D.², MacDonald M.D. F.R.C.S.C.² L De Wilde M.D. Ph.D¹

¹ Department of Orthopaedic Surgery and Traumatology, Ghent University Hospital, De Pintelaan 185, B-9000 Gent, Belgium
² PanAm Clinic, University of Manitoba, 75 Poseidon Bay, Winnipeg, Manitoba, R3M 3E4, Canada

(submitted Acta Orthopaedica Belgica)

Abstract

Background: Symptomatic degenerative sternoclavicular (SC) arthritis is rare and various treatment options have been described. The aim of this study is to evaluate current frequency and to identify clinical agreement on the treatment of this pathology and evaluate differences between shoulder societies.

Material and methods: A questionnaire was circulated to members of 6 different national and international shoulder societies. The questions focused on 1) frequency of the pathology in their practice and 2) treatment.

Results: A total of 342 shoulder surgeons responded on the survey. In general, 17.5% of respondents are seeing more than 5 patients a year with symptomatic degenerative SC arthritis. There was a general agreement to prescribe anti-inflammatory medication (87%) and not to perform a mediale clavicle excision (79%). There was no agreement concerning the treatment with a depot-corticoid infiltration (55%). Fourteen percent of all surgeons performed 5 or more medial resections. Forty-eight percent would evaluate this procedure as not worth the risk or high risk. There is a difference in proposed treatment options between societies.
Conclusion: Orthopedic surgeons do not frequently see patients with symptomatic degenerative arthritis. There is a difference in frequency between different societies. There is a general agreement on the use of anti-inflammatory but not on intra-articular steroid injections. In contrast to the good results of a medial clavicle resection in the literature, there is a general agreement to not perform this procedure. Half of the participants would evaluate a medial clavicle resection as not worth the risk or high risk. There are differences in proposed treatment options between societies.

Level of evidence: V - expert opinion

Keywords: sternoclavicular, degenerative arthritis, frequency, management, survey

Introduction

The sternoclavicular (SC) joint is the only synovial articulation between the upper extremity and the trunk (1). SC joint degeneration is common. Since Silberberg’s extensive review of 200 cases involving pathologic changes of osteoarthritis of the SC joint (2), several additional post-mortem studies have substantiated the marked prevalence of this condition (3-5). But SC joint degeneration seems to be well tolerated without clinical symptoms (2). Only a small number of studies have described symptomatic degenerative arthritis and its treatment (6-11).

The primary treatment of SC joint degeneration is conservative, including rest, modification of behavior with restrictions on lifting and reaching out, analgesics, and intra-articular injection of corticosteroids (12). A small number of articles have described the results of an excision arthroplasty with resection of the medial clavicle in patients who fail to respond to conservative measures for a minimum period of six months (6, 9-11).

There is a paucity of information in the literature on the incidence and management of SC joint degeneration in daily practice. In the current study, a survey of six national and international shoulder societies was conducted on these two topics. The aim of this study
was to identify areas of disagreement upon which basic science research and clinical trials can focus, and to create a greater understanding and more unified, evidence-based management approach to the treatment of symptomatic degenerative SC arthritis.

Material and Methods

Study Subjects

Approval was obtained from the appropriate research ethics board prior to commencement of study activities. Orthopedic surgeons who were listed as active members of their respective organizations were invited by email to take part in an internet-based survey. Members of the following six national or international shoulder societies were invited to participate: Japanese Shoulder Society (JSS; 1500 members), Latin American Shoulder and Elbow Society (LASES; 300 members), South-African Shoulder and Elbow Society (SASES; 40 members), Shoulder and Elbow Society Australia (SESA; 100 members), European Shoulder and Elbow Society (SECEC; 540 members) and American Shoulder and Elbow Society (ASES; 400 members).

Survey Design and Distribution

A questionnaire was developed for the current study, comprised of six multiple-choice questions regarding years of experience, numbers of cases of degenerative symptomatic SC osteoarthritis seen in the past year, treatment preference, number of medial clavicle excisions ever performed and evaluation of the risk. The questionnaire was trialed on three fellowship-trained orthopedic sports medicine surgeons not involved in the study, revised accordingly, and then distributed. Survey distribution and analysis followed a similar process as was outlined in a previous survey study on the natural history and management of anterior cruciate ligament (ACL) injury (13). An email invitation including a link to the survey was sent to all active members of each society via SurveyMonkey.com™ (Palo Alto, California) by the secretary of each society. Reminder emails were sent out by each
society at one and three months after the initial email. Responses were de-identified using study numbers and were kept separate from the names/emails of the respondents.

Data Analysis

Frequency distributions were generated for all questions. Areas of clinical agreement were identified and described. Prior definitions of “clinical agreement” in the literature have been inconsistent and somewhat arbitrarily defined. Wright et al. defined agreement as >90% of physicians answering similarly on a survey (14), whereas Tierney et al have suggested that a value of >95% indicates strong agreement and a value of >60% indicates general agreement (15) and for the purposes of the study we used this threshold. This threshold is, of course, arbitrary and is only used to highlight areas of consensus. Actual counts and percentages are provided in the Results section below to allow for deriving ones’ own conclusions regarding clinical agreement.

Statistical analysis

The Chi-squared test was used to evaluate the significance between the several groups.

Results

The email invitation to participate was sent out to all eligible orthopedic surgeons of whom 342 responded (12%). Of those 342, 54 were members of JSS (4%), 87 from LASES (29%), 14 from SASES (35%), 30 from SESA (30%), 83 from SECEC (15%) and 74 (18%) from ASES members.

Seventy-nine percent of surgeons who responded (272/342) indicated seeing one or more patients per year with symptomatic degenerative arthritis and 18% (61/342) seeing five or more per year (Table 1). The number of cases seen each year varied widely between societies. The smallest proportion of respondents indicating seeing one or more patients per year was JSS with 54% while the highest proportion was SASES and SESA, both with 93%.
Table 1: How many patients with symptomatic degenerative sternoclavicular arthritis do you see each year?

<table>
<thead>
<tr>
<th>Society</th>
<th>less than 1</th>
<th>1 or 2</th>
<th>3 and 4</th>
<th>more than 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>JSS</td>
<td>46% (25/54)</td>
<td>39% (21/54)</td>
<td>11% (6/54)</td>
<td>4% (2/54)</td>
</tr>
<tr>
<td>LASES</td>
<td>25% (22/87)</td>
<td>34% (30/87)</td>
<td>24% (21/87)</td>
<td>16% (14/87)</td>
</tr>
<tr>
<td>SASES</td>
<td>7% (1/14)</td>
<td>57% (8/14)</td>
<td>21% (3/14)</td>
<td>14% (2/14)</td>
</tr>
<tr>
<td>SESA</td>
<td>7% (2/30)</td>
<td>53% (16/30)</td>
<td>20% (6/30)</td>
<td>20% (6/30)</td>
</tr>
<tr>
<td>SECEC</td>
<td>16% (13/83)</td>
<td>28% (23/83)</td>
<td>31% (26/83)</td>
<td>25% (21/83)</td>
</tr>
<tr>
<td>ASES</td>
<td>9% (7/74)</td>
<td>28% (21/74)</td>
<td>41% (30/74)</td>
<td>22% (16/74)</td>
</tr>
<tr>
<td>ALL</td>
<td>21% (71/342)</td>
<td>35% (119/342)</td>
<td>27% (92/342)</td>
<td>18% (60/342)</td>
</tr>
</tbody>
</table>

Only 4% of JSS respondents indicated seeing more than 5 cases per year compared to 25% of SECEC respondents and 22% of ASES respondents.

Concerning treatment, 87% (299/342) of responding surgeons indicated prescribing anti-inflammatory medication ranging from 83 to 100% between societies, which signifies general agreement’ (Fig 1).

Fig 1: Different treatment options

Respondents did not agree on the appropriateness of performing an infiltration. Overall, 55% (186/342) would perform an infiltration, There was a general agreement not to perform a medial clavicle excision (79% (270/342). There were substantial differences between societies with respect to these options. Only 17% of respondents from JSS indicated performing infiltration and 2% medial clavicle resection. The highest proportion
of respondents performing infiltration was in the SASES (93%) and performing medial clavicle resection was SESA (40%).

Fifty-four percent (184/342) of respondents had never performed a medial clavicle resection ranging from 28% in ASES to 94% in JSS (Table 2).

Table 2: How many medial clavicle resections for with symptomatic degenerative sternoclavicular arthritis did you perform during your career?

<table>
<thead>
<tr>
<th></th>
<th>none</th>
<th>1 or 2</th>
<th>3 or 4</th>
<th>5 or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>JSS</td>
<td>94% (51/54)</td>
<td>4% (2/54)</td>
<td>0% (0/54)</td>
<td>2% (1/54)</td>
</tr>
<tr>
<td>LASES</td>
<td>62% (54/87)</td>
<td>28% (24/87)</td>
<td>2% (2/87)</td>
<td>8% (7/87)</td>
</tr>
<tr>
<td>SASES</td>
<td>57% (8/14)</td>
<td>14% (2/14)</td>
<td>14% (2/14)</td>
<td>14% (2/14)</td>
</tr>
<tr>
<td>SESA</td>
<td>47% (14/30)</td>
<td>13% (4/30)</td>
<td>13% (4/30)</td>
<td>27% (8/30)</td>
</tr>
<tr>
<td>SECEC</td>
<td>43% (36/83)</td>
<td>27% (22/83)</td>
<td>14% (12/83)</td>
<td>16% (13/83)</td>
</tr>
<tr>
<td>ASES</td>
<td>28% (21/74)</td>
<td>32% (24/74)</td>
<td>16% (12/74)</td>
<td>23% (17/74)</td>
</tr>
<tr>
<td>ALL</td>
<td>54% (184/342)</td>
<td>23% (78/342)</td>
<td>9% (32/342)</td>
<td>14% (48/342)</td>
</tr>
</tbody>
</table>

Overall, 48% (163/342) would evaluate this procedure as not worth the risk or high risk (Table 3).

Table 3: How do you consider operative treatment of the degenerative sternoclavicular arthritis?

<table>
<thead>
<tr>
<th></th>
<th>not worth the risk</th>
<th>high risk</th>
<th>moderate risk</th>
<th>no risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>JSS</td>
<td>19% (10/54)</td>
<td>20% (11/54)</td>
<td>57% (31/54)</td>
<td>4% (2/54)</td>
</tr>
<tr>
<td>LASES</td>
<td>21% (18/87)</td>
<td>31% (27/87)</td>
<td>44% (38/87)</td>
<td>5% (4/87)</td>
</tr>
<tr>
<td>SASES</td>
<td>14% (2/14)</td>
<td>29% (4/14)</td>
<td>43% (6/14)</td>
<td>14% (2/14)</td>
</tr>
<tr>
<td>SESA</td>
<td>33% (10/30)</td>
<td>23% (7/30)</td>
<td>43% (13/30)</td>
<td>0% (0/30)</td>
</tr>
<tr>
<td>SECEC</td>
<td>22% (18/83)</td>
<td>34% (28/83)</td>
<td>41% (34/83)</td>
<td>4% (3/83)</td>
</tr>
<tr>
<td>ASES</td>
<td>18% (13/74)</td>
<td>20% (15/74)</td>
<td>54% (40/74)</td>
<td>8% (6/74)</td>
</tr>
<tr>
<td>ALL</td>
<td>21% (71/342)</td>
<td>27% (92/342)</td>
<td>47% (162/342)</td>
<td>5% (17/342)</td>
</tr>
</tbody>
</table>

There were significant differences between the number of procedures and the risk evaluation of the procedure. Fifty-four percent of respondents that had never performed this procedure (100/184) evaluated the risk as not worth the risk or high risk while 44% (48/110) of those that have performed between 1 and 4 procedures and 31% (15/48) of those that performed 5 or more procedures assessed that same high or prohibitive level of risk (p=0.010).
Discussion

This study illustrates the diversity of approaches in current practice in the treatment of symptomatic sternoclavicular arthritis. The response rate for different societies was between 4 and 35%, which in most cases is lower than the rate of other surveys of this type (16-18). In our opinion, one of the main reasons for this low rate is the fact that symptomatic degenerative sternoclavicular arthritis is rare in contrast to pathologies discussed in other surveys and operative treatment is uncommon in daily practice (19). Surgeons may feel that their opinion is not relevant due to their lack of experience in this area. This hypothesis is also described by Chassin et al. as the ‘enthusiasm hypothesis’ which postulates that the variation is due to differences in surgeons’ enthusiasm for procedures, which may not be evidence-based (19, 20).

Another possible reason is the fact the survey was internet-based. It seems that internet-based survey to surgeons result in a significantly lower response rate than a traditional mailed survey (21). The lowest response rate was from the member of the Japanese shoulder society. This low response rate of Japanese surgeons can probably partially explained by language barriers. An international web-based survey concerning oesophageal cancer had an overall reponse rate of 47% but the response of Japanese surgeons was only 22% (22). But also cultural reasons are possible. A japanese web-based study of Yasunga et al to all japanese thoracic surgeons described only a response rate of 7,3% (20).

The frequency of symptomatic degenerative arthritis has not been described before. In contrast, the prevalence of sternoclavicular osteoarthritis on technical investigations has been described in several cadaveric studies (2-5), all conducted in North America. Kier et al described that moderate or severe radiographic changes of osteoarthritis were uncommon in specimens younger than age 40, but present in 53% older than age 60 (4). To our knowledge only one study described differences in rates of sternoclavicular degeneration based on ethnicity. Silberberg described that there was a higher susceptibility
to arthritis in African Americans as compared to European Americans based on the considerably lower age (28.5 years as compared to 41.3 years) at which articular age changes were seen in the former. When evaluating osteoarthritis in other joints, it seems that the prevalence in other parts of the world are the same or even higher than the causation population. (23, 24). This would suspect that the prevalence of degenerative osteoarthritis on technical investigations is also minimally the same in the rest of the world.

Our survey results suggest that the prevalence of symptomatic degenerative arthritis may be less common in Japan compared to Europe and North-America. This may explain, at least in part, the lower number of medial clavicle resections performed by respondents from the JSS compared to other societies. Respondents from JSS indicated the procedure as high-risk or not worth the risk which may be related to the relatively lower experience in this area. Currently there is no clear reason to describe this difference.

There was a general agreement on the use of anti-inflammatory medication, but no clinical agreement was found on the use of intra-articular injections. Degenerative arthritis of the acromioclavicular joint is commonly treated with the intra-articular injections (25) using a combination of a local anaesthetic and cortico-steroids. After accurate infiltration, reduced pain and increased shoulder function can be expected in up to 3 weeks (26, 27). In contrast, only 55% of the responding surgeons would perform an intra-articular injection of the SC joint in case of symptomatic degenerative pathology. Limited understanding of the anatomy and infiltration technique is a possible reason (5). It has been described that intra-articular injection at the sternoclavicular joint is a challenging procedure and even a highly experienced physician cannot guarantee success (28). In difficult or doubtful cases, ultrasound guidance of the intra-articular puncture is recommended as a means of preventing unintended peri-articular injection and subsequent complications (28).

Concerning medial clavicle resection, there was a general agreement not to perform this
procedure. Only 21% of the surgeons would perform a medial clavicle resection if conservative treatment failed in degenerative symptomatic sternoclavicular osteoarthritis. In contrast, lateral clavicle resection (open or arthroscopic) for degenerative acromioclavicular arthritis is commonly performed if conservative treatment fails (29). To our knowledge, only five articles have described the results of medial clavicle resection in cases of degenerative arthritis. In 1942, Westermann was the first to describe the procedure in one patient with a good result (6). Arlet et al described good results in two patients (30). Bremer et al described good results in six patients that were treated with a synovectomy and excision of the medial inch of the clavicle (9). Pingsmann et al described the mid-term clinical results of the surgical treatment of primary degenerative arthritis of the sternoclavicular joint in eight women. Four patients had an excellent result, three good, and one poor (10). In 2013, Tytherleigh-Strong et al reported the results of a series of 10 patients who underwent an arthroscopic excision of the sternoclavicular joint for osteoarthritis. The clinical results were rated as excellent in seven patients, good in two, and fair in one (11). This means, in total, the results of only 27 cases have been described in literature. In contrast, 18% of survey participants responded that they have performed 5 or more medial clavicle resection during their career. This means that this procedure is probably performed more frequently than would be expected in literature.

When performing operative treatment in the region of the sternoclavicular joint there are several concerns, including damage to the underlying mediastinal structures, instability, and scarring (11). Forty-eight percent of survey participants described medial clavicle resection as either high-risk or not worth the risk. Even though there was a difference in the percentage of surgeons that performed more than 5 operations, the impact on their evaluation of risk of the operation was small. Life-threatening events have been described after traumatic posterior dislocation, but also from inappropriate surgical management. These iatrogenic complications are most notable when using K-wires to stabilize the joint
in posttraumatic lesion (31-35). These wires can break or migrate, perforating the large
coloes or the cardiac cavities. In contrast, the literature describing the results of
medial clavicle resection did not describe any per- or postoperative complications (9-11).
The significance of survey studies like ours is that this information allows for the
identification of areas of disagreement, and can direct future research. Based on the
findings of the current study, it would be useful to investigate both the effects of
infiltration in patients with SC degenerative arthritis and complications in a larger series of
medial clavicle resections. A major limitation of this study is the low response rate,
attributable, in part, to the low incidence of this condition with a limited number of
surgeons actually involved in managing such cases.

Conclusion
To conclude, we can state that orthopaedic surgeons do not frequently see patients with
symptomatic degenerative arthritis of the SC joint. There is a general agreement to treat
these patients with anti-inflammatory medication. There is a general agreement not to
perform a medial clavicle resection. This is in contrast with the acceptable results of this
operative treatment described in literature. There seems to be a difference in frequency and
proposed treatment options between national and international societies in managing such
cases.

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3. Diagnostic values of tests for sternoclavicular joint pain

A Van Tongel M.D.¹, A Karelse M.D.¹, ², B Berghs M.D.³, T Van Isacker M.D.⁴,  L DeWilde M.D. Ph.D.¹.

¹ Department of Orthopaedic Surgery and Traumatology, Ghent University Hospital, De Pintelaan 185, B-9000 Gent, Belgium
² Department of Orthopaedics and Traumatology, Zorgsaam Terneuzen Wielingenlaan 2, 4535 PA Terneuzen, The Netherlands
³ Department of Orthopaedics and Traumatology, Upper Limb Unit, AZ Sint-Jan AV Brugge - Oostende, Campus Brugge, Ruddershove 1, B-8000 Brugge, Belgium
⁴ Department of Orthopaedics and Traumatology, AZ Sint-Lucas Brugge , Sint Lucaslaan 29, B 8310 Brugge, Belgium

(submitted BMC)

Abstract

Background: Sternoclavicular (SC) arthropathy is an uncommon cause of mechanical pain. To our knowledge no clinical and imaging tests have been evaluated to determine which tests are most helpful in diagnosing SC joint pain. The aim is to evaluate the diagnostic value of 5 clinical tests and CT-scan imaging in patients with sternoclavicular arthropathy.

Material and methods: All patients between June 2011 and October 2013 that visited our departments with atraumatic pain in the area of the SC joint were evaluated. Prominence, pain at palpation, pain during arm elevation, and CT images were evaluated. In addition two newly described tests were evaluated: pain during active scapular protraction and retraction. Next the patients were divided into two groups according to whether they had a ≥50% decrease in pain following the sternoclavicular joint injection with a local anesthetic.

Sensitivity and specificity for the 5 clinical tests and CT-scan was measured.

Results: Forty eight patients were included in this study and SC joint pain was confirmed in 44 patients. The tests with highest sensitivity are pain on palpation, (93% sensitivity)
and pain during active scapular protraction (86%). CT-scan showed a sensitivity of 84%.
Prominence showed a high specificity (100%)

Conclusion: Tenderness and pain during active scapular protraction have a high diagnostic value in patients with sternoclavicular arthropathy.

Introduction

Patients experience joint pain as pain localized in the area of the joint. Clinically this is reproducible by pain provocation tests, and ideally completely relieved by infiltration of the symptomatic joint with local anesthetics (1).

Sternoclavicular (SC) joint pain is uncommon but the joint is subject to the same disease processes that occur in other joints. Patients are mostly consulting because of localized swelling and/or mechanical pain at the level of the SC joint (2-4). However pathology of the SC joint can also cause referred pain to areas distant from the joint. This pain should be differentiated from pain originating from the cervical spine, glenohumeral or acromioclavicular joint or costochondritis (5-7). The most common used imaging technique to evaluate SC pathology is computertomography (CT) (8-11).

In contrast to commonly used active tests of the shoulder girdle (12-15), to our knowledge, no clinical and imaging tests for evaluation of SC arthropathy have been evaluated.

The aim of this study is to evaluate the diagnostic value of three common shoulder tests, two new clinical tests and of CT-scan imaging used in patients with SC arthropathy.

Material and methods

All patients that visited our department between June 2011 and June 2013 with a history of atraumatic pain in the area of the SC joint included in this retrospective study.

Exclusion criteria included (1) previous sternoclavicular surgery, (2) atraumatic SC instability, (3) previous or known allergies to lidocaine and (4) refusal of a reference
standard injection lidocaine test.

Age, sex, hand dominance, affected arm, onset and duration of pain were documented. All patients were examined bilaterally in upright and supine position using a standard protocol. This included inspection and clinical examination of the neck and shoulder region. Prominence of the SC joint (Fig 1) and pain on palpation of the SC were registered.

Figure 1: clinical prominence of the right clavicle

We measured the active and passive range of motion of the neck. With regard to the shoulder, active and passive forward flexion, abduction, internal and external rotations were measured by visual estimation. If active flexion above 100° was painful at the SC joint area, the test was called positive. Next the patient was asked to actively perform maximal protraction and retraction of the shoulder girdle in an upright position and pain during these tests was evaluated (Fig 2).

Fig 2a: normal position  Fig 2b: active scapular retraction  Fig 2c: active scapular protraction
Reference Test Standard

The reference test standard was an ultrasound guided SC joint infiltration, of 1 mL of 2% (v/v) lidocaine (16). All patients with pain in the SC area were injected by one of the authors. Patients sensing alleviation of pain with 50% or more, within ten minutes after the lidocaine injection, were considered to have SC joint pain; i.e., they had a positive reference test standard. Patients with less than 50% pain relief were considered to not have SC joint pain (1). If there was a positive reference test is an ultrasound guided SC joint infiltration of 1 mL (40 mg) of methylprednisolone was given (16, 17).

Imaging Studies

All patients were positioned in the CT gantry according to a previously described method, i.e., in dorsal recumbency, with a cushion on the belly and a strap around the body and this cushion, to keep the arm adducted in the coronal plane and the forearm flexed in the sagittal plane of the body (18). This standardized position mimics a reproducible surgical position and minimizes positional errors (18). Radiographic parameters of rheumatoid or osteoarthritis (bone cyst, osteophytes, narrowing of the joint space, anterior subluxation), hyperostosis of the sternum, clavicles, and upper ribs (sternocostoclavicular hyperostosis (SCCH)), obliteration of the marrow space (condensing osteitis), irregularity of SC joint with bony destruction of medial end of clavicle (friederich disease) or joint effusion, bone and cartilage erosions, gas within the joint, and soft tissue swelling (septic arthritis) or no abnormality were checked on the CT.

If no abnormality was found on CT but the patient had a positive reference standard test, the pathology was called monoarthritis e causa ignota.

Statistical analysis

Sensitivity, specificity, positive and negative predictive values of the clinical diagnostic
tests were determined with the methods described by Sackett et al.(19).

A likelihood ratio expresses the odds of a diagnostic test result being found in a patient with, as opposed to a patient without, abnormality of the acromioclavicular joint. In the case of single tests, the formula for determining the likelihood ratio (LR) is \( LR = \frac{\text{sensitivity}}{1 - \text{specificity}} \).

To investigate the value of clinical and imaging tests for predicting pain due to sternoclavicular joint abnormality, forward stepwise regression was used with the result of the sternoclavicular joint infiltration as the dependent variable. At each step, an explanatory variable was automatically added to the model, provided that the variable was significant. All statistical calculations were performed with SigmaStat for Windows (SPSS, Chicago, Illinois).

**Results**

*Patient demographics*

Between June 2011 and June 2013 48 patients with unilateral atraumatic pain in the area of the SC who met our inclusion criteria were enrolled in this study.

There were 9 men and 39 women, with an average age of 60 years, ranging from 23 to 74 years. 41 patients were right-handed and the dominant shoulder was involved in 40, while the nondominant arm was affected in 8. All patients reported an insidious onset of symptoms. Average duration of symptoms was 11 months (range, 3-24).

No patients showed clinical signs of cervical pathology.

*SC arthropathy*

44 patients were confirmed to have SC joint abnormality by their response to the SC joint injection. Thus, the prevalence of SC arthropathy in this patient population was 90%. This high prevalence indicates that pain in the SC region is itself a reliable sign for SC joint pain. 4 patients had no relief of pain after the injection.
These positive and negative (control) groups were compared with regard to their responses to the clinical and imaging tests.

The most sensitive clinical test for identifying SC joint abnormality as the cause of shoulder pain was examination for local SC joint tenderness (93% sensitivity), followed by the pain during active protraction (86%). CT showed a sensitivity of 84% (Table 1). When each test was considered on its own, prominence and CT-imaging were found to have the highest likelihood ratio as a result of the high specificity. 4 different pathologies were diagnosed (Table 2).

Table 1: sensitivity, specificity, predictive value of clinical and imaging test

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>sensitivity</th>
<th>specificity</th>
<th>positive predictive value</th>
<th>negative predictive value</th>
<th>likelihood ratio for positive test</th>
</tr>
</thead>
<tbody>
<tr>
<td>tenderness</td>
<td>93%</td>
<td>25%</td>
<td>93%</td>
<td>25%</td>
<td>1,24</td>
</tr>
<tr>
<td>prominence</td>
<td>61%</td>
<td>100%</td>
<td>100%</td>
<td>0%</td>
<td>∞</td>
</tr>
<tr>
<td>pain active protraction</td>
<td>86%</td>
<td>50%</td>
<td>95%</td>
<td>25%</td>
<td>1,72</td>
</tr>
<tr>
<td>pain active retraction</td>
<td>45%</td>
<td>75%</td>
<td>95%</td>
<td>11%</td>
<td>1,8</td>
</tr>
<tr>
<td>pain active elevation</td>
<td>84%</td>
<td>50%</td>
<td>93%</td>
<td>14%</td>
<td>1,68</td>
</tr>
<tr>
<td>CT</td>
<td>84%</td>
<td>100%</td>
<td>100%</td>
<td>0%</td>
<td>∞</td>
</tr>
</tbody>
</table>

Table 2: differential diagnosis

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Number of patients</th>
<th>average age (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degenerative arthritis</td>
<td>33</td>
<td>56 years (44-74)</td>
</tr>
<tr>
<td>sternocostoclavicular hyperostosis</td>
<td>2</td>
<td>37 and 42 years</td>
</tr>
<tr>
<td>Reumatoid arthritis</td>
<td>2</td>
<td>38 and 62 years</td>
</tr>
<tr>
<td>Monoarthritis e cause ignota</td>
<td>7</td>
<td>36 years (24-46)</td>
</tr>
</tbody>
</table>

Stepwise regression analysis was carried out with use of the response to the injection as the dependent variable and age, sternoclavicular joint tenderness, prominence, pain during active protraction, pain during active retraction, pain during elevation and CT-imaging as the independent variables. Age, sternoclavicular joint tenderness, prominence, pain during
active protraction, pain during active retraction, pain during elevation did not significantly add to the ability of the equation to predict who had true sternoclavicular joint pain. Thus, they were not included in the final equation. The only independent variables retained in the stepwise regression model was CT-imaging (unstandardized coefficient 0.274, standard error 0.092, P value 0.005).

**Discussion**

SC arthropathy is an uncommon cause of pain. The location of pain originating from the SC joint can be diverse and patients are often not able to identify the exact location. Because of its rarity, accurate diagnosis is often delayed. Clinical tests of the joint that can be included in the normal shoulder examen could help to obtain a sooner diagnosis and treatment for patients with SC arthropathy.

In literature, three clinical tests have been described: tenderness by palpation, a prominent clavicle and pain during active elevation (20-23). But to our knowledge this is the first time the sensitivity and specificity of these test have been evaluated.

Local tenderness is the most sensitive test for SC arthropathy (93%) but with a low specificity. Tenderness is also the most sensitive test in evaluating acromioclavicular arthropathy (1).

Pain in the SC region during arm elevation above 100° showed a high sensitivity (84%). But a problem with this test is that it requires the combined motion of the SC, acromioclavicular, glenohumeral, and scapulothoracic joints. This means that in some cases of glenohumeral pathology (frozen shoulder, pseudoparalysis) this test cannot be used. This is a reason why we described the active scapular protraction and retraction. In our opinion, this motion tries to isolate the SC motion as much as possible. Inman et al described that during scapular protraction and retraction of the shoulders, no appreciable motion occurs at the acromioclavicular joint or any great rotation of the clavicle. He stated
that scapular protraction and retraction is occurring predominantly at the SC joint (24). Abott et al described that during retraction and protraction of the shoulder the scapula describes an arc of 50 degrees around the SC joint. In the average individual the clavicular motion is 35 degrees at the SC joint and scapular movement at the acromioclavicular joint accounts for 15 degrees (25). By performing active scapular protraction and retraction the motion at the glenohumeral joint and the acromioclavicular joint is minimized.

Anatomical study of the SC joint showed that the articular surface of the clavicle is located antero-inferiorly. This means active scapular protraction creates a compression and active scapular retraction a distraction of the joint.

Scapular protraction showed a high sensitivity (91%) in contrast to scapular retraction (39%). It also shows a higher specificity than tenderness. Similar to the clinical test for the AC joint it seems that compression of the SC joint is more sensitive to diagnose sternoclavicular arthropathy than distraction (26).

The high specificity of clavicular prominence for SC pathology is probably not correct because for example bone tumors also can be a cause of prominence of the medial clavicle but we did not see those patients in our clinic.

14% of the patients were diagnosed with mono-arthritis e causa ignota because no pathology was withhold on CT-images. We did not perform bone-scanning or a magnetic resonance imaging because they all had a longterm positive effect of the infiltration.

CT has been described as superior to other imaging techniques to evaluate sternoclavicular arthropathy (8-11). Possible diagnosis that can be missed by CT-scan are meniscal tear, crystal deposition disease and first-stages of inflammatory or degenerative arthritis. Atraumatic anterior subluxation is another atraumatic disorder of the sternoclavicular joint but is in contrast to the other atraumatic pathologies not painful. CT was the independent variable to predict who had true sternoclavicular joint pain. But a problem is the fact that the negative control group was small. Signs of degenerative osteoarthritis are a common
finding on technical investigations in elderly people (8, 27). If the negative group would have been larger, the significance of positive CT-images would probably not be that important.

This study is unique because, to our knowledge, no one has previously described active isolated thoracoscapular to evaluate SC arthropathy. This is also the first time the value of different tests used to diagnose sternoclavicular joint pain is evaluated.

Our study also has several weaknesses. First, the study group consisted of a relatively small number of patients who fulfilled the inclusion criteria. Second, several other causes of SC arthropathy (seronegative spondyloarthropathic, septic arthritis) were not seen in our patient population.

**Conclusion**

Tenderness and pain during active scapular protraction have a high diagnostic value in patients with sternoclavicular arthropathy.

**References**


**Acknowledgements**

We want to thank Iwein Piepers for his statistical support.
4. Relationship of the medial clavicular head to the manubrium in normal and symptomatic degenerative sternoclavicular joints.

A Van Tongel M.D., J Valeke Msc., I Piepers Msc., T Verscheuren M.D., L De Wilde M.D. Ph.D.

Department of Orthopaedic Surgery and Traumatology, Ghent University Hospital, De Pintelaan 185, B-9000 Gent, Belgium

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Abstract

Background: Clavicular prominence is common in patients with symptomatic degenerative sternoclavicular (SC) arthritis. It is unclear if this is caused by enlargement or subluxation of the clavicle. The aim of this study is to describe a reproducible measuring technique to evaluate the relationship of the medial clavicular head to the manubrium.

Material and methods: 100 normal SC joints, 25 SC joints with symptomatic degenerative arthritis and 25 non-symptomatic SC joints at the contra-lateral side were 3D reconstructed using computer modeling. A frontal plane based on the manubrium was determined. Next, through the clavicular notches, an axial plane was created perpendicular to the frontal plane. The greatest width (AP) and height (SI) of the clavicle in sagittal plane were measured. Next the position of the anterior border and superior border of the medial clavicle and the distance to respectively the frontal plane (AFr) and axial plane (SAx) were evaluated. At last the ratio AP/AFr was measured to evaluate the anteroposterior position of the clavicle and the ratio SI/SAx to evaluate its superoinferior position. If the ratio was not in the 95% prediction interval, the clavicle was defined as subluxated. The reproducibility of this technique was evaluated using inter- and intra-observer reliability.

Results: This technique showed a good inter and intra-observer reliability. The mean
antero-posterior and supero-inferior distance was significant larger in symptomatic SC arthritis compared to the normal SCJ (p<0.001). The clavicle in symptomatic SC arthritis was anterior subluxated in 22 out of 25 but not superior subluxated.

Conclusion: The medial clavicular head in degenerative SC arthritis is significant larger than in the normal population. In this group of symptomatic sternoclavicular arthropathy clavicles most clavicles are anterior subluxated.

Introduction
Symptomatic degenerative sternoclavicular (SC) arthritis is infrequent (1, 2) and effective management is often hindered by a limited understanding of the anatomy and the pathology (3). Often these patients are consulting because of swelling and/or mechanical pain at the level of the sternoclavicular joint. Clinical examination sometimes reveals a prominent clavicle (4-7). To our knowledge, it has not been evaluated if this prominence is caused by bony enlargement and osteophytes or by a subluxation of the clavicle.

In the past the relationships between the bones of a joint was evaluated with 2D imaging techniques (8). Currently, three-dimensional measurement techniques are used. 3D CT scan reconstruction improves the accuracy of the measurements because of its independence from positional errors. This technique can facilitate determination of the amount and the direction of the joint subluxation (9, 10).

The aim of this study is to describe a reproducible measuring technique to evaluate the relationship of the medial clavicular head and the manubrium in a normal population and patients with painful prominence related to SC arthritis.

It was hypothesized that the prominence was caused by both an enlargement of the clavicle due to osteophytes and an anterosuperior subluxation of the clavicle.
**Material and methods**

Approval was obtained from the local ethical committee.

Two groups of patients were evaluated: a group (Group 1) of young adult patients without any sign of pathology at the sternoclavicular joint and a group (Group 2) of patients with painful prominence of the related to SC arthritis.

Group 1 included patients between 24-35 years old for whom a CT-scan was planned for evaluation of pathology of a shoulder and who did not have sternoclavicular pathology. Both shoulders and sternoclavicular joints were scanned simultaneously, therefore obviating the need for supplementary irradiation. Other pathology of the sternoclavicular joint to be studied (traumatic or atraumatic instability, inflammatory disease like sternocostoclavicular hyperostosis or reumatoid arthritis, osteitis condensans, septic arthritis) was excluded by physical examination and history. The CT scans were inspected for structural bony lesions of the clavicle (e.g., cysts and visible bony deformations of clavicle) and if such lesions were present, the subject was excluded. The final group of 50 subjects included patients with instability (30), calcifying tendinitis (7), frozen shoulder (5) and fractures of the proximal humerus (8). The age of the patients (25 females and 25 males) was between 24 and 35 years (mean 26.9 years).

Group 2 all had clinical signs of symptomatic SC arthritis. (mechanical pain at the SC joint and swelling) and this was confirmed on CT (bone cyst, osteophytes, narrowing of the joint space) (Fig 1).
The mean age was 61.6 years. All patients were positioned in the CT gantry according to a previously described method, i.e., in dorsal recumbency, with a cushion on the belly and a strap around the body and this cushion, to keep the arm adducted in the coronal plane and the forearm flexed in the sagittal plane of the body (11). This standardized position mimics a reproducible surgical position and minimizes positional errors.

Image analysis and interpretation

A Somatom Volume Zoom – Siemens CT (Siemens, Erlangen, Germany) with a matrix set to 512Å~512, kV:140/eff. mAs: 350 was used. The field of view (FOV) was adapted to each individual patient. This resulted in a maximum of 500 mm for both shoulders and 180 mm for 1 shoulder with a pixel size of no more than 0.97 or 0.35 mm, respectively. The glenohumeral and sternoclavicular joint was scanned with maximum 1.5-mm interval slices.

Three independent investigators imported the DICOM CT images into medical imaging computer software (Mimics 14.12 for Intel X86 Platform V14.0.0.90 1992-2012 Materialise n.v. Haasrode Belgium) to create three dimensional images of the sternoclavicular joint. Both bones of the sternoclavicular joint could be separated digitally and virtually manipulated.
An important part of this technique is the definition of the frontal plane. To our knowledge, this study is the first to describe a frontal plane as a best fitting plane on an area on the manubrium. This consistent area appears to represent a structural adaptation of bone to mechanical loading as have been described in other bones (12, 13). This triangular area is based on the Y-shaped area that can be seen when putting the manubrium against a bright light or in 3D CT-reconstructed manubrium (Fig 2).

Figure 2: a manubrium held against a light

This is the area that was described by Xiu et al as the bare area that can be used to take autologous bone-graft (14). The attachment of the pectoralis major covers the medial and lateral border of the triangle (14).

With the use of computer modeling (3-matic®) the best fitting plane was determined, according to this triangular zone (Fig 3) and this plane was called the frontal plane.

Figure 3: determination of the best fitting plane based on a consistent triangular area in the manubrium
The axial plane was the plane perpendicular to the frontal plane and going through the highest point left and right from the presternal notch (suprasternal notch) (Fig 4).

Subsequently, using the same computer modeling technique, in the sagittal plane of the body, we determined the intersection point of the most anterior (A) and posterior (P) point of the medial clavicle with a plane parallel to the frontal plane. Also the intersection point of the most superior (S) and inferior (I) point of the medial clavicle with a plane parallel to the axial plane (Fig 5).

Figure 4: determination of the axial plane

Figure 5: determination of point A,S,P and I on the medial clavicular head
Next the distance between point A and point P was measured (AP distance) and the distance between point A and the frontal plane (AFr) (positive if posterior to the frontal plane, negative if anterior to frontal plane) (Fig 6).

![Distance frontal plane - point A](image)

Figure 6: measurement of distance between point A and frontal plane

Also the distance between point S and point I (SI distance) was measured and the distance between point S and the axial plane (SAx) (positive if superior to the axial plane, negative if inferior to axial plane) (Fig 7).

![Distance axial plane - point S](image)

Figure 7: measurement of distance between point S and axial plane
This was done for the 100 normal SC joints, the 25 joints with symptomatic SC arthritis and the 25 contralateral SC joints.

Next the ratio between AFr/AP and SAx/SI was measured for all patients. This ratio was used to evaluate the position of the clavicle and to exclude the variability of the AP and SI. The 95% prediction interval was measured for the AFr/AP and Sax/SI of the normal population. If the ratio of the clavicle of the symptomatic degenerative arthritis and the non-symptomatic SC joints at the contra-lateral side was not in this normal range, the clavicle was defined respectively anterior or posterior subluxated or superior or inferior subluxated.

An intra- and interobserver reliability was calculated for all parameters. Two different examiners determined all planes and points and measured all parameters on 30 (20 normal, 5 arthritic side, 5 non-arthritic side). One examiner repeated the measurements with a time interval of 14 days. The intra- and interobserver reliability was assessed by Intraclass Correlation Coefficients (ICC) based on two-way random effect models, using an absolute agreement definition (15). Concerning the interpretation of the ICC: ICC < 0,4 : bad; 0,4 < ICC < 0,59 : acceptable; 0,6 < ICC < 0,74 : good and ICC > 0,74 : excellent.

To evaluate the correlation between the different parameters, the student-t test was used for the normally distributed parameters. For the not normally distributed parameters, Mann Whitney U test was used.

Source of funding

There was no external funding source
**Results**

The intra-observer correlation coefficient and interobserver correlation coefficient was excellent for all measured parameters (Table 1).

**Table 1: intra- and interclass correlation Coefficients**

<table>
<thead>
<tr>
<th></th>
<th>Intraclass correlation</th>
<th>95% confidence interval</th>
<th>Interclass correlation</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal plane</td>
<td>0.93</td>
<td>[0.884-0.984]</td>
<td>0.9</td>
<td>[0.820-0.969]</td>
</tr>
<tr>
<td>Axial plane</td>
<td>0.93</td>
<td>[0.904-0.964]</td>
<td>0.91</td>
<td>[0.845-0.976]</td>
</tr>
<tr>
<td>Distance AP</td>
<td>0.91</td>
<td>[0.842-0.983]</td>
<td>0.92</td>
<td>[0.790-0.974]</td>
</tr>
<tr>
<td>Distance SI</td>
<td>0.89</td>
<td>[0.798-0.989]</td>
<td>0.92</td>
<td>[0.765-0.974]</td>
</tr>
<tr>
<td>Distance point A- Frontal plane</td>
<td>0.93</td>
<td>[0.892-0.975]</td>
<td>0.87</td>
<td>[0.805-0.944]</td>
</tr>
<tr>
<td>Distance point S- Axial plane</td>
<td>0.89</td>
<td>[0.826-0.961]</td>
<td>0.99</td>
<td>[0.960-0.995]</td>
</tr>
</tbody>
</table>

The dimensions measured are listed in in Table 2.

**Table 2: mean distance and standard deviation of the several parameters**

<table>
<thead>
<tr>
<th></th>
<th>AP distance (mm)</th>
<th>SI distance (mm)</th>
<th>distance A - frontal plane (mm)</th>
<th>distance S - axial plane (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>normal (N=100)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>left (50)</td>
<td>23.6 +/- 3.3</td>
<td>23.1 +/- 3.3</td>
<td>0.8 +/- 2.6</td>
<td>17.6 +/- 3.9</td>
</tr>
<tr>
<td>right (50)</td>
<td>23.5 +/- 2.8</td>
<td>23.4 +/- 3.3</td>
<td>0.8 +/- 2.8</td>
<td>18 +/- 3.9</td>
</tr>
<tr>
<td>female (50)</td>
<td>22.4 +/- 2.2</td>
<td>22.7 +/- 3.2</td>
<td>0.8 +/- 2</td>
<td>17.5 +/- 4.2</td>
</tr>
<tr>
<td>male (50)</td>
<td>24.9 +/- 3.2</td>
<td>23.5 +/- 3.4</td>
<td>0.8 +/- 3.1</td>
<td>17.6 +/- 3.8</td>
</tr>
<tr>
<td>symptomatic SC arthrosis (N=25)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>female (20)</td>
<td>27.8 +/- 3.7</td>
<td>26.0 +/- 2.8</td>
<td>-7.4 +/- 2.8</td>
<td>19.4 +/- 3.1</td>
</tr>
<tr>
<td>male (5)</td>
<td>32.1 +/- 4.3</td>
<td>27.4 +/- 1.3</td>
<td>-6.6 +/- 2.3</td>
<td>20.9 +/- 2.6</td>
</tr>
<tr>
<td>asymptomatic contralateral (N=25)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>female (20)</td>
<td>25.0 +/- 2.5</td>
<td>23.5 +/- 2.0</td>
<td>-1.2 +/- 2.1</td>
<td>18.1 +/- 4.2</td>
</tr>
<tr>
<td>male (5)</td>
<td>23.8 +/- 2.1</td>
<td>23.4 +/- 3</td>
<td>-1.3 +/- 2.4</td>
<td>17.8 +/- 4.0</td>
</tr>
</tbody>
</table>

In the Group 1 (normal population), the AP distance was greater in males when compared to females (p < 0.001). There was no significant difference between normal male and female for all the other parameters. There was no significant difference for all parameters.
between left and right. Also in the symptomatic and the contralateral side the AP distance is greater in males when compared to females (p= 0,002 and p < 0,001).

The AP distance of the clavicular head was greater on the symptomatic arthritic side compared to the non-symptomatic contralateral side (p= 0,004) and compared to the normal population (p<0,001). There was no significant difference in the AP distance between the non-symptomatic contralateral side and the normal population (p=0,085). The SI distance of the clavicular head is greater in the symptomatic arthritic side compared to the non-symptomatic contralateral side (p= 0,01) and compared to the normal population (p<0,001). There is no significant difference for the SI distance between the non-symptomatic contralateral side and the normal population (p=0,279).

The distance of point A and the frontal plane is greater in the symptomatic arthritic side compared to the non-symptomatic contralateral side (p<0,001) and compared to the normal population (p<0,001). The distance of point A and the frontal plane also is greater in the non-symptomatic contralateral side compared to the normal population (p<0,001).

The 95% prediction interval of AFr/AP in the normal population was between 0.17 and -0.17 (mean 0). In 22 out of 25 patients the symptomatic arthritic involved side had anterior subluxation with a ratio between -0.13 and -0.51). On the non-symptomatic contralateral side 2 out of 25 patients had anterior subluxation. The ratio in the non-symptomatic contralateral side group was between 0,12 and -0,20 (Fig 8).

The distance of point S and the axial plane was greater in the symptomatic arthritic side compared to the normal population (p=0,0034). There was no significant difference between the distance of point S and the axial plane between the symptomatic arthritic side compared to the non-symptomatic contralateral side (p=0,219) and between non-symptomatic contralateral side and the normal population (p=0,551).
The 95% prediction interval of SAx/SI in the normal population was between 0.55 and 0.97 (mean 0.76). In the arthritic side no patients showed signs of superior subluxation with a ratio between 0.64 and 0.93. The non-arthritic side of the subject patients did not have superior subluxation. The ratio of the non-arthritic groups was between 0.62 and 0.93. (Fig 9).

Discussion
Symptomatic sternoclavicular arthrosis is not common. The swelling in patient with SC arthrosis has been described clinically as a subluxation. CT evaluation of subluxation of the clavicle has been done before but this was in 2D without any quantification and in patients with osteitis condensans (16). To our knowledge this is the first time that the subluxation have been quantified in these group of patients with symptomatic degenerative arthritis.

The present study demonstrates that the three-dimensional sternoclavicular relationship can
be quantified reliably with low variability using three-dimensional computed tomography (CT) reconstruction in vivo.

When defining the best fitting plane of the bare area of the manubrium (14) the intra-observer correlation coefficient and interobserver correlation coefficient was excellent (0.93 and 0.9).

In patients with symptomatic degenerative arthritis, clinical examination sometimes reveals a prominent clavicle. Two reasons may attribute to this prominent clavicle 1) the clavicle is anteriorly subluxated and/or 2) the clavicle is larger. The width of clavicle is indeed statistically larger than in the normal population (on average 4,2 mm) but this widening is not as high as the anterior displacement (on average 8,4 mm difference). This means anterior subluxation of the clavicle is certainly involved.

In the sagittal plane the articular surface is, on average, directed 70 degrees inferiorly (17). This means that a superior subluxation component would be suspected if there is anterior
subluxation. This study showed that although there was a significant difference of the distance of point S and the axial plane between the arthritic side compared to the normal population, no patients were superior subluxated. A possible explanation can be found in the fact that the joint space has diminished. Another possibility could be that there is also an erosion of the anterior surface of the manubrium. This means that the clavicle would not need to migrate that much superior to obtain an anterior migration.

The first line treatment for symptomatic sternoclavicular arthritis is conservative with NSAID, relative rest or an intra-articular corticosteroid injection.

If conservative treatment fails medial clavicle resection has been proposed (18-21). Several different techniques of resection have been proposed (18, 22, 23) and the results have been described in only a few case-reports as good (24).

The clinical importance of this study lies in the fact that this current treatment of a medial clavicle resection will not correct the degenerative process of subluxation but it is not known if this correction is necessary to obtain a good result.

There are several weaknesses concerning this study. We did not have an objective score for all symptomatic patients to obtain a correlation between the degree of subluxation and the clinical symptoms. Another weakness is the fact we used the asymptomatic side as a control group and not a normal population of the same age. However, because there was no statistical difference between the normal young population and the asymptomatic side, we believe the asymptomatic side can be indicative normal population of the same age.

Conclusion

With the use of this new developed reproducible measuring technique, the morphology and the position of the medial clavicular head relative to the manubrium can be evaluated adequately. With the use of this technique it has been demonstrated that the clavicular prominence in patients with symptomatic sternoclavicular arthropathy is the result of both
bony enlargement and anterior subluxation of the clavicle. Determination of the clinical relevance of these findings will require further research.

References


5. Arthroscopy of the sternoclavicular joint: an anatomic evaluation of structures at risk

A Van Tongel M.D.1, T Van Hoof PT Ph.D.2, N Pouliart M.D. Ph.D.3, P Debeer M.D. Ph.D.4, K D’Herde M.D. Ph.D.2, L De Wilde M.D. Ph.D.1

1 Department of Orthopaedic Surgery and Traumatology, Ghent University Hospital, De Pintelaan 185, B-9000 Gent, Belgium
2 Department of Basic Medical Sciences, Anatomy and Embryology group, University of Ghent, Ghent, Pintelaan 185, B-9000 Gent Belgium.
3 Department of Orthopaedics and Traumatology, Universitair Ziekenhuis Brussel, Laarbeeklaan, 101, 1090 Brussels, Belgium.
4 Department of Musculoskeletal Science, Division of Orthopedics, Pellenberg University Hospital, Weligerveld 1, B-3212 Pellenberg, Belgium


Abstract

Introduction: Recently arthroscopy of the sternoclavicular joint (SCJ) has been described in clinical setting. The aim of this study is to examine the accessibility and safety of the SCJ by arthroscopy in a cadaveric model.

Material and Methods: An inferolateral and superomedial portal to the SCJ was created in 20 cadaveric specimens. After debridement, the specimens were dissected with a needle positioned in the portal tracts. The distance between the needles and bony landmarks, tendons and ligaments were measured. The integrity of the posterior capsule was evaluated macroscopically. In 8 specimens, after anterior dissection, the needles were replaced by K-wires that perforated the posterior capsule to evaluate the distance to the neurovascular structures behind the SCJ.

Results: Both portals were found to be safe while allowing good access to the joint. The superomedial portal went through the tendon of the sternocleidomastoideus muscle and the
inferolateral portal through the pectoralis major muscle. The portals entered the capsule medial and lateral to the anterior sternoclavicular ligament. The posterior capsule was never perforated during debridment. The perforating K-wires, however, usually perforated either a major vein or artery, but were at a safe distance from the vagal nerve.

Conclusions: In this cadaver study, arthroscopy of the sternoclavicular joint could be used as a minimally invasive procedure allowing debridement of the joint without damaging the posterior capsule of the joint. If the capsule is inadvertently be breached, a major risk of neurovascular damage exists. We advise to have a backup of a cardiothoracic surgeon when performing this procedure.

Keywords: arthroscopy; sternoclavicular joint; aorta; innominate vein; nervus vagus; safety.

Introduction

Pathologies of the sternoclavicular joint (SCJ) are infrequently reported in the medical literature (1). Nevertheless, the SCJ is subject to the same disease processes that occur in other joints, including degenerative arthritis, rheumatoid arthritis, infection and trauma. Most of these conditions present with swelling of the joint, which may be associated with pain and/or tenderness (2). If conservative treatment fails, operative treatment is sometimes proposed (3-6).

In contrast to an expanding range of indications for open or arthroscopic surgery for the glenohumeral and acromioclavicular joints, techniques for the treatment of SCJ pathology are rarely described. In contrast to many articles on arthroscopy in other joints, only three case-reports discussed the use of arthroscopy in the SCJ (7, 8). To the best of our knowledge, no studies have been described examining the safety or accessibility of arthroscopy of the SCJ.

The purpose of this study was to examine the safety and accessibility of the SCJ by
arthroscopy with debridement of the joint through inferolateral and superomedial portals in a cadaveric model. We hypothesized that arthroscopic debridement of SCJ is feasible without damaging the ligaments and without perforating the posterior capsule.

**Material and Methods**

Twenty specimens of 10 adult cadavers were used for this study. The mean age was 80 years old (range from 62 to 92 years old). None of the cadavers had any previous surgery in this area (no signs of sternotomy, no incisions in the clavicular or shoulder regions). None of the cadavers had macroscopic signs of malunion or non-union of the clavicle. There was no stiffness during shoulder movement. Each specimen was placed in the supine position with a small sandbag between the shoulder blades.

For an increased working range, especially for instruments in the superomedial portal, the head was positioned in slight extension and contralateral rotation on a head-ring. The surgeon (AVT) was positioned ipsilaterally and the video tower contralaterally at the height of the thorax of the patient.

Each sternoclavicular joint was submitted to the following protocol. The inferolateral portal was established with a needle at the level of the joint line, just lateral to the anteroinferior border of the clavicle, which was angulated +/- 45° to frontal plane and +/- 30° to axial plane. The needle needed to perforate through the thin anterior-inferior part of the capsule where it is only attached to a small rim on the anterior part of the clavicle (9).

Next a superomedial portal needed to be made. The soft spot medial from the anterior SC ligament can be used to gain access to the sternal part of the joint (9). The superomedial portal was established with a second needle at the joint line in the sternal notch, which was angulated +/- 60° to the frontal plane and +/- 60° to axial plane. This places the needle lateral to the intra-articular disc (Fig 1).
Fluoroscopy was not used for portal placement. Satisfactory portal placement and trajectory were confirmed by when water injected through the inferolateral needle evacuated freely through the superomedial needle. Also clinically there were no signs of subcutaneous extracapsular extravasation.

After making stab incisions with a No. 11 blade, the needles were replaced with a 2.7 mm 30° arthroscope in the inferolateral portal, and a probe in the superomedial portal. A pressure-controlled pump was used with a standard pressure of 25 mm Hg that could be augmented to 50 mmHg during one minute during the procedure. The intra-articular disc was evaluated for signs of degeneration. Then the arthroscope and probe were switched and the intra-articular disc was reevaluated. Finally, debridement of the intra-articular disc with a 3 mm full-radius arthroscopic shaver was performed until a small stable rim was obtained (Fig 2).
Fig 2: View after debridement of the intra-articular disc looking medially from the inferolateral portal

To achieve this, the shaver was initially positioned in the superomedial portal and subsequently switched to the inferolateral portal.

After debridement of both sternoclavicular joints, all specimens were dissected with the needles repositioned in the four portals (left and right side). First, the sternocleidomastoid and pectoralis major muscle were dissected free and evaluated for damage. The width of the sternal part of the sternocleidomastoideus, the distance between its medial border and the superomedial portal as well as the distance between the clavicular attachment of the pectoralis major muscle and the inferolateral portal were measured (Fig 3).

Fig 3a: Anatomic dissection of sternocleidomastoid and pectoralis major muscle following placement of a needle in the inferolateral and superomedial portal.

Fig 3b: Illustration of performed measurements of the portal positions compared to the sternocleidomastoid and pectoralis major muscle.
Then, the sternocleidomastoid and pectoralis major muscles were removed from their bony attachments on sternum and clavicle to disclose the anterior capsule. Damage to the coracoclavicular and anterior SC ligament was evaluated and the distance between the both portals and the anterior SC ligament was measured (Fig 4). All distances were measured with digital calipers with an accuracy of 1 mm.

Fig 4a: Anatomic dissection of both sternoclavicular joints following placement of a needle in the inferolateral and superomedial portal.

Fig 4b: Illustration of performed measurements of the portal positions compared to the anterior sternoclavicular ligament.

In the final 8 specimens (4 cadavers), the needles were replaced by 1.2 K-wires that were pushed through the posterior capsule and the adjoining neurovascular structures along the direction of the portals. These K-wires were cut a short as possible. Subsequently, both complete SC joints - with the K-wires in place in 8 specimens - were removed by transecting the clavicle through its middle 1/3rd, cutting the manubrium between the first and the second ribs and cutting the first rib just anterior to the scalene tubercle to allow inspection of the posterior capsule. During these maneuver, because of its fixation in the posterior soft-tissues, the K-wires rest in place. Finally, after resection of the musculus sternohyoideus, the medio-lateral distance of the K-wires to the major
neurovascular structures (arch aorta, brachiocephalic artery, left common carotid artery, left subclavian artery, superior vena cava, right innominate vein, left innominate vein, right nervus vagus, left nervus vagus) on the ipsilateral side was measured (Fig 5).

Fig 5a: Evaluation of the relation of the K-wires with the major artery and vein

Fig 5b: Evaluation of the relation of the K-wires with the major artery and nervus vagus

Fig 5c: Illustration of the different positions of the K-wire compared to the major artery, vein and nervus vagus

**Results**

The standard procedure with resection of the disc to a small stable rim could be performed in all 20 joints.
The superomedial portal always perforated the tendon of the sternal part of the sternocleidomastoid muscle at a mean distance of 6.5 mm to its medial border. The mean width of the sternal part of this muscle was 14 mm. (Table 1).

Table 1: data anatomical dissection

SCM: sternocleidomastoideus, SM: superomedial, IL: inferolateral, PM: pectoralis major, ASCL: anterior sternoclavicular ligament

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<th>distance SM portal - medial border SCM (mm)</th>
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The inferolateral portal always perforated the muscle fibers of the pectoralis major at a mean distance of 5 mm to its clavicular attachment.
The superomedial portal entered the joint medial to the anterior SC ligament at a mean distance of 1 mm to its medial border. The inferolateral portal entered the joint lateral to the ligament at a mean distance of 2 mm.

The costoclavicular ligament was never perforated.

The posterior capsule showed neither macroscopic signs of perforation nor any breaches with fluid injection.

The K-wire introduced in the inferior portal always perforated the artery (Table 2).

Table 2: Evaluation of the relation of the K-wires with the major artery, vein and nervus vagus.

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In 6 out of 8 cases it perforated the arch of the aorta, in one case the brachiophalic artery and in one case the left subclavian artery. In 6 of out 8 cases it also perforated the vein (3/6 superior vena cava, 0/6 right innominate vein, 3/6 left innominate vein).

The K-wire introduced in the superomedial portal never perforated the artery, but in 6 out of 8 cases it perforated the vein (2/6 superior vena cava, 2/6 right innominate vein, 2/6 left
innomiate vein). The mean distance between the K-wire and the ipsilateral vagal nerve was 5.3 mm for the right IL portal, 3.25 mm for the right SM portal, 8.75 mm for the left IL portal, 4 mm for the left SM portal.

**Discussion**

The sternoclavicular (SC) joint is a point of articulation between the upper extremity and the axial skeleton. It is classified as a double arthrodial synovial joint, and is reported to have little intrinsic stability (10). The joint is formed by the sternal end of the clavicle, the clavicular notch of the manubrium and the cartilage of the first rib (11-13). The joint has an articular disc that interposes between the sternal end of the clavicle and the clavicular notch of the sternum (9). Ligamentous structures in this region include the anterior and posterior sternoclavicular ligaments, costoclavicular ligament, and interclavicular ligament (11-14).

This study shows that the sternoclavicular joint can be accessed arthroscopically and debrided with an arthroscope in an experimental setting. This can be performed without damaging the posterior capsule. The procedure nevertheless carries a high risk of damaging a vital neurovascular structure if the posterior capsule is violated with an instrument.

Both portals enter the joint through the thin anterior capsule, respectively lateral and medial to the anterior SC ligament. These thinner parts of the capsule have been described as the preferred location for intra-articular injection of the sternoclavicular joint (9). Although the posterior capsule is the most important restraint for anterior as well as posterior translation of the SCJ, the anterior SC ligament has been shown to be an important restraint for anterior translation (15). During open approaches the ligament is transected and sutured at the end of the procedure. By passing next to it in an arthroscopic approach can preserve stability of the SCJ. A limitation of the present study is that no
biomechanical stability testing was done after the arthroscopic procedure, as it was not our purpose. It could be a topic for further research.

Concerning the angulation of the instruments, Wijeratna et al described the mean angles of the articular surface of the manubrium compared to the three planes. The mean angle of the joint-line was 62.4° in the axial plane, 149.3° in the frontal plane and 69.8° in the sagittal plane (16). The superomedial portal is more in line with the manubrium articular surface than the inferolateral portal. The proposed angulation of the introduction of the instruments in the inferolateral portal is 45° to frontal plane and 30° to axial plane and it the superomedial portal an angulation of +/- 60° to the frontal plane and +/- 60° to axial plane.

A major concern for orthopaedic surgeons in the surgical treatment of SCJ pathology are the posterior vital structures, including the innominate artery and vein, the vagal and phrenic nerve, the internal jugular vein, the trachea and esophagus. A curtain of muscles—the sternohyoid, sternothyroid, and scalene muscles—is all that separates these structures from the SCJ. Extravasation from the joint during arthroscopy might compromise them. This study has shown that arthroscopy with debridement can be performed adequately without breaching or perforating the posterior capsule of the SCJ. However, when an instrument breaches the posterior capsule, there is a high risk of damaging a vital neurovascular structure. The inferolateral portal carries the highest risk because its direction is always into a vascular structure. If only a diagnostic arthroscopy is necessary, we propose to use the superomedial portal. The risk of damaging the nervus vagus is smaller than damaging the vascular structures. Therefore, it would be extremely unwise to attempt a sternoclavicular arthroscopy without the backup of a cardiothoracic surgeon.

The present study only evaluated the feasibility of resection of the intra-articular disc. In line with indications for arthroscopy in other joints, especially at the other of the clavicle, indications for the sternoclavicular joint maybe can be broadened. The most common condition affecting the sternoclavicular joint is osteoarthritis (OA), especially with
advancing age, either mono-articular or as part of a systemic process (2). Although this usually remains asymptomatic, some patients experience chronic pain and swelling (17). Most patients with symptomatic OA respond to nonsurgical treatment, such as rest, anti-inflammatory medication, and local corticosteroid injection (2). If unresponsive to nonsurgical treatment for at least 6 months, surgery has been proposed. In early stages, open resection of the degenerative intra-articular disc has been performed with success (18). The present study has shown that this procedure can be done arthroscopically. In more advanced cases, resection arthroplasty is proposed with the intent of preventing bony abutment in both rotationally and axially loaded shoulders. Pingsmann et al. have shown good results for open medial clavicle excision for primary degenerative OA (6). Tavakkolizadeh et al. have published a case-report of arthroscopic excision of the sternoclavicular joint in a patient suffering from monoarticular sternoclavicular rheumatoid arthritis unresponsive to conservative treatment with good results (8). Unfortunately their images do not allow adequate evaluation of the performed resection. Possibility of adequate arthroscopic excision of the sternal end of the clavicle could be a topic for further study.

Another indication for arthroscopic resection of the intra-articular disc may be injury to the disc resulting from an indirect trauma to the SCJ (18). The literature reports on 7 cases where an open excision of the disc was been performed for chronic SCJ pain due to disc injury without signs of degeneration with good results (18-20). Tytherleigh-Strong described good results after arthroscopic resection of the disc in two patients (7).

Finally, arthroscopic debridement could be entertained as an alternative to open incision and drainage of the SCJ in case of infection. Septic arthritis of this joint is a rare entity in healthy persons, but occurs more commonly in immunocomprised patients or in intravenous drug users (21). Because of its infrequent presentation, management is not well standardized (22). Usually, surgery is reserved for cases when antibiotic therapy alone fails.
and has been reported on with good results when there are no signs of osteomyelitis (21, 22). Since arthroscopic debridement and irrigation combined with a systemic antibiotic regimen is considered as an efficient way of treating septic arthritis in other joints (23), this could apply to the SCJ as well.

This study has several technical limitations. First, although measurements between instruments and neurologic structures may provide relative margins of safety, an anatomic study is insufficient to detect neurologic injury. Second, the number of specimens was limited to 20 because of cadaver availability at our institution. The second part of the study was only performed on the last 8 cadavers. Next in this setting it was not possible to measure the anteroposterior distance between the posterior capsule and the neurovascular structures. Next there is the inability of cadaveric specimens in a laboratory setting to accurately simulate live patients in the operating room. Great efforts were made to create a realistic operating room environment, but certain inherent differences will always be present in anatomic studies, such as lack of blood flow to a cadaveric limb. At last it was impossible to evaluate the consequence of possible extravasation of the water during arthroscopy in this region. This can be of importance to evaluate the risk of breathing problems due to this extravasation.

In this cadaver study, arthroscopy of the sternoclavicular joint could be used as a minimally invasive procedure allowing debridement of the joint without damaging the posterior capsule of the joint. If the capsule is inadvertently breached, a major risk of neurovascular damage exists. We advise to have a backup of a cardiothoracic surgeon when performing this procedure.

**Acknowledgments**

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References
Chapter IV: General Discussion
Degeneration of the sternoclavicular joint seems to be a common process of ageing and seems to be well tolerated without clinical symptoms (1). In contrast, symptomatic degenerative sternoclavicular osteoarthritis can be defined as an articular disease in which this degeneration is associated with mechanical pain and/or swelling at the sternoclavicular joint (2-7). To obtain a better understanding of this pathology and to evaluate current treatment options, several studies were performed while focusing on 5 topics (anatomy, frequency, clinical manifestation, radiological manifestation and treatment).

1) Anatomy of the sternoclavicular joint

Little attention has been paid to a detailed anatomical description of the sternoclavicular joint, in contrast to anatomical studies of the soft-tissue structures and the cartilaginous surfaces of the acromioclavicular joint (8, 9). With the first study, we determined the location of the articular clavicular surface and the morphology of the capsule and ligaments of the sternoclavicular joint. In contrast to current literature, posteriorly we found a thick capsule but without any soft spot or clear separate posterior sternoclavicular ligament. This finding confirmed the tightness of the posterior capsule that was previously demonstrated in a biomechanical study (10). In accordance with previous literature, our study observed that the intra-articular discs and clavicular cartilages degenerated earlier, more frequently, and more severely than the sternal surfaces (1, 11, 12).

Our study also described that only the antero-inferior surface of the sternal end of each clavicle was covered by cartilage (13). In our opinion, the knowledge of these anatomical features is necessary when performing operative treatment of the sternoclavicular joint.

2) Frequency of the symptomatic degenerative sternoclavicular osteoarthritis

The frequency of symptomatic degenerative sternoclavicular arthritis in daily practice of a shoulder surgeon was evaluated in the second study. This pathology is uncommon, even
for members of national or international shoulder societies. Eighty-two percent of respondents to the survey stated seeing less than five patients a year. Our study also demonstrated that there are geographical differences in the frequency of this pathology. For example, shoulder surgeons from Japan are seeing these patients less frequently than colleagues from Europe.

In the literature, most patients with symptomatic degenerative arthritis are women between 35 and 65 years of age with an average of 56 years (2-7). This was confirmed in our study population, with symptomatic degenerative arthritis, being identified in patients aged between 44 and 74 years with a mean age of 56 (third study).

The low frequency of symptomatic sternoclavicular osteoarthritis is in contrast with the common symptomatic acromioclavicular osteoarthritis (14-17).

There are some similarities between both pathologies. As described for the sternoclavicular joint, also osteoarthritis of the acromioclavicular joint is age-related and a common finding on technical investigations (18). Also the average age of the patients with symptomatic degenerative acromioclavicular arthritis is in the same decade as symptomatic degenerative sternoclavicular arthritis although there seems to be an equal amount of male and female patients (18, 19).

But the question remains why there is such a difference in clinical manifestation of this degenerative pathology between joints on both sides of the clavicle.

An important remark is the fact that currently it is still unclear what the correlation is between joint pain and signs of degenerative osteoarthritis on technical investigations (20, 21). Many patients with joint pain show only limited signs of osteoarthritis on technical investigation but in contrast, many patients with extensive osteoarthritis on technical
investigation are asymptomatic. The onset of pain would depend on local, neurogenic and
neuromuscular factors.

The question remains why these factors are probably more excited in the acromioclavicular
joint than in the sternoclavicular joint.

From a biomechanical point of view, there are theoretical several possibilities.

First, two studies have shown that the forces involved in performing everyday movements
at the level of the acromioclavicular joint are up to 6 times larger than the sternoclavicular
joint (22, 23). These higher forces may be a cause of more stress and irritation on the
capsule of the degenerative joint.

Second, the acromioclavicular joint shows a greater bony congruency than the
sternoclavicular joint (8). This may be a possible reason for a faster bony conflict of this
more "constrained" joint.

Third, the subluxation of the joint, as described in the fourth study, seems to be common in
patients with symptomatic degenerative sternoclavicular arthritis and this subluxation may
be one of the contributing factors of joint pain. It has been described that also the
acromioclavicular joint shows a specific pattern of degeneration (24). Maybe this specific
pattern is also caused by a subluxation and is this subluxation more frequent than in the
sternoclavicular joint. However, this has not been quantified on 3D.

3) Clinical manifestation of symptomatic degenerative sternoclavicular osteoarthritis

In literature, it has been described that patients are consulting because of a gradual onset of
a lump over the sternoclavicular joint, with slight aching in the swollen region as well as
along the clavicle and in the shoulder. The pain is aggravated by the use of the arm and can
irradiate in three directions, to the lateral aspect of the neck, to the shoulder joint, and to
the breast (2). Normally, there is no history of injury, and no evidence of other joint
involvement or constitutional illness can be found (5).
The two most common described clinical symptoms are pain at palpation and pain during elevation of the arm (1-3). Surprisingly, to the best of our knowledge, no diagnostic value of these two tests has been described. We demonstrated in our second study that both clinical tests have a high sensitivity to diagnose a painful degenerative sternoclavicular joint (respectively 93% and 84%, respectively) but a low specificity. Because testing the pain during arm elevation requires the combined motion of the sternoclavicular, acromioclavicular, glenohumeral, and scapulothoracic joints elevation of the arm may not be possible in some shoulder pathologies. This was the reason why we also looked for new clinical tests that focus only on isolated sternoclavicular motion such as active protraction and retraction. Active scapular protraction can be seen as a compression test and active scapular retraction can be seen as a distraction test of the joint. Our study described that active scapular protraction shows a high sensitivity (86%) to diagnosing a symptomatic arthropathy of the sternoclavicular joint and a higher specificity than tenderness. This was similar to compression tests of other degenerative joints (14, 25).

With respect to swelling, Bremner and colleagues described that during examination, there is a slightly tender, soft and sometimes fluctuant swelling of the affected sternoclavicular joint (5). This observation is in contrast with other studies that described a hard prominence (2-4, 6, 7). The findings in our second study corroborated the presence of a hard prominence in 75% (25/33) of patients with symptomatic degenerative arthritis.

4) Radiological manifestation of symptomatic degenerative sternoclavicular osteoarthritis

It is accepted that the clinically visible and palpable prominence is due to an anterior subluxation of the clavicle but this has never been established (26, 27). In our fourth study, we analysed the relationship of the clavicle and the sternum in a normal population and compared this with patients with symptomatic degenerative sternoclavicular arthritis using a 3D CT scan reconstruction technique. We demonstrated that the proximal part of the
clavicle in the arthritic SC joints was statistically larger anteroposterior than in the normal population (p<0.001). But this widening was not as important as the anterior displacement that showed a clear anterior subluxation of the clavicle versus the sternum in this pathological condition.

A possible explanation for the anterior subluxation can be found in the forward direction of the moment arm of the pectoralis major (28). This effect has already been seen in the displacement of medial clavicle fracture where a shortening and anterior displacement of the lateral part of the clavicle can be seen (29).

Several anatomic features can be seen to counter this anterior moment arm of the pectoralis major in the normal population: the strong posterior capsule, the inferior direction of the articular surface of the manubrium (10, 30). It is possible that due to some dysplasia of the manubrium or weakening of the biomechanical properties of the posterior capsule with ageing (31), the factors can not counter the anterior moment arm anymore.

5) Treatment of symptomatic degenerative sternoclavicular osteoarthritis

A. Conservative treatment.

The primary treatment of symptomatic sternoclavicular osteoarthritis is conservative, including rest, modification of behavior with restriction of lifting and reaching out, analgesics, and intra-articular injection of corticosteroids (32). In our survey, there was a clinical agreement on the use of anti-inflammatory medication, but no clinical agreement is found on the use of intra-articular injections. Degenerative arthritis of the acromioclavicular joint is commonly treated with the intra-articular injections (33) using a combination of a local anesthetic and corticosteroid-steroids. After accurate infiltration, reduced pain and increased shoulder function can be expected in up to 3 weeks (34, 35). In contrast, only 55% of the responding surgeons would perform an intra-articular injection of the sternoclavicular joint in case of symptomatic degenerative pathology. Limited
understanding of the anatomy and infiltration technique is a possible reason (13). Our first study described that an intra-articular injection of the clavicle part of sternoclavicular joint should be done through the thin anterior-inferior part of the capsule where it is only attached to a small rim on the anterior part of the clavicle. The soft spot medial from the anterior sternoclavicular ligament can be used to gain access to the sternal part of the joint. If the disc is intact, the fluid will only reach one of both parts of the joint. In describing the effect of injections, until now this differentiation between the two parts has not been mentioned (36). As the disc frequently appears to be degenerated in patients with symptomatic degenerative SC joint arthritis, both parts of the joint would be connected. In that case, it would not matter into which part an injection is given. In difficult or doubtful cases, ultrasound guidance of the intra-articular puncture is recommended as a means of preventing unintended peril-articular injection and subsequent complications (37).

B. Surgical treatment.
With failure of conservative treatment, the surgeon can propose a surgical treatment. Excision of the medial clavicle has been proposed as a treatment option for symptomatic degenerative sternoclavicular osteoarthritis (2, 5, 7, 38). This procedure is comparable with and based on the excision of the lateral clavicle in degenerative acromioclavicular arthritis that is a reliable treatment with good results. Because of the proximity of vital neurovascular structures to the sternoclavicular joint, a thorough knowledge of the anatomy of the joint is crucial to perform this procedure safely.
In our opinion, the knowledge of the anatomical features described in the first study are necessary to perform a correct medial clavicle excision. Currently we perform an open limited resection of 5 mm of the anteroinferior part of the clavicle while retaining the posterior capsule and the costoclavicular ligaments. This technique is also based on the findings of Carrera and colleagues concerning the costoclavicular ligament. They
described a mean distance of 1.26 cm between the inferior articular surface of the medial clavicle and the most medial clavicular insertion of the costoclavicular ligament (39).

This surgical technique is in contrast with other described techniques. For example, Bremner advises a synovectomy and excision of the medial 2.5 cm of the clavicle (5). Similarly Rockwood removes more bone superiorly compared to inferiorly, thereby removing the posterior capsule (40). Pingsmann et al. remarks that the direction of the osteotomy and the amount of bone removed varied in all cases (7). Future research will be necessary to clinically evaluate our new surgical technique.

The clinical results of a medial clavicula resection seem to be satisfying. But to our knowledge, only five articles have described the results of medial clavicle resection in cases of degenerative arthritis. In 1942, Westermann was the first to describe the procedure in one patient with satisfying results four years postoperatively (41). In total 27 cases have been described with good to excellent results in 25 cases (2, 5, 7, 42).

In contrast to the promising results according to the literature, our first study showed that there is a general agreement not to perform this procedure even after failed conservative treatment. An important reason may be the fact that a lot of surgeons described this procedure to be a high-risk operation or not worth the risk (48%). This contrasts with the literature where no peri- or postoperative complications were ever reported (2, 5, 7, 41, 42). The resection of the medial clavicle for traumatic instability also showed no major complications (40, 43).

Recently medial claviculectomy has been performed arthroscopically (44, 45) but the safety of this procedure was not been evaluated. In our fifth study we demonstrated that this procedure can be performed safely if several precautions are taken into account (46). The procedure carries a high risk of damaging vital neurovascular structures if the
posterior capsule is violated with an instrument. Two portals are used: the inferolateral and superomedial. The inferolateral portal carries the highest risk because its direction is always into a vascular structure. If only a diagnostic arthroscopy is necessary, we propose the use of the superomedial portal. The morbidity of damaging the vagal nerve is more limited than damaging the vascular structures.

Resection arthroplasty is one of the oldest surgical procedure to treat osteoarthritis. In 1861 Ferguson described his 5 year results of a resection arthroplasty in knee for osteoarthritis and reported ‘satisfactory’ results (47). In 1899 Blenke described an resection arthroplasty of a hip in a patient with severe unilateral osteoarthritis (48). Concerning resection arthroplasty in the shoulder, as early as in 1916, Nové-Joserand reported on the functional outcome of 237 resection arthroplasties. His main conclusion was that the function of the shoulder was lost. Garre performed 105 resection arthroplasties and in 76 cases ‘a final cure for all conditions was obtained’(49).

Nowadays in these joints, this treatment option for degenerative pathology has been completely abandoned as a first treatment option and good result are seen with total joint arthroplasty.

In contrast, in smaller joints (the acromioclavicular (50), trapeziometacarpal (51), radiocapitellar (52) or the first metatarsalphalangeal joint (53)) resection arthroplasty is still used as a treatment option for symptomatic degenerative osteoarthritis.

More recently the resection arthroplasty of the first metatarsalphalangeal has fallen out of favor, due to a high incidence of transfer metatarsalgia and poor function of the joint post-operatively (53). Nowadays an arthrodesis or an total joint arthroplasty is being proposed with both good results (54).

Also at the level of the thumb more and more total joint arthroplasties are being performed in favor of the partial or total trapezectomy. Degeneration at the carpometacarpal joint can
be compared with degeneration of the sternoclavicular joint because subluxation is also seen in degenerative rhizartrosis (55, 56). In these cases it seems that bony dysplasia is the primary problem causing a capsuligamentous decompensation and degeneration with ageing. Correction of this dysplasia may stop partially the degenerative process (57).

Two different options have been proposed: 1) ligament reconstruction as augmentation of the resection arthroplasty or 2) total joint arthroplasties. Recent studies showed that from biomechanical point of view, a total joint arthroplasty has significant biomechanical advantages compared to trapezectomy with or without ligament reconstruction.

Also a radiocapitellar prosthetic arthroplasty has been introduced to treat isolated degenerative arthritis of the radiocapitellar joint (58).

With this knowledge, we developed recently a total joint arthroplasty for the sternoclavicular joint, type reversed (Fig 1). The provision of a reverse prosthesis, forming a ball-and-socket joint with the socket positioned on the sternal end of the clavicle and the ball positioned on the clavicular notch of the manubrium, can allow for correcting the subluxation of a clavicle and can result in a increased stability of the joint. More particularly, the prosthesis described may result in a complete neutralization of the lever arm exerted on the sternal component, which can lead to an improved bone ingrowth and reduced implant loosening.

More particularly, we developed a sternoclavicular endoprosthesis, comprising:

(a) a first prosthetic component configured for positioning on the manubrium comprising (Fig 2a):
   - a spherical dome; and
   - an anchor peg provided at the base of said dome; and

(b) a second prosthetic component comprising (Fig 2b):
   - a cup comprising a concave surface configured for receiving said dome;
   - a base configured for attachment to the diaphysis of a clavicle;
- a fixation stem provided at said base, configured for fixation of said second prosthetic component in the diaphysis of a clavicle.

Fig 1: design sternoclavicular arthroplasty

Fig 2a: sternal component  
Fig 2b: clavicular component
Recently we have treated one patient with this reversed sternoclavicular arthroplasty. This patient suffered from mechanical pain and instability of the joint during daily activities after a resection arthroplasty for chronic anterior sternoclavicular instability (40) (Fig 3). The short term results are promising (Fig 4).

![Pre-operative CT](image)

**Fig 3: pre-operative CT**

![Post-operative X-ray](image)

**Fig 4: post-operative X-ray**
Conclusion

To conclude, we can state that the incidence of symptomatic degenerative sternoclavicular arthritis is low and that there seems to be geographical differences in prevalence. The clinical tests with the highest sensitivity to evaluate sternoclavicular arthropathy are pain at palpation and the newly described active scapular protraction test. The common complaint of prominence is caused by an anteroposterior widening of the bone and an anterior subluxation of the clavicle versus the sternum. The articular surface of the sternal end of the clavicle is located antero-inferior and there is a thick posterior capsule without clear posterior sternoclavicular ligament. If an arthroscopy of the sternoclavicular joint is performed, it is crucial not to perforate this posterior capsule. Recently a sternoclavicular arthroplasty was developed as an alternative to treat this pathology but future research is necessary to evaluate the short and longterm results.

References


Chapter V: Future research
The knowledge gathered in this PhD has produced some answers, but also raised some new research questions that need further investigation. This thesis could not answer the question why degenerative sternoclavicular joints sometimes become symptomatic and why this is less common than symptomatic acromioclavicular arthritis. Some theoretical biomechanical differences have been proposed but these hypotheses need to be tested during future research.

The reason why some clavicles are subluxating while others remain balanced is still unclear. Subluxation is also seen in degenerative rhizarthrosis (1, 2). In these cases it seems that bony dysplasia is the primary problem causing a capsuligamentous decompensation and degeneration with ageing. Correction of this dysplasia may stop the degenerative process. It is not clear if there is also a pre-existing bony dysplasia in patients in which an anterior subluxation of the clavicle will occur.

Currently, anterior subluxation of the clavicle is not corrected by either an open or arthroscopic medial clavicle excision. This might explain why there are some failures with this type of treatment. Correction of the subluxation in degenerative pathology (3, 4) seems to be important to obtain good lasting results in other joints (first carpometacarpal, glenohumeral and metatarsophalangeal joints) (4, 5). But it is not clear if correction of sternoclavicular subluxation is needed to obtain better results.

Recently we developed a sternoclavicular arthroplasty and one patient is already included in the clinical study. We hope to include more patients into this study in the near future. Future research will focus on the short term and longterm follow-up of these patients and optimalization of the arthroplasty.
Reference


Chapter VI: Summary
Symptomatic degenerative sternoclavicular arthritis is uncommon and research on this topic is scarce. The main goal of this thesis was to gain a better understanding of this pathology and its surgical treatment options.

The first article describes the anatomy of the joint and the use of the anterior sternoclavicular ligament as a landmark to enter into the clavicular or sternal part of the sternoclavicular joint. This information can help to perform infiltrations or arthroscopy of the joint more adequately. Posteriorly there is a thick capsule without a softspot or clear posterior sternoclavicular ligament. Concerning the articular surface, only the antero-inferior surface of the sternal end of the clavicle is covered by cartilage.

The second article describes the frequency and management of symptomatic degenerative sternoclavicular arthritis. Orthopedic surgeons do not frequently treat this pathology. There is general clinical agreement on the use of anti-inflammatory medication. There is no clinical agreement concerning treatment with respect to intra-articular injection. There is a general agreement not to perform a medial clavicle resection, even after failed conservative treatment. There seems to be a difference in frequency and treatment options between different national and international societies in managing such cases.

The third article evaluates the diagnostic value of clinical test to diagnose sternoclavicular arthropathy. Active scapular pro- and retraction has been described as new clinical tests that attempts to isolate the sternoclavicular joint motion as much as possible. Tenderness and pain during active scapular protraction are found to be positive clinical indicators for sternoclavicular arthropathy.

The fourth article evaluates the relationship of the medial clavicular head to the manubrium in normal and symptomatic degenerative sternoclavicular joints. The medial clavicular head in degenerative sternoclavicular arthritis is significantly larger than in the normal population. In this group, most clavicles are also anterior subluxated.

The fifth article shows that arthroscopy of the sternoclavicular joint can be used as a
minimally invasive procedure allowing debridement of the joint without damaging the posterior capsule of the joint. If the capsule is inadvertently breached, a major risk of neurovascular damage exists. We advise to have a backup cardiothoracic surgeon involved when performing this procedure.

To conclude, this thesis describes the frequency and the geographical differences of this pathology, evaluates the clinical and radiological image of the anterior subluxation of the clavicle and describes safe open and arthroscopic approach to the joint.

Future research will focus on three topics: 1) the etiology of the anterior subluxation, 2) the clinical importance of not correcting this subluxation with the current surgical treatment option and 3) the clinical results of the developed sternoclavicular arthroplasty.
Chapter VII: Samenvatting
Symptomatische degeneratieve sternoclaviculaire artrose is zeldzaam en wetenschappelijk onderzoek over dit onderwerp is schaars. Het belangrijkste doel van dit proefschrift was om een beter inzicht te krijgen in deze pathologie.

Het eerste artikel beschrijft de anatomie van het sternoclaviculair gewricht en toont aan dat het voorste sternoclaviculair ligament kan worden gebruikt als een herkenningspunt voor de splitsing van het gewricht in een claviculair en een sternaal deel. Deze informatie kan helpen om een correcte infiltratie of een arthroscopie van het gewricht uit te voeren. Achteraan is er een dik kapsel aanwezig zonder duidelijk afgelijnd achterste sternoclaviculair ligament. Daarnaast beschrijft het artikel dat alleen het antero-inferieure oppervlakte en niet het volledige mediale deel van de clavicula bedekt is met kraakbeen.

Het tweede artikel beschrijft de frequentie van symptomatische degeneratieve sternoclaviculaire artrose in de dagelijkse praktijk bij leden van verschillende nationale en internationale schouderorganisaties. Deze groep schouderchirurgen zien deze pathologie niet vaak maar er blijken wel regionale verschillen te bestaan. Daarnaast beschrijft de studie ook welke behandelingen deze chirurgen voorstellen aan de patiënt. Er is een klinische consensus over het gebruik van ontstekingsremmers maar er is geen consensus met betrekking tot intra-articulaire injectie. Bovendien is er een klinische consensus om voor deze pathologie geen mediale clavicula resectie voor te stellen.

Het derde artikel evalueert de diagnostische waarde van verschillende klinische testen bij patiënten met sternoclaviculaire artropathie. Actieve scapulaire pro- en retractie worden beschreven als twee nieuwe klinische testen die proberen de sternoclaviculaire beweging zoveel mogelijk te isoleren en op die manier de specificiteit van de test te verhogen. De studie heeft aangetoond dat drukgevoeligheid en pijn tijdens actieve scapulaire protractie de beste klinische diagnostische hulpmiddelen zijn voor de evaluatie van sternoclaviculaire artropathie.
Het vierde artikel evalueert de relatie van de mediale clavicula met het manubrium bij normale patiënten en bij patiënten met symptomatische degeneratieve sternoclavicular lijden. In deze laatste groep is de mediale clavicula significant groter dan in de normale populatie. In deze groep is de clavicula echter ook naar voor gesubluxeerd.

Het vijfde artikel toont aan dat via een arthroscopische benadering een debridement van het sternoclaviculaire gewricht mogelijk is zonder beschadiging van het achterste kapsel. Als het achterste kapsel per ongeluk toch wordt beschadigd, bestaat er een groot risico op neurovasculaire schade. Wij adviseren daarom ook om een cardiothoracale chirurg standby te hebben bij het uitvoeren van deze procedure.

Toekomstig onderzoek zal zich focussen op drie onderwerpen: 1) de etiologie van de anteriele subluxatie, 2) het klinische belang van het niet-corrigeren van deze subluxatie met de huidige chirurgische behandelingen en 3) de klinische evaluatie van een onlangs ontwikkelde sternoclaviculaire prothese.
Chapter VIII: Curriculum Vitae
Personal Details

Surname: Van Tongel
Fornames: Alexander Godelieve Christian
Date of Birth: August 27th, 1978
Work address: Shoulder – Elbow surgery
Department of Orthopaedic surgery
University of Ghent
De Pintelaan 185
9000 Gent
Belgium
E-Mail: Alexander.vantongel@uzgent.be
Contact: 003293321020

Education

Secondary Education: Secondary Degree at Klein Seminarie, Roeselare

Higher Education: Academic degree in Medicine at the KU Leuven
ECG (2007)
Radioprotection (2005)
Board Exam Orthopaedic surgery (2009): primus
Pfizer Educational Award (2009)
Herodicus Fellowship (2011)

Surgical Training

1st and 2nd degree resident at the Heilig Hart Hospital, Roeselare

3rd degree resident at the UZ Pellenberg

4th – 5th degree resident at the AZ Sint Jan, Brugge
01-Aug-2005 – 31-Jul-2008 : Orthopaedic Surgery

6th degree resident at the UZ Pellenberg
01-Aug-2008 – 31-Jul 2009: Orthopaedic Surgery

Fellowship shoulder and elbowpathology
01- Sep- 2009 – 31- Dec 2009: UZ Gent – Prof L De Wilde
01- Jan-2010 – 30 Jun-2010: Pan Am Clinic Winnipeg (Canada)
Prof P MacDonald
01- Jul- 2010 – 30- Jun-2011: Reading Shoulder Unit(United Kingdom)
Prof Ofer Levy
Memberships

Member Elbow committee ESSKA (2013-present)
Ordinary member SECEC 2013-present
Member Board BOTA (Belgian Orthopaedic Trauma Association) 2012-present
Member Board BVOT (Belgische Vereniging van Orthopedie en Traumatologie) 2005-2013
Founding President BOTRA (Belgian Orthopedic and Resident Association) 2008-2009
Member Board FORTE (Federation of Orthopaedic trainees in Europe) 2008-2009
Member Board Montanus (society with interest in the history of medicine) 2006-2008
Member FLESSS (Flemish elbow and shoulder surgeon society) 2009-present
Member ABA (Belgian Arthroscopy Society) 2004-present
Presis Young KULAK Alumni 2001-2004
Presis KULAK 1998-1999

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3. Van Tongel A, De Wilde L Résultat des reprises de prothèse totale anatomique par prothèse totale inversée (accepted for publication)

4. Sys G, Van Tongel A, De Wilde L RSA in the setting of tumors in the proximal humerus (accepted for publication)
5. Poncet D, Van Tongel A, De Wilde L DELTA XTEND Reverse Shoulder Prosthesis (accepted for publication)

Presentations


2. 04/10/2006 De Groote, W and Van Tongel A: The Late medieval medicine in Bruges *WMS Congress Bruges 2006*


4. 30/03/2007 Van Tongel A: Compartmentsyndrome *Belgische vereniging gipsmeesters*

5. 11/10/2007 De Groote, W and Van Tongel A: Human consequences of postoperative infections for patients and surgeons *Prevention of surgical site infection*


7. 22/11/2007 Van Tongel A. Total Knee Arthroplasty in combination with a one-stage tibial osteotomy in a patient with Bessel-Hagen disease. *Belgian Knee Society*

8. 26/02/2008 Van Tongel A. Stuyck J. Septic Arthritis After Arthroscopic Anterior Cruciate Ligament Reconstruction: postgraduaat Ugent


10. 18/04/2008 Van Tongel A. Vandekerckhove B, Treatment of bone deficiences with bone substitutes. *BVOT congres 2008*

11. 21/03/2009 Van Tongel A: session moderator: Anterior knee pain symposium


13. 26/06/2009 Van Tongel A BOTA symposium: tricky questions: anterior instability

14. 14-15/10/2010 Van Tongel A Knot or not to Knot- Reading shoulder course, Brunel university, Faculty member

16. 22-23/11/2010 Van Tongel A Portal Placement in shoulder arthroscopy’A Cadaveric Arthroscopy of the Shoulder Course, Brunel University, Faculty member ‘


18. 11/12/2010 Van Tongel A, Van Isacker T, Pouliart N. Chronic sternoclavicular dislocations – FLESSS


21. 22/06/11 Van Tongel A, Bernat A, Huysmans T, Sijbers J, Van Glabbeek F. Mediolaterale shape and curvature analysis of the clavicle, BESS meeting Newcastle

22. 23/06/11 Atoun E, Narvani A, Van Tongel A, Levy O, Arthroscopic fusion of os acromiale. BESS meeting Newcastle – prize best case presentation


25. 09/11/2011 L De Wilde, Van Tongel A Résultat des reprises de prothèse totale anatomique par prothèse totale inversée SOFCOT 2011


28. 13-15/06/2012 3D CT-scan evaluation of the humeral head subluxation in shoulder arthropathy Beuckelaers E, Verstraeten J, De Backer H, , Van Tongel A, De Wilde L BESS Torquay E-poster

29. 21/06/2012 Van Tongel A : AC joint injuries BVOT Congress 2012 Brugge
30. 15/09/2012 Van Tongel A. The use of the clavicular part of the pectoralis major as augmentation after failed osteosynthesis of the clavicle BOTA congress Kortrijk

31. 20/09/2012 Beuckelaers E, Van Tongel A, De Wilde L 3D CT-scan evaluation of the pattern of erosion in B2 glenoids SECEC Dubrovnik podium presentation

32. 21/09/2012 De Wilde L, Dayerizadeh N, C Basmania, Van Tongel A Fully uncemented glenoid component in total shoulder arthroplasty – a minimally two years follow SECEC Dubrovnik podium presentation

33. 21/09/2012 Middernacht B, De Wilde L, Van Tongel A Revision of reversed shoulder arthroplasty SECEC Dubrovnik podium presentation


35. 22/09/2012 3D CT-scan evaluation of the pattern of erosion in B2 glenoids ISTA Sydney podium presentation


37. 19-22/09/2012 3D CT-scan evaluation of the pattern of erosion in B2 glenoids ISTA Sydney podium presentation


39. 4/10/2012 Middernacht B, De Wilde L, Van Tongel A Revision of reversed shoulder arthroplasty ISTA Syndey podium presentation

40. 4/10/2012 Beuckelaers E, Van Tongel A, De Wilde L 3D CT-scan evaluation of the pattern of erosion in B2 glenoids ISTA Sydney podium presentation

41. 19/10/2012 Van Tongel double or single row Reading Shoulder Course UK

42. 22-24/11/2012 Tutor 1st cadaver lab SECEC Nice

43. 01/12/2012 Biomechanics of the normal and instable shoulder Alexander Van Tongel, Acta Orthopaedica Belgica Brussels

44. 18/01/13 3D GlenoHumeral Relationship in Shoulder Arthropathy A. Van Tongel, E. Beuckelaers, M. Jacxsens, J. Verstraeten, H. De Backer, L. De Wilde (Ghent, Belgium) Brussels hand/upper limb international symposium
45.  10/04/13 Morphology of the Medial Clavicular Head and its Relationship to the Manubrium in Normal and Symptomatic Arthritic Sternoclavicular Joints Alexander Van Tongel, Thomas Verschueren, Jens Valcke, Lieven De Wilde UZ Ghent, Gent, Belgium, ICSES Nayoga

46.  11/04/13 Does Reverse Shoulder Need a Stem? 2-7 Years Follow Up with Stemless Reversed Shoulder Prosthesis Ofer Levy, Ehud Atoun, Ali Amir Narvani1, Ruben Abraham, Nir Hous, Tirtza Even, Jai Relwani1, Stephen A. Copeland, Giuseppe Sforza, Alexander Van Tongel podium presentation ICSES Nagoya


48.  27/06/13 Tricepsrupture Van Tongel FLESSS-casuistiek

49.  21/09/13 Morphology of the Medial Clavicular Head and its Relationship to the Manubrium in Normal and Symptomatic Arthritic Sternoclavicular Joints Alexander Van Tongel, Thomas Verschueren, Jens Valcke, Lieven De Wilde UZ Ghent, Gent, Belgium, Closed meeting SECEC

50.  21/09/13 Does Reverse Shoulder Need a Stem? 2-7 Years Follow Up with Stemless Reversed Shoulder Prosthesis Ofer Levy, Ehud Atoun, Ali Amir Narvani1, Ruben Abraham, Nir Hous, Tirtza Even, Jai Relwani1, Stephen A. Copeland, Giuseppe Sforza, Alexander Van Tongel closed meeting SECEC

51.  21/09/13 Can an extracorporeal glenoid aiming device be used to optimize the position of the glenoid component in total shoulder arthroplasty? Verstraeten Tom, Berghs Bart, Van Tongel Alexander, De Wilde Lieven closed meeting SECEC

52.  13/03/14 Morphology of the Medial Clavicular Head and its Relationship to the Manubrium in Normal and Symptomatic Arthritic Sternoclavicular Joints Alexander Van Tongel, Thomas Verschueren, Jens Valcke, Lieven De Wilde UZ Ghent, Gent, Belgium, wetenschapsdag UGent

53.  14/03/14 Shoulder prosthesis : anatomic or reversed : Alexander Van Tongel LVO Ede/Wageningen

54.  23/04/14 Elbow anatomy – causes of degeneration Alexander Van Tongel – Acta Orthopaedica Belgica Antwerp

55.  25/04/14 Tips and tricks to prevent complications in osteosynthesis proximal humerus fractures Alexander Van Tongel – Acta Orthopaedica Belgica Antwerp

56.  15/05/14 Basics of elbow arthroscopy ESSKA Amsterdam

57.  05/06/14 One-stage revision in shoulder arthroplasty EFORT London
Board Courses

1. 23/03/12 Cadavercourse UZ Gent – TerBrugGen – UZ Leuven: clavicle
2. 22-13/11/12 1st SECEC cadavercourse: Nice
3. 16/03/13 Cadavercourse UZ Gent – TerBrugGen – UZ Leuven: shoulder instability
4. 21-22/11/13 2nd SECEC cadavercourse: Nice
5. 04/04/14 Cadavercourse UZ Gent – TerBrugGen – UZ Leuven: shoulder arthroplasty

Courses

1. AO Course Principles of Operative Treatment 12-17/12/2004 Davos
2. Hands on training course Ex-Fix 5/11/2005 Mol
3. Workshop on Cadavers Traumatology of the Upper Extremity 24/06/2006 Gent
4. AO Course Advances in Operative Fracture Management 10-15/12/2006 Davos
5. Workshop on Cadavers Traumatology of the Upper Extremity 24/06/2007 Gent
7. Shoulder Arthroscopy Course 29-30/11/2007 Strasbourg
8. Bone substitutes 14-15/04/2008 Nice
9. Shoulder Muscle transfer 30-31/01/2009 Gent
10. Shoulder course 24-25/04/2009 Leuven
11. Advanced Techniques in Shoulder Arthroscopy, Arthroplasty & Fractures 30/04-1/05/2010 Mayo Clinic
12. Sheffield Elbow Course 6-7 October 2011
15. ArthroLatarjet course 25-26 Nov 2012

Interest

Running
History of Medicine

Language

Dutch – mother language
English - fluent
French – fluent
Spanish – 1 year of education (2005)
Appendix
**Abbreviations**

AC = acromioclavicular

ASES = American Shoulder and Elbow Society

ASL = anterior sternoclavicular ligament

CT = computertomography

JSS = Japanese Shoulder Society

LASES = Latin American Shoulder and Elbow Society

SASES = South-African Shoulder and Elbow Society

SC = sternoclavicular

SCJ = sternoclavicular joint

SECEC = Société Européenne pour la Chirurgie de l'Epaule et du Coude/ European Society for Surgery of the Shoulder and the Elbow

SESA = Shoulder and Elbow Society Australia
Acknowledgments
‘En waarover gaat je doctoraat?’

‘Over het sternoclaviculair gewricht’

‘Het wadde?’

‘Het sternoclaviculair gewricht – het gewrichtje tussen het sleutelbeen en het borstbeen’.

Op dat ogenblik toon ik meestal bij mezelf met mijn rechterwijsvinger waar het gewrichtje ligt.

‘Zo’n klein gewrichtje?’ Ook de andere persoon voelt nu met zijn rechterhand aan het uiteinde van het sleutelbeen maar weet eigenlijk niet goed wat hij moet voelen. ‘Kan je daar last van hebben?’

‘Zelden’

Gedurende de laatste 4 jaar was dit meestal het begin van het gesprek als mijn doctoraat ter sprake kwam. En nu heeft u mijn boekje eindelijk in handen en kan u uw vakantieavonden vullen met het lezen van deze wetenschappelijke literatuur. Ofwel houdt u het enkel bij het lezen van dit dankwoord en probeer ik het nog eens uit te leggen bij een andere gelegenheid.

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