Diplomarbeit

Medical diagnosis and treatment of sternoclavicular empyema
A retrospective analysis

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Foreword

This diploma thesis was written in cooperation with the division of Plastic, Reconstructive and Aesthetic Surgery at the Medical University of Graz, 8010 Austria. The idea derived from a conversation with my supervisor Ao. Univ. Prof. Dr. med. univ. Michael Schintler. He mentioned the diagnosis and treatment of deep wound infections and came up with an interesting idea. Sternoclavicular empyemata are rare but often occure in correlation with certain risk factors. Therapy ranges from simple intravenous antibiotic therapy to radical surgical debridement and plastic surgical soft tissue reconstruction but unfortunately there is no classified or standardised therapy design. This thesis confirms our therapeutic approaches in the treatment of sternoclavicular joint infections during the last ten years. It classifies a therapy design, which from our point of view, presents the best management of deep joint infections regarding minor complications and best functional outcome.

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Abstract

We retrospectively studied and analysed medical records of eight patients who were treated for sternoclavicular joint infections during the past ten years at the Medical Universitiy of Graz, Austria. Our results classify a diagnosis and therapy design, which from our point of view, is the best management of sternococlavicular joint infections, regarding minor complications, best functional and cosmetic outcome. Sternoclavicular joint infections are rare with about 0,5% - 1% of all joint infections [1, 2]. However an abscess is present in 20% of all cases [3]. The infection occurs in correlation with different risk factors like intravenous drug abuse, diabetes, HIV, hepatitis C, oncologic surgery, radiotherapy and central line placement. The infection is mainly caused by an invasion of the sternoclavicular joint with pathogens resulting in osteomyelitis, septic arthritis, necrosis and joint destruction. The spreading of pathogens into the sternoclavicular joint can occur directly through the skin, by ascending or descending regional infections or through the blood stream. Clinical diagnosis is provided by anamnesis, inflammatory signs and symptoms like rubor, calor, tumor, dolor and functio laesa, an increased CRP and by imaging like CT scan or a MRI. Bacterial swabs taken by joint puncture or during surgery certify diagnosis, while bacterial cultures allow targeted antimicrobial therapy. The intraarticular located focus, resulting in septic arthritis with osteomyelitis, necrosis and local destruction needs aggressive surgical approach. Optimal therapy resulting in best clinical, functional and cosmetic outcome consists of four therapeutic steps. 1. Targeted intravenous antibiotics. 2. An aggressive surgical debridement with resection of the sternoclavicular joint, the sternal part of the clavicle, half of the manubrium and the first costal cartilage. 3. Negative wound pressure therapy. 4. Local reconstruction with an ipsilateral pectoralis major advancement flap. A two ore more stage surgical procedure is essential for infection control and to avoid recurrence of infection.

Zusammenfassung

Wir untersuchten und analysierten medizinische Dokumentationen von acht Patienten, die wegen Infektionen des Sternoclaviculargelenks, in den letzten zehn Jahren am Universitätsklinikum LKH Graz behandelt wurden. Unsere Ergebnisse klassifizieren ein Diagnostik- und Therapiedesign, das aus unserer Sicht das beste Management von Infektionen des Sternoclaviculargelenks ist, hinsichtich minimaler Komplikationsrate, bestem funktionellen und kosmetischen Ergebnis.

Sternoclaviculargelenksinfektionen sind mit einer Rate von 0,5% – 1% innerhalb aller Gelenksinfektionen selten [1, 2]. Allerdings zeigt sich ein Abszess in 20% aller Fälle [3]. Die Infektion tritt in Verbindung mit verschiedenen Risikofaktoren wie intravenösem Drogenabusus, Diabetes, HIV, Hepatitis C, onkologischen Operationen, Radiotherapie und dem Einsatz von Zentralvenenkathetern auf. Die Infektion wird haupsächlich durch eine Infiltration des Sternoklaviculargelenks mit pathogenen Keimen verursacht woraus eine Osteomyelitis, septischer Arthritis, Nekrose und Gelenkszerstörung resultiert. Die Ausbreitung der Keime in das Sternoclaviculargelenk kann direkt über die Haut, über aufsteigende oder absteigende regionale Infektionen oder über den Blutstrom erfolgen. Die klinische Diagnose erfolgt nach genauer Anamnese, durch Entzündungszeichen wie Rötung, Überwärmung, Schwellung, Schmerz und eingeschränkter Funktion, durch erhöhtes CRP und durch ein CT oder ein MRT. Die Gewinnung bakteriologischer Abstriche durch eine Gelenkspunktion oder intraoperativ bestätigt die Diagnose. Bakterienkulturen und Resistenztestung ermöglichen eine gezielte Antibiotikatherapie. Der intraartikulär imponierende Herd als Ursache einer septischen Arthritis, Osteomyelitis, Nekrose und lokaler Zerstörung benötigt eine aggressives chirurgisches Vorgehen. Eine optimale Therapie resultiert, mit bestem klinischen, funktionellen und kosmetischen Outcome, aus vier therapeutischen Schritten. 1. Die zielgerichtere intravenöse Antibiose 2. Aggressives chirurgisches Debridement mit Resektion des Sternoclaviculargelenks, dem sternalem Teil der Clavicula, der Hälfte des Manubriums und dem ersten Rippenknorpel. 3. Eine Vakuumtherapie 4. Lokale Rekonstruktion mit einem ipsilateralen M. pectoralis major Verschiebelappen. Ein

zwei- oder mehrzeitiges chirurgisches Vorgehen ist für eine Infektkontrolle und Vermeidung eines Infektrezidives entscheidend.

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Glossary and Abbreviations

AIDS	=	Acquired immunodeficiency syndrome
CT	=	Computertomography
CRP	=	C-reactive protein
DNA	=	Deoxyribunocleic acid
E.Coli	=	Escherichia coli
Fig.	=	Figure
HBO	=	Hyperbaric oxygen
HIV	=	Human immunodeficiency virus
HLA-B27	=	Human leucocyte antigen B 27
MRI	=	Magnetic resonance imaging
PET	=	Positron emission tomography
RNA	=	Ribonucleic acid
SAPHO	=	Synovitis, acne, pustulosis, hyperostosis and osteitis
Tab.	=	Table
VAC	=	Vacuum assisted closure
WHO	=	World Health Organisation

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1 Introduction

Sternoclavicular joint infections are rare and are reported in the literature with about 0.5% - 1% of all joint infections [1, 2]. However an abcess is present in 20% of all cases [3]. The infection occurs in correlation with different risk factors like intravenous drug abuse, diabetes, HIV, immunodeficiency, rheumatological diseases or central line placement. The infection is mainly caused by an invasion of the sternoclavicular joint with pathogens resulting in chronic osteomyelitis and septic arthritis. The spreading of pathogens into the sternoclavicular joint can occur directly through the skin by central line placement, intraarticular puncture or injection, by ascending or descending regional infections or through the blood-stream. The most commonly found pathogenic organisms are *Staphylococcus aureus*, which is demonstrated by Ross JJ et al. in up to half of all cases followed by *Pseudomonas* [2, 4]. Strategic therapeutic approaches include antibiotic therapy, local surgical debridement with resection of the sternoclavicular joint, local negativ pressure wound therapy and plastic surgical reconstruction with a pectoralis major flap [5-8].

1.1 Questioning and aim

The main questioning and aim of this thesis is concerned with the causal relations between etiology, pathogenesis, risk factors, therapy and clinical outcome of sternoclavicular joint empyemata in patients during the past ten years in the LKH University Hospital Graz, Austria and comparison with the literature.

- What relations have been monitored between the occurrence of sternoclavicular joint empyemata in correlation with other diseases and what kind of medical therapy has been done from plastic surgical point of view?

- What are the risk factors, the etiology and the pathogenesis of sternoclavicular joint empyemata and what relations do they have with each other?

- Are there microbiological differences?

- What are differential diagnoses and resulting complications?

- What is the therapeutic strategy from a plastic surgical point of view?

- What is the clinical outcome of the therapy in reference to movements of the pectoral shoulder girdle and freedom from symtoms?

- Are there differences in age, sex and personal environment?

The achieved information is going to be collected, evaluated and presented in clinical case studies and furthermore compared with the literature concerning the following aspects:

- Risk factors like diabetes, intravenous drug abuse, alcohol and nicotine abuse, HIV, general immunodeficiency, tuberculosis, endocrinologic diseases, rheumatological diseases, local intraarticular punctures or injections, central line placement, local radiotherapy, bone fractures around the sternoclavicular joint, renal failure, haemodialysis and malignant illnesses.

- Signs, diagnosis, complications, microbiology and therapy, particularly concerning antibiotic therapy, surgical debridement, local negativ pressure wound therapy and plastic surgical reconstruction with a pectoralis major flap.

- Clinical outcome and follow up of patients involved in sternoclavicular joint resections and local plastic reconstruction in reference to movements of the pectoral shoulder girdle and freedom from symptoms.

1.2 Embryology

The skeletal system develops from paraxial and lateral plate mesoderm and from neural crest [9]. Blocks of segmented tissue on each side of the neural tube are formed, which are called somitomeres for the whole head region and somites for the rest of the skeleton. Somites differentiate into the ventromedial sclerotome and the dorsolateral dermomyotome. At the end of the fourth week, sclerotome cells become polymorphous and form the mesenchyme. Mesenchymal cells migrate and differentiate differently into fibroblasts, chondroblasts or osteoblasts. This procedure also occures in the parietal layer of the lateral plate mesoderm. This is where the bones of the pelvic and shoulder girdles, limbs and sternum are formed. Except for mesenchymal cells in the skull region, which differentiates through intramembranous ossification directly into bone, in most other bones mesenchymal cells first differentiate into hyaline cartilage models, which become ossified by endochondral ossification [9].

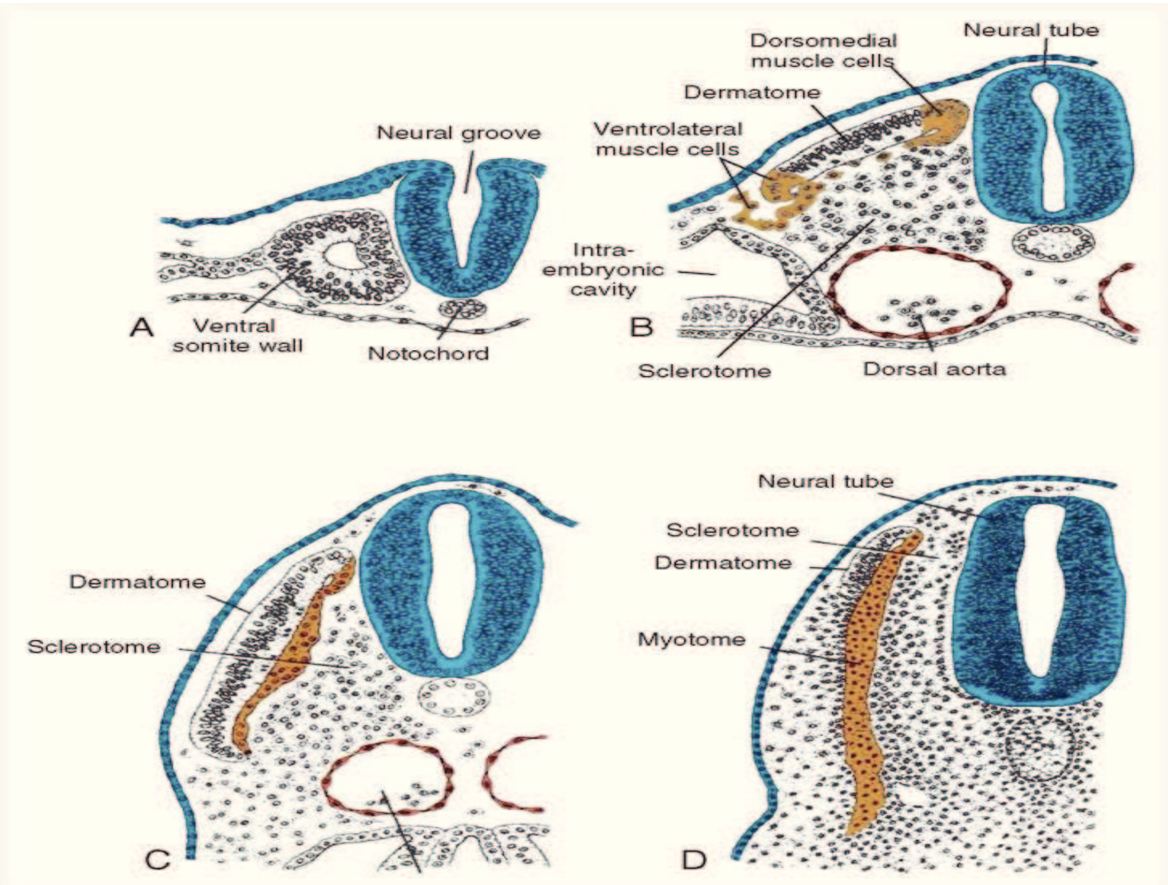

Fig. 1 [9] Development of the somit, T.W. Sadler - Langman's Medical Embryology, 11th Edition, 2009

1.2.1 The development of the clavicle

In 14 mm embryos the clavicle is a band of condensed mesenchyme between the acromion and the top of the first rib [10]. Medial and lateral zones of early cartilage transformation occur here. Soon the sternal and acromial ends become true cartilage. Length increases by interstitial growth of these terminal cartilages and diameter increases by subperichondral and subperiosteal deposition. Intramembranous centres of ossification appear and fuse. The clavicle is the first bone of the body which begins to ossify. On the one hand the shaft is ossified in condensed mesenchyme from two primary centres, lateral and medial which appear during the fifth week of intrauterine life and fuse about the 45th day of life and on the other hand from a secondary centre of ossification for the sternal end of the clavicle (diaphysis) which appears in the early twenties and completely fuses in the early thirties. An acromial secondary epiphysis sometimes develops at around 18 to 20 years which must not be mistaken for a fracture. Defects of ossification in the clavicle may occasionally coincide e.g. in cleidocranial dysostosis [10]. Sometimes the fusion of the two ossification centers fails to occur and a bony defect forms between the lateral and medial clavicular third which can also be mistaken for a fracture. When doubt exists, a simple x-ray image of both clavicles can secure the diagnosis, because this congenital defect is usually bilateral [11].

1.2.2 The development of the sternum

The sternum is built of two cartilaginous sternal plates by fusion. The ossification of the manubrium is performed from three centres of ossification and starts in the fifth fetal month [10]. The first to the fourth sternebrae of the mesosternum ossify consecutively in between the fifth to the eighth month. The fourth sternebrae may even be absent. The xhiphoid process begins to ossify in the third year or later. The centres of ossification in the third and fourth sternebrae are usually paired but analysis show a wide variety. In some persons all centres are paired, in others the manubrian centre is single. Nevertheless the union between all the centres begins at puberty and by the age of 25 years, all are united [10].

1.3 Anatomical Basics

1.3.1 Important local bones and their structure

The most important bones are the clavicle and the manubrium sterni which form the sternoclavicular joint. The acromion, a protuberance of the scapula is also attached to the clavicle forming the acromioclavicular joint. The mesosternum and the xiphoid process are the intermediate and inferior parts of the sternum.

1.3.1.1 The clavicle

The clavicle is localized horizontally at the base of the neck and is directly palpable through the skin. The smaller lateral or acromial end of the bone articulates with the medial side of the acromion forming the acromioclavicular joint. The larger medial or sternal end articulates with the manubrium sterni and with the first costal cartilage forming the sternoclavicular joint. The medial two-thirds of the shaft is convex forwards and the lateral third is concave forwards, resulting in a curved form which resembles the italic letter „*f*“. [10]. The internal structure of the clavicle is trabecular with thick compact bone in its shaft and has no medullary cavity. The female clavicle is shorter, thinner and less curved [10]. The clavicle varies more in shape than most other long bones, dependent of regional anatomy and muscular mass. The blood supply is provided by the suprascapular artery [10].

Fig. 2 [10]. Superior view of the left clavicle: Gray´s Anatomy, 40th Edition – The Anatomical Basic of Clinical Practice, Expert Consult by Susan Standring, PhD, Dsc, 2008:

1. Sternocleidomastoid (clavicular head). **2.** Sternal end. **3.** Pectoralis major. **4.** Trapezius. **5.** Acromial end**. 6.** Deltoid.

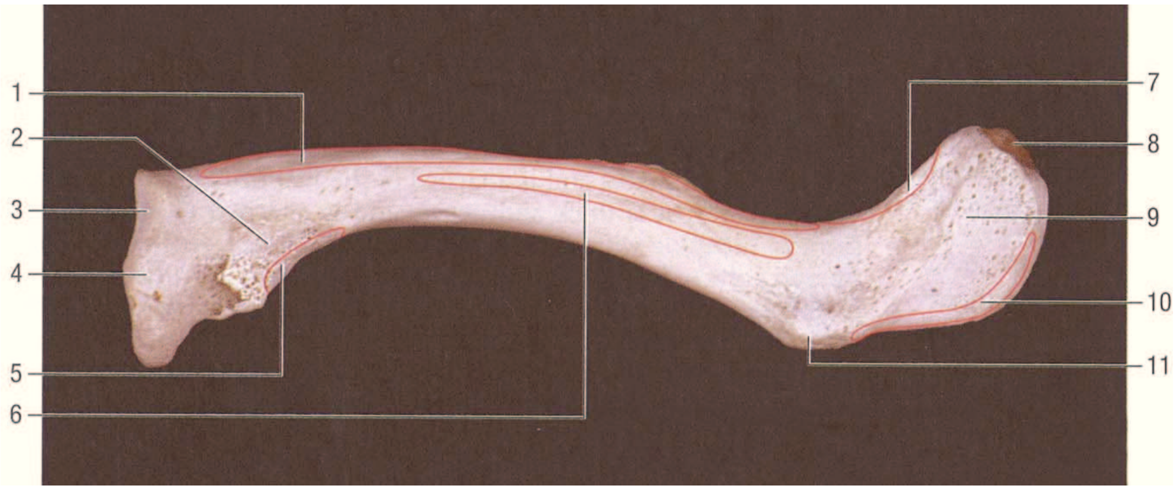

Fig. 3 [10]. Inferior view of the left clavicle. Gray´s Anatomy, 40th Edition – The Anatomical Basic of Clinical Practice, Expert Consult by Susan Standring, PhD, Dsc, 2008:

1. Pectoralis major. **2.** For costoclavicular ligament. **3.** For first costal cartilage. **4.** For sternum. **5.** Sternohyoid. **6.** Subclavius. **7.** Deltoid. **8.** For Acromion. **9.** Trapezoid line. **10.** Trapezius. **11.** Conoid tubercle.

Lateral Third

The lateral side of the clavicle is evened and consists of a superior and inferior surface and has an anterior and posterior border. The anterior border is thin, roughened and concave [10]. The posterior border is convex backwards. The superior surface can be felt directly through the skin. A conoid tubercle and a trapezoid line, which give attachment to both parts of the coracoclavicular ligament can be found on the inferior surface. The subclavius muscle, the anterior part of the deltoid muscle and the posterior part of the trapezius muscle are attached to the lateral third of the shaft. The inferior surface is attached to the clavipectoral fascia [10].

Medial two-thirds

The form of the medial two-thirds of the shaft is cylindrical and prismoid and has four surfaces. The anterior surface forms the upper boundary of the infraclavicular fossa. The upper surface is structureless. The costoclavicular ligament is attached to the inferior surface and spreads from the clavicle to the first rib. The posterior surface is grooved. The medial two-thirds of the shaft provide attachement for the clavicular head of the pectoralis major muscle, the clavicular head of the sternocleidomastoid muscle, the subclavius muscle and for the sternohyoid muscle. The sternohyoid muscle seperates the medial sternal part from the lower end of the internal jugular vein. Generally this whole area is related to the internal jugular and the subclavian veins as well as to the subclavian artery and the trunks of the brachial plexus which passes behind the medial two-thirds of the clavicle [10]. The clavicle is often fractured in children by indirect forces as a result of violent impact to the arm or shoulder. The break occurs usually at joint between the lateral and intermediate third, the weakest part of the shaft [12].

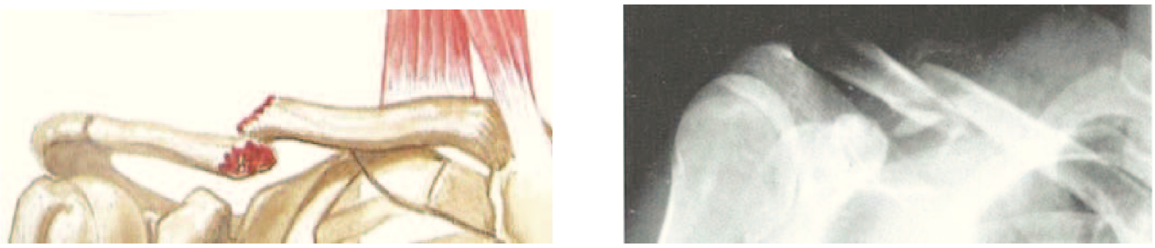

Fig. 4 [12] Fracture of the clavicle in its weakest point. Anterior topographic view and x-ray in a.-p. Netters Klinische Anatomie, 2. Auflage, John T. Hansen, David R. Lambert, Thieme, 2006

Sternal end

The sternal end of the clavicle articulates with the clavicular notch of the manubrium sterni. The surface is quadrangular and gives attachement for the interclavicular ligament, for the sternoclavicular capsule and articular disc, and for the first costal cartilage. The sternal end can be felt and seen directly through the skin in the wall of the jugular fossa [10].

1.3.1.2 The sternum

The sternum has three main body parts. The cranial manubrium, an intermediate mesosternum and a caudal xiphoid process. Its front side is convex and the back side is concave. The total lenght is about 17 cm in males and less in women. The sternum contains highly vascular trabecular bone enclosed by a compact layer.

The thickest region is in the manubrium between the clavicular notches. Inside the sternum is a medulla which contains haemopoietic bone narrow. The blood supply is provided by the internal thoracic artery through an anterior and posterior network of vessels. Perforating arteries are also found at each intercostal space and some other branches go directly into the sternum. The venous system consists of large vessels which drain into the peripheral sternal network or into the internal thoracic vein. The innervation of the manubrium is supplied by the supraclavicular and the first intercostal nerves. The mesosternum is supplied by anterior brances of the costal nerves. The xiphoid is supplied by the phrenic nerve [10].

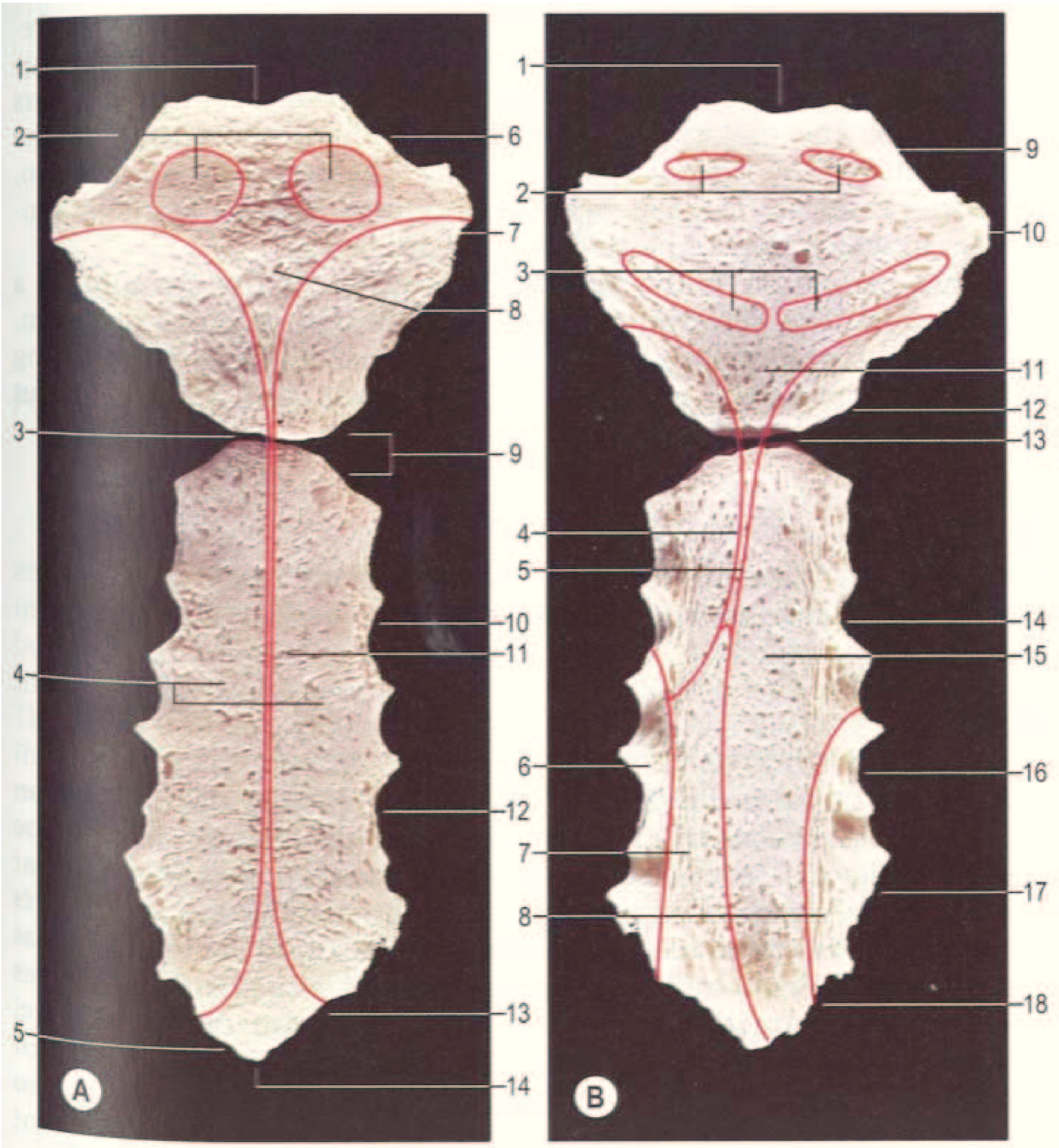

Fig. 5 [10] The sternum. Gray´s Anatomy, 40th Edition – The Anatomical Basic of Clinical Practice, Expert Consult by Susan Standring, PhD, Dsc, 2008:

Part A Anterior aspect: **1.** Jugular Notch. **2.** Attachment for sternocleidomastoid. **3.** Sternal angle and manubriosternal joint. **4.** Attachment for pectoralis major. **5.** Notch for seventh costal cartilage. **6**. Clavicular notch. **7.** Notch for first costal cartilage. **8.** Manubrium. **9.** Notch for second costal cartilage. **10.** Notch for third costal cartilage. **11.** Body of sternum. **12.** Notch for fourth costal cartilage. **13.** Notch for sixth costal cartilage. **14.** Xiphisternal joint.

Part B Posterior aspect: **1.** Jugular notch. **2.** Attachment for sternohyoid. **3.** Attachment for sternothyroid. **4.** Edge of area covered by left pleura. **5.** Edge of area covered by right pleura. **6.** Attachment for transversus thoracis. **9.** Clavicular notch. **10.** Notch for first costal cartilage. **11.** Manubrium. **12.** Notch for second costal cartilage. **13.** Sternal angle and manubriosternal joint. **14.** Notch for third costal cartilage. **15**. Body of the sternum. **16.** Notch for fourth costal cartilage. **17.** Notch for fifth costal cartilage. **18.** Notch for seventh costal cartilage.

The manubrium

The manubrium lies approximately at the same height as the third and fourth thoracic vertabrae. The upper region and the superior border are thick and broad and contain a suprasternal notch and two clavicular notches which form the articulation surfaces for the sternal ends of both clavicles. The jugular notch provides attachment to fibres of the interclavicular ligament. The inferior border forms the articulation surface with the sternal body. The lateral borders on each side feature the notch for the first costal cartilage. Unlike all other sternocostal joints, the manubriocostal joint is an unusual form of synarthrosis. The anterior surface is smooth, transversely convex and vertically concave. The sternal part of the pectoralis major muscle and sternocleidomastoid muscle are attached to this area. The posterior surface is concave and is attached to the sternothyroid muscle [10].

The body (mesosternum)

The body is longer and thinner than the manubrium and lies at the same height as the ninth thoracic vertebrae. The anterior surface is flat and is attached to the articular capsules of the sternocostal joints and to fibres of the pectoralis major muscle. The posterior surface is concave and provides the attachment surface for the transversus thoracis muscle. The upper part is oval and forms together with the manubrium the manubriosternal joint. The lower end is narrow and continues with the xiphoid process forming the xiphisternal joint. On each lateral side five costal notches articulate with the second to sixth costal cartilages. The external intercostal membranes are attached between this area. The inferior angle provides together with the xiphoid process the last costal notch which articulates with the seventh costal cartilage [10].

The xiphoid process

The xiphoid process lies in the epigastrium and is the smalles sternal element. Its form varies individually. In youth it is still cartilaginous but more or less ossified in adults. The upper and anterior regions articulate with the mesosternum and also with the seventh costal cartilage. The xiphoid provides the attachment surface for fibres of the rectus abdominis muscle, for the aponeurosis of the external and internal oblique muscle, and for the transversus abdominis muscle [10].

1.3.1.3 The acromion

The acromion is a protuberance of the scapula and projects almost at right angles as a direct continuation from the end of the scapular spine and posesses a lateral, a lower and a medial border. The medial border of the acromion articulates with the lateral end of the clavicle, forming the acromioclavicular joint. Horizontal fibres of the trapezius muscle are attached to this area. The irregular and thick lateral border as well as the tip of the acromion can be felt directly through the skin and middle fibres of the deltoid muscle and the lateral end of the coraco-acromial ligament are attached to this region. The smooth inferior aspect of the acromion, the coraco-acromial ligament and the coracoid process, together, form a protective arch over the shoulder joint. Below the acromion passes the tendon of the supraspinatus muscle and is separated from it by the subacromial bursa [10].

1.3.2 Important local joints – composition and functionality

The most important joint is the sternoclavicular joint which is formed by the medial end of the clavicle, the manubrium sterni and the first costal cartlilage. The lateral part of the clavicle articulates with the acromion, building the acromioclavicular joint. Movements in both joints are inevitably connected with the scapula and therfore the sternoclavicular and acromioclavicular joints are called the scapulothoracic articulation. About 5 cm below, the inferior part of the manubrium forms, together with the mesosternum, the manubriosternal joint. Intraarticular empyemata are a rare disease but analysis show a tendency to affect the sternoclavicular joint. Therefore the acromioclavicular joint is not described in detail [10].

1.3.2.1 The sternoclavicular joint

The sternoclavicular joint is a synovial sellar joint and is the only skeletal articulation between the upper limb and the axial skeleton. The sternal end of the clavicle, the clavicular notch of the manubrium and the superior surface of the first costal cartilage, together provide the articulating surfaces. The joint is convex vertically and concave sagittally. The articulating surface of the clavicle is larger than the manubrial and covered by fibrocartilage. Both surfaces are divided by an intraarticular disc. The joint is strengthend and stabilised by four ligaments which make dislocation a very rare event. It is also surrounded by a fibrous capsule which is thickened in front and behind, but in bulk above and below. The sternoclavicular joint is supplied by the internal thoracic and suprascapular arteries and innervated by the supraclavicular and the subclavian nerves [10].

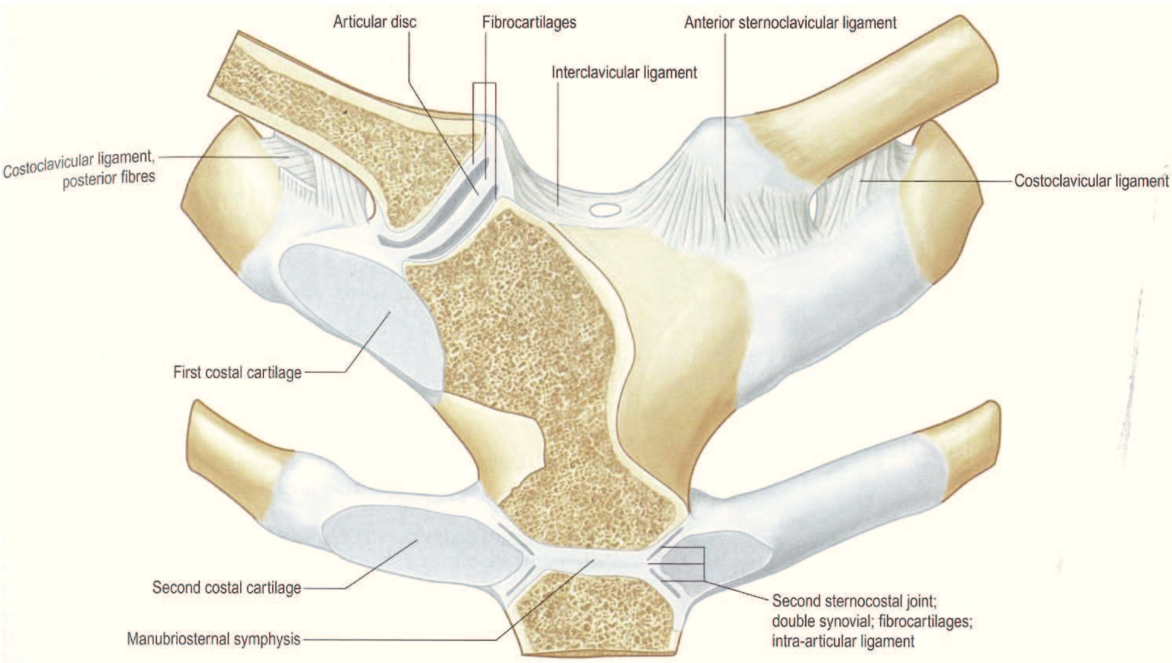

Fig. 6 [10] Sternoclavicular joints: anterior aspect; left joint intact and right in coronal section. Gray´s Anatomy, 40th Edition – The Anatomical Basic of Clinical Practice, Expert Consult by Susan Standring, PhD, Dsc, 2008

Ligaments

The joint is stabilised by four ligaments, the anterior and posterior sternoclavicular ligaments, the costoclavicular ligament and the interclavicular ligament. The anterior sternoclavicular ligament is wide and is attached to the upper region of the sternal end of the clavicle. It spreads to the upper region of the manubrium and the first costal cartilage. The posterior sternoclavicular ligament runs behind the joint from the posterior region of the sternal end of the clavicle to the posterior upper region of the manubrium. The costoclavicular ligament is short and flattened. It runs from the upper surface of the first rib and costal cartilage to the inferior clavicular surface and fuses with the fibrous capsule. The interclavicular ligament is a continuation of the cervical fascia and connects the sternal ends of both clavicles with each other [10].

Articular disc

The articular disc is circular and lies between the sternal and clavicular surfaces. It is attached to the superior region of the articular surface of the clavicle, to the first costal cartilage and to the capsule. The upper region is thicker with a more lax capsule than the inferior one [10].

1.3.2.2 The acromioclavicular joint

The acromioclavicular joint is a synovial plane joint with an articulating disc which seperates the articulating surfaces only partially. It is formed by the medial acromial margin and by the acromial end of the clavicle and covered by fibrocartilage. The joint is completely covered by a fibrous capsule which is strengthend above the arcomioclavicular ligament. The acromioclavicular ligament spreads from the lateral end of the clavicle to the acromion and weaves in to the trapezius muscle and deltoid muscle. A second ligament, the coracoclavicular ligament, which consists of a trapeziod part and a conoid part connects the coracoid process of the scapula. The vascular supply is provided by the suprascapular and thoracoacromial arteries. The joint is innervated by the suprascapular and lateral pectoral nerves. Movements at the joint occur in the same way as at the sternoclavicular joint, all passive by by the movement of the scapula. The sternoclavicular joint and the acromioclavicular joint, together allow about 60° of scapular rotation [10].

1.3.2.3 The manubriosternal joint

The manubriosternal joint is a symphysis covered by hyaline cartilage and lies between the manubrium and the sternal body. The joint is surrounded by a fibrous membrane and sometimes in persons over the age of 30 years it is grown together but complete ossification occurs only in the elderly .[10].

1.3.3 Movements of the pectoral (shoulder) girdle

Movements in the sternoclavicular and acromioclavicular joints are inevitably connected with movements of the scapula, the shoulder and the humerus and together allow about 60° of scapular rotation. The sternoclavicular joint is passively involved in all movements of the pectoral shoulder girdle like scapular elevation and depression, protraction and retraction or lateral and medial rotation. The range of motion between the sternal end of the clavicle is larger than that between the disc and the manubrium. The sellar shape of the articular surfaces allows movement in sagittal and vertical planes, and also some rotation about the long axis of the clavicle. Movements at the acromioclavicular joint occur in the same way as at the sternoclavicular joint, all passive by the movement of the scapula. The manubriosternal joint permits only small angulation and little anteroposterior displacement which occur by respiratory excursions of the sternum during inspiration and expiration [10].

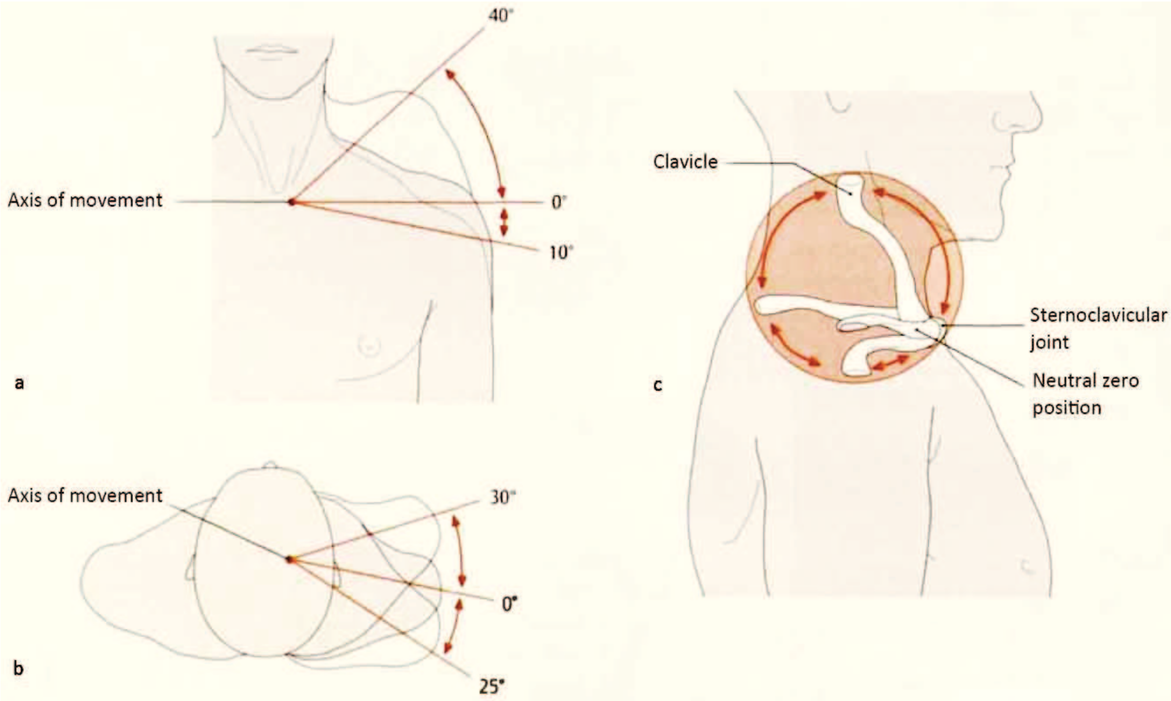

Fig. 7 [13] Movements of the sternoclavicular joint, Prometheus LernAtlas der Anatomie, Michael Schünke et al., Thieme, 2007: **a.** Elevation and depression. **b.** Protraction and retraction. **c.** Range of movement of the clavicle.

1.3.3.1 Elevation and depression

Shrugging the shoulders leads to scapular elevation and depression. In scapular elevation the sternal end of the clavicle rotates around its own axis and slides down over the articular disc. This is achieved by the trapezius muscle and the levator scapulae muscle by rotating the scapula in opposite directions and antagonized by the costoclavicular ligament and the capsule. Depression usually occurs by gravitational force alone, but can actively be achieved by tension of the serratus anterior muscle and pectoralis minor muscle. The movement is antagonized by the interclavicular ligament, the sternoclavicular ligaments and the articular disc. The acromioclavicular joint swings a little in both movements [10].

1.3.3.2 Protraction and retraction

During protraction, which occurs in pushing, thrusting and reaching movements, the lateral end of the clavicle moves forward while the sternal end undergoes a posterior translation. Simultanously the acromion rises over the clavicular aspect and the shoulder moves forward. This is mainly achieved by the serratus anterior and the pectoralis minor muscles, but also assisted by the latissimus dorsi muscle. Protraction is antagonized by the anterior sternoclavicular and the costoclavicular ligaments. Retraction occurs by bracing back the shoulders and reverses the discribed movements. It is actively achieved by the trapezius and the rhomboid muscles and antagonized by the posterior sternoclavicular and costoclavicular ligaments [10].

1.3.3.3 Lateral and medial rotation

Scapular rotation requires movements at both sternoclavicular and acromioclavicular joints. During lateral rotation the scapula turns the glenoid cavity almost directly up. This requires the acromial end of the clavicle to rise and the sternal end to rotate around its longitudinal axis. The acromioclavicular joint rises up until 30° until it is depressed by maximum tension of the conoid part of the coracoclavicular ligament. The movement is achieved by the trapezius and the serratus anterior muscles. Medial rotation reverses these movements and is accomplished by gravity, but can actively be performed by the levator scapulae, the rhomboid and the pectoralis minor muscles [10].

1.3.4 Important local muscles

The largest and most important muscle in the sternoclavicular joint region is the pectoralis major muscle. Local debridement of sternoclavicular joint infections and osteomyelitis with resection of the medial half of the clavicle, the lateral manubrium and the first costal cartilage, leaves a signifant deformity with exposed vascular vessels [14-17]. The pectoralis major muscle is often used for local plastic surgical reconstruction of the defect. A common method is a split pectoralis major rotational muscle flap [5]. Other important local muscles are the subclavius, the sternocleidomastoid, the sternohyoid and the sternothyroid muscles. The trapezius and the deltoid muscles are also attached to the lateral part of the clavicle and irrelevant for diagnosis and treatment of sternoclavicular empyemata. The pectoralis minor muscle lies posterior to the pectoralis major and is attached to the coracoid process of the scapula [10].

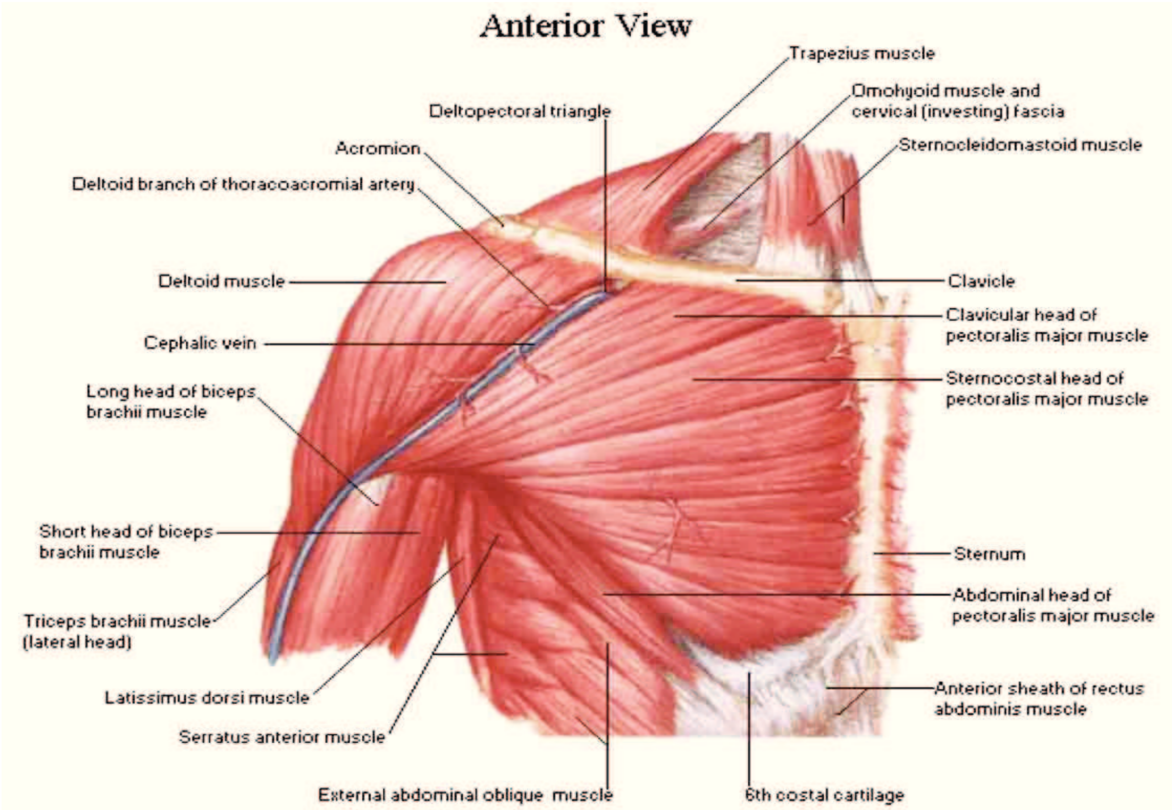

Fig. 8 [18] Anterior view of the muscles of the upper thorax, Frank H. Netter, MD, Atlas of Human Anatomy 5th. Edition, Saunders, 2010

1.3.4.1 The pectoralis major muscle

The pectoralis major muscle is a thick fan shaped muscle which consists of two main parts, the clavicular part and the sternal part [10]. It arises from the sternal half of the clavicle, half of the sternum, the first to seven costal cartilages, the sixth rib and from the aponeurosis of the external oblique muscle and is attached to the lateral lip of the intertubercular sulcus of the humerus. The thick anterior part is formed by fibres from the manubrium, the posterior part by twisted fibres from the sternum and from the external oblique muscle which turn around the inferior border. The upper and lateral borders are seperated from the deltoid muscle by the cephalic vein which lies together with the deltoid branch of the thoraco-acromial artery in the infraclavicular fossa. The anterior axillary fold is formed by the lower border of the pectoralis major muscle. The vascular supply is mainly provided by a dominant pectoral branch of the thoraco-acromial artery. Other secondary supplying vessels are the deltoid and clavicular branch of the thoraco-acromial artery as well as the internal thoracic and superior thoracic arteries. Because of the presence of a dominant vascular pedicle, a musculocutaneus flap, the pectoralis major musculocutaneus flap, can be surgically raised solely on the pectoral branch and used for the reconstruction of missing tissue in the neck or head as a result of cancer resections [6, 9]. The innervation is supplied through the medial and lateral pectoral nerves and directly through the cervcial plexus [10].

Muscle function

The whole muscle assists adduction and medial rotation of the humerus by moving the extended arm forwards. Elevation in the glenohumeral joint is assisted by contractions of the clavicular part relaxation of the sternal part. Depression is usually done gravity alone. The pectoralis major is also active in deep inspiration and draws the trunk up and forwards [10].

Congenital anomalies

A rare and etiologically unexplained congenital anomaly is the Poland Syndrome occuring in 1:50000 live births and resulting in hypoplasia of the thoracic chest wall muscles and the ipsilateral arm and hand. The main aspect is the abcence of the sternocostal head of the pectoralis major muscle and all of the pectoralis minor muscle. All other regional muscles may also be affected [10].

1.3.4.2 The subclavius muscle

The subclavius is a small muscle between the first rib and the clavicle which arises from the first costal cartilage and is attached to the middle third of the clavicle. It lies directly under the clavicle, anterior to the subclavian vessels and posterior to the clavipectoral fascia. The vascular supply is provided by the thoraco-acromial and the suprascapular arteries. The innervation is supplied by the nerve to subclavius. Its function is not fully explained but it fixes the clavicle to the sternoclavicular joint [10].

1.3.4.3 The sternocleidomastoid muscle

The sternocleidomastoid muscle arises from two different structures. Its clavicular head arises from the superior surface of the sternal end of the clavicle and its sternal head arises from the anterior surface of the manubrium. Both heads ascend along the side of the neck and unite about the middle of the neck, forming a thick muscular fibre which is attached to the lateral surface of the mastoid process and to the superior nuchal line. The vascular supply of the upper part of the muscle is provided by the occipital and the posterior auricular arteries. The middle part is provided by the superior thyroid artery and the lower part is provided by the suprascapular artery [10]. A superiorly based musculocutaneus flap can be raised to reconstruct the lips, the floor of mouth and the inner aspect of the cheeks [9]. The innervation is supplied by the accessory nerve. Each sternocleidomastoid muscle tilts the head to the ipsilateral shoulder and rotates the head to the contralateral side. Both muscles together raise the head upwards and also help elevating the thorax during forced inspiration [10].

1.3.4.4 The sternohyoid and the sternothyroid muscles

The sternohyoid muscle arises from the sternal end of the clavicle and the upper region of the manubrium sterni and is attached to the hyoid bone. It is supplied by the superior thyroid artery and by the ansa cervicalis. The muscle depresses the hyoid bone. The sternothyroid muscle arises from the upper manubrium inferior to the origin of the sternohyoid and from the first costal cartilage and is attached to the thyroid cartilage. The blood supply is provided by the superior thyroid and lingual arteries. The innervation is supplied by the ansa cervicalis. The muscle draws the larynx downwards [10].

1.3.5 Important local vessels and their anatomical course

There are some important regional arteries and veins which run anterior, posterior, superior or inferior to the clavicle and its joints which need careful surgeons' attention during reconstructive surgical procedures of chest wall defects in the upper thorax with a pectoralis muscle flap. The most important local arteries are the subclavian, the suprascapular, the supraclavicular, the thoraco-acromial, the superior thoracic, the internal thoracic and the lateral thoracic arteries. The most important regional vein is the subclavian vein, which is often used for central line placement or even drug abuse. The subclavian artery and vein are also a vulnerable point for being accidently punctured during an infraclavicular block anaesthesia [10].

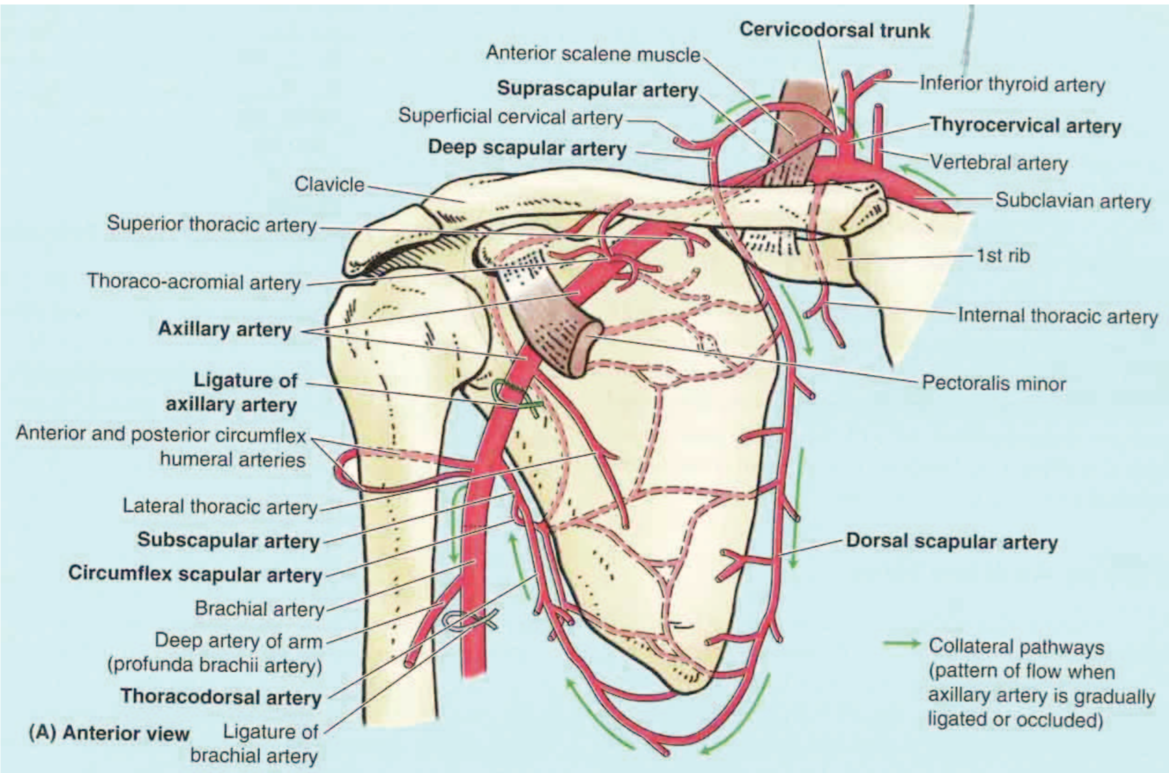

Fig. 9 [11] Anterior view of the arteries in the upper thorax, Clinical Orientated Anatomy, 6th. Edition, Keith L. Moore, Arthur F. Dalley, Anne M. R. Agur, Lippincott Williams & Wilkins, 2009

1.3.5.1 The subclavian artery

The right and left subclavian arteries differ in their origins. The right subclavian artery arises from the brachiocephalic trunc directly behind the right sternoclavicular joint and ascends above the clavicle to the scalenus anterior muscle and descends further between the clavicle and the first rib to the axilla where it becomes the axillary artery. On its way it is crossed by the vagus nerve, the sympathetic trunk, the internal jugular vein and by the vertebral vein. The left subclavian artery arises from the aortic arch behind the left carotid artery and ascends to neck and further to the the scalenus anterior muscle and to the axilla. The most superficial part of the subclavian artery is in the supraclavicular triangle where its pulsations may be felt through the skin. At this area the artery could be compressed against the first rib by depressing the shoulder. Branches of the subclavian artery are the thyreocervical and costocervical trunks, the vertebral and the internal thoracic arteries [10].

1.3.5.2 The suprascapular artery

The suprascapular artery arises from the thyreocervical trunk of the subclavian artery and descends between the scalenus anterior muscle and the internal jugular vein. Further on it crosses the subclavian and the vertebral arteries and runs behind and parallel with the clavicle to the superior border of the scapula, passing through the supraspinous fossa and lying on the posterior side of the scapula, where it anastomoses with the circumflex scapular and the transvers cervical arteries. The suprascapular artery supplies the sternocleidomastoid, the subclavius and the infraspinatus muscles. A branch which crosses the sternal end of the clavicle supplies the skin of the upper thorax. It also supplies the clavicle, the acromioclavicular joint and the the scapula [10].

1.3.5.3 The supraclavicular artery

The supraclavicular artery is a small vessel which arises either from the transverse cervical or the superficial cervical artery. It runs above the clavicle and supplies the skin over the acromial end of the clavicle [10].

1.3.5.4 The thoraco-acromial artery

The thoraco-acromial artery arises from the axillary artery and runs under the pectoralis minor muscle until it pierces the clavipectoral fascia and divides into four branches which supply the pectoralis major and the pectoralis minor muscles as well as the skin over the clavipectoral fascia and the anterior region of the deltoid muscle. The pectoral branch is the largest and enters the pectoralis major muscle and supplies the breast and the skin over the pectoralis major muscle. The acromial branch runs under the deltoid muscle and anastomoses with the suprascapular and the posterior circumflex arteries. The clavicular branch supplies the sternoclavicular joint and the subclavius muscle. The deltoid branch accompanies the cephalic vein between the pectoralis major and the deltoid muscle and supplies both [10].

1.3.5.5 The superior thoracic artery

This small vessel springs from the axillary artery and runs between the pectoralis major and pectoralis minor muscles to the thoracic wall and anastomoses with the internal thoracic artery. It supplies both named muscles [10].

1.3.5.6 The internal thoracic artery

The internal thoracic artery arises from the subclavian artery above the sternal end of the clavicle and descends behind it and the internal jugular vein down under the first costal cartilage. From there it enters the thorax and descends behind the first six costal cartilages and divides into musculophrenic and superior epigastric branches. Sternal branches supply the transversus thoracis muscle and the sternal red bone marrow. The anterior intercostal branches run along the upper six intercostal spaces and supply the intercostal and pectoralis muscles as well as the breast and the thoracic skin. The perforating branches pierce and supply the pectoralis major muscle and become direct cutaneus vessels that supply the skin. These cutaneous vessels provide the anatomical basis for surgical reconstruction of missing tissue in the head and neck with a deltopectoral skin flap [10].

1.3.5.7 The lateral thoracic artery

The lateral thoracic artery arises from the axillary artery and runs along the lateral border of the pectoralis minor muscle and passes further to the surface of the pectoralis major muscle. It anastomoses with the internal thoracic, subscapular and intercostal artieries and supplies the serratus anterior, the pectoralis minor, the pectoralis major and the subscapularis muscles as well as the skin above the lateral border of the pectoralis major muscle. In females the vessel is larger and has also mammary branches [10].

1.3.5.8 The subclavian vein

The subclavian vein arises from the axillary vein, closely above the first rib and the pleura, as a direct continuation. It runs up to the scalenus anterior muscle, where it anastomoses with the internal jugular vein, forming the brachiocephalic vein. The vein lies posterior to the clavicle and anterior to the subclavian artery. The external jugular, the dorsal scapular and the anterior jugular veins are its tributaries. Sometimes also a small branch from the cephalic vein, which runs in front of the clavicle, joins the subclavian vein. The right subclavian vein receives the thoracic duct and the left subclavian vein receives the right lymphatic duct [10]. The subclavian vein is often used for central line placement, which is a risk factor for sternoclavicular joint infections [12].

1.3.6 Important local nerves and their anatomical course

The most important local nerves around the sternoclavicular joint are the medial supraclavicular nerve and the nerve to subclavius, both supplying the joint itself. Directly posterior to the clavicle, there are the posterior, the lateral and the medial cords of the brachial plexus which divide approximately in the lower axilla into nerves that supply the upper limb. The medial and lateral pectoral nerves supply the pectoralis major muscle [10].

1.3.6.1 The supraclavicular nerves

The supraclavicular nerves arise from a trunk of the cervical plexus which descends under the cervical fascia and divides into the medial, intermediate and lateral supraclavicular nerves. The medial supraclavicular nerves run inferior across the external jugular vein and supply the sternoclavicular joint as well as the skin between the clavicle and the second rib. The intermediate supraclavicular nerves cross the clavicle and supply the skin over the pectoralis major and deltoid muscles. The lateral supraclavicular nerves run posterior and supply the skin of the posterior part of the shoulder [10].

1.3.6.2 The nerve to subclavius

The nerve to subclavius is a small nerve and arises form the supraclavicular part of the brachial pexlus. It descends anterior to the subclavian artery and passes superior to the subclavian vein and supplies the subclavius muscle and the sternoclavicular joint [10].

1.3.6.3 The posterior, medial and lateral chords of the brachial plexus

The posterior chord arises from the posterior divisions of the superior, middle and inferior trunks of the bracial plexus. The lateral chord arises from the anterior divisions of the superior and middle trunks and the medial chord arises from the anterior division of the inferior trunk. All three chords pass posterior and inferior to the clavicle and divide approximately in the lower axilla into nerves of the upper limb [13].

1.3.6.4 The lateral pectoral nerve

The lateral pectoral nerve is larger than the medial and arises from the anterior divisions of the superior and middle trunks. It may sometimes even arise directly from the lateral chord. The nerve runs anterior to the axillary artery and vein and supplies the pectoralis major muscle. It anastomoses with the medial pectoral nerve, forming a loop in front of the axillary artery. This branches supply the pectoralis minor muscle [10].

1.3.6.5 The medial pectoral nerve

The medial pectoral nerve arises from the medial chord and curves between the axillary artery and vein. It rejoins with the lateral pectoral nerve and supplies the pectoral minor muscle. Some branches pierce through the pectoralis minor muscle and supply the pectoralis major muscle [10].

1.4 Etiology and risk factors of sternoclavicular empyema

Sternoclavicular joint empyemata are rare and related to risk factors like diabetes, intravenous drug abuse, HIV, liver cirrhosis, chronic hepatits B/C, immunosuppression, tuberculosis, syphilis, endocrinologic diseases, rheumatological diseases, local intraarticular injections, central line placement, local radiotherapy, sternoclavicular fractures, head and neck surgery, renal failure, haemodialysis and malignant illnesses [2, 7, 8, 19-36]. The etiology is an infiltration of the sternoclavicular joint and attached bones with pathogens primary or secondary to one of the above risk factors, resulting in local infection, septic arthritis or osteomyelitis. Spontaneous sternoclavicular joint infections are uncommon and rare but have also been reported in the literature [37-42].

1.4.1 Intravenous drug abuse

Sternoclavicular joint infections are rare and reported in literature with about 0.5% - 1% of all joint infections [1, 2, 43]. However 17% of these infections occur in intravenous drug users [2, 43]. The complications of intravenous drug abuse range from soft-tissue complications like cellulitis, ulceration, abscess, pyomyositis and necrotizing fasciitis, to vascular and lymphatic complications like haematoma, arterial aneurysm, thrombosis, thrombophlebitis and lymphandenopathy and even to osseus complications like osteomyelitis and septic arthritis [44-51]. Intravenous drug abuse remains a worldwide problem, with about 625,000 drug related visits to emergency departments in the United States every year [52]. In drug injection, infectious agents may gain acces to bone and joints by haematogenous seeding, by direct implantation of pathogens beneath the periosteum or by spread of pathogens from adjacent infections in the subcutaneus tissue, resulting in osteomyelitis and septic arthritis [44]. First signs of sternoclavicular joint infections in drug users may be pain in the upper limb, shoulder and chest, fever and chills, reduced moving ability of the pectoral shoulder girde and local tenderness of the skin [43].

1.4.2 Central line placement

Central line placement account for about 90% of catheter-related bloodstream infections [53]. Between 500 and 4000 patient deaths are associated with blood stream infections in the United States a year [54]. Reviewing the literature shows, that catheterisation of the subclavian vein may lead to septic arthritis or osteomyelitis of the sternoclavicular joint or the attached bones [14, 19]. Venous catheter-related infections may be a result of haematogenous bacteraemia, but a direct inoculation of the sternoclavicular joint during attempts at percutaneous vein catheterisation with a contaminated catheter is more contemplable [7]. Although central line placement is a surgical procedure with full aseptic precautions, a minimal risk of local infection still remains. It is practically impossible to guarantee absolute sterility. Central line placement is a standard procedure in all intensive care units all over the world and the minimisation of risks of infections should always have high priority in order to reduce morbidity, mortality and health care related costs. Pronovost P. et al. suggested in a recent study, that infections caused by central line placement can be prevented by applying 5 measures - hand hygiene, using full barrier precautions during the insertion of central venous catheters, cleaning the skin with chlorhexidine, avoiding the femoral site if possible, and removing unnecessary catheters [55]. The most commonly found organism is *Staphylococcus aureus* [14, 56].

Fig. 10 [57] Thoracic inlet 3D volume-rendered image depicts the right sternoclavicular joint infection in a patient with a central venous catheter in the right jugular vein: Lawler LP, Fishman EK. Multi-detector row CT of thoracic disease with emphasis on 3D volume rendering and CT angiography. Radiographics. 2001 Sep-Oct;21(5):1257-73.

1.4.3 Intraarticular Injections

Diagnostic and therapeutic joint injections of either corticosteroids, local anesthetics or hyaluronic acid are a common and standard procedure in all daily medicine. Although current guidelines of practice recommend it, most of these procedures especially in the knee or shoulder region are done without the use of imaging guidance resulting in poor hit accuracy of the intended target, even if the confidence of the clinician is high [58-60]. Accuracy is very important and multiple studies have shown, that applying the medication to the right target joint reduces adverse effects and improves clinical outcome of patients [58, 61]. Several adverse effects from mild ones like local pain or transient inflammatory response to moderate ones like heamarthrosis or adjacent injury of nerves and vessels and up to severe ones like septic arthritis, complex regional pain syndrome or even life-threatening reactions have been reported in the literature [62-64]. The most serious complication is septic arthritis with an estimated occurrence rate of 1 in

10,000 to 1 in 50,000 injections [64-67]. Therefor the use of careful sterile techniques is very important, but it does not completely eliminate the risk of joint infections [58, 68]. Components of a sterile technique require the doctor to wear a mask, to desinfect his hands, to wear sterile gloves, to desinfect the skin with either a iodine-containing solution or alcohol, to drape the area with sterile towels and to avoid injections when the overlying skin is infectious or is affected by inflammatory diseases, wounds, psoriasis or mycosis [58, 68, 69].

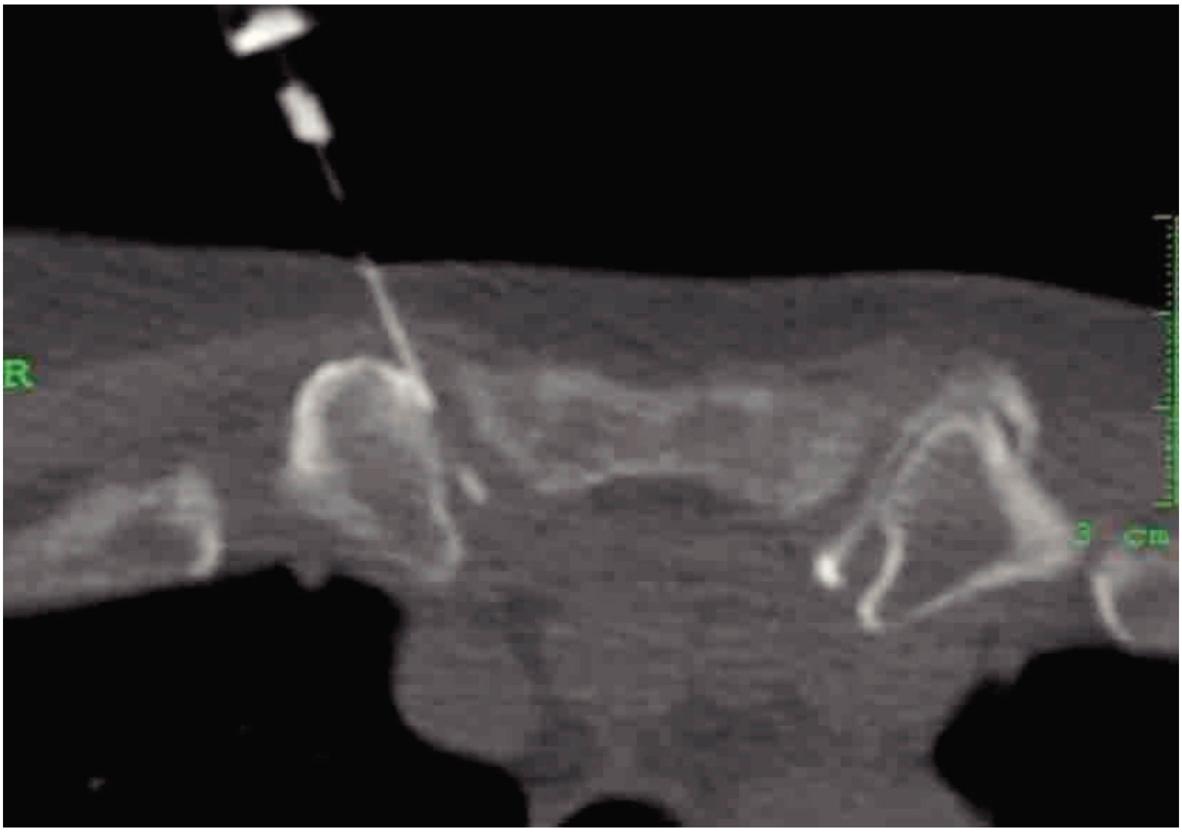

Fig. 11 [22] CT-guided sternoclavicular joint injection: Peterson C, Hodler J. Adverse events from diagnostic and therapeutic joint injections: a literature review. Skeletal Radiol. 2011 Jan;40(1):5-12.

1.4.4 Diabetes mellitus

The literature describes several cases of sternoclavicular joint infections in patients with diabetic underlying disease [2, 8, 19, 32, 33]. Diabetes mellitus is based on a glucose-metabolism disorder, resulting in relativ or absolute lack of insulin with chronic hyperglycaemia and is one of the most common diseases of the western world. Diabetes is classified in diabetes mellitus type 1, induced by immunological or idopathic beta cell destruction; or in diabetes mellitus type 2, induced by a reduced effect of insulin with insulin resistence or a disturbed insulin secretion [27]. Over 90% of all diabetics are type 2 and only about 5% are type 1 [27]. The cause of this allocation is a worldwide continuously rising high rate of people with obesity, hypercaloric diet and lack of exercise, resulting in a metabolic syndrome. Continuous hypergylcaemia over a long time results in the building of advanced glycation endproducts [70]. These irreversible glycosylated proteins adhere to various receptors, e.g. from endothel, macrophages, lymphocytes or mesangium cells and affect and modify many biological functions like secretion of cytokines, migration of macrophages, surface modifications of endothel with increased permeability and hypercoagulation, or increased proliferation rates of fibroblasts and smooth muscle cells [70]. All these modifications lead to a relative immunodeficiency, which increases the risk of infection and disturbance of wound-healing. Neurological complications are partly induced by intracellular toxycity of glucose. A high level of intracellular glucose leads to a an increased aldose-reductase function with intracellular accumulation of sorbitol. An increased intracellular osmolarity results, which damages the cell by increasing the water inflow [70]. Furthermore long time diabetes results also in microangiopathy, especially affecting the kidneys and the eyes. The incorporation of blood plasma components like low-densitiy-lipoproteins into the vascular wall of arteries accelerates atherosclerosis and increases the risk of myocardial infarction, apoplexy and gangrene. Diabetic polyneuropathy, affecting the sensibility of the lower limb, is a result of demyelination of peripher nerves and damage of their axons.

1.4.5 Liver cirrhosis

Liver cirrhosis is mainly caused by alcohol abuse or chronic infections with hepatits B or C virus [27]. Permanent damage of liver cells results in the destruction of the hepatic lobes and the vascular structure. Inflammation occures and activates the forming of fibrous connective tissue and nodes. Functional consequences are hepatic failure, portal hypertension and the development of intrahepatic porto-systemic shunts between the arteries and the veins. Insufficient hepatic perfusion and hepatic failure results in symptoms like jaundice, haemorragical diathesis, hepatic encephalopathy or carcinoma. Signs and symptoms of liver cirrhosis are spider naevi, palmar or plantar erythema, pruritus, vascular ectasia and leukonychia. Disturbances of the hormone system with hairloss and gynaecomastia occure in men, while menstrual dissorders and amenorrhea occure in women. Another main problem is the affliction of the immune system increasing the risk for chronic infections. Coagulopathy with clotting disorders is also a severe complication of liver cirrhosis [27].

1.4.6 Immunosuppression and immunodeficiency

Immunodeficiency is a general risk factor for any kind of local or systemic infection by a functional reduction of typical immune cells like leucocytes and lymphocytes. The literature reports several cases of clavicular osteomyelitis in immunosuppressed patients after transplantation [71, 72]. On the one hand the lack of celluar defence continuously keeps the path open for many pathogens, resulting in local or systemic infections like skin abcess or pneumonia, but on the other hand it also increases the risk for malignant illnesses. Furthermore, even harmless skin related pathogens could become a thread. Immunodeficiency is related to several conditions like chronic diseases, malignant illnesses, leucaemia, drug abuse, advanced age, or infection with the human immunodeficiency virus. It can also be caused by medical drugs during chemotherapy or after organ transplantation by immunosuppression. Immunosuppression after organ transplantation is necessary in order to prevent a rejection reaction and to increase quality of life.

1.4.7 Infectious Diseases

1.4.7.1 Human immunodeficiency virus (HIV)

HIV is caused by a RNA retrovirus and is mainly transmitted by blood, semen and vaginal fluid during sexual intercourse [70]. Although the HIV incidence has fallen in several countries in the last decade, the Joint United Nations Programme of

HIV/AIDS estimated about 2.6 million newly infected people in 2009 [73]. Several case reports in the literature describe sternoclavicular joint infections caused by different pathogens in patients infected with HIV [28-31]. On the one hand the infection with HIV may lead to an acquired immunodeficiency syndrom (AIDS), which drastically increases the risk of any local or systemic infection, but on the other hand it also influences the bone metabolism. Ofotokun et al. described that the skeletal renewal is strongly influenced by the immune system, basing on integration and centralisation of common cell types and cytokine mediators, which has been termed as the „immuno-skeletal interface“ [74]. Therefor skeletal renewal, being a common feature of inflammatory conditions, associated with immune activation, is also associated with conditions of immunodeficiency [74]. It has been established, that the prevalence of bone abnormalities in HIV-infected patients is several fold higher than in age, race and sex matched control groups [74-78]. A recent meta-analysis of 884 HIV-infected patients and 654 controls showed, that rates of osteopenia and osteroporosis were as high as 67% and 15% among the HIV-infected groups [79]. Furthermore HIV is also associated with disturbences of the parathyroid hormone and vitamin D metabolism, which are also related to low bone mass [80]. Moreover, several recent studies also showed, that the standard and necessary treatment of HIV-infected patients with antiretroviral drugs even worsens the bone loss and increases the risk of bone fractures [76, 81].

1.4.7.2 Chronic hepatitis B

Hepatits B is a infectious disease caused by the hepatitis B virus. It is a hepatotrophic DNA virus consisting of a surface, a core, its DNA and a DNA polymerase. About 6% of the world population is infected with hepatitis B and resulting in over 1 Million deaths a year [27]. Transmission results from exposure to infectious blood or body fluids, mainly during sexual intercourse or re-use of contaminated needles. A perinatal vertical infection is a main problem in endemic countries. The virus replicates itself in the liver cells and disturbes the cellular synthesis. The main liver is not initiated by the virus itself, but by the immune response. Infected hepatocytes are completely destroyed by cytotoxic T-cells. Chronic infections induce permanent cellular liver damage followed by repair mechanisms and results in liver fibrosis and liver cirrhosis [27].

1.4.7.3 Chronic hepatitis C

So far to my best knowlegde we are the first authors in the English and German literature to report about two cases of sternoclavicular joint empyemata in patients with chronic hepatitis C infection. Hepatitis C is an infectious disease caused by the hepatitis C virus. It is a RNA virus descending from the viral family of Flaviviridae. About 3% of the world population is infected with and about 40% of all viral related hepatic cirrhosises are caused by the hepatitis C virus. Transmission mainly occures by blood or body fluids during sexual intercourse, drug abuse, piercing or tatooing. 75% of all infections results in chronical states. Unlike the hepatitis B virus, the hepatitis C virus directly affects and damages hepatic cells. Activated cytotoxic T-cells induce further damage by killing infected cells. 20% of all chronic permanent cellular liver damage by hepatitic C, followed by repair mechanisms results in liver cirrhosis during the first twenty years after the infection [27].

1.4.7.4 Tuberculosis

Although being a worldwide dreaded, but due to modern antibiotics a cureable disease, the incidence of tuberculosis has increased in the last decade. The WHO estimated about 9 million new cases of tuberculosis world wide in the year of 2009 and on top of that, multidrug-resistant tuberculosis threatens to turn the tide against the medical advances of the past century [82]. Tuberculosis is caused by mycobacteria and transmitted by droplet infection from patients with active tuberculosis. The bacteria affects the lungs resulting in tubercular granuloma and caseous necrosis of lung parenchym [70]. A dreaded complication is the affliction of other organs like the kidneys, the adrenal gland, the ovarian tube or the bones and joints by haematogenous or contiguous spread. Nonetheless the affliction of the sternoclavicular joint is uncommon and extremely rare but has been discribed in the literature [21, 83-87]. The source of infection in all cases is believed to be fresh or reactivated pulmonary tuberculosis, affecting the sternoclavicular joint by contiguous spread from apical pulmonary lesions [83, 86].

1.4.7.5 Untreated syphilis

Syphilis is caused by *Treponema pallidum*, a species of spirochaete bacteria and transmitted by sexually intercourse [70]. The disease proceeds in four stages. The primary stage of syphilis affects only the skin and results in a local high infectious chancre. Secondary syphilis occures about 6 to 18 weeks after the infection and results in a haematogenous spread of the bacteria affecting the mucosa, the liver, the spleen, the kidneys, the vascular system, the nerval system and the joints. Quite frequently the sternoclavicular joint [88]. Latent syphilis describes a serologic proof of infection without clinical signs and the tertiary stage occures between 2 to 20 years after the first infection and results in neurosyphilis, cardiovascular syphilis and gummatous syphilis [89]. Kent et al. described lues as a disease, that plagued mankind for centuries. Although beeing cureable since the mass production of penicilliin in 1945 and with low epidemic rates in the last two decades, syphilis has reemerged worldwide especially in several developed countries [89, 90]. On top of that, antibiotic-resistant treponema pallidum threatens the medical treatment and bears a global challange [90]. Several reports in the literature describe patients with inflammatory signs and arthro-osteitis of the sternoclavicular joint or the sternum during secondary syphilis [88, 91, 92]. Treponema pallidum was identified in the material from osteoarticular biopsy. Rheumatic disorders from secondary syphilis generally affect the large joints, but also affect the sternoclavicular joint quite frequently [88].

1.4.8 Regional trauma and surgery

1.4.8.1 Trauma

Clavicular traumata often occure in children by indirect forces as a result of violent impact to the arm or shoulder. The fracture occurs usually at the joint between the lateral and intermediate third, which is the weakest part of the shaft [12]. Surgical fixation of the clavicle increases the risk for infiltration of the clavicle with pathogens. In the worst case clavicular osteomyelitis could occure and affect also adjacent structures. Primary clavicular osteomyelitis in children is reported by several cases in the literature occuring by haematogenous spread [93, 94].

Moreover a resulting sternoclavicular joint dislocation also needs direct local surgical manipulation of the joint itself. A typical treatment for sternoclavicular joint dislocation is a minimally invasive fixation with a Kirschner wire, again opening the path for potential pathogens [95].

Fig. 12 [57] Clavicular Trauma, coronal volume rendered image. Lawler LP, Fishman EK. Multi-detector row CT of thoracic disease with emphasis on 3D volume rendering and CT angiography. Radiographics. 2001 Sep-Oct;21(5):1257-73.

1.4.8.2 Oncologic surgery of the head and neck

Although being uncommon and rare, several case reports in the literature show an association of major head and neck surgeries with clavicular osteomyelitis [71, 72, 96]. Cesare Piazza et al. described the most important risk factor in the development of osteomyelitis to be the impairment of vascularisation, due to surgical disruption of the periosteum and/or cortical bone [25]. Head and neck surgery may be indicated in treatment of malignant illnesses and can result in cervical lymphadenectomy, extirpation of local lymphoma or complete neck dissection. Furthermore oncologic patients may also suffer from poor nutritional status with anaemia or from adverse affects of chemo- and radiotherapy, resulting in immunodeficiency and increasing the risk for infections and osteomyelitis.

1.4.8.3 Median sternotomy

Sternal wound infections are a major and common complication of median sternotomy after coronary artery bypass grafting or prosthetic valve replacement. Several severe and feared complications like sternal osteomyelitis or mediastinitis have been reported in the literature [97-101]. Grossi et al. described 32 of 77 patients with sternal wound infections, that showed a concomitant infection at other sites with the same cultured organism [97]. The main strategy to minimize the risk and to prevent sternal wound infections after median sternotomy, is to avoid a combined revascularisation and valve replacement, a prolonged postoperative ventilatory support over 24 hours, postoperative reexplorations for bleeding and a prolonged low cardiac output syndrome [97].

1.4.9 Malignant Illnesses – signs and therapy

1.4.9.1 Lymphoma or regional metastasis

Non-Hodgkin lymphoma of the medial clavicle and other neoplasms of the clavicle are rare but have been reported in the literature [26, 34-36]. Any occult sternoclavicular mass has to be analysied for dignity, because the majority of tumors of the clavicle are malignant [36, 102, 103]. A CT guided biopsy of the sternoclavicular joint is necessary and increases the risk of infiltration of the joint with pathogens. Several other reports in the literature describe the appearance of sternoclavicular osteomyelitis after surgery of head and neck cancer [15, 72, 96]. The operations involved lymphadenectomy of cervical lymphnodes, neck dissections or other extirpation of regional metastasis or lymphoma. Moreover oncologic patients may also suffer from poor nutritional status with anaemia or from adverse affects of chemo- and radiotherapy, resulting in immunodeficiency and increasing the risk for infections and osteomyelitis.

1.4.9.2 Local radiotherapy

A previous radiation therapy decreases the local blood supply by direct damage of the local vessels. The local impairment of the vascularisation leads to a lower blood supply of the periost and the cortical bone and therefor increases the risk of osteomyelitis [25]. A decreased blood supply also leads to a disturbance in the process of wound healing, resulting in chronic ulceration, which permanently keeps the path open for pathogens. Several reports in the literature show the appearance of sternoclavicular osteomyelitis in patients with previous local irradiation [71, 72, 104]. Another severe complication of radiation is soft tissue necrosis, which needs a wide surgical debridement of the devitalized tissue and following plastic surgical reconstruction with soft tissue coverage [105].

1.4.9.3 Chemotherapy

Chemotherapy is a standard, life saving and common therapy of several malignant illnesses. Unfortunately it has a wide range of adverse effects, which affect the body, the gastrointestinal tract, several physiological processes and especially the immune system. The resulting immunodeficiency increases the risk for local and systemic infections.

1.4.10 Chronic renal failure and haemodialysis

The etiology of chronic renal failure has a wide range. Chronic renal failure can be the result of several diseases like diabetic nephropathy, primary or secondary glomerunephritis, chronic tubulointerstitial disorders, vascular nephropathy, polycystic renal diseases and other rheumatic or metabolic diseases which affect the kidneys [27]. The result is a failure of the excretoric and incretoric renal function with decreased secretion of erythropoietin, renin, active vitamin D and prostaglandines; electrolyte and acid-base imbalances, as well as toxic organic lesions, caused by retained urinous substances [27]. Vitamin D has a main role in the regulation of the bone metabolism and the calcium level. A reduced vitamin D level may lead to osteomalacia with bone mass loss and bone deformities. Chronic renal failure is a life-threatening condition and needs long-time treatment. The single cureable option is renal transplantation. Patients are treated and kept alive with haemodialysis until a suitable organ donor is found. Unfortunately recent studies from 2011 report, that long time haemodialysis has a wide range of adverse effects, starting from several infections, to cardiovascular events and up to life threatening conditions like peritonitis [106-109]. Another main problem of haemodialysis is a weakened immune system with increased risks of infection and several cases of bone and joint infections have been reported in the literature [110]. The sternoclavicular joint has also been involved [111]. Moreover several reports from the literature present haemodialysis-related amyloidosis of the sternoclavicular joint and other bones and joints [112-115].

1.4.11 Other

1.4.11.1 Chronic diseases

Several chronic diseases like rheumatic, vascular or autoimmune disorders, which may directly affect the bones and joints or may weaken the immune system, are a risk factor for joint infections. A review of the literature shows several case reports of patients with diseases like systemic lupus erythematodes, rheumatoid arthritis, psoriatic arthritis, systemic sclerosis or sarcoidosis in combination with osseos disorders like osteonecrosis, aseptic osteomyelitis and bone destruction [116-118].

1.4.11.2 Coronary Angiography

In a recent single case report from 2008, Hoseini et al. reported about a patient, who developed septic arthritis of the sternoclavicular joint after coronary angiography [119]. The catheter entrance is often located at the left groin through an incision of the femoral artery. The catheter is pushed upwards through the abdominal aorta, the thoracic aorta and the arch of the aorta into the coronary artieries of the heart. A haematogenous spread of pathogens from a contaminised catheter may occur at the arch of the aorta into the subclavian artery and may affect the sternoclavicular joint.

1.4.11.3 Spontaneous appearance without any known risk faktors

A review of the literature shows several cases of spontaneous sternoclavicular arthritis in previously healthy patients without any known risk factors [38-42]. 2008 El Ibrahimi et al. reviewed the literature and mentioned 27 cases of sternoclavicular septic arthritis in previously healthy patients between 1966 and

2001 [41]. The clinical presentations of spontaneous sternoclavicular arthritis are often sudden with atraumatic pain in the shoulder, neck or chest and limited motion of the upper extremeties for days to months [41]. The infection is often caused by *Staphylococcus aureus* [2].

1.5 Signs, symptoms and complications

1.5.1 Signs and symtoms

The five typical signs of infection are rubor, calor, tumor, dolor and functio laesa. However reviewing the literature shows, that the signs and symptoms of sternoclavicular joint infections vary from patient to patient and may even be unspecific. The majority of signs and symptoms of sternoclavicular joint infections have been reported to be soft tissue swelling over the affected joint, dermal erythema, local tenderness, pain in the upper chest, upper limb or shoulder region, fever and limited movement of the pectoral shoulder girdle [2, 8, 14, 15, 22, 25, 37-41, 49]. Fever or even pain can be absent [42]. In his review of 180 cases, Ross et al. reported leucocytosis in 56% and bacteraemia in blood culture in 62% [2]. Sternoclavicular joint infections are generally unilateral, but several cases of bilateral affliction have been reported in literature [7, 19, 120, 121].

1.5.2 Complications

Common complications of sternoclavicular septic arthritis have been reported to be osteomyelitis and locoregional abscesses [14-16, 23, 41, 49, 122]. The most severe and life threatening complication is mediastinitis, which occured in less than 15% of cases [2]. Acute mediastinitis has a high mortality rate caused by rapid progess of septic schock with multiple organ failure and therefor has to undergo rapid diagnosis, targeted intravenous antibiotics and surgical treatment. Another serious, but rare complication, is thrombosis of the subclavian vein or superior vena cava [2]. Septic shock may occure, but the majority of sternoclavicular arthritis remains a localized process [41].

1.6 Diagnosis

The clinical diagnosis is made from several aspects including anamnesis, case history and possible risk factors, clinical signs and symptoms, laboratory findings, imaging, a smear test and blood culture. Because typical clinical signs and symptoms may be unspecific or even absent, a CT scan of the chest and an MRI are recommended to identify bone destruction, retrosternal spread and soft tissue involvement [1, 2, 41, 123-126]. A non infectious degenerative process caused by rheumatic or vascular disorders could also be masked behind typical signs of infection and therefor the final diagnosis is made from culture of the joint fluid obtained using needle aspiration or open biopsy [41].

1.7 Microbiology

Microbiological studies are used to identify pathogens for targeted and optimized antibiotic treatment and therefor are one of the most important aspects of clinical diagnosis and therapy of sternoclavicular empyemata. The culture from joint fluid can be obtained using needle aspiration or open biopsy [41]. The most common pathogen is *Staphylococcus aureus*, which was reported by Ross et al. in 49% of 180 cases of septic arthritis in the sternoclavicular joint [2]. *Pseudomonas aeruginosa* and *Candida* species have been reported in intravenous drug users with septic arthritis of the sternoclavicular joint [127]. Several cases of mycobacterial infections have also been reported in the literature [83-87]. Rare sternoclavicular joint infections with *Salmonella spp*. and *Kingella kingae* have been reported [38, 128]. Other pathogens like *E.Coli, Haemophilus influenzae, Streptococcus pneumoniae, Neisseria gonorrhoeae, Streptococcus pyogenes* and *Candida albicans* have been reported in patients infected with HIV [2, 28-30]. Nelson et al. reported three cases of septic arthritis with *Clostridium novyi, Clostridium bifermentans* and *Bacteroides funduliformes* [129, 130]. A recent detailed analysis and review of the microbiology and management of joint and bone infections due to anaerobic bacteria, which was done by Brook Itzhak reports about several other possible organisms in septic arthritis [4].

1.8 Therapy

Several therapeutic approaches have been reported in the literature. Optimal therapy has been reported to consist of four combined aspects: Targeted antibiotic therapy, local aggressive debridement with resection of the sternoclavicular joint, vacuum assisted closure therapy and local reconstruction with a pectoralis major flap [5, 7, 8]. 2009 Fordham et al. reported about the optimal management of sternoclavicular septic arthritis and stated, that surgical and antibiotic therapy is required to limit bony destruction and potential complications [131]. Local reconstruction may not be an obligatory measure as recently reported by Varun Puri et al. who compared two surgical approaches in 20 patients, 10 patients with aggressive debridement and open wound care with no local reconstruction and 10 patients with aggressive debridement and immediate reconstruction with a pectoralis major advancement flap [132]. The patients with open wound management showed less complications than the group, who underwent local plastic reconstruction [132]. A two ore more stage surgical procedure is essential for infection control and to avoid recurrence of infection.

1.8.1 Targeted antibiotic therapy

Targeted antibiotic therapy is one of the most important aspects in the clinical treatment of sternoclavicular septic arthritis in order to successfully eradicate the pathogenic agents and minimising the risk of severe complications. Therefor a microbiologic study is indispensable in order to successfully identify the involved pathogen. The culture from joint fluid can be obtained using needle aspiration or open biopsy [41].

1.8.2 Aggressive surgical debridement with joint resection

Song HK et al. reported 2002 about the optimal surgical management of sternoclavicular infections and described that simple antibiotic therapy, local drainage and tissue debridement were generally ineffective and lead to a recurrence of the infection [8]. Song HK also draw the conclusion that only an aggressive surgical management with resection of the sternoclavicular joint including resection of the medial clavicle, half of the ipsilateral manubrium, the first costal cartilage and the anterior first rib with a pectoralis major muscle flap closure would appear to be the preferred treatment for extensive infections of the sternoclavicular joint, resulting in no wound infection and excellent upper extremity function at long-term follow up [8]. In 2009 Fordham et al. stated that surgical and antibiotic therapy is required to limit bony destruction and potential complications [131].

1.8.3 Vacuum assisted closure (VAC) therapy

A recent review of the literature reveals several hundred studies that have been published reporting the outcome and methods of vacuum assisted closure for wounds, arising from congenital defects, trauma, infection, tumour, burns, pressure ulceration and postsurgical complications [133]. Negative pressure wound therapy has become commonly used for the treatment of a wide variety of complex wounds and works through mechanisms, that include fluid removal, wound retraction, microdeformation and moist wound healing [134]. Vacuum assisted closure provides an occlusive environment, in which wound healing can take place under clean and sterile conditions, which is not given by conventional dressings [135]. Negative pressure wound therapy increases the rate of granulation in the wound [136] and also reduces pain caused by the wound [137]. Moreover fresh granulation indicates good wound healing by beeing part of the proliferative stage of natural wound healing [138]. Banwell et al. reported that VAC therapy induces three-dimensional stress across the whole area of the wound, also known as macro-strain that draws wound edges inwards and shrinks the wound [139]. On top of that Morykwas et al. stated that VAC therapy also achieved a clinically significant reduction in bacterial load of chronic wounds on a swine by the fifth day [140]. Adverse effects of negative pressure wound therapy are skin irritation, painful dressing changes, gastro-intestinal fistulae and the risk of bleeding in patients using anticoagulants [141]. Serious complications including bleeding and infection have recently been reported by the U.S. Food and Drug

Administration in a small number of patients [142]. Although vacuum assisted therapy, with several systems on the market and many more to come, has changed the way complex wounds are treated, Orgill et al. are convinced, that the rapid introduction of this treatment has occured faster than large scale randomized controlled studies have been conducted and that further clinical studies are necessary to fully understand the evidence and use of this technology in future [134].

1.8.4 Reconstruction with a pectoralis major muscle flap

A unilateral or bilateral pectoralis major muscle flap is commonly used for the plastic surgical reconstruction of several superficial or internal upper chest wall and skeletal defects resulting from sternectomy, lumpectomy, aggressive resection of malignant tumours and metastasis or from extending mediastinitis [143-147]. The resection of the sternoclavicular joint including resection of the medial clavicle, half of the manubrium, the first costal cartilage and a part of the first rib leaves a significant defect exposing important local and major anatomical structures. This includes the exposure of the subclavian artery, the subclavian vein and several other smaller local arteries and nerves. Well perfused soft tissues are essential for wound healing, cosmesis and mechanical stress [14]. Several reconstructive approaches after sternoclavicular joint resection have been reported in the literature utilising a pectoralis major advancement flap or a split pectoralis major muscle flap or [5, 8].

1.8.4.1 The pectoralis major advancement flap

The pectoralis major advancement flap is commonly used for soft tissue reconstruction after sterncolavicular joint resection [8]. After local debridement of avital tissue and resection of the sternoclavicular joint, the upper third of the pectoralis major muscle down to the deltopectoral groove is mobilized, including the superior detachment of the muscle from the clavicle, the lateral detachement from the humerus and the medial detachment from the sternum. After surgical sectioning of the muscle from its medial intercostal supplying arteries and seperation from the underlying pectoralis minor muscle, the muscle is advanced superomedial into the defect, pediculed on its thoracoacromial artery vascular supply and attached to the surrounding structures [8].

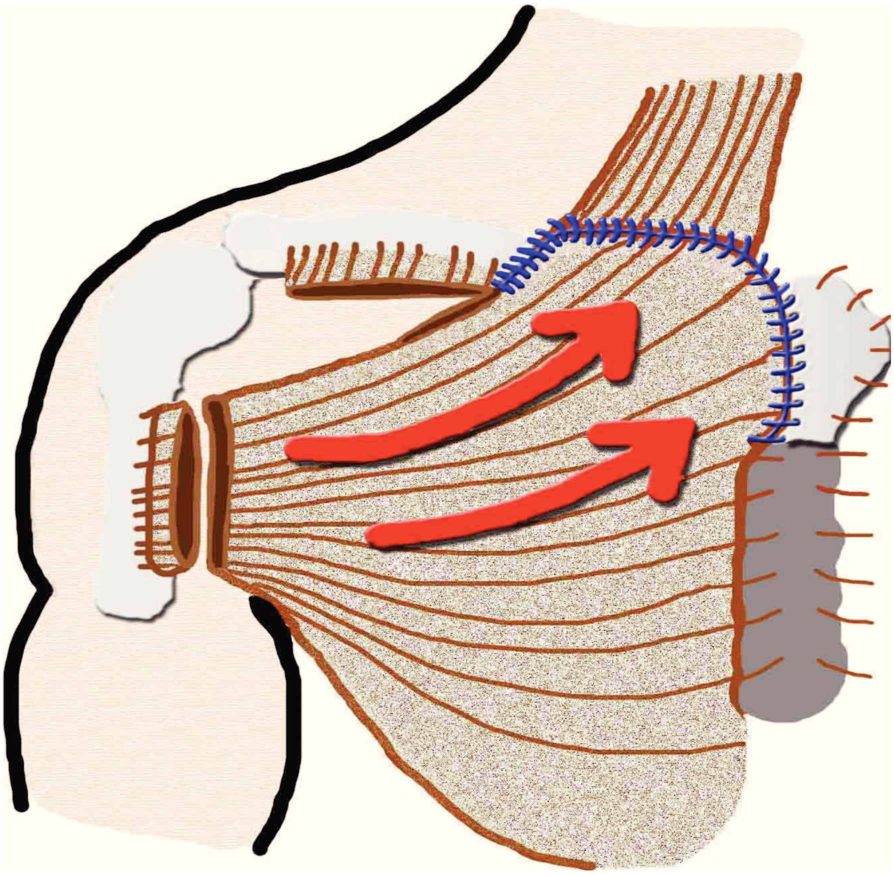

Fig. 13 Pectoralis major advancement flap

1.8.4.2 The split pectoralis muscle flap

Zehr et al. described, that although being the standard use for soft tissue reconstruction, providing a large vascularized muscle mass to fill a significant defect, the pectoralis major flap results in the complete loss of the pectoralis major function and therefor, he reported about a technique using a split pectoralis muscle flap [5]. The superior one half of the muscle is transected allowing a free dissection from the underlying pectoralis minor muscle [5]. The medial dissection is extended at the basis of its medial vascular perforators creating a spilt pectoralis major flap, which can be easily rotated 45 to 60 degrees to fill the upper defect [5]. The flap is attached to the platysma and the remaining half of the manubrium.

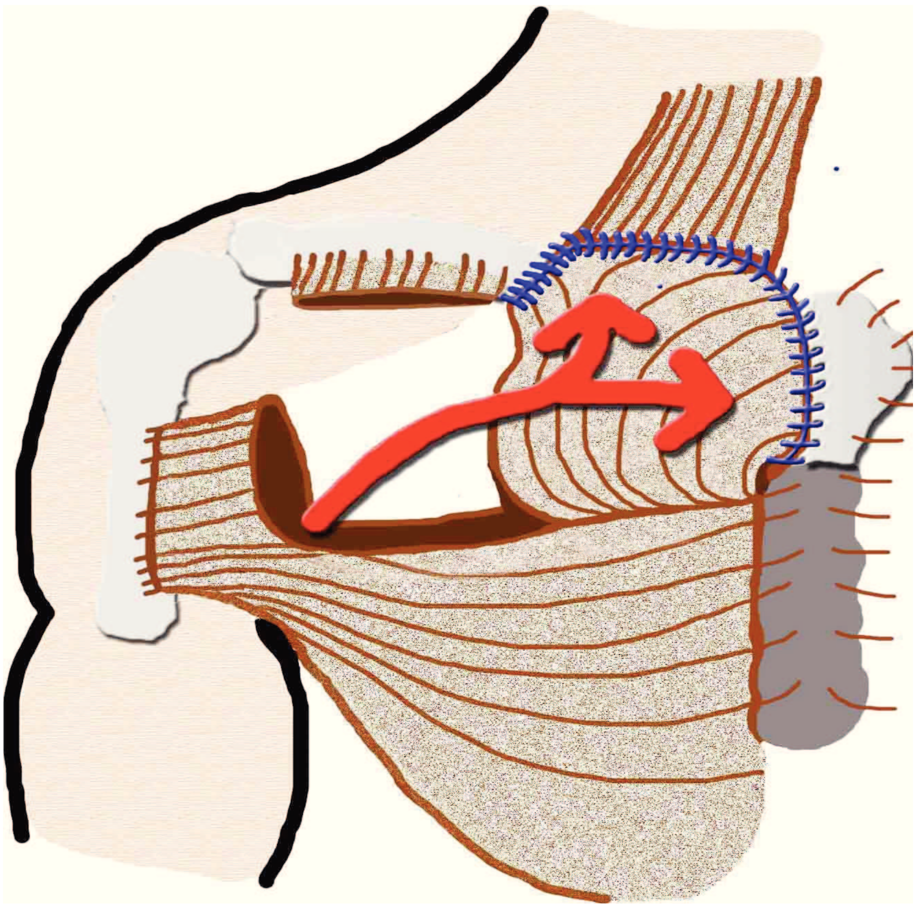

Fig. 14 Split pectoralis major muscle flap

1.8.5 Differential diagnosis

1.8.5.1 SAPHO syndrome (sternocolavicular syndrome)

The acronym SAPHO stands for a syndrome consisting of synovitis, acne pustulosis, hyperostosis and ostitis and belongs to the clinical picture of rheumatic disorders and diseases. Schilling et al. presented several case reports of patients with pustulosis palmo-plantaris, sterno-costo-clavicular hyperostosis, spondylopathy and chronic recurrent multifocal non purulent osteomyelitis [148]. Sallés et al. recently reported about 52 patients with diagnosed SAPHO syndrome, 93,3% showing increased scintigraphic uptake mainly in the sternoclavicular and manubriosternal joints [149]. A CT scan showed sclerosis, erosions, hyperostosis and soft tissue involvement [149]. The majority of patients complain about pain of the upper chest wall and show typical skin changes like pustulosis and acne [150].

1.8.5.2 Psoriatic arthritis

Psoriatic arthritis is found in 5 to 7% of all patients suffering from psoriasis vulgaris, belongs to the heriditable diseases and is associated with the human leucocyte antigen B 27 (HLA-B 27) [151]. Taccari et al. reported about 10 patients with psoriatic arthritic affliction of the sternoclavicular joint and presented CT images which showed erosions, subchondral cysts and sclerosis of the sternoclavicular joint [152]

1.8.5.3 Ankylosing spondylitis

Ankylosing spondylitis, also known as Bechterew´s Disease, is a chronic, inflammatory autoimmune disease, which primary affects several joints in the spine or in other regions [153]. An affliction of the sternoclavicular joint is rare, but has been reported in the literature [154-156]. The joint is primary affected by cortical bone erosions, joint space narrowing and sclerosis [156].

1.8.5.4 Tietze syndrom

The Tietze syndrome is a benign and self-limiting condition, characterised by tender swelling of the affected region [26, 157]. It refers to an inflammation of the costochondral junctions or chondrosternal joints of the anterior chest wall, resulting in local tenderness and chest pain [157]. The treatment is based on the avoidance of activities involving the chest muscle in combination with anti-inflammatory medication [157].

1.8.5.5 Clavicular condensing osteitis and hyperostosis

Condensing osteitis of the clavicle is rare and a benign condition, which affects the medial end of the clavicle and results in sclerosis and expansion of the inferior part of the clavicular head [158]. Signs and symptoms are regional tissue swelling, tenderness and pain. Sng KK et al. reported about follow-up of 9 patients after 9 to 77 months of treatment with physiotherapy, showing subjective improvement in the pain symptoms [158].

1.8.5.6 Sternoclavicular joint dislocation

Sternoclavicular dislocations are uncommon, rare and classified in acute, fractured, chronic, habitual or Salter-Harris fracture before the age of 25 [159]. The treatment serves the severity of the dislocation and can occur by non-operative measures or by surgical fixation [159]. Surgical fixation can occur by different techniques, but the most commonly used technique is a minimaly invasive procedure with a Kirschner wire [95]. Marker et al. termed the posterior sternoclavicular dislocation as an Americal football injury often seen in connection with American football [160].

1.8.5.7 Malignant tumours

Sternoclavicular or clavicular neoplasms are rare but have been reported in the literature [26, 34-36]. Local swelling and tenderness can indicate an infection, but any aggressive sternoclavicular mass should be analysed for dignity, because the majority of tumors of the clavicle are malignant [36, 102, 103].

1.8.5.8 Other

Several other rheumatic disorders and diseases affecting the bones and joints like rheumatoid arthritis, systemic lupus erythematodes or systemic sclerosis may be mimicking an inflammatory process and have to be considered as possible differential diagnoses [88, 116-118].

2 Patients and Methods

2.1 Patients

We retrospectively studied the medical records of eight patients (n=8), four females and four males, that were treated for sternoclavicular joint empyemata between 2001 and 2011 at the Medical University of Graz, Austria. The male median age was 66,75, the female median age was 62,5 and overall median age was 64,62. All patients were showing typical signs and symptoms of sternoclavicular joint infections. None of them was excluded.

2.2 Methods

2.2.1 Data acquisation

Medical records of eight patients showing signs and symptoms of sternoclavicular joint empyemata, who were admitted to hospital between 2001 and 2011, were retrospectively reviewed and analysed. Sternoclavicular joint empyemata were defined as sternoclavicular joint infections, sternoclavicular abcesses, sternoclavicular septic arthritis, sternoclavicular osteomyelitis or sternoclavicular phlegmons. Case reports were individually reviewed and all clinical monitored data were collected for each patient and analysed. Follow-up was obtained through outpatient clinical visits. None of the patients was excluded. Long term functional outcome was assessed by follow-up telephone interviews with patients. A successfull therapy was defined as complete nonirritated wound healing with no signs and symptoms of inflammation. The therapy duration was defined in months and differentiated for both conservative and aggressive surgical therapy approaches. It includes the time between first diagnosis and successful wound healing, independent of being hospitalized or at home.

2.2.2 Monitoring parameters

Main monitored parameters were age, sex, general health condition, risk factors, comorbidities and infectious diseases. Diagnostic parameters were signs and symptoms, complications, imaging, laboratory values, microbiologic and histopathologic results. Therapy parameters were antibiotic therapy, conservative therapy and/or surgical therapy. All clinical data were individually collected and presented in a detailed excel tables.

2.2.3 Imaging

Imaging was performed either by one or by more x-rays scans, computertomography scans, magnetic resonance imaging, scintigraphic scans or by a positron emission tomography. The choice of the imaging technique depended on the inflammatory expansion and the occuring complications.

2.2.4 Therapy design

The overall first-line therapy was an intravenous antibiotic therapy with broad-spectrum antibiotics. A targeted antibiotic therapy was added after gaining microbiologic results. We individually differentiated between a conservative = non-surgical / minimal surgical and an aggressive surgical therapy approach. The choice depended on the patient´s general health condition, the patient´s consent, the inflammatory expansion and the occuring complications. A vacuum assisted wound closure therapy after debridement of necrotic soft tissue was considered for both therapy designs. The aggressive surgical approach consisted of local necrotic soft tissue debridement, aggressive bone and joint resection and plastic surgical reconstrucion with a pectoralis major flap. In two cases a skin graft was also necessary and in three cases an adjunct hyperbaric oxygen therapy was performed.

2.2.5 Plastic surgical reconstruction

The resection of the sternoclavicular joint including resection of the medial clavicle, half of the manubrium, the first costal cartilage and a part of the first rib leaves a significant defect exposing important local and major anatomical structures. This includes the exposure of the subclavian artery, the subclavian vein and several other smaller local arteries and nerves. Soft tissue is also essential for wound healing, cosmesis and mechanical stress. The local reconstruction was accomplished with an ipsilateral pectoralis major advancement flap.

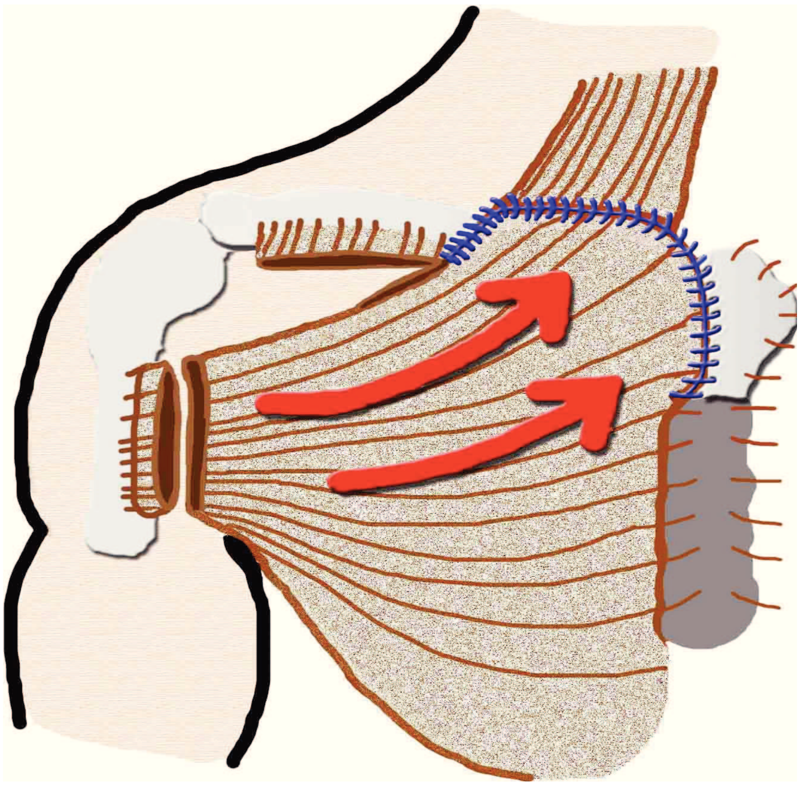

Fig. 15 Pectoralis major advancement flap

After local debridement of avital tissue and resection of the sternclavicular joint the upper third of the pectoralis major muscle down to the deltopectoral groove is mobilized including the superior detachment of the muscle from the clavicle, the lateral detachement from the humerus and the medial detachment from the sternum. After surgical sectioning of the muscle from its medial intercostal supplying arteries and seperation from the underlying pectoralis minor muscle, the muscle is advanced superomedial into the defect, pedicled on its thoracoacromial artery vascular supply and attached to the surrounding structures.

2.2.6 Outcome and follow-up

Follow-up was obtained through outpatient clinical visits. None of the patients was excluded. Clinical outcome of the patients, who were involved in sternoclavicular joint resections and local plastic reconstruction was measured on the extent of movements of the pectoral shoulder girdle and freedom from symptoms. Long term functional outcome, as well as the subjective health condition of every patient, was assessed by follow-up telephone interviews with patients.

2.2.7 Case reports

Two case reports were chosen to be presented in the following segment of the results. Two patients presented a chronic hepatitis C virus infection. To my best knowledge no other case reports of sternoclavicular joint infections, in patients with hepatits C infection, were presented in the English or German literature.

3 Results

3.1 Medical data

Eight patients (n=8), four females and four males were treated for sternoclavicular joint empyemata between 2001 and 2011 at the Medical University of Graz, Austria. The male median age was 62,7, the female median age 62,5 and the overall median age 62,6. Three of the eight patients were admitted to hospital in a good general health condition, two in an adequate and three in a poor general health condition.

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	MEDIAN Age
Age	62	58	72	59	88	72	49	41	62,6
Sex	male	male	male	male	female	female	female	female	
General condition	good	good	poor	adequate	adequate	poor	good	poor	

Tab. 1 General parameters

All eight patients presented one or more risk factors for sternoclavicular empyema. Three patients (37,5 %) had a history of diabetes mellitus and two patients suffered from mallignant illnesses followed by regional radiotherapy. Two patients (25%) had a history of alcohol abuse, liver cirrhosis and hepatitis C infection. To my best knowlegde, we are the first authors to report about two cases of sternoclavicular joint infections in patients with chronic hepatitis C infection in the English and German litarature. The youngest patient was a female of 41 years, presenting a history of nicotine abuse and diabetic mellitus and the oldest patient was a female of 88 years presenting a history of local trauma with no further risk factors. None of the eight patients had a history of intravenous drug abuse.

INFECTIOUS DISEASES	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	%
Hepatitis C	X						X		25
Tuberculosis			X						12,5

Tab. 2 Infectious diseases

RISK FACTORS	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	%
Alcohol abuse	X						X		25
Nicotine abuse			X				X	X	37,5
Central Line Placement			X			X			25
Diabetes mellitus				X		X		X	37,5
Local trauma					X				12,5
Local surgery		X	X						25
Malignant illnesses		X	X						25
Regional radiotherapy		X	X						25
Liver chirrhosis	X						X		25

Tab. 3 Risk factors

Other comorbidities like Parkinson´s disease , depression, Graves` disease, COPD, osteoporosis, hypertonia, coronary artery disease and hyperthyreosis were found in all eight patients.

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8
Comorbidities	Parkinson Depression Amaurosis	Graves`Disease COPD	Esophageal stenosis Aortic aneurysm Subclavian stent implantation	St.p. septic Schock Polyneuropathy Retinopathy	Pleural weeping Osteoporosis Struma	Hypertonia Hyperlipidaemia Coronary artery disease	Depression Multiple skin abscesses	Pneumonia Hypertonia Hyperthyreosis Adipositas

Tab. 4 Comorbidities

3.2 Diagnostic results

All eight patients have been showing typical signs and symptoms of inflammation like erythema, warming, swelling, tenderness and pain. Local erythema and tissue swelling were present in all eight patients (100%). Two patients (25%) had high fever and only two patients (25%) had restriction of movements in the pectoral shoulder girdle. Pain was present in seven patients (87,5%).

SIGNS AND SYMPTOMS	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	%
Erythema	X	X	X	X	X	X	X	X	100
Ternderness			X	X		X	X	X	62,5
Warming	X	X	X	X		X	X	X	87,5
Swelling	X	X	X	X	X	X	X	X	100
Pain	X	X	X	X		X	X	X	87,5
Fever							X	X	25
Movement restrictions			X				X		25

Tab. 5 Signs and Symptoms

An abscess with osteomyelitis and local destruction of the sternoclavicular joint occured in all eight patients (100%). Three patients (37,5%) developed severe complications and showed signs of septic shock at the time of the referral.

COMPLICATIONS	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	%
Osteomyelitis	X	X	X	X	X	X	X	X	100
Local destruction	X	X	X	X	X	X	X	X	100
Abscess	X	X	X	X	X	X	X	X	100
Mediastinits			St. p.					X	12,5
Septic Shock				X	X			X	37,5

Tab. 6 Associated complications at the time of referral

Fig. 16 Septic arthritis of the sternoclavicular joint - signs and symptoms A (Patient 2)

Fig. 17 Septic arthritis of the sternoclavicular joint – signs and symptoms B (Patient 2)

Both pictures show an advanced sternoclavicular joint empyema. The clavicle is exposed. A local erythema, swelling, necrotic tissue with osteomyelitis and joint destruction are present.

The laboratory values showed, that at the time of admission, the C reactive protein was elevated in 100% of all patients, with 17,7 mg/L as the lowest value and a peek of 331,3 mg/L as the highest value. The median value of CRP was 154,88 mg/L. Leucocytosis (>10 G/L) was present in two patients (25%) with 18,38 G/L and 20,15 G/L. The median value of the leucocytes was 8,72 G/L. In both patients a left shift was also present, indicating more immature band cells as the result of an attempt of fighting an active infection.

LABORATORY VALUES	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	Median	% Pos
C-Reactive Protein (mg/L)	66,2	64,6	325,7	102,4	275	55,8	17,7	331,3	154,8	100
Leucocytes (G/L)	3,7	6,6	9,8	7,39	20,15	3,71		18,38	8,72	25

Tab. 7 Laboratory values

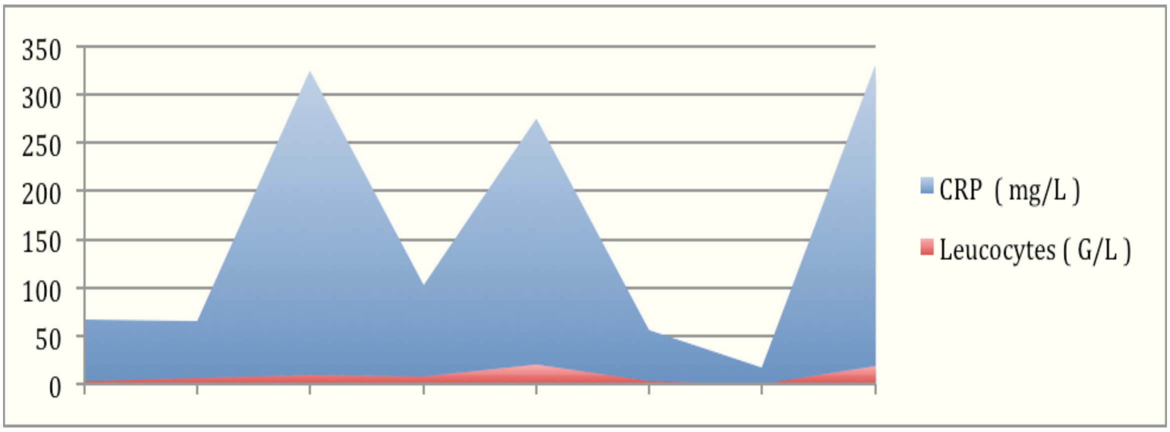

Fig. 18 Correlation of the quantity of CRP and the number of leucocytes

The above results show a slight correlation between the quantity of the C reactive protein and the number of leucocytes. An elevated CRP value does not automatically correspond to a Leucocytosis, although a very high CRP value also correlates with a very high number of leucocytes.

Microbiologic results were positive in three patients and showed bacterial wound infections with either one or more of the following pathogens: *Streptococcus* *agalactiae, Streptococcus pneumoniae, Staphylococcus aureus* and *Enterococcus faecalis*. In five patients (62,5%) the microbiologic results were negative, showing no pathogenic contamination.

MICROBIOLOGY	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	%
Staphylococcus aureus						X			12,5
Streptococcus agalactiae			X						12,5
Streptococcus pneumoniae								X	12,5
Enterococcus faecalis						X		X	25
NEGATIV	X	X		X	X		X		62,5

Tab. 8 Microbiologic Results

Imaging was performed in all eight patients. An X-ray scan was performed in four patients. A CT scan was performed in seven patients and an MRI in six patients. Two patients had a scintigraphy scan and a PET was done in one patient.

IMAGING DATA	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	%
X-ray	X	X	X	n/a	n/a	n/a	n/a	X	50
CT	X	X	n/a	X	X	X	X	X	87,5
MRI	X	n/a	X	X	X	X	X	n/a	0,75
Scintigraphy	n/a	n/a	X	X	n/a	n/a	n/a	n/a	25
PET	n/a	n/a	n/a	n/a	n/a	n/a	n/a	X	12,5

Tab. 9 Imaging data

The CT scans and the MRIs revealed abscesses and destruction with soft tissue necrosis and sternoclavicular joint osteomyelitis in 100% of all patients. The 3-phase bone scintigraphy scan showed a massive disposition of technetium in the sternoclavicular joint, indicating a severe osteomyelitis. The PET showed a significant tracer uptake in the sternoclavicular joint.

IMAGING RESULTS	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	%
Osteomyelitis	X	X	X	X	X	X	X	X	100
Local destruction	X	X	X	X	X	X	X	X	100
Abscess	X	X	X	X	X	X	X	X	100

Tab. 10 Imaging results

A histopathologic analysis was done in five patients (62,5%), showing a massive amount of inflammatory cells of neutrophile granulocytes. No signs of any malignant cells were found (0 %).

HISTOPATHOLOGY	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	%
Inflammatory cells	X	X	X		X		X		62,5
Malignant cells									0

Tab. 11 Histopathologic results

3.3 Therapeutic procedure

The overall first-line therapy of all patients was the intravenous application of broad-spectrum antibiotics. A targeted antibiotic therapy with clindamycin and fosfomycin was added in three patients after gaining microbiologic results. Four of eight patients received a primary conservative therapy. In all four patients a relapse was observed. Two patients secondary received an aggressive debridement with sternoclavicular joint resection followed by a negative wound pressure therapy. Afterwords a plastic surgical reconstruction was performed. The other both patients have not been operated. One patient could not be operated due to his poor multi-morbid health condition. He was conservatively treated with local antiseptic measures and oral antibiotics over 36 months without success resulting in multiple relapses. The other patient refused an aggressive joint resection because of possible postoperative movement restrictions, which would influence his daily yoga activities. He received a mild debridement of necrotic soft tissue without joint resection and was discharged. Further outpatient visits have not been reported since then.

CONSERVATIVE APPROACH	Patient 1	Patient 3	Patient 4	Patient 5	%
Antibiotics	X	X	X	X	100
VAC-Therapy	X			X	50
HBO-Therapy	X	X			50
UNSUCCSESSFULL	X	X	X	X	100

Tab. 12 Primary conservative = non-surgical / minimal surgical approach results

An primary aggressive surgical approach was done in four patients (50 %). Three underwent local debridement with aggressive bone and joint resection followed by a vacuum assisted wound closure. One patient received a limited surgical approach, resulting in a synovectomy without sternoclavicular joint resection. The defect was closed by a secondary suture. In two patients a skin graft over the sternoclavicular area was necessary due to the resection of necrotic tissue and skin. Two patients from the conservative group underwent a secondary aggressive surgical intervention with joint resection due to an unsuccessfull conservative therapy.

In total six patients (75%) underwent an aggressive surgical intervention with bone resection. Five received a resection of the sternoclavicular joint incuding the resection of necrotic soft tissue, the medial clavicle, half of the manubrium, the first costal cartilage and a part of the first rib. A plastic surgical reconstruction with an ipsilateral pectoralis major advancement flap was done in a further intervention.

AGGRESSIVE SURGICAL APPROACH	Patient 2	Patient 6	Patient 7	Patient 8	(Patient 1) SECONDARY	(Patient 5) SECONDARY	%
Antibiotics	X	X	X	X	X	X	100
Joint resection	X	X		X	X	X	83,3
VAC-Therapy	X	X	X	X	X	X	100
HBO-Therapy	X				X		33,3
Pectoralis major advancement flap	X	X		X	X	X	83,3
Skin Graft	X				X		33,3

Tab. 13 Primary and secondary aggressive surgical approach results in all five patients

The overall results show that a successful therapy has been achieved in all patients, who underwent an aggressive surgical joint resection. Both other patients who could not be operated showed a relapse and a missing wound healing.

SUCCESSFUL THERAPY RESULTS	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	%
Conservative									0
Surgical	X	X			X	X	X	X	75

Tab. 14 Successful therapy result rate

The therapy duration also showed significant varieties. All patients who have been primary treated with a conservative therapy approach had a much longer healing time than all patients who underwent an aggressive operation. All patients who underwent an aggressive surgical debridement had a median healing time of 1,75 months. All primary non-surgical treated patients with or without a secondary surgical intervention had a median therapy time of 13,5 months.

THERAPY DURATION IN MONTHS	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	Median
Conservative			36	1					13,5
(Secondary Surgical)	8				9				
Surgical		1				3	2	1	1,75

Tab. 15 Therapy duration in months

3.4 Outcome and follow-up

The first of the two non surgical treated patients, had multiple relapses over a time of 36 months. A surgical intervention with aggressive debridement could not be done, because of the patient´s poor and multi-morbid health condition. The conservative therapy with open wound management was unsuccessful. The last outpatient dressing change occured in April 2011 after 36 months from the time of diagnosis. No further medical records have been found since then.

The second conservatively treated patient strictly refused an aggressive surgical joint resection. In this case, the main septic focus with osteomyelitis of the sternoclavicular joint could not be resected. He was hospitalized for two weeks. He was not present at the planned outpatient visit after 14 days. No further medical records have been found since he was discharged.

Five of the in total six patients, who were treated by an aggressive surgical approach, showed a primary good wound healing with complete control of infection and no recurrence. Four patients presented themselves painless and subjectivley free of complains. The remaining last patient, a 72 year old woman, developed a complex regionary pain syndrome, although any signs of inflammation were negative with complete wound healing. She underwent a wide postoperative pain management over several months.

The five patients who underwent plastic surgical reconstruction with an ipsilaterlal pectoralis major advancement flap showed a minimal reduced active range of motion in the pectoral shoulder girdle. A complete active elevation of the ipsilateral upper limb was limited, due to the detachment of the pectoralis major muscle from its humeral attachement. Although a visible malfunction was presented in all five patients, the reduced active range of motion resulted in no influence and no restrictions in all activities of daily living.

OUTCOME	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	%
Painless	X	X			X		X	X	62,5
Non-irritated wound conditions	X	X	X	X	X	X	X	X	100
Wide movement range	X	X	X	X	X	X	X	X	100
Regressive signs of inflammation	X	X			X	X	X	X	75
THERAPY DURATION (months)	8	1	36	(1)	9	3	1+1	1	

Tab. 16 Successfull outcome and treatment duration

Fig. 19 Functional outcome after aggressive joint resection and plastic surgical reconstruction with an ipsilateral pectoralis major advancement flap. The detachment of the humeral attachment is clearly visible. The right shoulder is lowered. Complete elevation of the upper limb is limited. (Patient 2)

Fig. 20 Cosmetic outcome after aggressive joint resection and plastic surgical resonstruction. All signs of inflammation were absent. Wound healing occured with complete control of infection and no recurrence.. The skin graft healed completely. (Patient 2)

3.5 Case report 1

A 62 year old male in a general good health condition was admitted to hospital with a inflammatory process of the right sternoclavicular joint. An area approximately about 7 x 5 cm on the right sternoclavicular joint presented local erythema, warming, progressive swelling and pain on palpation. Fever was not reported. The patient had a history of chronic hepatitis C infection, alcohol abuse and liver cirrhosis. His medical history also included Parkinson´s disease, episodes of depression and amaurosis. Blood tests revealed an increased C reactive protein rate of 66,2 mg/L. Leucocytes were normal with 3,7 G/L. A CT scan revealed a progressive liquid imposing focus with destruction of the sternoclavicular joint, in the first place corresponding to a local empyema and distinct osteomyelitis. A therapy with broad spectrum antibiotics and analgetics was started, followed by a supplementary hyperbaric oxygen therapy. 14 days later a local debridement of necrotic tissue with resection of the medial part of the clavicle was performed. The whole sternoclavicular joint was necrotic and partially destroyed. An open wound management was performed over one week with antiseptic gauze. The wound condition was clean. A VAC-system was applied and the patient was discharged back into the care home for the elderly. 14 days later the patient was re-admitted to hospital for a definitive wound closure by a secondary suture. The wound condition was clean. A percutaneous drainage was fixed for 2 days. Removal and dressing changes were performed by a general practitioner. A wound inspection was performed 14 days later by an outpatient visit. The wound condition was nonirritated. The stiches were removed. Two months later a relapse occured presenting a local abscess, erythema, swelling and pain. A surgical revision was performend including an aggressive deep debridement with resection of the remaining bony structures including half of the manubrium and the first costal cartilage. A VAC-system was applied postoperatively, followed by a daily hyperbaric oxygen therapy. After optimal wound conditioning, the patient was prepared for a plastic surgical reconstruction with an ipsilateral pectoralis major advancement flap. The operation proceeded without complications. Wound closure was performed by a skin graft. The area above the sternoclavicular joint remained swollen and warming. A CT scan with contrast medium was done 14 days later and revealed a complex free liquid formation with considerable pathological enhancement. The next day a revision surgery was performed including a further aggressive debridement and necrectomy. A widespread antiseptic lavage was done with lavasorb (polihexanid / macrogol) and sodium chlorid. Wound closure was performed by a skin graft and metal clips. A 12-Redon drainage was applied for 5 days. One week later the wound condition was clean and the patient was discharged back into the care home. Further medical outpatient visits showed a good wound healing with no inflammatory signs and symptoms. No further medical records have been found since then.

3.6 Case report 2

A 41 year old female in a general good health condition was admitted to hospital with an abcess and septic arthritis of the right sternoclavicular joint. The area above the joint was warm, swollen, pressure-sensitive and very painful. Several attacks of fever were reported. The movements of the upper right shoulder girdle were restricted, due to heavy pain. The patient had multiple intraarticular infiltrations without therapeutic success at her general practitioner. She had a history of chronic hepatitis C infection, nicotine abuse, alcohol abuse and liver chirrosis. Further on a history of multiple skin abscesses were reported as well as multiple episodes of depression. Blood tests revealed an increased C reactive protein rate of 17,7 mg/L. Leucocytes were normal. An intravenous therapy with broad spectrum antibiotics and analgetics was started. Two days later a local debridement of necrotic tissue and a punction of the sternoclavicular joint was performed. The infection and necrosis did not pass the local borders of the joint. The articular disc was completely removed as well as the articular facet of the sternal end of the right clavicle. A wide antiseptic lavage with lavasept (polihexanid / macrogol) and sodium chlorid was done and a VAC-system was applied. The next day the patient was discharged. The VAC-system was kept for 21 days with outpatient dressing changes at regular intervals. An outpatient supplementary hyperbaric oxygen therapy was done over this period. The wound condition was clean, nonirritated, with plenty granulation tissue and was closed by a secondary suture three weeks after operation. Although the wound has healed completely after one month with no clinical signs of inflammation, a pronounced therapy-resistent pain syndrome persisted. Blood tests were also negativ. A wide pain management was performed over several months. An MRI scan revealed a ventral luxation of the clavicle without any signs of inflammation. The patient described pressure sensitive pain above the sternoclavicular joint, the sternum and the ventral tracheal wall. A sharp bony edge at the sternal end of the clavicle could be palpated with maximum pain intensity. 10 months after the first surgical intervention the patient was readmitted to hospital for a revision and resection of the sharp medial part of the clavicle. 4 cm of the medial clavicle were resected. A massive adhesion of the right subclavian vein as well as the right internal jugular vein to the dorsal part of the clavicle was present. An adhesiolysis was performed and both veins had required several stitches. The wound was closed by metal clips. A 10-Redon drainage was applied for 3 days. Dressing changes were performed daily. The wound condition was clean and nonirritated. With sufficient analgetics the patient was nearly free from pain already three days after operation and could be discharged in a good health condition. Further outpatient visits showed a good wound healing and a notable pain reduction. No further medical records have been found since then.

4 Discussion

Sternoclavicular joint infections are rare and represent about 0.5% - 1% of all joint infections [1, 2]. However an abcess is present in 20% of all cases [3]. Risk factors like intravenous drug abuse, diabetes, immunodeficiency, central line placement, malignant diseases or local radiotherapy are dominant. The infection can proceed directly through the skin, by ascending or descending regional infections or through the blood stream. The most commonly found pathogenic organism is *Staphylococcus aureus* and followed by *Pseudomonas aeruginosa* [2, 4]. Strategic therapeutic approaches include antibiotic therapy, local surgical debridement with resection of the sternoclavicular joint, local negativ pressure wound therapy and plastic surgical reconstruction with a pectoralis major flap [5-8]. Unfortunately there is no classifed or standardised therapy design. This thesis confirms our therapeutic approaches in the treatment of sternoclavicular joint infections during the last ten years. It classifies a therapy design, which from our point of view, is the best management of deep joint infections regarding minor complications and best functional and cosmetic outcome.

4.1 Reviewing the diagnostic results

Altogether eight patients, four females and four males with a median age of 62,63 were treated for sternoclavicular joint empyemata between 2001 and 2011 at the Medical University of Graz, Austria. All eight patients presented one or more risk factors for sternoclavicular empyema. Diabetes mellitus was present in 37,5%, mallignant illnesses, regional surgery, radiotherapy and central line placement in 25%. 25% had a history of alcohol abuse, liver cirrhosis and hepatitis C infection. To my best knowlegde, we are the first department to report about two cases of sternoclavicular joint infections in patients with chronic hepatitis C infection in the english and german literature. One patient (12,5%), a female of 88 years, presented a spontaneous sternoclavicular joint infection with no typical risk factors. She had a history of local trauma in her younger years.

All eight patients have been showing typical signs of inflammation like erythema, warming, swelling, tenderness and pain. Local erythema and swelling were presented in 100%. Pain was presented in 87,5% and fever was only reported in 25%. Local abscess, osteomyelitis and local destruction were present in 100%. Three patients developed severe complications and showed signs of septic shock at the time of admission.

Laboratory results showed that the C reactive protein was elevated in 100%, with 17,7 mg/L as the lowest value and a peek of 331,3 mg/L. The median value of CRP was 154,88. Leucocytes were normal in 75%. The level of CRP corresponds with the severity of the inflammation. The CRP was >100 mg/L in all patients with septic shock. The destruction of the sternoclavicular joint and local necrosis was also more severe in patients with a higher value of CRP. For this reason the value of CRP seems to be a good marker for the severity and extension of the inflammation.

Microbiologic results were negative in 62,5%. Although the pathogenic contamination was only present in three patients, showing contaminations with *Staphylococcus aureus, Streptococcus agalacticae, Streptococcus pneumoniae* and *Enterococcus faecalis*, we suggest that a contamination with microscopic pathogens were present in all patients. The high number of negative results can be explained, due to the intravenous antibiotic premedication at the time of the smear test and missing bone biopsies.

Imaging was performed in all patients. We have done either a MRI or CT scan in all patients. Depending on the severity of the inflammation sometimes both scans were necessary to identify the extent of the local abscess, osteomyelitis and destruction. This was important for the planning of the surgical intervention and the possibility of the reconstruction with a local pectoralis major flap.

4.2 Reviewing the therapy design

The overall first line therapy was the application of broad-spectrum antibiotics. A targeted antibiotic therapy, if necessary, was added after gaining microbiologic results. From our point of view, this is the first important antiphlogistic step and necessary for the eradication of microbes.

Four patients have been primary treated with a conservative approach and four with a primary aggressive surgical approach. The conservative therapy approach was unsuccsessful in all four patients. The extent of the infection passed the articular borders. A deep joint infection with osteomyelitis and local destruction was present in all patients. Although an aggressive surgical debridement with resection of the sternoclavicular joint was necessary in all four patients, two could not be operated. One refused a resection of the joint, because of possible postoperative movement restrictions, which would influence his daily yoga activities. He was strictly advised of the necessity of an agressive debridement of the infected and necrotic sternoclavicular joint. At the time of discharge at his own responsibility, the main imposing infected focus was not removed. From our point of view, the therapy was insufficient and unsuccessful. He was treated outpatient for one month with local antiseptic measures and oral antibiotics. He did not appear at the next outpatient appointment and no further medical data have been found since then.

The other one could not be operated due to his poor and multi-morbid health condition. He had a history of malignant lymphoma with neck dissection and radiotherapy. From several surgical and anaesthesiological points of view, an operation would worsen the patient´s health condition, resulting in postoperative wound healing disorders and possible death. He was treated with local antiseptic measures and antibiotics over thirty-six months. At the time of his last outpatient visit the wound condition was stable with mild signs of inflammation. Nevertheless the local destruction of the sternoclavicular joint was still progressive. In this case a conservative therapy was insufficient and unsuccessful.

In total six patients underwent an aggressive surgical debridement with joint resection. Five underwent resection of the medial party of the clavicle, half of the manubrium and the first costal cartilage. In one case the infection and necrosis did not pass the local borders of the joint. A resection of the articular disc and a synovectomy were sufficient for complete control of infection. The medial part of the clavicle was resected in a secondary intervention due to persisting pressure sensitive pain caused by a sharp bony egde of the sternal part of the clavicle.

A negative wound pressure therapy with a VAC-system was applied in all patients after debridement of necrotic tissue. Vacuum assisted closure provides an occlusive environment under sterile conditions and optimizes wound healing and increases the rate of granulation. We use VAC-systems for the treatment of a wide variety of complex wounds and it has notably improved wound healing in the last years.

The resection of the sternoclavicular joint including resection of the medial clavicle, half of the manubrium, the first costal cartilage and a part of the first rib leaves a significant defect exposing important local and major anatomical structures. This includes the exposure of the subclavian artery, the subclavian vein and several other smaller local arteries and nerves. The structures are very pressure sensitive to mechanical stress and damage and cannot be left directly under the skin. A rupture of the subclavian artery may lead to severe life bleeding with possible lethal outcome. For this reason the coverage with muscular soft tissue is very important. We used an ipsilateral pectoralis major advancement flap for the coverage of the local defect. From our point of view, this reconstructive technique results in secure wound closure with best mechanical resilience, minimal risks of complication and optimal functional and cosmetic outcome. The detachment of the pectoralis major muscle from its humeral attachment reduces the active range of motion in the pectoral shoulder girdle. A complete active elevation of the ipsilateral upper limb is limited. Although a visible malfunction was presented in all five patients, the reduced active range of motion does not result in any restrictions in the activities of daily living. Four patients presented themselves painless and subjectivley free of complaints. One of the remaining two patients, a 72 year old woman, developed a complex regionary pain syndrome, although any clinical signs of inflammation were negative. The wound has completely healed without recurrence of infection. A MRI scan showed no infiltrations, malformations or signs of inflammation. She underwent a wide postoperative pain management over several months. The pain could be stabilised and reduced to a minimal intensitity. The last patient, a 41 year old female developed a pronounced therapy-resistent local pain due to an insufficient removal of a sharp bony edge of the sternal part of the clavicle. After a surgical revision with removal of that trigger, a nearly complete analgesia could be achieved three days after operation.

4.3 Reviewing the outcome and therapy comparison

The conservative therapeutic approaches were unsuccessful in all four patients. The extent of the inflammation passed the articular borders resulting in a deep joint infection with osteomyelitis and local destruction. Debridement of necrotic soft tissue, local antiseptic measures and intravenous antibiotics were insufficient. The main imposing focus has to be resected in order to garantee a sterile environment. This could only be achieved by a complete resection of the sternoclavicular joint, including the resection of the sternal part of the clavicle, approximately half of the manubrium and the first costal cartilage. All four patients needed surgery with aggressive debridement. Both patients who were operated could be cured and presented themselves in a good health condition and free from any signs, symptoms or complaints. One who was not operated, was treated with local antiseptic measures and antibiotics over thirty-six months. At the time of his last outpatient visit, the wound condition was stable with mild signs of inflammation and mild persistent pain. Nevertheless the local destruction of the sternoclavicular joint was still progressive. The other one was discharged with mild pain at his own responsibility but the main imposing infected focus was not removed. From our point of view, the therapy was insufficient and unsuccessful. He was treated outpatient for one month with local antiseptic measures and oral antibiotics. Signs of inflammation were minimal but still positive. He did not appear at the next outpatient appointment and no further medical data have been found since then.

As earlier described, all six patients who were treated by an aggressive surgical approach, showed a primary good wound healing with nonirritated skin conditions. Analgesia could be achieved in nearly all operated patients. Moreover all patients, who primary underwent an aggressive surgery, benefitted from a significant shorter in-patient stay.

4.4 Hepatitis C and sternoclavicular joint infections

To my best knowlegde, we are the first authors to report about two cases of sternoclavicular joint infections in patients with chronic hepatitis C infection in the English and German litarature. The hepatitis C virus directly affects and damages hepatic cells. Permanent damage followed by repair mechanisms results in liver chirrosis. Functional consequences are hepatic failure, portal hypertesion and the development of intrahepatic porto-systemic shunts. Another main problem is the affliction of the immune system, increasing the risk for chronic infections. Coagulopathy with clotting disorders is also a severe complication of liver cirrhosis. From my point of view a chronic hepatitis C infection classifies as a risk factor for sternoclavicular joint infections and should be validated and added to the list of risk factors for sternoclavicular empyemata.

4.5 Comparison with the literature

The majority of our diagnostic and therapeutic results correspond with the results reviewing the literature and are described in the following segment. 17% of all sternoclavicular joint infections occur in intravenous drug users [2]. Other several reports can be found about patients infected with HIV. However none of our patients had a history of intravenous drug abuse or infection with HIV.

25% of our patients had a history of chronic hepatitis C infection. To my best knowlegde, we are the first authors to report about this two cases of sternoclavicular joint infections in patients with chronic hepatitis C infection in the English and German literature.

Central line placement account for 90% of catheter-related bloodstream infections [53]. Two of our patients had a history of central line placement.

Several cases of sternoclavicular joint infections in patients with diabetes mellitus are reported in the literature. 37,5% of our patients had a history of diabetes mellitus.

The affliction of the sternoclavicular joint by mycobacteria is uncommon and extremley rare but has been discribed in the literature [21, 83-87]. One of our patient had a history of a cured tuberculosis in his younger years.

Although being uncommon and rare, several case reports in the literature show an association of major head and neck surgeries with clavicular osteomyelitis [15, 71, 72, 96]. Cesare Piazza et al. described that the most important risk factor in the development of osteomyelitis seems to be the impairment of vascularisation due to surgical disruption of the periosteum and/or cortical bone [25]. 25% of our patients had a history of oncologic surgery and radiotherapy.

At the time of admission, all patients developed typical signs and symptoms like erythema, swelling, tenderness and pain. In all cases a local abscess and osteomyelitis with destruction of the sternoclavicular joint were present. Three developded signs of septic schock. The results correspond the the reports in the literature.

In his review of 180 cases, Ross et al. reported leucocytosis in 56%. He also reported the contamination with *Staphylococcus aureus* in 50%. Nevertheless only 25% of our patients showed leucocytosis but 100% had an increased value of CRP. *Staphylococcus aureus* was present in only one patient.

The VAC-therapy is a wide used tool for complex wounds. It works through mechanisms that include fluid removal, wound retraction, microdeformation and moist wound healing [134]. We used this method in 75% of our patients.

Reviewing the literature shows several reports of successful treatment of sternoclavicular joint infections by non-surgical conservative measures. Unfortunately non of our patients could be successfully treated by conservative measures. Simple intravenous antibiotics, local tissue debridement and local antiseptic measusres were insufficient. An aggressive debridement with joint resection was necessary in all cases. This corresponds to the results of Song HK et al. in 2002.

4.6 Conclusion and core statement

The comparison of both therapeutic approaches emphasizes a significant essence. From our point of view, the conservative therapy, consisting of intravenous antibiotics, necrotic soft tissue debridement and local antiseptic measures with gauze and drainage is insufficient and unsuccessful for the treatment of sternoclavicular joint infections. An intraarticular imposing focus, resulting in a deep joint infection and septic arthritis with osteomyelitis, necrosis and local destruction, needs aggressive surgery.

A conservative therapy with local antiseptic measures and open wound management, resulting in regular and painful dressing changes is also time intensive and decreases the patients quality of living. An aggressive debridement and following reconstruction provides a significant shorter therapy time and hospitalization.

Reviewing and analysing our results provides a significant conclusion for the optimal diagnostic and therapeutic management of sternoclavicular joint empyemata.

4.6.1 Proper diagnostic management of sternoclavicular joint empyemata

From our point of view, the best strategy for the diagnosis of sternoclavicular joint empyemata consists of the following 5 aspects:

1. Anamnesis
The anamnesis is very important and a medical case history may reveal several risk factors. Personal environment and living conditions often act a part and can provide the right path to diagnosis.

2. Clinical signs
The 5 typical signs of inflammation are rubor, calor, tumor, dolor and functio laesa. Fever can be absent but in all cases at least three of these facts are present and affect the sternoclavicular joint.

3. C-reactive protein
Laboratory results show that the level of CRP corresponds with the severity of the inflammation. The higher the CRP, the more severe the inflammation. For this reason the value of CRP is a good marker for the severity of the disease. Leucocytosis may be absent.

4. CT / MRI scan
A CT or an MRI scan are essential to identify the extent of the inflammation, a local abscess, osteomyelitis, necrosis and destruction. This is important for the planning of the surgical intervention and the plastic surgical reconstruction.

5. Smear test and bone biopsies
Final diagnosis is done with the microbiologic identification of the causing pathogenic agent. This is very important to ensure an optimal antiobiotic therapy. For optimal conditions the smear test must be implemented prior to the application of antiobiotics. Bacterial swabs taken by joint puncture or from bone biopsy during surgery certify diagnosis, while bacterial cultures allow targeted antimicrobial therapy.

4.6.2 Proper therapeutic management of sternoclavicular joint empyemata

From our point of view, the best strategy for the treatment of sternoclavicular joint empyemata consists of the following 4 steps:

1. Targeted intravenous antibiotics

This is the first important aspect in order to successfully eradicate the causing pathogenic agents and minimising complications.

2. Aggressive surgical debridement

This includes resection of the sternoclavicular joint, the sternal part of the clavicle, half of the manubrium and the first costal cartilage. The intraarticular imposing focus resulting in septic arthritis with osteomyelitis, necrosis and local destruction needs aggressive surgery. This also can reduce the duration of therapy and hospitalization.

3. Negative wound pressure therapy

Negative wound pressure therapy includes fluid removal, microdeformation and moist wound healing. The VAC-system provides an occlusive environment, increases the rate of granulation and reduces pain, resulting in an optimal wound conditioning. It also induces three-dimensional stress known as macro-strain, that draws wound edges inwards and shrinks the wound [139].

4. Reconstruction with an ipsilateral pectoralis major advancement flap

Joint resection leaves a significant defect exposing important local anatomical structures which are pressure sensitive to mechanical damage. The coverage with muscular soft tissue is very important. The ipsilateral pectoralis major advancement flap benefits in optimal wound closure with best mechanical resilience, minimal risks of complication and optimal functional and cosmetic outcome.

4.7 Last words

This diplomacy thesis classifies our results in the diagnosis and treatment of sternoclavicular joint infections during the last ten years at the division of Plastic, Reconstructive and Aesthetic Surgery at the Medical University of Graz, Austria. It classifies a therapy design, which from our point of view, is the best management of sternococlavicular joint infections, regarding minor complications and best functional outcome. I hope this benefits the goal of implementing an international standardised procedure for the diagnosis and treatment of sternoclavicular joint infections. Further controlled multi-disciplinary prospective studies are needed to implement standard guidelines to optimize the treatment algorithm of this rare disease.

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