About the ligaments of the pleural dome

(An anatomical exploration)

Master Thesis to obtain the degree

Master of Science in Osteopathy

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submitted at the **Wiener Schule für Osteopathie**

by
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Declaration

Hereby I declare that I have written the present master thesis on my own.

I have clearly marked as quotes all parts of the text that I have copied literally or rephrased from published or unpublished works of other authors.

All sources and references I have used in writing this thesis are listed in the bibliography. No thesis with the same content was submitted to any other examination board before.

Eidenham, December 10h 2007

Fred Scheiterbauer

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1 Preface

I would like to seize this occasion to thank all the people who made it possible for me to write this paper.

First of all my gratitude goes to all those who donated their body and thus made this kind of research possible in the first place.

Further, my thank goes to the Vienna Institute of Anatomy, in particular to Professor Dr. Firbas, the director of the Anatomy Department, who made it possible for me to carry out most of the dissections in the rooms of the Vienna Institute of Anatomy. I would also like to extend my gratitude to Professor Dr. Windisch who helped me with his knowledge and patience and supported me in my work. I also want to thank Ms. Eichinger and Mr. Pinzga of the Vienna Institute of Anatomy for their administrative and logistic support.

I owe a great debt of thanks to Todd Garcia of the Laboratories of Anatomical Enlightenment Inc. in Boulder/Colorado, who has known my anatomical curiosity for years and provided me with the necessary skills to satisfy it. Not to forget Gerhard Hesse and Fredericke Hauer with whom I spent many hours in the dissection room.

Thanks also to Mag. Kathi Musil and MSc. D. O.Peter Sommerfeld of the team of the Wiener Schule für Osteopathie (Vienna School of Osteopathy) who accompanied the master course, as well as Mag. Barbara Schnürch for the translation of the paper and Dr. Gebhard Woisetschläger for the statistical analysis of the results.

My deepest gratitude also goes to my family, in particular my wife Marion who provided me with the necessary time and space to work on this paper without disturbance and who gave me support whenever I needed it, as well as my children Malini and Matthias who always remind me of the things in life that really count.

This paper is a contribution to osteopathy. It was written in the tradition of anatomical research which is rooted in the work on cadavers, whether they are embalmed or not. But like every kind of research it only becomes alive if it is carried out not as an end of and in itself but can be seen in a greater context. This context is the work with people who trust in osteopathy as treatment method. If this paper can serve the purpose to understand some functions better an thus help to better understand and adjust the "machine man" so that the forces of nature can go to work as intended by Still, it was worth the effort no matter whether it will be rewarded with the title "Master of Science" or not.

I would like to conclude this preface on this note and finally present a quote by Paracelsus:

„...das grundlegende Prinzip der Medizin aber, ist die Liebe."

"...the most fundamental principle of medicine is love." (opus chirurgicum s.p., Theophrastus Pompastus von Hohenheim, named Paracelsus 1493-1541)

Fred Scheiterbauer, December 2007

2 Introduction

The objective of this work is to find out whether ligaments of the pleural dome as described in osteopathic literature really exist. The first description of these ligaments in osteopathic literature is that of Barral and Marcier. In their book “Visceral Manipulation” the ligamentous apparatus is described as follows:

“The suspensory ligament attaches the pleural dome to the skeleton….This ligament is not directly inserted into the parietal pleura, but rather into the intrathoracic fascia.” (Barral/Marcier 1988 page 38f)

“Because the superior diaphragm of the thorax is essentially made up of stringly structures, the pleural dome is fixed.” (Barra/Marcierl 1988 page 43)

The suspensory ligament thus connects the *pleural dome* via the *intrathoracic fascia* with the skeleton. According to this description it is a structure which has to be regarded as independent from the *intrathoracic fascia*. Since these structures which are called superior *diaphragm* by Barral and Marcier are ligamentous in essence the *pleural dome* is fixed by them.

Chapter 6 will look at these statements in more detail. For the time being I would like to present another quote from Barral and Marcier in which they describe the significance of these ligaments for osteopathic treatment.

“Faced with a complex of pleural adhesions and ligamentous restrictions, it may be difficult to decide which is the most important. Experience has shown us that one should place primary importance on the ligamentous system; treatment here will lead to improvements at every level.” (Barral/Marcier 1988 page 57)

If one is confronted with restrictions of the *ligaments* or adhesions of the *pleura*, it may be difficult to find the right therapeutic approach. According to Barral’s experience it is important to start to work on the ligamentous system provided that these *ligaments* exist as described by him.

The suspension system of the *pleural dome* will be shown in dissection preparations. This should provide the anatomical basis on which osteopathic considerations and the techniques resulting from these considerations can build on. This corresponds with the thoughts of A. T. Still in the early times of osteopathy.

"What is osteopathy? It is a scientific knowledge of anatomy and physiology in the hands of a person of intelligence and skill, who can apply that knowledge to the use of man when sick or wounded by strains…" (Still 1986, page 18)

This paper will also present and discuss the relevant literature about the *pleural dome* and its suspension system from both the field of osteopathic literature as well as publications from the field of anatomy.

In order to view this paper in a larger context the following chapter will take you on a journey into the history of anatomy in general and look at the importance of anatomical knowledge in osteopathy.

2.1 History of anatomy

The term anatomy designates the art of separating the parts of an organism. It is derived from the Greek anatome [ana- Greek: up, temnein Greek: to cut] the cutting up, the dissection (of bodies). (Pfeiffer 2000)

Only through cutting up and separating the structures of an organism anatomy can be learned. This means that the original meaning of anatomy designated the work on dissection preparations.

The beginnings in Antiquity:

The origins of anatomy reach back into ancient times. Already Hippocrates (who is above all known for his Hippocratic Oath all physicians have to take) studied the topics of anatomy. He represented the opinion that a physician should first recognize nature in its wholeness before treating patients. Also Aristotle can be called an anatomist who unlike Hippocrates already practiced dissections although only of animals.

Anatomy as it is understood today dates back into the third century before Christ. Two of the most renowned anatomists of this time are Herophilos of Chalkedon (ca. 340 BC) and Erassistratos of Julis (approx. 320 BC). Around this time dissections of animals as well as human bodies were carried out. Also vivisections ought to have taken place. The victims were slaves or prisoners. In Roman times dissections of human bodies were in general prohibited. (Toellner 1986)

Galen (129-199 BC) can be called the most important anatomist of late antiquity. We know of more than 30 anatomical essays by him. Due to the fact that dissections of human bodies were prohibited in the Roman Empire, Galen only dissected apes and pigs. This, however, led time and again to errors and wrong assumptions when the anatomical knowledge gained from the animals was applied to the human body. Nevertheless, Galen’s works were incontestable in the following centuries. This changed only at the beginning of modern times when new research and investigations of nature made Galen’s works loose in importance (Budde1998)

The art of anatomy in the Middle Ages:

Due to the conquest of Alexandria by the Arabs in 642 the Hellenistic-Late Antique tradition of anatomy was integrated in the Arabic culture. Baghdad and Basra became new centres of medical research. In the Middle Ages the anatomical writings of Late Antiquity that had been translated into the Arabic language were brought back to European universities and monasteries where they were translated back into Latin.

At the beginning of the 12th century only pigs were dissected in Salerno. The University of Bologna started to replace dissections of animals with dissections of human bodies. Salerno and Bologna in Italy and Montpellier and Paris in France were the main centres where anatomy was taught in the 13th century.

In the 14th century dissections were above all carried out on the bodies of hanged persons or persons who committed suicide because they were not entitled to a ceremonial funeral according to the then prevailing Christian doctrine. Nevertheless, dissections still met with a lot of resistance and religious bans. Over time this attitude changed and Pope Alexander V allowed that his corpse was dissected in 1410. The development of the letterpress helped to spread the sparse knowledge of anatomy. However, until well into the 16th century no real changes took place in the field of anatomy. (Toellner 1986)

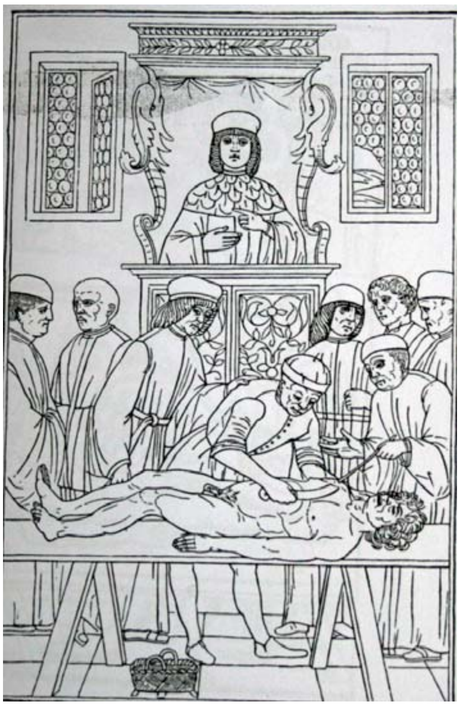

Figure 1: *Picture of a dissection from the Venetian edition of the "Anatomia Mundini", 1493.*

It illustrates a typical dissection of the time. The teacher reads from a book by Galen and the students search for the mentioned structures.

The golden age of anatomy:

The golden age of anatomy started at the beginning of the 16th century when the influence of humanism put the human being in the centre of reasoning for the first time since antiquity.

Andreas Vesalius has to be mentioned as one of the most prominent representatives of this time. In 1537 he was a teacher at the University of Padua and discovered many discrepancies between the dissections that he carried out himself and the descriptions of Galen. His findings were published under the title “Tabulae anatomicae”. The preface of the 1551 Nuremberg edition that was written by the surgeon Jakob Baumann reads:

„ *Da Gott der Allmächtige die Menschen nach seinem Ebenbild mit Leib und Seele erschaffen und ihnen angeordnet hat, dass sie vornehmlich mit jenen Dingen umgehen und sich beschäftigen sollen, die Gottes Ehre und die Seeligkeit anbelangen, ist es dementsprechend hinsichtlich der Beschaffenheit des Leibes am meisten vonnöten, dass sich der Mensch selbst kennen lerne...“* [*“Since God the Almighty created us in his image with a body and soul and commanded that we deal with and occupy ourselves mainly with the things that concern God’s glory and blessedness it is above all necessary that man gets to know himself with regard to the constitution of his body ...”*](orig. Baumann 1551 quoted according to Vesalius 2004 preface, translation B. Schnürch)

Basically, this means that since God has created us in his image, it is almost a divine order to study the structure and composition of our body. To do so would mean to honour the work of God. Thus dissection could be seen from a totally different angle. The dissection of human bodies finally could brush off the air of illegality. It could argue that it derived its right to exist directly from God, a right which is thus incontestable.

Figure 2: *Drawing of a human skeleton by Vesalius from 1551. The precision of the anatomical details was revolutionary at that time.*

Looking at this picture autopsy (see by yourself) could also be interpreted as see yourself.

“De humani corporis fabrica libri septem” was published in 1543 and is considered as Vesalius’ main work. He was only 28 years old when it was published and his anatomical pictures were trend-setting in their precision. What is understood by anatomy today can mainly be traced back to the works of Vesalius.

At that time dissections did no longer take place outside. They were performed in theatre-like auditoriums. The dissections developed more and more into a social event with a certain entertainment factor. (Toellner 1986)

Figure 3: *Detail from the cover picture of Tabulae anatomicae by Lancisi, Rome 1714*

From the beginning a big problem in dissection was the conservation of the bodies. Since the bones were the most resistant parts of the human body, a lot of importance was put on a complete preparation of the skeleton. Hatchets, knives, picks and chisels were used for disassembling the bodies. Alcohol was used for soft tissue preparations but the results were not satisfactory. Only after the discovery of the blood circuit by William Harvey in 1628 it was possible to achieve a better conservation. Instead of the blood fungicides and fixing solutions were filled in the vessels which allowed for a better preservation. By filling coloured wax into the arteries and veins of the body the blood vessels could be very well displayed. The surrounding tissue was then removed and what was left was a cast of the vessels. This kind of preparation is called corrosion anatomy. (Faller 1948)

But since muscles and hollow organs could not be prepared with this method one resorted to form wax models of these structures. The Florentine wax models acquired by Emperor Joseph II in 1785 can definitely be counted towards the most renowned specimens of this kind. They are exhibited at the Josephinum in Vienna. (Toellner1978)

The following quote is from an illustrated book on these wax models that was published in 2002.

„Ungeachtet ihres extremen Realismus sind die anatomischen Modelle niemals Abbildung der Wirklichkeit, sondern Repräsentation eines idealtypischen Bildes des menschlichen Leibes. Diese hybriden Abbildungen manipulieren in bis dahin ungekannter Weise mit realen Abdrücken der Natur. Jedes Detail ist Produkt einer empirischen Analyse des toten Leibes, resultiert aus

einem sorgfältigen Abguß eines anatomischen Präparates, das den herrschenden Idealbildern gemäß zugerichtet wurde.“... [*“Despite their extreme realism these anatomical models are never a true depiction of reality but only a representation of an ideal picture of the human body. These hybrid models use replicas of nature to manipulate in a way that was unknown until then. Every detail is a product of the empirical analysis of a dead body, the result of an accurate cast of an anatomical preparation that was adapted to fit the ideals of the time.”*] (orig. Almhofer 2002 Page 25, translation B. Schnürch)

These anatomical models are thus idealised depictions of reality that fit the zeitgeist of the era. They are a mixture of a true replica of nature and the idea of an ideal form. The result is a manipulation of reality.

Similar holds for anatomical drawings. They also provided a distorted picture of reality due to their embellished and schematic form of depiction.

Figure 4: *Wax model of the collection of anatomical and obstetric models at the Josephinum in Vienna.*

The discovery of formaldehyde by the chemist Hoffmann in 1868 represented a true breakthrough. Since formaldehyde has extraordinary cross-linking as well as conserving and microbiocide properties, diluted formaldehyde solutions are well-suited to preserve preparations for longer periods. First, the formaldehyde is filled into the body; afterwards the whole preparation is placed in a closed tank filled with formaldehyde where it remains for at least 9 months. (Fanghänel et al 2004)

I would like to summarize briefly where the cadavers come from: In earlier times the bodies of slaves and convicts were used for dissections. (Toellner1986). Today the specimens are people who donated their body to medical research. After the anatomical research is finished the bodies of the donators are incinerated and buried in a tomb of honour. We owe them our gratitude because without them there would be no anatomical research.

A lot more could be said about the history of anatomy but this would exceed the scope of this paper. Nevertheless, I would like to conclude this chapter with a few quotes that vividly describe the importance of anatomy and how indispensable the work in the dissecting room is.

The first statement is a quote of Anton Faller, 1948:

„ Man begnügt sich vielfach mit einer schematisierten Theorie vom Baue des Menschenkörpers und vergisst, dass auch heute noch das Präparat der Grundpfeiler jeder medizinischen Vorstellung ist. „ [*"Often we content ourselves with a schematic theory of the build-up of the human body and forget that still today the dissection is the cornerstone of every medical consideration."*] (orig. Faller 1948, page 1, translation B. Schnürch)

The next two statements are quotes of Josef Hyrtl one of the most important anatomists of his time:

„Nirgends ist die Arbeit des Geistes, das Denken, so abhängig von der Arbeit der Hände, wie in unserer Wissenschaft, welche auf ein Handwerk, im reinen Sinne des Wortes, gepfropft ist, und durch die Arbeit großgezogen wurde. Es gibt kein Denken in ihr, ohne Zerlegen, Greifen und Sehen." [*"In no other field the work of the mind, the thinking, is so much dependent on the work of the hands like in our science which is grafted on a manual craft in the true sense of the word and is nurtured through work. In it there is no thinking without separating, touching and seeing."*] (orig. Hyrtl 1860 page 7f, translation B. Schnürch)

„Die Beziehung der Anatomie zur Medizin ist aber nicht so aufzufassen, dass man nur eine gute anatomische Schule durchzumachen brauchte, um ein guter Arzt zu werden. Die Anatomie hat unbestreitbar, wie jede andere wissenschaftliche Forschung ihren Wert a n s i c h. Dieser bestimmt aber nicht immer ihren Werth als A n w e n d u n g. Man kann ein grosser Anatom, und dabei doch nur ein sehr mittelmäßiger Arzt sein..." [*"But the relationship of anatomy and medicine cannot be misunderstood as meaning that you only have to attend a good anatomical training to become a good doctor. Like any other scientific research anatomy indis-*

putably has i t s o w n v a l u e. But this does not necessarily determine its value w h e n a p p l i e d. You can be a great anatomist but at the same time only a mediocre doctor..."](orig. Hyrtl 1860 page 6, translation B. Schnürch)

Finally an inscription that according to Fanghänel can be typically found in dissecting rooms:

"Hic locus est, ubi mors gaudet succurrere vitae", [*"this is the place where death delights to help the living"*] (orig. Fanghänel et al 2004, translation B. Schnürch)

Summary:

The roots of anatomy in Europe date back more than 2000 years. Like any other science or form of art also anatomy has to be regarded always in the context of the main fundamental social currents of the time as it is also influenced by these currents. The beginnings of the art of preparation of tissues as we know it today date back to the 16^{th} century. Its most prominent proponent was Andreas Vesalius. One of the main problems of thorough anatomical studies was the conservation of the preparations. With the discovery of formaldehyde this problem could be overcome to a large extent.

Since the dissecting room is the place where the living can learn from the dead, it is indispensable to demand a respectful handling of the cadavers by everybody who carries out a dissection.

2.2 The significance of anatomy in osteopathy

The previous chapter presented a brief overview of the history of anatomy and tried to illustrate the importance of anatomy in medicine with a few quotes. This chapter will now look at the significance of anatomy in osteopathy. The emphasis will be put on A.T. Still, the founder of osteopathy.

For Still anatomy assumed an important place in osteopathy. The following quotes illustrate this clearly.

The first statement is taken from "The Philosophy and Mechanical Principles of Osteopathy":

"In early life I began the study of anatomy, believing it to be the "alpha and omega"..." (Still 1986 page 27)

Still's answer to the question which studies are necessary to become an osteopath was:

"As you contemplate studying this science and asked to know the necessary studies, I wish to impress it upon your minds that you begin with anatomy, and you end with anatomy, a knowledge of anatomy is all you want or need, as it is all you can use or ever will use in your practice, although you may live one hundred years." (Still 1995 page 16)

Anatomy is thus the key element in learning the art of osteopathy.

Still himself had already started his anatomical studies in his younger days. And he was not timid when it came to procuring his study objects:

"Since early life I had been a student of nature's book. In my early days in windswept Kansas I had devoted my attention to the study of anatomy. I become a robber in the name of science. Indian graves were desecrated and the bodies of the sleeping dead exhumed in the name of science. Yes, I grew to be one of those vultures with the scalpel, and studied the dead that the living might be benefited. I had printed books, but went back to the great book of nature as a chief study. The poet has said that, "The greatest study of man is man." I believed this, and would have believed it if he had said nothing about it. The best way to study man is to dissect a few bodies." (Still 2000 page 84)

Besides the studying of books the study of the book of Nature is the most important source of knowledge. For Still this was the opening of cadavers. However, the way how he proceeded to do these dissections can be regarded as questionable from an ethical point of view.

Still's works do not only emphasize the fact that anatomy is an important precondition of learning osteopathy he also described how the anatomy studies have to be organized:

The anatomy classes start with thorough studies of the descriptive anatomy contained in books. Then the students move to the dissecting room and finally continue to study physiology and histology, which according to Still's way of thinking are extended subjects of anatomy. Only when the students have passed all these phases they may enter the clinic rooms where they become familiar with the abnormalities of anatomy and their effects on the organism and learn how to treat them. (Still1995).

In 1894 Still founded the first school of osteopathy in Kirksville, Missouri. Given the time the school was well equipped with material for the teaching of anatomy, among other things it disposed of fresh and embalmed preparations, books and display boards as well as spacious research and lecture rooms. (Still 1995)

Figure 5: *This picture shows the "old doctor" among an anatomy class.*

Right to the end of his life Still regarded anatomy as the cornerstone of the teachings of osteopathy and osteopathic training. Still did not tire of emphasizing this again and again. For him the role of an osteopath was that of a mechanic who tries to restore the natural state of the "machine man" in the case of disease, a machine that was created by God in a perfect form.

"The God of Nature is the fountain of skill and wisdom and the mechanical work done in all natural bodies is the result of absolute knowledge. Man cannot add anything to this perfect work nor improve the functioning of the normal body. Disease is an effect only, and a positive proof that a belt is off, a journal bent, or a clog broken or caught. Man's power to cure is good as far as he has a knowledge of the right or normal position, and so far as he has the skill to adjust the bones, muscles and ligaments and give freedom to nerves, blood secretions and excretions, and no farther. We credit God with wisdom and skill to perform perfect work on the house of life in which man lives. It is only justice that God should receive this credit and we are ready to adjust the parts and trust the results." (Still 1992 xxiii/Preface)

From Still's point of view the work of the "God of Nature" is perfect and does not need any improvement. Disease is only the manifestation of a mechanical impairment. And man's way to treat is only good as long as it tries to re-establish the normal condition under which the body can fulfil its tasks. For Still this meant to cherish God through respecting and acknowledging his work, the human body. Osteopathic treatment is based on the perfection of God's work.

William Garner Sutherland was one of the most renowned students of Andrew Taylor Still and like his teacher he conceded similar importance to anatomy. In his book “Teachings in the Science of Osteopathy” we can read:

“The perfect anatomical picture is a necessary background for understanding what you see in many living heads.” (Sutherland 1990, page 6)

In chapter 7 Sutherland talks about the complicated anatomy of the face and he vividly describes how he had experienced the anatomy classes at the American School of Osteopathy:

“Study the delicate, intricate, little things in the facial mechanism and begin to apply the mechanical physiology of the region. This is applied anatomy. It is the subject that we studied under Dr. William Smith in the early days at the American School of Osteopathy in Kirksville, Missouri. If you didn’t apply that osteopathic physiologic reasoning, Dr. Still was often there, with his walking staff, to see that the members of the faculty regularly brought in the osteopathic point of view.” (Sutherland 1990, page 81)

This is another quote which illustrates how important it was to study anatomy. Anatomical studies served as basic knowledge to draw osteopathic conclusions that were essential for treatment.

Sutherland always emphasized that the cranial concept was not a special field of osteopathy but it was osteopathy applied to the cranium. He did not see it as form of therapy but as scientific knowledge which helped to handle problems in the human body. (Sutherland 1998)

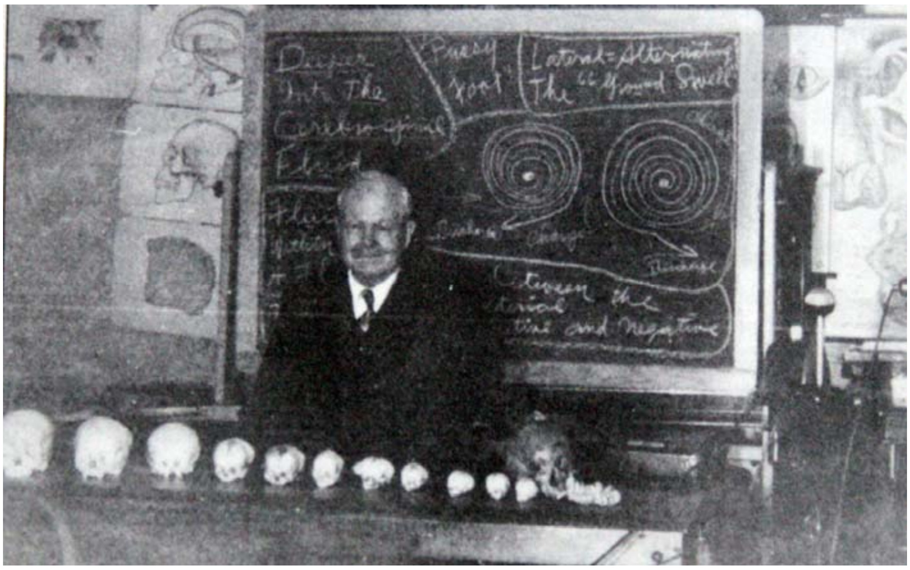

Figure 6: *W.G. Sutherland during one of his lectures.*

When in 1950 he learned that there were thoughts about discontinuing the classes of functional anatomy he said during one of his lectures:

"Dr. Still's fundamental principle of anatomy in the normal, properly understood, should be of primary importance in teaching the science of osteopathy." (Sutherland 1998, page 245)

To conclude the array of statements on the importance of anatomy in osteopathy also Rolin Becker, a student of Sutherland, has to be quoted.

"Osteopathy is primarily a thinking profession, with a thinking diagnosis and a thinking treatment. … It takes a peculiar type of mind to think anatomy and physiology, to correlate and coordinate the tissue pattern that we call the osteopathic lesion with the problem within the patient." (Becker 2000, page 105)

It is not sufficient to merely learn the anatomical terms. The foundations of osteopathy are the recognition of interconnections and the resulting conclusions concerning the treatment What makes osteopathy a "thinking profession" is how the things that are learned are applied in practice.

In his book "Life in motion" Becker describes the tools that are necessary to practice osteopathy:

"The primary boss is inside...Secondly, we need to study the details of the anatomicophysiological mechanism in a living body…We are adding these details to the anatomy and physiology we learned in school. When I went to my first class with Dr. William Garner Sutherland, I told him I had not come to learn his work, I had come to extend my knowledge of anatomy and physiology to include the craniosacral mechanism, which we had not been taught in school. Dr. Sutherland gave that to the profession and now we are giving it to you. You are here to continue your study of the anatomy and physiology of the living body, which includes the primary respiratory mechanism…The work of A.T. Still gave us the science of osteopathy. The work of W.G. Sutherland gave us the primary respiratory mechanism with its detailed anatomy and physiology, not as a separate component of the work of Dr. Still but as an integrated unit with the science of osteopathy." (Becker 1997, page 5 ff)

This quote cannot be more "osteopathic" in Still's original intention. The driving forces ("the boss inside", or "God of Nature") reside in every human being. The task of the osteopath is to support these forces by continuing anatomical and physiological studies. It is of primary importance not only to study the anatomy in a dead body but also to recognize and understand the function of anatomical and physiological mechanisms in the living body. This again shows that the work of Sutherland must not be seen as separate but as integrated part of the science of osteopathy.

Summary:

Given the quotes of the founder of osteopathy and his students the question arises whether osteopathic training as it is designed today can meet the requirements.

Considering all the statements we can rightfully say that anatomical studies are of primary importance in osteopathy. In this context the term anatomy is used in its wider sense. It comprises both the study of the human body in the dissecting room and through anatomy books as well as the study of the living body with all its physiological interconnections and interactions. In addition, you need a quick mind that can apply the anatomical and physiological knowledge of the healthy body also to a body in lesion and utilize the knowledge for treatment. The objective of an osteopathic treatment is to recognize the effects of diseases on the body, that is a perfect creation of the forces of nature, and to re-establish the body‘s normal state. The body is endowed with divine perfection that must not be called into question; it rather serves as the fundamental force that cannot be improved by any means.

After this short journey into the history of anatomy and the role of anatomy in osteopathy we will approach the actual topic of this paper. At first, we will look at the function of the suspension system of the *pleural dome.*

3 The function of the suspension system of the pleural dome

To understand the function of the *pleural dome* it is necessary to look at the embryological development and the physiology of thoracic breathing. From the mechanics of breathing and the development of the lungs in the *pleural cavity* we can deduce the function of the *pleural dome* and why it is necessary that it has some sort of fixation system.

3.1 The development of the pleural cavity and the lungs:

The development of the *respiratory tract* is a consequence of the descent of the heart during embryologic development. The descending heart takes part of the wall of the gut with it to its new situation. The preliminary formations of what will later become the *respiratory tract* start to develop from this wall of the gut. Once the heart-liver complex starts to grow the angle to the spine enlarges which creates a suction field. The suction causes an invagination of the e*ndoderm*. The invaginating tissue represents the lung bud. The region between heart, liver and lung contains a body cavity. Due to the increasing growth of the organs the body cavity grows as well and starts to divide into the *pericardial cavity*, the *peritoneal cavity* and the two *pleural cavities*. (Blechschmidt 1978.)

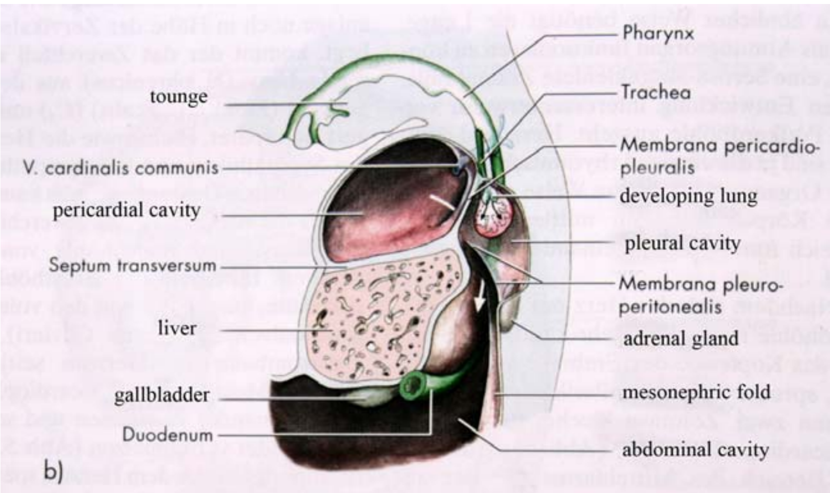

Figure 7: *Development of the body cavities*

Rohen and Lütjen-Drecoll (2006) describe the development similarly. The development of the lungs starts from an *endodermal gut tube*. The embryonic gut tube is divided into four parts which undergo different developments. In the region of the foregut pocket-like structures start to evaginate. These evaginations are called *branchial* or *pharyngeal pouches*. These pouches continue to develop into the respiratory organs. The development of the lungs can be divided into four phases. The first phase is the separation of the lung bud from the *foregut*. This phase starts approximately in the fourth week. Already before this phase of development the body cavities start to develop. From the *pericardial cavity* a duct starts to form which starts to connect with the s*erosa* of the *peritoneal cavity*. This happens around day 24. Then the *pleural cavity* becomes separate from the *pericardial cavity*. Together they form the thoracic cavity. The *Membrana pleuroperitonealis* separates the thoracic cavity from the abdominal cavity (about day 44 of the embryonic development). The final formation of the *pleural cavity* with the preliminary structures of the lungs happens around day 52. The development of the body cavities starts from the middle germ layer (*mesoderm*), while the lungs develop from the inner germ layer (*endoderm*). (Rohen/Lütjen-Drecoll 2006).

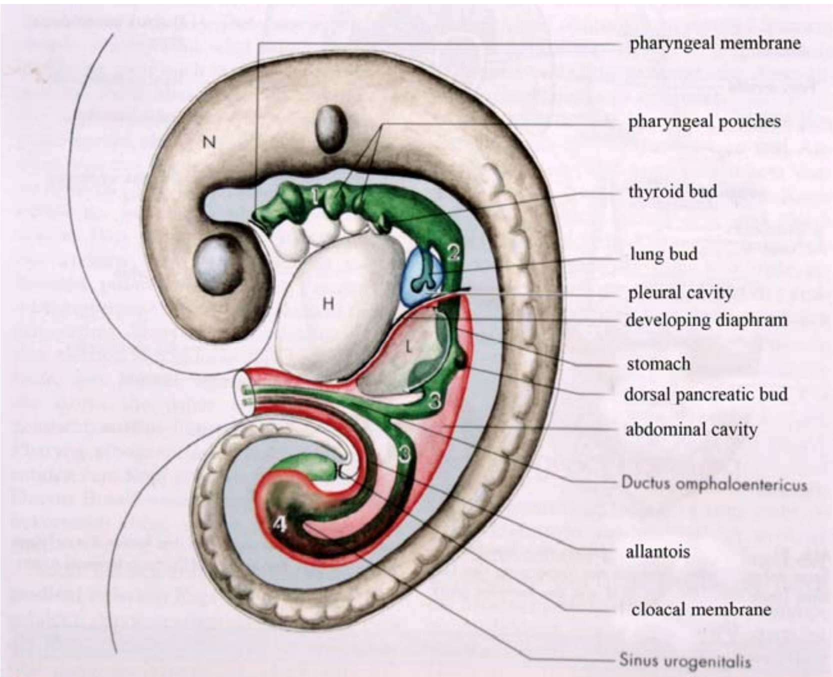

Figure 8: *Development of the lungs in the pleural cavity*

The germ layers develop from a germ disc. In the 3rd week the bilaminar germ disc becomes trilaminar. A table from Drews' "Taschenatlas der Embryologie" (1993) will help to better understand which structures of the body originate from which germ layer.

Ectoderm				
	neural tube		Central nervous system	
	neural crest		Peripheral nervous system	
	placodes		Sense organs	
	surface epithelium		epidermis	skin
mesoderm				
	somites	dermatome	corium, subcutis	
		myotome	muscles	
		sklerotome	spine	
	notochord			
	intermediate mesoderm		kidneys, genital tubes	
	lateral plate	parietal		
		mesoderm	body wall,	
			parietal peritoneum	
		visceral		
		mesoderm	visceral peritoneum,	
			Layers of the intestir	stomach-intestinal tube
endoderm				
		gut tube	epithelial lining	
			of the gastrointestinal tract	

Table 1: *The germ layers and the structures deriving from them*

The table shows that all the supporting and connective tissues as well as the muscles and bones develop from *mesoderm* (Drews 1993). These are the elements that are necessary to fix the *pleural dome.*

Summary:

The descriptions of the embryologic development show that the body cavities develop before the actual organs. All the structures which are necessary to form the body cavities and later on play a role in forming the suspension system of the *pleural dome* originate in the middle germ layer. The lungs develop from the inner germ layer. This is important in that the mechanics of breathing depend on the reciprocal effect of the lungs on the one hand and the layers that are covering it on the other hand. This reciprocal relationship is ultimately responsible that the *pleural dome* needs to have some sort of fixation system. The chapter on the mechanics of breathing will look at this in more detail.

3.2 The mechanics of breathing

The expansion of the thorax takes place against the resistance of the elastic tension of the lungs. This is a result of the development during which the *thorax* grows faster than the lungs. The elastic components of the lungs are stretched. Even in *expiration* the lungs are in a state of tension. This tension is counteracted by the muscles, the bony components of the *thorax* and the connective tissue. (Fanghänel et al. 2003)

This system generates the factors that are responsible for the change in the volume of the lungs during respiration: on the one hand the action of the muscles of respiration and the elasticity of the bony *thorax* and the surrounding connective tissues (*mesoderm*) and on the other hand the elasticity of the lungs (*endoderm*).

From this point of view one could say that the apparatus that is responsible for breathing consists of two hollow organs (lungs and *thorax*) that are nested one into the other. In the resting position the *alveolar pressure* is zero. The *pleural pressure* is slightly negative and the pulmonary pressure is equally slightly positive. This means the lungs want to contract while the *thorax* wants to expand. The fact that neither lungs nor *thorax* follow the forces that act upon them can be attributed to the fact that there is a fluid in the space between the *parietal* and *visceral pleura*, which ensures that the layers can glide over each other without friction but are also held together like two glass plates with a fluid film between them that can be shifted but not separated. (Klinke Silbernagel 2000).

The *thorax* and the lungs are connected through the *endothoracic fascia (Fascia endothoracica)*, which directly adheres to the outer layer of the *pleura*. This outer layer is called *Pleura parietalis*. It is separated from the inner layer of the *pleura* by a small space with negative pressure. The inner layer, *Pleura pulmonalis* (or *Pleura visceralis*) directly adheres to the lungs. To a large extend the *Fascia endothoracica* is attached to the internal surface of the thorax. (Hafferl 1957).

Since the *pleural dome* reaches about two finger's breadth above the first rib, a suspension system is necessary in this region, which ensures that the force of the tension of the lungs is counteracted.

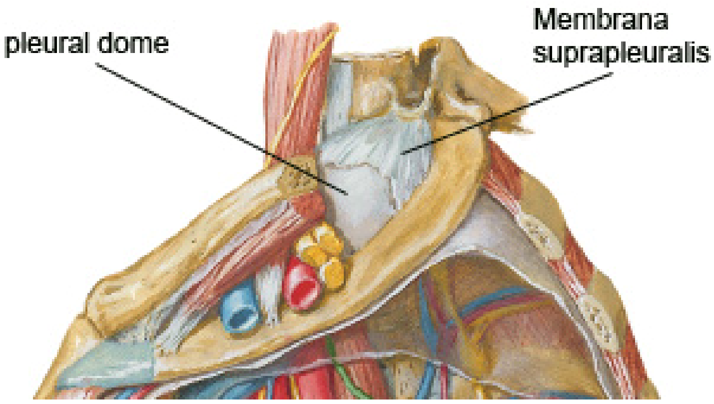

Figure 9: *The pleural dome embedded in the ring of the first rib*

3.3 Summary:

The *pleural cavity* develops before the lungs. In addition, the lungs and the *pleural cavity* develop at different rates.

The lungs originate from the inner germ layer. The *pleura* and all structures that support the *pleura* and connect it with the *thorax* originate from the middle germ layer. The tension that results from the different rates of development and the diversity of the tissues is an essential component of the mechanics of breathing.

Since the apex of the lungs reaches beyond the first rib and therefore does not have the bony support for the *Fascia endothoracica* and thus the *pleura*, another form of fixation is necessary to counteract the forces of the lungs. If there was no fixation system, the *adhesion forces* of the lungs would pull the *pleura* down.

We will look at the anatomical build-up of the *pleural dome* in more detail in the next chapter which will list and discuss the structures that contribute to form the *pleural dome*.

4 Anatomical considerations

The previous chapter presented the embryologic development and the mechanics of breathing to demonstrate that the function and fixation of the pleural dome can be deduced from these factors. This chapter will look at some anatomical considerations concerning this region and describe and discuss the structures that contribute to the build-up of the *pleural dome*.

The term *pleural dome* designates the part of the *Pleura parietalis* that is embedded in the ring of the first ribs and covers the apex of the lungs in the form of a dome (Hafferl 1939). The bony ring is made up by the first thoracic vertebra, the first rib on both sides and the *Manubrium sterni* and is also called *thoracic inlet* (Wurzinger 2007).

4.1 The bony support structures

The bony structures that have a direct relationship with the *pleural dome* are the first thoracic vertebra and the two first ribs that together form a bony ring. The first rib has an internal and external edge and a superior and inferior surface. The structure of the first rib differs slightly from the other ribs because it has a broad superior and inferior surface. In contrast to the other ribs the first rib's internal and external border are curved and look inward and outward while the broad superior and inferior surfaces of the bone look cranially and caudally. In addition, the first rib is much more curved than the second rib. Therefore the first rib is not only situated above but also inside the arch of the second rib. (Hafferl 1939)

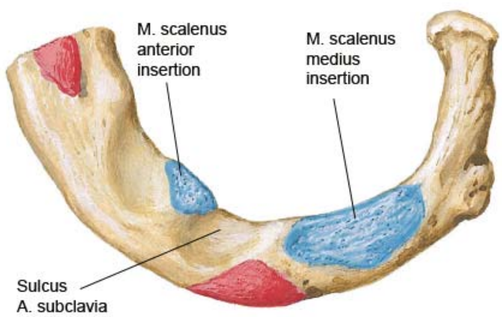

Figure 10: *The first rib on the left side. Note the strong curve and the broad superior surface.*

Like all ribs also the first rib serves as attachment for the *Fascia endothoracica*. It thus represents an important support for the *pleural dome*. Bouchet (1991) even says that the first rib is the key structure for the support of the *pleural dome*.

It has to be mentioned that anatomical particularities like a longer transverse process of C7 or the presence of a cervical rib can have an influence on the *pleural dome*. Gruber (1869) describes that large cervical ribs can have a cartilaginous attachment on the first rib or are connected with it through a *ligament*. Law (1920) reports that in case of a longer transverse process of C7 often also a *ligament* can be found, which either inserts onto the first rib or merges with the *pleural dome* (in Wanke 1940).

4.2 Fascia endothoracica

The structure that forms the connection between the *Pleura parietalis* and the *thorax* is the *Fascia endothoracica.* This connection cannot only be found in the region of the *pleural dome* but persists throughout the whole *Pleura parietalis*. The *Fascia endothoracica* completely covers the internal surface of the *thorax.* It is connected with the ribs and the intercostal muscles. Hyrtel (1846) was the first one to describe this structure.

Der äußere Ballen (der Pleura) ruht unten auf dem Zwerchfell (Pleura phrenica) und ist an dieses, sowie an die innere Oberfläche der Brustwand durch kurzes Zellgewebe angeheftet, welches sich, gegen die Wirbelsäule zu, als besondere Schichte entwickelt, festere Textur annimmt, und von mir als Analogon der Fascia transversa abdominis betrachtet, als Fascia endothoracica aufgeführt wird.“ [*“The external bulge (of the pleura) rests on the diaphragm (Pleura phrenica) and is attached to it and to the internal surface of the thoracic wall through short cell tissue, which develops as a special tissue layer towards the spine and assumes a more compact texture. I consider it analogous to the Fascia transversa abdominis and call it Fascia endothoracica.”*](orig. Hyrtel 1846 page 483, translation B. Schnürch)

Thus the *Fascia endothoracica* is an analogue structure to the *Fascia transversa abdominis*. It is the layer that forms the connection between the internal thoracic wall and the *Pleura parietalis* and lines the whole thoracic cavity.

Luschka (1859) points out that the various sections of the *Fascia endothoracica* have to be considered with regard to the surrounding tissues because it varies in thickness depending on the structures in the vicinity. In addition, he mentions that the thickness of the fascia increases with age and that it also becomes increasingly fibrotic.

Merkel (1899) agrees with Luschka in as far as the thickness of the fascia varies depending on the location.

Other descriptions that are in line with Luschka's opinion can be found from Langer/Toldt (1921), Singer (1935) Braus (1936) and several other authors.

Fanghänel (2003) goes more into detail when it comes to the description of the *pleural dome*. He describes the *Fascia endothoracica* as a layer of loose connective tissue which takes on a more solid structure only in the region of the *pleural dome* and is also called Gibson fascia.

Also Cunningham (1991) describes the *Fascia endothoracica* as shape-giving structure which forms the *pleural dome*. For him it is a thin layer of connective tissue that can be seen as independent layer only in its posterior part (the part that looks towards the spine). It becomes a discernable, stronger, more fibrotic layer only in the region of the *pleural dome.* According to his description it attaches to the internal border of the first rib and extends posteriorly to the anterior surface of the transverse process of C7. He called this layer *suprapleural membrane.*

In Gray´s Anatomy the *Fascia endothoracica* is described as a thin layer of loose connective tissue, which has a connection to the transverse abdominal fascia at its lower end and reinforces the *Pleura cervicalis* at its upper end. This upper part is called *suprapleural membrane* and extends from the internal border of the first rib posteriorly to the transverse process of C7 (Shah 2005).

Finally, the explanation of the anatomy atlas "Prometheus" should also be presented in particular because it contains a good picture (cf. Fig. 11) of the *Fascia endothoracica* and especially the *pleural dome*. The description in this book basically follows that of Gray´s Anatomy. It also mentions the connection with the abdominal *Fascia transversalis* and that the part that reinforces the *Pleura cervicalis* is called *suprapleural membrane*. In contrast to Waldeyer who talks about a Gibson fascia, here we find mention of a Sibson fascia. (Schünke et al. 2005).

A more detailed explanation has to be provided in order to guard against confusion because suddenly there is also a *Pleura cervicalis*. The *Pleura cervicalis* is a part of the *Pleura parietalis*. The *Pleura parietalis* envelops the whole lung as a serous bag. Depending on the region it carries different names. It can be divided into the following sections: The part that adheres to the *diaphragm* is called *Pars diaphragmatica*, the part that is located close to the *mediastinum* is called *Pars mediastinalis*, the part that is connected with the ribs is called *Pars costalis* and the part that is located in the region of the apex of the lungs is called *Pars cervicalis*. (Shah 2005)

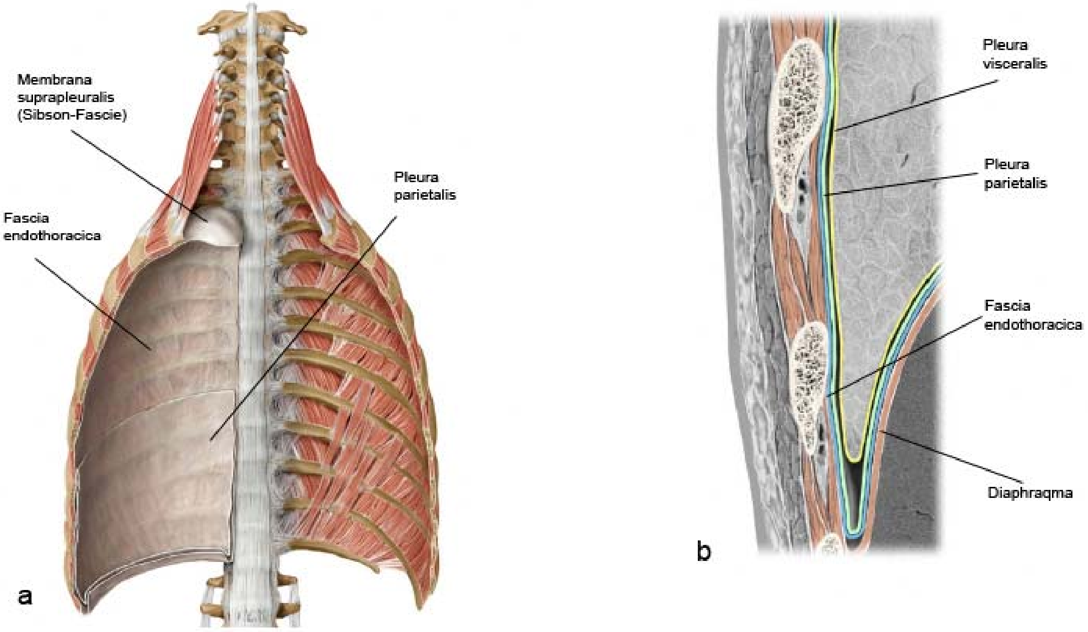

***Figure 11: a** Fascia endothoracica with Membrana suprapleurale, **b** the connection of the Pleura parietalis with the Fascia endothoracica in the cross-section*

Summary:

The authors quoted in this paper agree that the *Fascia endothoracica* is the layer that connects the *pleura* with the *thorax.*

It is a layer of loose connective tissue and can be seen as an independent structure in its posterior region facing the spine. In the region of the *pleural dome* it forms a clearly discernable fibrous layer which is called *Membrana suprapleurale*. (Cunningham 1991, Shah 2005, Schünke et. al. 2005). In addition, Luschka (1859) observes that with age the *Fascia endothoracica* increases in thickness and fibrosity.

Further, there is a connection between the *Fascia endothoracica* and the *Fascia transversalis abdominalis*. (Hyrtl 1846, Schünkt et. al. 2005, Shah 2005)

The most superior bony structure where the *Fascia endothoracica* can attach to is the ring that is formed by the first thoracic vertebra, the first rib on both sides and the *Manubrium sterni*. This ring is called *thoracic inlet*.

Regarding the disagreement concerning the designation of the fascia as Sibson or Gibson fascia I subscribe to the view of “Prometheus” because I think the fascia is named after Francis Sibson who examined and compared the region of the *pleural* *dome* in various animals and also in the human body and presented his results in his work “On the Mechanism of Respiration” (Sibson 1846).

The next section will look at the structures that support the *Membrana suprapleurale*.

4.3 Fascia praevertebralis

The deep layer of the *Fascia cervicalis* is called *Fascia praevertebralis*. The *Fascia cervicalis* can be divided into the *Fascia cervicalis lamina superficialis*, *Fascia cervicalis lamina praetrachealis* and *Fascia cervicalis lamina praevertebralis*. The superficial layer envelops the whole neck, the *praetracheal* layer envelops the infrahyoidal muscles and the *Fascia praetrachealis* envelops the *Mm. Scaleni,* the praevertebral muscles and the autochthonous muscles of the back (Schünke et al.2005). Cf. also Berkovitz (2005) and Hafferl (1957).

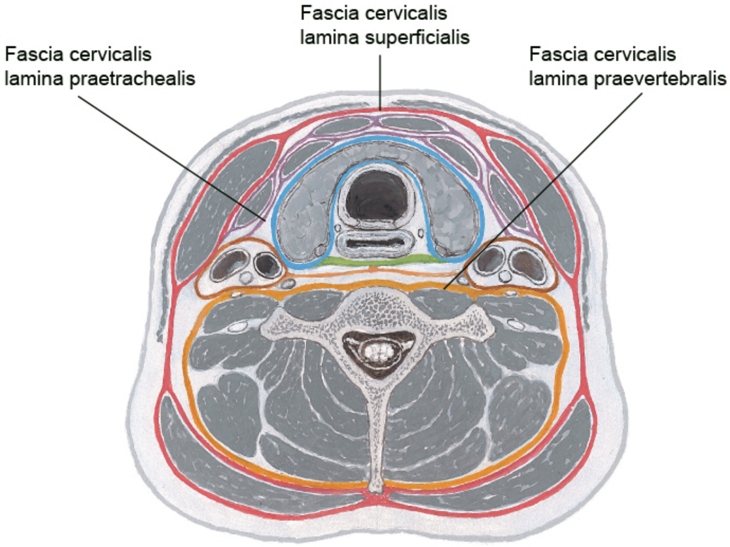

Figure 12: *The various layers of the cervical fascia*

Lanz and Wachsmuth (1955) quote Eisler (1912) who describes firm strands of connective tissue that originate from the *Fascia praevertebralis* at about the level of C3 and extend caudally merging with the connective tissue envelop of the pharyngeal muscles and the connective tissue capsule of the thyroid gland. From there plate-like strands continue towards the *thoracic inlet*, the first rib and the pleura. Dorsally these strands of connective tissue merge with the *Fascia pleurovertebralis* and the *Ligamentum pleurovertebrale*.

In Waldeyer's "Atlas der Anatomie des Menschen" connective tissue fibres are depicted that originate from the *Fascia cervicalis lamina praevertebralis* in the region of C6 to D1. These fibres are called *Ligamentum pleurovertebrale* (Fanghänel et al. 2003)

Moll and Moll (1978) argue that the *Membrana suprapleuralis* (continuation of the *Fascia endothoracica* covering the *pleural dome*) is closely attached to the first rib and the *Fascia praevertebralis*.

I would also like to mention Willard (2007) who sees the *Fascia transversalis abdominalis,* the *Fascia endothoracica* and the *Fascia praevertebralis* as one continuous structure and calls it *Axial Layer*. Willard deduces this from the embryonic development. According to him the structure only has different names depending on the surrounding tissues. Cf. also chapter 4.2 where you can find similar statements concerning the *Fascia endothoracica* and the *Fascia transversalis abdominalis* by Hyrtel (1846), Schünke et. al. (2005) and Shah (2005).

Summary:

All authors agree that there is a connection between the *Fascia cervicalis* and the *Fascia endothoracica*.

For the first time there is mention of a connective tissue structure as *ligament*. Eisler (1912) and Fanghänel et. al. (2003) call the two fascias *Lig. pleurovertebrale*. The origin of this *ligament* can be found in the *Fascia cervicalis lamina praevertebralis*.

Willard (2007) sees the *Fascia endothoracica* and the *Fascia cervicalis* as one continuous layer of connective tissue which only has different names depending on the region. He calls this bag of connective tissue Axial Layer.

4.4 The group of the scalene muscles

The group of the scalene muscles represent the deep layer of lateral muscles in the cervical region. One could say they correspond to intercostal muscles that are fused. We can differentiate between a *M. scalenus anterior, M. scalenus medius, M. scalenus posterior* and *M. scalenus minimus*. With a few strands the *M. scalenus anterior* originates from the *Tubercula anteriora* of the transverse processes of C3-6 and inserts onto the *Tuberculum musculus scaleni anteriores*. The *M. scalenus medius* originates from the *Tubercula anteriora* of the transverse processes of all cervical vertebrae and inserts onto the first rib behind the *Sulcus arteriae subclaviae*. The *M.scalenus poste-*

rior originates from the *Tubercula posteriora* of the transverse processes of C5 and C6 and inserts onto the superior border of the second rib. The *M. scalenus minimus* originates at the transverse process of C7 and merges with the *pleural dome.* It can be found in 30 % of the cases (Fanghänel et al. 2003).

Let us first look at the *M. scaleni anterior* and *medius*. The *M. scalenus minimus* will be discussed separately.

In the anatomy atlas Rauber Kopsch (Leonhardt et al. 1987) it is generally argued that there is a close topographic relationship of the *M. scalenus anterior* and *medius* with the *pleural dome*.

According to Hafferl:

„ Der M. scalenus ventralis, der von oben herab zur ersten Rippe zieht, liegt der Kuppel von vorne und oben auf, so daß sie durch Bindegewebe an seine zarte Fascie fixiert ist. Von der Endsehne können außerdem verschieden starke Züge abzweigen und an der Kuppel nahe dem Tuberculum scaleni inserieren; sie haben daher auf den lateralen und vorderen Teil der Kuppel Einfluß.“ [*“The M. scalenus ventralis runs inferiorly towards the first rib and lies anteriorly and cranially on the pleural dome so that it is fixed onto its delicate fascia by connective tissue. From the end tendon differently strong strands can branch off and insert onto the dome in the vicinity of the Tuberculum scaleni; thus they have an influence on the lateral and anterior part of the dome.“*] (orig. Hafferl 1939 page 57, translation B. Schnürch)

The *M. scalenus anterior* can have branches that merge with the anterior and lateral part of the *pleural dome.* In addition, its fascial envelop is connected with the dome by connective tissue.

Kubik (1968) describes that both the *M. scalenus anterior* and the *M. scalenus medius* can insert onto and merge with the *pleural dome*.

In Gray’s Anatomy a completely different consideration regarding the *M. scalenus medius* is presented: *“... it has been suggested that the suprapleural membrane is the tendon of scalenus medius.”* (Shah 2005).

This would mean that the *Membrana suprapleuralis* is an extension of the tendon of the *M. scalenus medius*. However, a description like that could not be found in any other of the books or studies quoted in the bibliography of this paper.

The *M. scalenus minimus* has the strongest connection with the pleural dome. Since it represents an essential component of the suspension of the pleural dome, it has to be discussed in more detail.

Sibson (1846) whom the *Membrana suprapleurale* is named after in some books, said:

"In addition to the ordinary scaleni, there is usually a special scalenus to expand the summit of each lung. This pleural scalenus arises from the transverse process of the seventh cervical vertebra, becomes tendinous and aponeurotic, and is inserted by a funnel-like tendinous web into the whole circuit of the first rib." (page 534).

Sibson thus sees the *M. scalenus minimus* that originates in the region of C7 and inserts into the whole region of the *pleural dome* as a muscle that keeps the *pleural dome* open.

Zuckerkandl (1876) describes the muscle as follows:

Verschieden von diesen [M. scalenus medius] an Körper und gewiss auch an Funktion, findet sich hinter dem Scalenus anticus in der Tiefe des unteren Halsdreieckes ein Muskel, der Scalenus minimus Albini, den man nach seiner Lage auch wohl M. subscalenus und nach seiner Wirkung Tensor pleurae nennen könnte. Eine für alle oder doch nur für viele Fälle ausreichende Beschreibung dieses Muskels ist schwer zu geben, so sehr variiert er an Form und Stärke. [*"Differing from this [the M. scalenus medius] in its structure and certainly also function a muscle, the Scalenus minimus Albini, can be found behind the Scalenus anticus in the depth of the lower cervical triangle; due to its location it could also be called M. subscalenus or due to its function it could be called Tensor pleurae. It is difficult to provide a description of this muscle, which is satisfactory for all or at least many cases, because it varies so much in form and size*]. (orig. Zuckerkandl 1876, page 57, translation B. Schnürch)

Also Zuckerkandl regards the *M. scalenus minimus* as decisive structure that regulates the tension of the *pleural dome*. With regard to its function he calls the muscle *Tensor pleurae* even though he concedes that it is difficult to describe its form and size because of the great variability.

Lawson and Mc Kencie (1951) argue that the *M. scalenus minimus* originates from the anterior tubercle of the transverse process of C7 and continues via the *pleural dome* towards the first rib. It has a direct contact with the *Membrana suprapleurale*.

Descriptions like that of Lawson and Mc Kencie (1951) can also be found from Upmalis (1958), Fanghänel (2003) and Shah (2005).

According to Merkel (1899) the *M. scalenus minimus* – if present – originates either at the transverse processes of C6 and C7 or only at that of C7 and extends via the *pleural dome* to the first rib. Its undersurface is connected with the *pleural dome* and can be described as tensor of the *pleural dome*. In case the *M. scalenus minimus* is absent it is often replaced by a structure of connective tissue that is called *Lig. costo-pleuro-*

vertebrale. Cf. Hafferl (1939).

„Der Scalenus minimus tritt sowohl in seinem Verlaufe als auch mit seinen Ansätzen in direkte Beziehung zur Kuppel. Sein Verlauf führt ihn über deren hinteren Abhang. Die zarte Fascie des Muskels ist sowohl durch Bindegewebe mit der Kuppel in Verbindung, doch läßt sich diese leicht auslösen. Das Ende des Muskels aber setzt nicht nur an der ersten Rippe an, sondern ein großer Teil seiner Fasern geht direkt in die Kuppel über, so daß er in deren Gewebe selbst verankert ist. Der Muskel führt daher den Namen Tensor pleurae, den ihm ZUCKERKANDL gegeben hat, mit Recht.“ [*"The M. scalenus minimus has a direct relationship with the pleural dome both along its path and with its insertions. Its path follows along the dome's posterior slope. The delicate fascia of the muscle is connected with the dome through connective tissue but it can be easily detached. The end of the muscle does not only insert onto the first rib a large part of its fibres also merge with the pleural dome so that it is anchored in the dome's tissue itself. Thus the muscle is rightfully called by its name Tensor pleurae, which ZUCKERKANDL had attributed to it."*](orig. Hafferl 1939 page 58 ff., translation B. Schnürch)

Hafferl's description strongly refers to Zuckerkandl and he agrees with him also with regard to the function of the *M. scalenus minimus*. He also argues that the *M. scalenus medius* has a connection with the *pleural dome* along its path (through its fascia) and also at its insertion.

Also Wanke (1940) takes the same line in his study on the *scalene syndrome*. The only difference is that in his description a structure of connective tissue, called *Lig. vertebropleurale*, takes the place of the *M. scalenus minimus*.

The descriptions above already showed that the *M. scalenus minimus* is not a consistent structure. It can be present unilaterally, bilaterally or not at all (Zuckerkandl 1876). The indications concerning its presence vary very much. According to various authors the *M. scalenus minimus* is present in:

Rusnak-Smith et al. (2001) 10 %, Hafferl (1939) 25 %, Fanghänel et al. (2003) 30%, Wanke (1940) 50%, Upmalis (1958) 50%, Okamoto 54% in adults 72% in children and Zuckerkandl (1876) 71%

Summary:

The group of the scalene muscles undoubtedly plays a major role in fixating the *pleural dome*. Even if they do not merge with the *pleural dome* they support the function of the *Fascia endothoracica*, which is connected to the first rib with its undersurface, through their insertion onto the first rib.

The quoted authors agree that the *M. scalenus anterior* and *medius* have a close relationship with the *pleural dome*.

Leonhardt et. al. (1997), Kubik (1968) and Fanghänel et. al. (2003) argue that both the *M. scalenus anterior* and the *M. scalenus medius* can equally merge with the *pleural dome*.

Shah (2005) thinks the *M. scalenus medius* takes on a primary role and assumes that the region of the *pleural dome* can be seen as the end tendon of the *M. scalenus medius.*

Hafferl (1957) on the other hand says that it is mainly the end tendon of the *M. scalenus anterior* that merges with the *pleural dome*.

Among the scalene muscles it is the *M. scalenus minimus* that is most important. Zuckerkandl (1876) as well as Merkel (1899) and Hafferl (1957), who follow Zuckerkandl in their descriptions, call it *Tensor pleurae*. Sibson (1846) does not call it the same name but agrees with the aforementioned authors as far as its function is concerned.

Fanghänel et. al. (2003), Lawson and Mc Kencie (1951), Upmalis (1958) and Shah (2005) report a direct contact of the *M. scalenus minimus* with the *pleural dome* but they do not describe its function in more detail.

All authors agree that the *M. scalenus minimus* can vary considerably with regard to its form and especially its presence in the body.

A ligament-like structure is also described in the context of the scalene muscles. Merkel (1899) and Wanke (1940) say that in case of absence of the *M. scalenus minimus* the muscle is replaced by a strand of connective tissue, which is called *Lig. costo-pleuro-vertebrale* or *Lig. vertebropleurale*.

4.5 The ligaments of the pleural dome

This chapter will discuss the anatomical literature on the *ligaments* of the *pleural dome*. There are a number of renowned anatomy books which do not mention these *ligaments* at all. Also these books will be listed.

Since the term l*igament* is quite a broad one, the first author I would like to quote is Gegenbauer (1883) who comments on the various kinds of *ligaments* in his atlas on human anatomy.

*„**Von den Bändern.** Als Bänder oder Ligamente bezeichnet man Züge oder Stränge von faserigem Bindegewebe, durch welche meist Skelettheile, aber auch andere Organe unter einander verbunden werden. Bereits oben bei dem Baue der Gelenke ist eines Theiles dieser Bildungen als Sonderungen der Gelenkkapsel Erwähnung geschehen. Nach der speciellen Beschaffenheit des Gewebes sind zwei differente Zustände zu unterscheiden: I) straffe Bänder. sie werden durch sehniges Bindegewebe repräsentiert dessen Textur mit den Sehnen der Muskeln im Wesentlichen übereinkommt, wie sie. auch das gleiche atlasglänzende Aussehen darbieten. Die Richtung der Faserzüge entspricht jener des Bandverlaufes. sie dienen einer strafferen Verbindung von Skelettheilen oder erscheinen auch zwischen Vorsprüngen eines und desselben Knochens. Die Verbindung mit den Skeletteilen geschieht auf direkte Weise, und an den bezüglichen Stellen der Knochen prägen sich allmählich gegen das Band eingreifende Rauhigkeiten, oder auch größere Vorsprünge aus. Bei mehr flächenhafter Ausbreitung stellen diese Bänder Membranen dar, in welchen der Faserverlauf meist verschiedenartige Richtungen aufweist. Hierher gehören z. B. die Membranae interosseae. 2) Elastische Bänder werden vorwiegend aus elastischen Fasern gebildet, welche in spärliches fibrilläres Bindegewebe eingebettet sind. Die elastischen Faserzüge(vergl. Fig. 21) erscheinen in parallelem Verlaufe mit der Längsrichtung des Bandes. Der gelblichen Färbung des elastischen Gewebes gemäß werden manche dieser Bänder als Ligamenta flava benannt. Außer diesen beiden Gruppen werden noch viele andere Theile als Bänder aufgeführt, welche des anatomischen Charakters eines Bandes entbehren und entweder nur durch künstliche Präparation dargestellt oder Einrichtungen ganz anderer Art sind, die bezüglich ihrer Mächtigkeit zu dem Volum der zu befestigenden Theile oft in argem Missverhältnisse stehen. Zu diesen Pseudoligamenten gehören manche, oft nur aus einfach faserigem Bindegewebe geformte Züge, die an bestimmten Stellen nur wenig stärker als an anderen entfaltet sind, und nach Entfernung des benachbarten Gewebes Ligamente vorstellen."* [*"**About the ligaments.** The term ligament designates strands or bands of fibrous connective tissue which usually connect parts of the skeleton or other organs with each other. Some of these structures have already been mentioned above as particularity of the capsule in the context of the build-up of joints. Depending on the special characteristics of the tissue two kinds can be differentiated: I) tight ligaments: they are made up of tendinous connective tissue*

whose texture can basically be compared to the tendons of the muscles and also has a similar silvery grey and shiny colour. The direction of the fibres corresponds to the direction of the ligament. Their function is to connect two parts of the skeleton in a tighter way but they can also occur between processes of one and the same bone. The connection with the parts of the skeleton is a direct one. The respective sites on the bones are characterized by the development of a certain roughness or by the formation of larger processes. If the structures have a boarder expansion they rather represent membranes where the fibres usually run in different directions. One example for this would be the interosseous membranes. 2) Elastic ligaments: they are mainly composed of elastic fibres which are embedded in fibrillous connective tissue. The strands of elastic fibres (cf. Fig. 21) are arranged parallel to the longitudinal direction of the ligament. Due to the yellowish colour of the elastic tissue some of these ligaments are called Ligamenta flava. Besides these two groups many other structures are called ligaments, which however lack the anatomical characteristics of a ligament and are exposed only through artificial preparation or are structures of a totally different kind, whose size is often extremely disproportionate to the parts they are supposed to fix. Local strands of thicker fibrous connective tissue can seem to resemble ligaments when the surrounding tissues are removed. These structures belong to the group of pseudo-ligaments."] (orig. Gegenbauer1883,page 118 f, translation B. Schnürch).

There are various kinds of *ligaments*. We can distinguish tight *ligaments*, which connect bones with each other and have a texture that resembles that of muscle tendons. These tight structures can also have a broader expansion like the *Membrana interossea* of the forearm. The other kind of *ligaments* are elastic *ligaments*. Due to their mainly elastic fibres they are characterized by a slightly yellowish colour and thus are called *Ligamenta flava*. In addition, there are a number of ligament-like structures that do not really deserve this name. They are an artificial product of dissections, where it can happen that structures are separated and tissue removed but strands of connective tissue remain and give the impression of a ligament. Such structures are called *pseudo-ligaments*.

After this brief description of *ligaments* and *pseudo-ligaments* let us focus on the *ligaments* of the *pleural dome.*

According to Hafferl (1939) the following system of *ligaments* is described in the surgical literature as *ligaments* of Zuckerkandl and Sebileau. Independent from each other Zuckerkandel and Sebileau were the first to describe these *ligaments* and this paper will mainly focus on the descriptions by Zuckerkandl (1876). The quote below will serve as introduction to Zuckerkandl's work and help to better understand the following description of the *ligaments*:

„So lange sich an den bindegewebigen Befestigungsmitteln des Pleurakegels kein vornehmlich ausgeprägter Entwicklungsgrad bemerkbar macht, sind ihre anatomischen Verhältnisse schwer zu ergründen, da die Exposition von bindegewebigen Ausbreitungen, wie jeder erfahrene Anatom weiss, durch die Präparation nur allzu häufig eine gekünstelte wird." [*"As long as the connective tissue structures of the suspension system of the pleural dome are not very well developed, their anatomical relationships are difficult to explore because every experienced anatomist knows that preparation often can produce and expose artificial structures."*] (orig. Zuckerkandl 1876, page 58, translation B. Schnürch)

Zuckerkandl's (1876) statement goes along the lines of Gegenbauer (1883). He also points out that the preparation of tissues can artificially produce the impression of a *ligament*. The same holds for the region of the *pleural dome* if the connective tissue structures are not clearly developed.

The quote below contains a description of these ligamentous structures:

„Das Ligamentum costo-pleuro-vertebrale. Wenn man nach Abtragung des Muskulus scalenus anticus den Pleurakegel des unteren Halsdreieckes freilegt und einen Scalenus minimus nicht antrifft, so zeigt sich dafür häufig ein fibröser Strang von sehr verschiedener Stärke und ganz geringer Breite, der am 6. und 7. Halswirbelquerfortsatze, oder nur an letzterem entspringt, über die Pleurakuppel verläuft, mit dieser verwebt ist und schließlich an der ersten Rippe, hart neben dem Musculus scalenus anticus endigt....Dieser Streifen ist zuweilen zweigespalten, zuweilen ähnlich der Sehne des Scalenus minimus gänsefussartig über die vordere Pleurakuppelfläche ausgebreitet." [*"The Ligamentum costo-pleuro-vertebrale: If the Mucsculus scalenus anticus is removed to expose the pleural dome in the lower cervical triangle and no Scalenus minimus is present, a fibrous strand of varying dimension can often be detected instead. It is not very broad and originates from the transverse processes of C6 and C7 or only from that of C7 and runs over the pleural dome, is connected with it and inserts onto the first rib close by the insertion of the Musculus scalenus anticus....This strand of connective tissue is sometimes bifurcated and sometimes connects with the anterior surface of the pleural dome in the shape of a goose foot similarly to the tendon of the Scalenus minimus."*] (orig. Zuckerkandl 1876,page 62, translation B. Schnürch).

The *Ligamentum costo-pleuro-vertebrale* is located behind the *M. scalenus anterior* and can be found when there is no M. *scalenus minimus*. This *ligament* originates in the region of C6 and C7 and its insertion has a strong connection with the *pleural dome*.

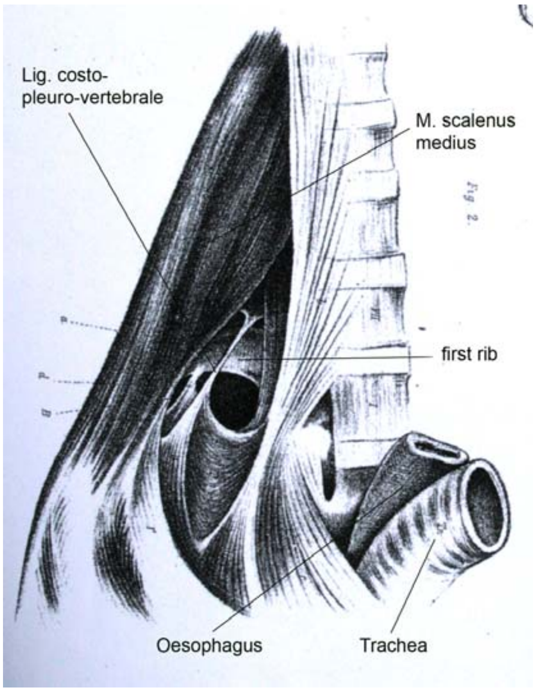

Figure 13: *Picture of the Lig. costo-pleuro-vertebrale by Zuckerkandl*

As regards the frequency of this *ligament* being present in the body, Zuckerkandl indicates that in a total of 60 cadavers it was present bilaterally in ten cases and unilaterally in eleven cases with a *M. scalenus minimus* on the other side. In one case Zuckerkandel could find a *M. scalenus minimus* and a *ligament* on the same side.

Zuckerkandl (1876) describes another *ligament* as follows:

„*Das Ligamentum costo-pleurale. Dieses Band, welches nicht so häufig als das Ligamentum costo-pleuro-vertebrale auftritt, dürfte für eine ganz besondere Entwicklung jenes Bindegewebes aufgefasst werden, welches die Pleurakuppel an das Hälschen der ersten Rippe heftet....es bildet einen cylindrischen Strang von der Stärke einer schwachen Taubenfeder, welcher am vorderen Rande des ersten Rippenhälschens entsteht, die vordere Wand der Pleurakuppel tangirt und sich knapp neben dem Scalenus anticus wieder am inneren Rande der Rippe fixiert, oder es ist mehr breit als dick. In jedem Falle ist es fest an die Rippenfellkuppel angeheftet, und häufig sieht man sogar einzelne Bündel von demselben sich ablösen und strahlenförmig in die Pleura übergehen....Dieses Band ist also brückenartig zwischen dem vorderen und hinteren Rande der ersten Rippe ausgespannt, und an seine untere Fläche bindet sich das Rippenfell und wird von ihm in Suspension gehalten.“* [“*The Ligamentum costo-pleurale: this ligament less often present in the body than the Ligamentum costo-pleuro-vertebrale. It can be regarded as a particular development of the connective tissue which attaches the pleural dome to the neck of the first rib.....it forms a cylindrical strand the size of a delicate dove feather, which originates* *from the anterior border of the neck of the first rib, runs tangentially to the anterior wall of the pleural dome and inserts next to the Scalenus anticus onto the internal border of the rib. It can also be broader than thick. In any case it is closely attached to the pleural dome. Often several strands of it merge with the pleura in a ray-like arrangement.....This ligament spans like a bridge between the anterior and posterior border of the first rib. The pleura is attached to its undersurface and is held in suspension by it."*] (orig. Zuckerkandl 1876,page 62 f., translation B. Schnürch)

This *ligament* is found less often than the *Ligamentum costo-pleuro-vertebrale* and it is a particularity of the connective tissue (*Fascia endothoracica*) that attaches the *pleural dome* to the first rib. This *ligament* originates anteriorly from the neck of the rib and inserts in the region of the *M. scalenus anterior* onto the internal surface of the first rib; several strands of fibres can also merge with the *pleural dome.* Like the *Ligamentum costo-pleuro-vertebrale* this ligament is closely connected with the *pleural dome* and is called *Ligamentum costopleurale*.

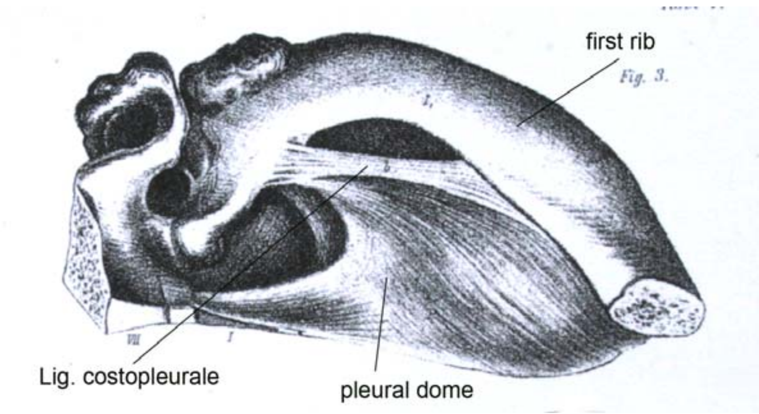

Figure 14: *Picture of the Lig. costo-pleurale by Zuckerkandl*

Concerning the *ligament's* frequency of being present in the body he indicates that in a total of 60 cadavers it was present bilaterally in one case, in other cases it could be found only unilaterally either in combination with the *M. scalenus minimus* or the *Lig. costo-pleuro-vertebrale.* In total it could be found in 14 cases.

Hafferl (1939) describes the *Lig. costo-pleuro-vertebrale* as a strand of connective tissue. It originates from the lower cervical vertebrae with one part extending towards the first rib and the major portion merging with the *pleural dome* in the shape of a goose-foot. The *Lig. vertebropleurale* consists of delicate strands of tissue that originate from the first thoracic vertebra and go to the posterior part of the *pleural dome*. This structure can always be detached bluntly from a normal *pleura*. Hafferl sees the *Lig. costo-pleurale* as the most consistent structure. It originates medially from the neck of the first rib and extends above the *pleural dome* like the chord of an arrow to insert onto the anterior part of the rib. It does not directly merge with the *pleural dome* but is connected with it by connective tissue. In addition, Hafferl also describes a *Lig. oesophagopleurale* and a *Lig. tracheopleurale*. These strands of connective tissue (*Lig. oesophagopleurale* and *Lig. tracheopleurale)* are commonly described as visceral fascia of the neck.

His description of the ligaments ends as follows:

Es erscheint begreiflich, daß die Beschreibungen der verschiedenen Autoren sehr voneinander abweichen, da in einem Fall das eine, im anderen Fall das andere Band gut ausgebildet ist." [*"It is understandable that the description of the ligaments differ from author to author because in one case one ligament in the other case the other ligament is well developed."*](orig. Hafferl 1939 page 60 f., translation B. Schnürch)

This statement shows that the presence of these *ligaments* in the body can vary considerably.

Fanghänel et al. (2003) mention a *Lig. pleurovertebrale* and a *Lig. costopleurale*. The location of these *ligaments* corresponds to that described by Hafferl.

In this context I also want to refer to the descriptions by Eisler (cf. chapter 4.3 Fascia praevertebralis) and Merkel (cf. chapter 4.4 The group of the scalene muscles).

The Ohio State University produced an interesting study in 1964. A total of 64 bodies were dissected and various ligamentous structures were discovered. These structures were named *vertebromembranous band*, *transversomembranous band* and *costomembranous band*. Concerning the latter two there was a strong suspicion that they represent *fibrous* remains of the *M. scalenus minimus*. However, it is not mentioned in how many cases these *ligaments* were found. (Gaughran 1964).

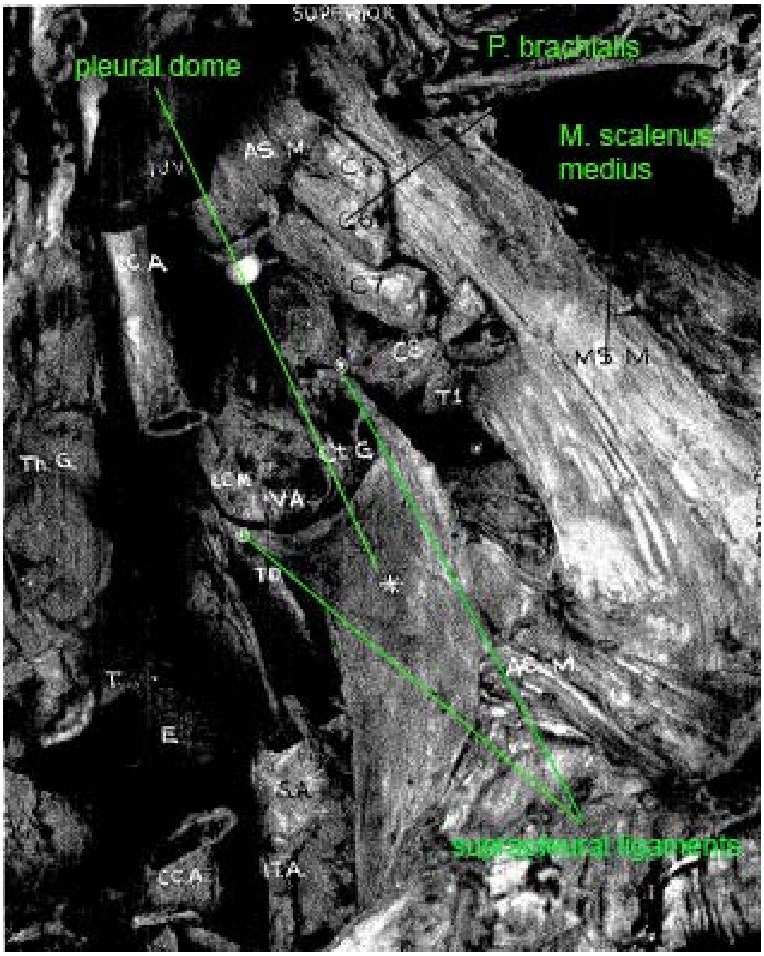

***Figure 15:** The ligaments of the pleural dome as described in the Ohio State University study (Gaughran 1964). This is the only photograph of the ligaments of the pleural dome that could be found in the literature listed in the bibliography of this paper.*

Finally a description from the francophone world: *Au sein de ce diaphragme cervico-thoracique on a voulu individualiser des formations fibreuses ou **ligaments suspenseurs de la plévre** (ligaments costo, vertebro et transverso-pleuraux). En réalité ces pseudo-ligaments ne sont le plus souvent que des artifices de dissection et n´ont en tout cas aucune valeur mécanique, la «suspension» du dôme pleural étant assurée en fait par l`adhérence de la plèvre pariétale au périoste de la premiére côte.* [*"Within this cervicothoracic diaphragm some wanted to identify fibrous structures or **suspensory ligaments of the pleura** (costopleural, vertebropleural and transversopleural ligaments). In reality these pseudo-ligaments are most of the times artificial products of dissection. They do not have any mechanical value since the "suspension" of the pleural dome is effected through the adherence of the parietal pleura to the periosteum of the first rib"*] (orig. Bouchet A. et Cuilleret J. 1991 page 790, translation B. Schnürch)

No description of the *ligaments* could be found from the following authors: Putz und Papst (1993), Netter (1997), Schiebler and Schmidt (1999), Tittl (2003), Benninghoff and Drenkhahn (2003), Lippert (2003), Standring (2005), Schünke et al. (2005)

Summary:

If we consider the explanations of Gegenbauer (1883) concerning the different kinds of *ligaments* and Zuckerkandl (1876) concerning the risk to create artificial *ligaments* in the region of the *pleural dome* if the connective tissue structures are not clearly developed, we realize that in this region we can talk about true *ligaments* only with the utmost reservation.

Zuckerkandl, who was the first to describe *ligaments* in this region besides Sebileau, talks about a *Ligamentum costo-pleuro-vertebrale* and a *Ligamentum costopleurale*. In a total of 60 cadavers the *Lig. costo-pleuro-vertebrale* could be found bilaterally in 10 cases and unilaterally in 11 cases with the presence of a *M. scalenus minimus* on the other side. A bilateral *Ligamentum costo-pleurale* was detected only in one case, while it was combined with a *M. scalenus minimus* or a *Lig. costo-pleuro-vertebrale* on the other side in 14 cases.

Besides the already mentioned two *ligaments* Hafferl (1939) also describes a *Lig. vertebropleurale, Lig*. *oesophagopleurale* and *Lig. tracheopleurale*. He explains that extremely varying descriptions of the *ligaments* can be found in the literature because of the individual differences in the human body which make it possible to recognize the various ligamentous structures more easily in some cases or not at all in others.

Fanghänel et. al. (2003) describe the *Lig. pleurovertebrale* and *Lig. costopleurale* similarly to Hafferl but for them like for Eisler (1912) the *Lig. pleurovertebrale* originates from the *Fascia praevertebralis*.

Merkel (1899) mentions a *Lig. vertebropleurale* that can be present instead of a *M. scalenus minimus*. He thus follows the explanations of Zuckerkandl.

In a study conducted by the Ohio State University (Gaughran 1964) a *vertebromembranous band*, a *transversomembranous band* and a *costomembranous band* are described.

However, all authors except Zuckerkandl fail to clearly mention in how many instances they really found these *ligaments.*

It is, however, notable how diverse the descriptions are. What can be said for sure is that none of these *ligaments* is a consistent structure that occurs in every human body. Rather they are structures that are developed quite differently and can vary from individual to individual. This holds for their presence in the body and also for their exact path.

4.6 The blood vessels and nerves and their fascia

For the sake of completeness these structures will be discussed as well, even though most authors who are quoted in this paper do not mention them. Only Fanghänel et al. (2003), Kubik (1968) and Hafferl (1939) list them as structures that support the *Fascia endothoracica*.

Kubik (1968) talks very generally about a connective tissue bridge to the *Fascia endothoracica* formed by the neurovascular bundle of the arm. Fanghänel et al. (2003) present a similar description.

Hafferl (1939) writes that the vessels and nerves play a subordinate role, which, however, must not be ignored. Especially the *A. subclavia* and the *A. thoracica interna* are full with blood in the living being and thus represent stabilizing structures. Among the neural structures he mentions the brachial plexus *(P. brachialis)* in particular as structure which supports the *Fascia endothoracica*.

4.7 Summary

The structure that forms the connection between the *thorax* and the *parietal pleura* is the *Fascia endothoracica.* In the region of the *pleural dome* this fascia becomes stronger and is named *suprapleural fascia* or *Sibson's fascia*.

In the region of the *pleural dome* the first rib provides essential support to the fascia. Due to the rib's considerable broadness the *suprapleural fascia* has a large surface for attachment. From cranial the *Fascia praevertebralis* provides additional support for the *suprapleural fascia*. The various authors either talk about a connection of the two fascias or describe them as continuous structures. If the connection is limited to certain spots, ligament-like structures may develop.

The scalene muscles are also important structures that support the region of the *pleural dome*. Both the *M. scalenus anterior* and the *M. scalenus medius* can have certain fibres merging with the *pleural dome*. But regardless of these fibres theses muscles also support the *Fascia endothoracica*, which is attached to the undersurface of the first rib, through their insertion onto the first rib. If it is present in the body, the *M. scalenus minimus* has the strongest connection with the *pleural dome*. Some authors call this muscle *Tensor pleurae* due to its function. If this muscle is not present in the body, a *ligament* can take its place, which is called *Ligamentum vertebropleurale*.

Besides Sebileau, Zuckerkandl (1876) was the first to describe the *ligaments* of the region of the *pleural dome*. He called them *Ligamentum costo-pleuro-vertebrale* and *Ligamentum costopleurale.* He described the *ligaments* as inconsistent structures and explicitly pointed out that if these structures are only poorly developed an artificial preparation of *ligaments* can happen in dissections. Also the explanations of Gegenbauer (1883) on *ligaments* and *pseudo-ligaments* go along these lines.

Hafferl (1939), too, mentions *ligaments* in this region and justifies the different descriptions of various authors with the fact that these structures can be differently strong developed in each individual.

A few other authors also describe *ligaments* of the *pleural dome* but none of them mentions in how many cases these structures can be found. Many authors do not refer to them at all.

The support of the *pleural dome* provided by vessels and nerves can be defined as minor.

The previous chapters have looked at the anatomical build-up of the *pleural dome* and provided an overview of how it is described in the majority of the anatomical literature. The elements which are directly responsible for the fixation of the *pleural dome* have been presented and discussed. The resulting picture of the function and suspension system of the *pleural dome* is thus quite comprehensive.

The next chapter will discuss the significance of the suspension system of the *pleural dome* for allopathic as well as for osteopathic medicine. In addition, it will take a closer look at the descriptions of the *pleural dome* in osteopathic literature since these descriptions triggered my interest in the topic in the first place and prompted me to write this paper.

5 The significance of the suspension of the pleural dome in allopathic medicine

The suspension of the *pleural dome* plays a major role especially with regard to the *Thoracic Outlet Syndrome* (TOS). The term thoracic outlet syndrome designates *neurovascular compression syndromes*. Clinical pictures like the *Pectoralis Minor Syndrome*, *Costoclavicular Syndrome*, *Scalene Syndrome*, *Hyperabduction Syndrome*, *Shoulder-Arm Syndrome* and the *Thoracic Inlet Syndrome* fall in this category. The TOS is characterized by a compression of the *Plexus brachialis* and *A.* and *V. subclavia* by bony, muscular or fibrous structures in the region of the *upper thoracic aperture*. This can cause neurological, arterial or venous symptoms of varying intensity that can occur individually or combined. (Universität Düsseldorf 1998).

In his paper on the *scalene syndrome* Wanke (1940) describes that connective tissue structures may damage the *brachial plexus* and the *subclavian artery*. The treatment combines conservative physical therapy measures with surgical interventions. Depending on the impairment either a muscle or connective tissue structures are severed or the first rib is removed completely or in part.

The *pleural dome* also is an issue in thoracic surgery. The *thoracic inlet* is a possible way of access to carry out surgical interventions in the region of the apex of the lungs. In his book “Die Anatomie der Pleurakuppel, ein anatomischer Beitrag zur Thoraxchirurgie” Hafferl (1939) quotes various authors who report that sometimes ligamentous structures can be found in this region, which have to be ligated to prevent bleeding.

6 The suspension of the pleural dome from an osteopathic point of view

Like in allopathic medicine also in osteopathy the region of the suspension of the *pleural dome* is seen as the cause of a number of complaints in the areas of the *thorax,* the superior lobes of the lungs and the upper extremities.

I thus would like to present the osteopathic literature on this topic. Since the descriptions in the osteopathic literature were to a large part responsible for the fact that I carried out my investigations I will look at it quite in detail. The descriptions from the osteopathic literature below are listed in chronological order.

6.1 The description of the suspension by J.P. Barral and P. Mercier

In their book "Visceral Manipulation" Barral and Mercier describe the suspension of the *pleural dome* as follows:

"The suspensory ligament attaches the pleural dome to the skeleton (Illustration 2-1). It consists of muscular fibres of the scalenus minimus (sometimes mixed with fibres of the anterior and medial scalene), plus the fibrous fasciculi… (Barral/Mercier 1988 page 38 f)

In addition, the *suspensory ligament* does not directly insert onto the *Pleura parietalis* but rather onto the *Fascia intrathoracica*. This fascia forms a connective tissue dome at the level of the apex of the lungs where it forms a *septum* together with the *Ligamentum suspensorium*. This *septum* is anatomically independent from the *Pleura parietalis* and is called the *fibrous cervicothoracic septum* (Barral/Marcier 1988).

This is illustrated by the following picture:

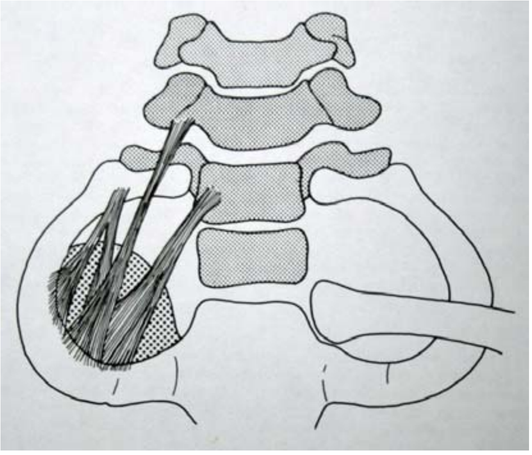

Figure 16: *The ligaments of the pleural dome according to Barral und Marcier 1988*

In the chapter on the mobility of the lung Barral writes on page 43 that the *superior diaphragm* consists mainly of ligamentous structures and therefore provides a fixation of the *pleura*.

On page 56 in the chapter "Restrictions of the *Ligamentum suspensorium*" he points out that the *Ligamentum suspensorium* is made up mainly by tendinous fibres mixed with some muscle fibres of the *scalene muscles* and that these fibres form a network which delimits the upper half of the *thorax* and inserts tangentially onto the *Fascia intrathoracica* of the *pleural dome*. Below you find an illustration from Barral's book:

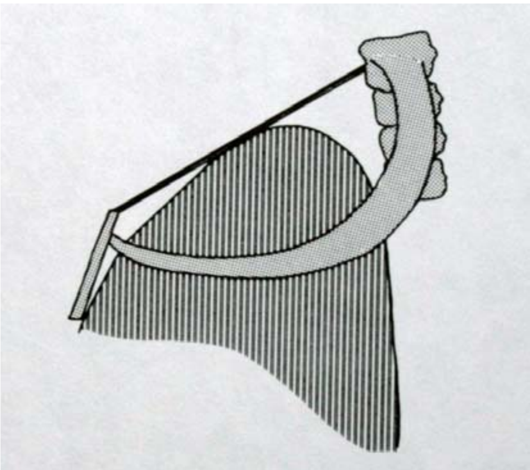

Figure 17: *Schematic representation of the ligaments of the pleural dome according to Barral and Marcier 1988*

Summary:

In this description many different anatomical terms are used. For instance, Barral talks about a superior diaphragm. In contrast to the inferior thoracic aperture there is only the *Fascia endothoracica* in the region of the superior thoracic aperture. How the *Fascia endothoracica* is supposed to form a *diaphragm* (diaphragm [Greek], partition wall; Fanghänel et. al. 2003) together with the *Ligamentum suspensorium*, which is a network of tendinous and muscular fibres, is a legitimate question. A structure that in its texture and form could be put on a par with the *diaphragm* of the inferior thoracic aperture or the pelvic floor is completely absent.

The authors talk about fibrous fasciculi and tendinous fibres that mix with the muscle fibres of the *scalene muscles* and then merge with the *Fascia intrathoracalis* to form a fibrous dome. Where do the fibrous fasciculi come from, and what layer can they be attributed to?

According to the picture of the *suspensory ligament* (Fig.16) this ligament could correspond with the following structures that are also known in the anatomical literature: the *Lig. costopleurale*, the *Lig. costo-pleuro-vertebrale* or the *Lig. vertebropleurale*.

The schematic representation of the *Lig. suspensorium* (Fig.17) gives the impression that the direction of pull of this *ligament* goes from the spine towards the direction of the *manubrium sterni*. Based on the descriptions of Barall and Mercier themselves and on the descriptions of the anatomical literature this has to be considered wrong.

The descriptions of Barral and Mercier give rise to more questions than they provide answers, particularly because the assertions are hard to check due to the lack of any references.

In addition, it is worth mentioning that Barral and Marcier are the only authors who talk about a *Fascia intrathoracalis*. One might thus reasonably suspect that they mean the *Fascia endothoracica*.

6.2 Lectures at the Wiener Schule für Osteopathie (Vienna School of Osteopathy)

In the unpublished handout on visceral osteopathy of Ligner (1998) the region of the *pleural dome* and its fixation is presented as follows: Ligner describes 3 *ligaments* that are called *Ligamentum vertebropleurale*, *Ligamentum transversopleurale* and *Ligamentum costopleurale*. Besides the group of the scalene muscles these *ligaments* are the structures that suspend the *pleural dome*.

The *Ligamentum vertebropleurale* extends from the body of C7 to the medial region of the *pleural dome.*

The *Ligamentum transversopleurale* originates from the *transverse process* of C7 and merges with the lateral region of the *pleural dome*.

The *Ligamentum costopleurale* originates from the first rib in the region of the *Tuberculum costae* and divides into two parts, one portion merging with the posterior region of the *pleural dome*, the other running to the first rib. The *spinal nerve* of the first thoracic vertebra passes through this bifurcation.

Below a picture of the *ligaments* as described by Ligner (1998):

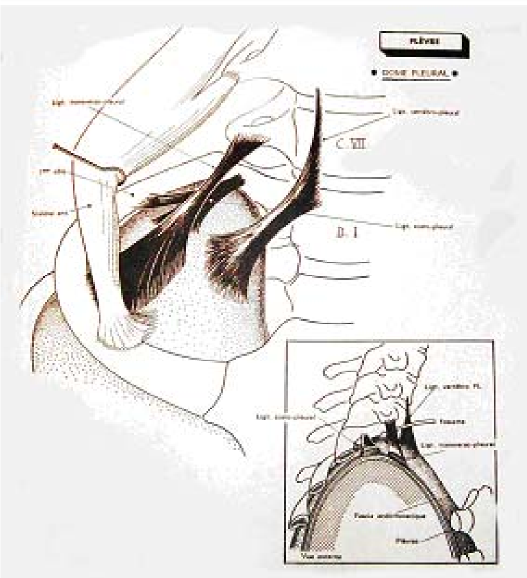

Figure 18: *The ligaments of the pleural dome as depicted in the handouts of Ligner*

This description of the ligaments corresponds by and large with the descriptions found in the anatomical literature. However, there is lack of any indication as to how often the *ligaments* truly occur in the human body and thus it gives the impression that they are consistent structures that can be found in everybody.

6.3 The suspension of the pleural dome according to Serge Paoletti

The *pleural dome* is closely connected to the *Fascia endothoracica* which is thicker in this region. It forms a *cervicothoracic diaphragm* where various *suspensory ligaments* can be discerned. These are the *Lig. costopleurale*, the *Lig transversopleurale* and the *Lig vertebropleurale.* Paoletti points out that his description follows those of Bourgerey and Sebileau. *(Paoletti 2002)*

The illustration below shows the *ligaments* according to Paoletti (2002).

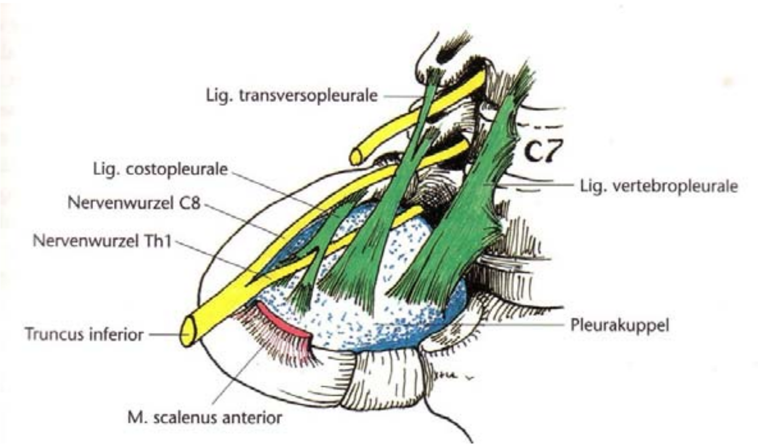

Figure 19: *The ligaments of the pleural dome according to Serge Paoletti*

This illustration resembles very much the schematic representation of the *ligaments* in the handout of Bernard Ligner. This is the first description with at least a name reference (Bourgerey and Sebileau), even though other bibliographic details are missing.

6.4 The suspension of the pleural dome according to the "Leitfaden für Viszerale Osteopathie"

In the chapter "Fixation der Lunge" (Fixation of the lung) the *Lig. vertebropleurale, Lig. transversopleurale, Lig. costopleurale* and *Lig. transversum cupulare* and the *M. scalenus minimus* are mentioned to be responsible for the fixation of the lung together with the negative pressure in the *pleural cavity* and the *Lig. pulmonale*. It also provides an illustration which quite resembles those of Paoletti (2002) and Ligner (1998). However, the *Lig. transversum cupulare* that is mentioned in the text is not pictured in the illustration. (Liem 2005).

6.5 The suspension of the pleural dome in Visceralosteopathie - Grundlagen und Techniken (Visceral osteopathy – basic principles and techniques)

Also this last description corresponds basically with the above mentioned. Again there are the *Lig. costovertebrale*, *Lig. transversopleurale* and *Lig. vertebropleurale* that are responsible for the suspension of the *pleura.* There is no illustration of the *ligaments*. (Hebgen 2005)

6.6 Summary

The descriptions of Barral and Marcier (1988) have already been discussed in detail. (cf. chapter 6.1)

In summary, in the literature on visceral osteopathy mainly ligamentous structures are held responsible for the suspension of the *pleural dome*. The authors agree on the existence and the exact path of these ligaments even though they do not always use the same names for them.

Many things could be said concerning the techniques that are described for the *pleural dome*. But this is not the topic of this paper, therefore I only want to give an example from the book "Leitfaden Viscerale Osteopathie": In the chapter "Test der *Ligg. Suspensoria* der *Cupula pleurae*" (Tests of the *suspensory ligaments* of the *pleural dome*) every *ligament* (*Lig. vertebropleurale, Lig. costopleurale*, *Lig. transversopleurale*) is described individually and for each *ligament* a different treatment position is proposed. (Puylaert 2005)

In this chronologic list of descriptions the first description comes from Barral and Marcier (1988). It can thus be assumed that other authors have followed their explanations even though they did not emphasize this in particular.

In addition, it has to be pointed out that in all the osteopathic literature used as basis for writing this paper there is no mention of how often these *ligaments* are present in the body. Thus it gives the impression that these structures are consistent and present in everybody. In this respect the osteopathic literature differs considerably from the anatomical literature.

Now the focus of this paper will turn away from the literature and towards the practical exploration of the topic in the dissecting room. The next chapter will describe the dissection procedure on the one hand and on the other hand present the results of the individual dissections.

7 The dissection procedure

There are two possible ways to reach the region of the *thoracic inlet*. One possibility is to come from dorsal. This way is often chosen in surgical interventions concerning the region of the upper lungs. Contrary to the way in from the front the access from posterior bears a considerably smaller risk to injure a nerve or vessel (Hafferl 1939). Since this risk is not relevant in dissections the access from anterior and superior was chosen in this case. This way of access allows best to display the *pleural dome* in its entirety. The way of access will be illustrated with pictures of the respective dissection. Pictures of different dissections are being used depending on where the specific structures could be best displayed. Every picture is labelled with the number of the dissection.

The first skin incision starts a little bit below the medium end of the *clavicle* and goes to its lateral third from where it continues upwards until just in font of the mastoid process (*Proc. mastoideus)* and then anteriorly along the *mandible* to the midline. From there it goes back down to the SC joint *(Art. sternoclavicularis)*. Once the skin and the fatty tissue underneath the skin are removed you can see the *platysm.*

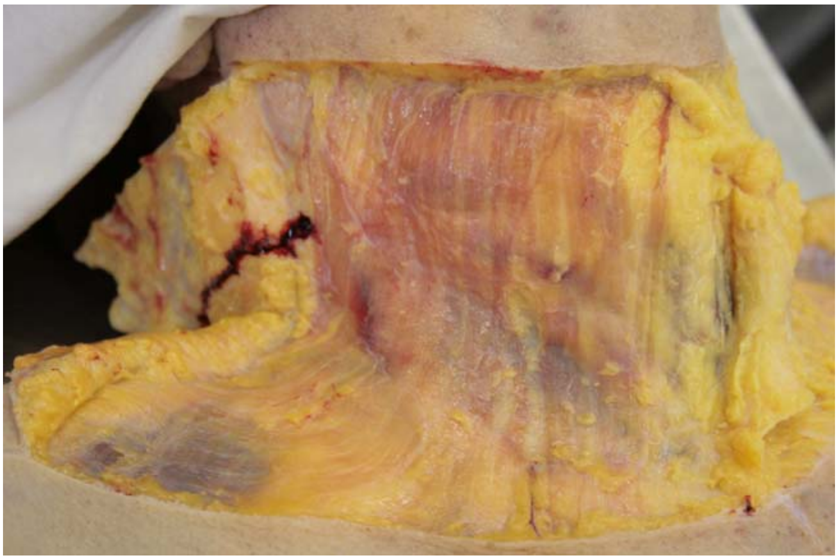

Figure 20: *The platysm is the first layer that can be seen after the skin is removed. The fatty tissue underneath the skin can be quite thick in this region. (Dissection 15)*

Once the *platysm* is removed the *Fascia cervicalis lamina superficialis* is exposed.

Figure 21: *Fascia cervicalis lamina superficialis (Dissection 2)*

When the *Fascia cervicalis lamina superficialis* is removed the sternocleidomastoid muscle (*M. sternocleidomastoideus)* with its *sternal* and *clavicular* head can be observed. The *clavicular* portion of the trapezius (*M. trapezius)* can be seen laterally. Between the two muscles also part of the omohyoid muscle (*M. omohyoideus) can be recognized.*

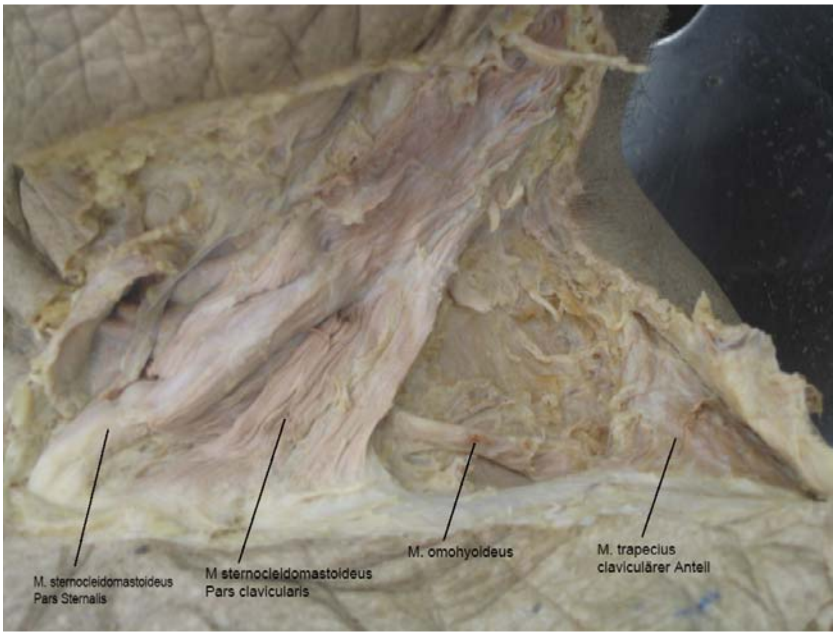

Figure 22: *After the removal of the Fascia cervicalis lamina superficialis you can take a look at the muscles that are covered by it (Dissection 1)*

Then the *M. sternocleidomastoideus* is removed to reveal the *M. omohyoideus* in its totality. It is enveloped in the *Fascia cervicalis lamina praetrachialis* which also covers the *M. sternothyroideus*.

Figure 23: *M. omohyoideus enveloped by the Fascia cervicalis lamina praetrachealis (Dissection 1)*

After removal of the *Fascia cervicalis lamina praetrachealis* also the *M. omohyoideus* is removed. Underneath this layer the internal jugular vein (*Vena jugularis interna)* and a fascial envelop that contains the common carotid artery (*A. carotis communis)* and the vagus nerve (*N. vagus)* become visible. After the removal of the *internal jugular vein* the dissection continues in the region of the *clavicle*. First the *greater pectoral muscle* (*M. pectoralis major)* and the *subclavian muscle* (*M. subclavius)* are carefully removed from the *clavicle* which is then cut in the region of its lateral third. The *sternoclavicular joint* (*Articulatio sternoclavicularis)* is exposed. The joint is disarticulated and the *clavicle* removed. (cf. Fig. 24)

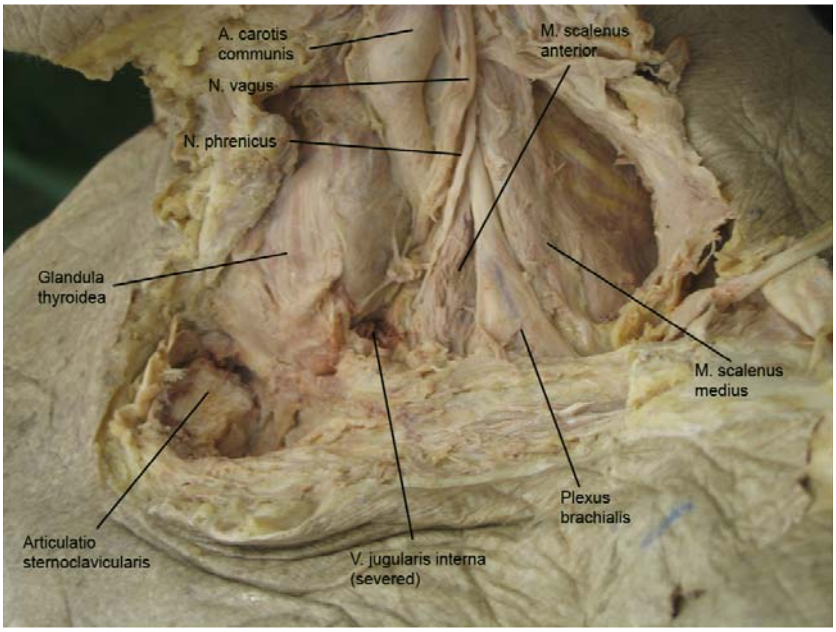

Figure 24: *The internal jugular vein and the clavicle have been removed. This provides a first view of the scalene muscles. (Dissection 1)*

Now the anterior (*M. scalenus anterior)* and medial (*M. scalenus medius)* scalene muscles are visible. The *M. scalenus anterior* is attached to the *Tuberculum scaleni* of the first rib. The phrenic nerve (*N. phrenicus)* runs along it. In the lower region of the posterior scalene gap next to it the *A. subclavia* can be seen in the proximity of the attachment of the *M. scalenus anterior*. The *M. scalenus medius* has a broad attachment in the posterior region of the first rib. The *A. subclavia* and the *P. brachialis* pass through the posterior scalene gap.

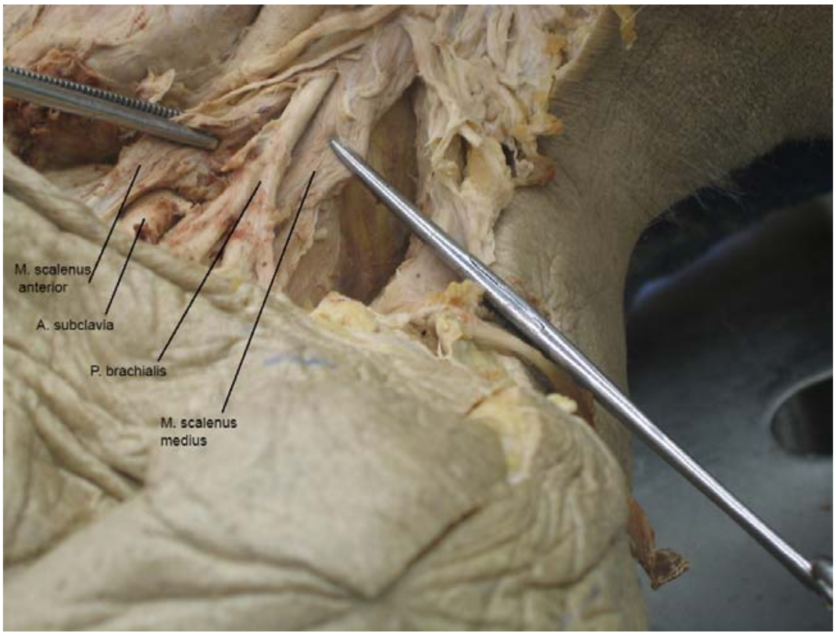

Figure 25: *The posterior scalene gap (Dissection 1)*

The *A. subclavia* on the left branches directly off the *Arcus aortae*, the right *A. subclavia* comes from the *Truncus brachio-cephalicus* which branches off the *Arcus aor-*

tae. This means that on the right side the *Truncus brachio-cephalicus* passes up through the anterior scalene gap while on the left side the *A. carotis communis sinistra* and the *A. subclavia* run through it. On both sides the *A. subclavia* loops posterior around the *M. scalenus anterior* and continues down into the arm together with the *P. brachialis*. The *A. subclavia* and the inferior portion of the *P. brachialis* lie directly on the *pleural dome*. The posterior scalene gap is limited laterally by the *M. scalenus medius*. Once the *M. scalenus anterior* is removed the *A. subclavia* becomes visible. It lies directly on the pleural dome. Once the *M. scalenus medius* has been removed also, only the *P. brachialis* and the *A. subclavia* remain to cover the *pleural dome.*

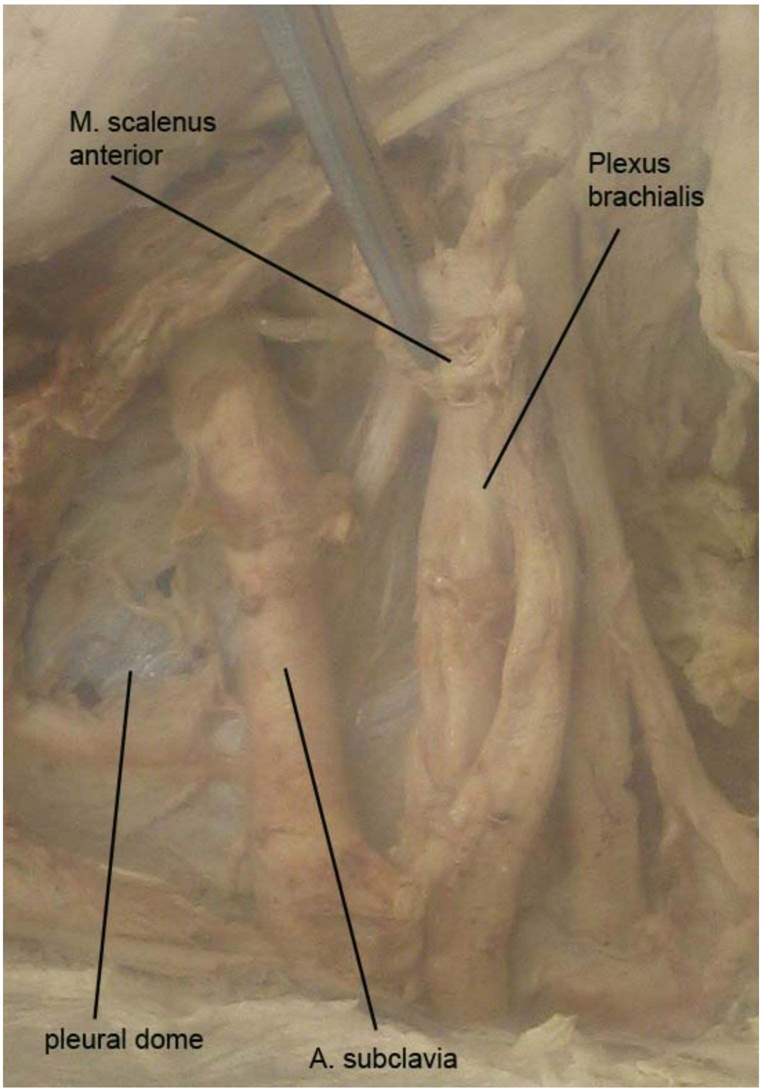

Figure 26: *The A. subclavia and the P. brachialis are the last structures to cover the view of the pleural dome. (Dissection 1)*

Once these structures are removed the *pleural dome* is completely exposed.

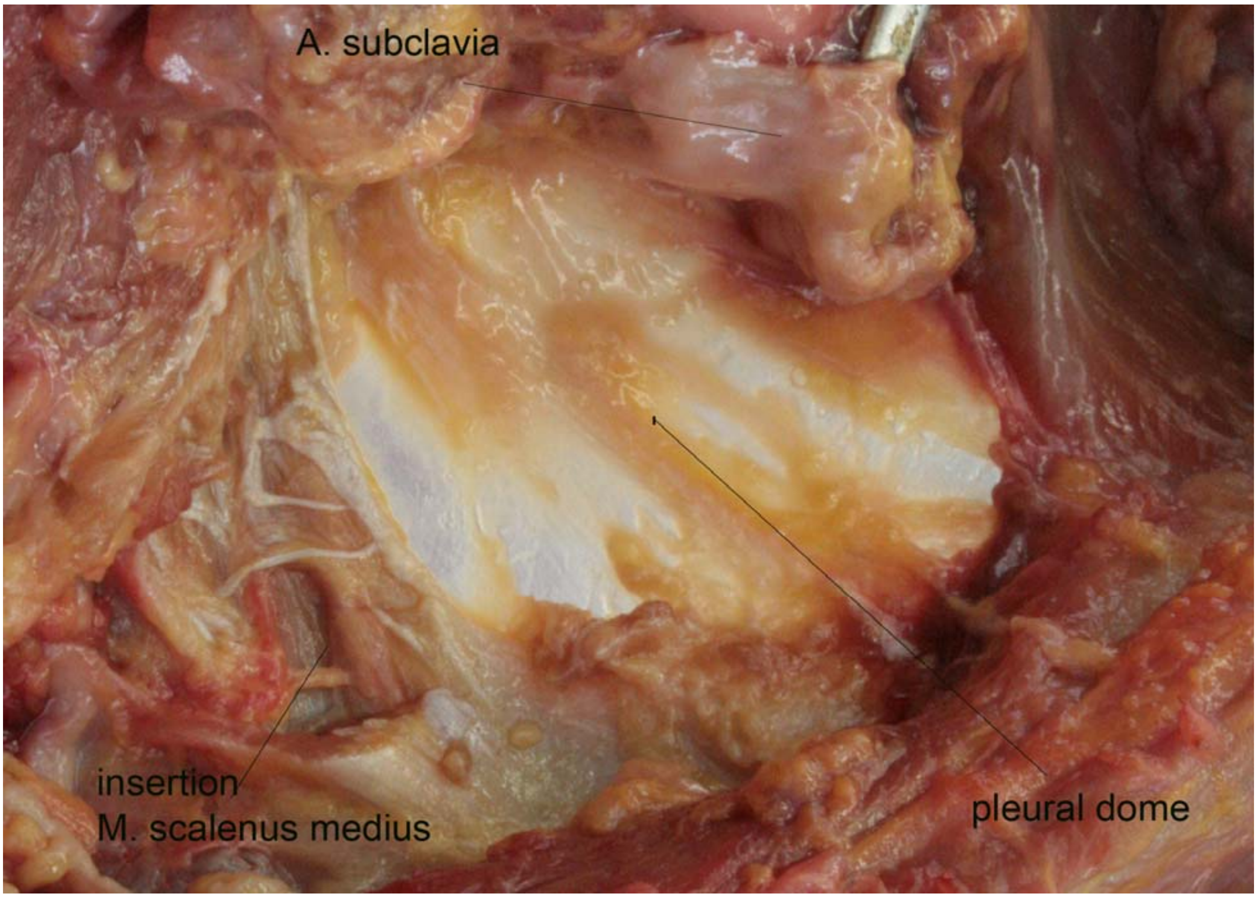

Figure 27: *The right pleural dome (Dissection14)*

The connective tissue covering the *pleural dome* is visible. The *pleural dome* itself is exposed where the *A. subclavia* and the *P. brachialis* have been removed.

8 The individual dissections

General:

Except dissection 11 and 12 all dissections were carried out at the Vienna Institute of Anatomy. Dissections 11 and 12 took place in the Laboratories of Anatomical Enlightenment Inc. in Boulder/Colorado.

The dissections were performed on 12 embalmed and 8 non-embalmed cadavers. Preservation through embalming has the advantage that the cadavers do not perish so fast, the blood looses its natural texture and bleeding due to severed vessels cannot occur. The downside is that the tissues become clearly stiffer and loose their natural colour. In a non-embalmed cadaver the tissues present closer to reality. The individual structures are nicely coloured and can be well differentiated. The main problem in the dissection is the risk of haemorrhage due to damage of a vessel since that would colour all tissues red which would make it almost impossible to discern the individual structures. Progressive decomposition does not pose a major problem in the case of such a small and clearly delimited area.

The question of nomenclature has still to be resolved since different names are used for the *ligaments* in osteopathic literature and also in comparison with the anatomical literature. In chapter 6 the *pleural dome* was discussed from the point of view presented in osteopathic literature. Three *ligaments* were mentioned: The *Ligamentum vertebropleurale* runs from C7 to the medial region of the pleural dome. The *Ligamentum transversopleurale* originates at the *Processus transversus* of C7 and merges with the lateral region of the *pleural dome*. The *Ligamentum costopleurale* originates from the region of the *Tuberculum costae* of the first rib and bifurcates into one portion that merges with the posterior part of the *pleural dome* and one part that goes back to the rib. The *spinal nerve* of the first thoracic vertebra goes through this bifurcation (cf. Ligner, Paoletti, Liem). Barral simplifies the name of the ligaments by simply talking about the “suspensory ligament“. If figure 16 (Barral 1988) is compared with figures 18 (Ligner 1998) and 19 (Paoletti 2002) one can conclude that the same structures are being described.

Chapter 6.5 presented the anatomical literature on the *ligaments* of the *pleural dome*. Zuckerkandl (1876) describes two *ligaments*. On the one hand the *Lig. costo-pleuro-*

vertebrale, which extends from the transverse processes of C6 and C7 to merge with the *pleural dome* in the vicinity of the insertion of the *M. scalenus anterior* onto the first rib, and on the other hand the *Lig. costopleurale*, which originates from the neck of the first rib and merges with the *pleural dome* at its insertion. Hafferl (1938) also mentions a *Lig. vertebropleurale*, which originates at the first thoracic vertebra and inserts onto the posterior region of the *pleural dome*.

A comparison of the osteopathic and anatomical literature shows that both agree with regard to the *Lig. costopleurale.* Both also mention a *Lig. vertebropleurale* but describe a slightly different origin and insertion. The *Lig. transversopleurale* mentioned in the osteopathic literature has the same origin as the *Lig. costo-pleuro-vertebrale* in the anatomical literature but the path and insertion differ.

Henceforth the terms *Lig. costopleurale, Lig. vertebropleurale*. and *Lig. transversopleurale* will be used in this paper.

Methodology:

A table for each dissection will list the structures that could be found in the respective body in a clear and concise way. It contains the *Ligamenta vertebropleurale, costopleurale* and *transversopleurale* as well as the *Musculi scaleni anterior, medius* and *minimus*. Since the purpose of the dissections was in particular to identify the presence of the *ligaments* of the *pleural dome* on the one hand and the *M. scalenus minimus* on the other hand, the table will indicate whether these structures were present (1) or not (0). Another objective was to examine whether fibres of the *M. scalenus anterior* and *M. scalenus medius* merge with the *pleural dome*. If fibres of the respective muscles merge with the *pleural dome*, it will be indicated with 1 in the table. If the *M. scalenus anterior* or *M. scalenus medius* do not send any fibres into the *pleural dome*, the appropriate column in the table is marked with 0.

If a *ligament* or a *M. scalenus minimus* is found, the structure is documented with a photograph. Wherever possible also the *M. scalenus anterior* and the *M. scalenus medius* as well as the *pleural dome* are illustrated with pictures.

Every *ligament* that could be found was measured in length and breadth. Since the pictures of the structures vary in their degrees of enlargement for the purpose of a better illustration, they do not represent the true size of the structures.

The dissection procedure will not be explained again in detail because it was already described in the previous chapter.

8.1 Dissection one:

General remarks:

Embalmed female body

Right side:

After the insertion of the *M. scalenus anterior* is cut the muscle is reflected. The same holds for the *Plexus brachialis*. The curve of the *A. subclavia*, which lies on the *pleural dome*, becomes visible. It is interesting that the *A. carotis communis* can be located underneath the enlarged *Glandula thyroidea*. Overall the right side differs from the left in its quality. The fascias are thicker and the structures have a greater tension. After the *A. subclavia* has been cut a *M. scalenus minimus* becomes visible. It is clearly more tendineous than on the other side. The *pleural dome* can be well prepared and on the *pleural dome* strands of connective tissue running in all directions can be detected but no regions that are thicker and resemble a *ligament*. The *M. scalenus anterior* is well-developed but there are no fibres that merge with the *pleural dome*. The *M. scalenus medius* is less developed than on the left side, but some fibres insert onto and merge with the *pleural dome*.

Left side:

After the *M. scalenus anterior* has been removed the *pleural dome* becomes clearly visible. Behind the *M. scalenus anterior* there is also a well-developed *M. scalenus minimus* with a strongly tendineous portion and some fibres merging with the *pleural dome* and some inserting onto the internal surface of the first rib. At the upper end of the *M. scalenus minimus* connective tissue fibres can be detected that run from the *oesophagus* towards the direction of the *pleural dome*. Once the *M. scalenus minimus* has been carefully removed (it can be easily detached from the *pleural dome*) the *pleural dome* is visible. Lines of connective tissue can be seen on it, but they do not run in any particular direction. No continuous layer of fascia can be recognized. The *M. scalenus medius* has a broad attachment on the first rib and some muscle fibres have a delicate insertion onto the posterior region of the *pleural dome*. The *pleural dome* itself appears as shiny thin membrane. No *ligaments* can be discerned.

	Lig. vertebro-pleurale	Lig. transverso-pleurale	Lig. costo-pleurale	M. scalenus minimus	M. scalenus anterior	M. scale-nus medius
Right	0	0	0	1	0	1
Left	0	0	0	1	0	1

Table 2: *Results of the first dissection*

Figure 28: *The pleural dome on the right side with a well-developed M. scalenus minimus*

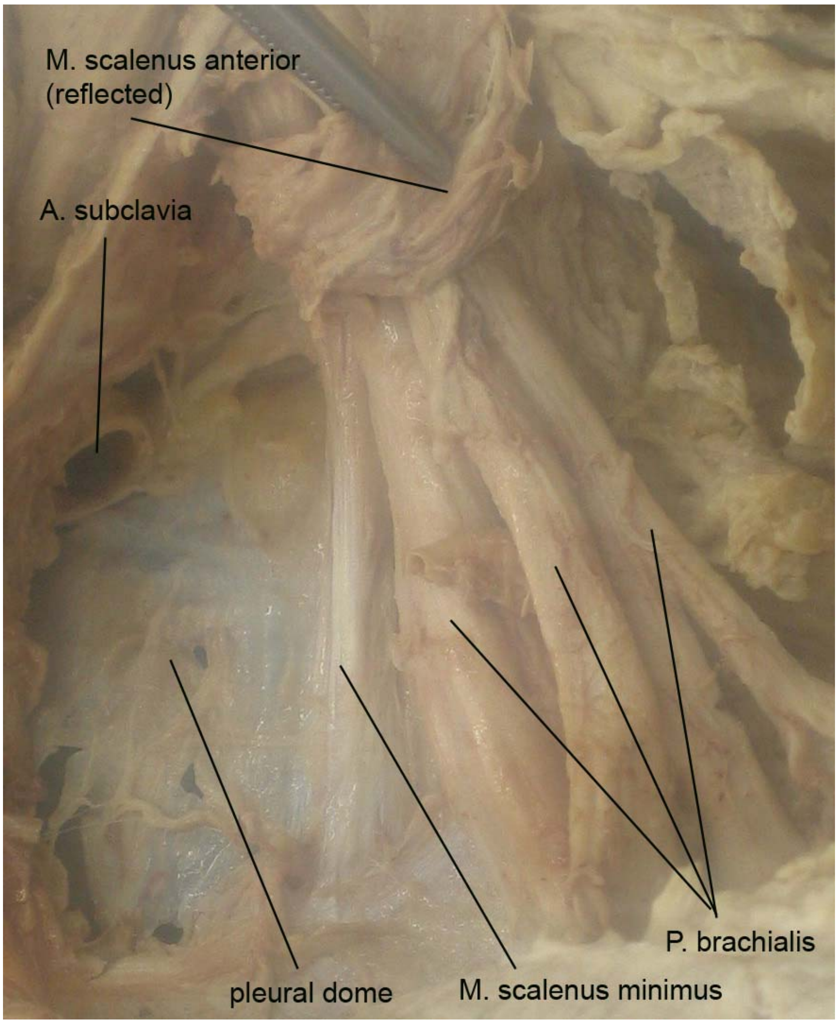

Figure 29: *The pleural dome on the left side where the M. scalenus minimus is quite tendinous. The connective tissue on the pleural dome can still be seen in parts.*

8.2 Dissection two

General remarks:

Non-embalmed male body

Right side:

On the right side of the body the upper thoracic aperture is smaller than on the left side. The posterior scalene gap is considerably narrower. Both the *P. brachialis* and the *A. subclavia* are crowded by the *M. scalenus medius* and *M. scalenus anterior*. It is interesting that the whole region of the *thoracic inlet* and the *pleural dome* has a high tension and is strongly dispersed with connective tissue. It can be suspected that an old fracture of the rib dorsally in the vicinity of the rib head is the reason for that. Once the *M. scalenus anterior* and the *M. scalenus medius* are cut and the *A. subclavia* and *P. brachialis* have been removed neither *ligaments* nor a *M. scalenus minimus* can be detected. Both the *M. scalenus anterior* and the *M. scalenus medius* have fibres merging with the *pleural dome*.

Left side:

After the well-developed *M. scalenus anterior*, which does not send any fibres to the *pleural dome*, has been cut a ligamentous structure can be seen. This *ligament* originates in the region of the body of C7 and some fibres insert onto and merge with the *pleural dome*. The measurement showed a length of 50.15 mm and a breadth of 2.34 mm. Its origin and insertion corresponds to the descriptions of the *Lig. vertebropleurale* in the literature. Underneath the *Lig. vertebropleurale* a structure that runs from the posterior border of the first rib anteriorly to merge with the *pleural dome* and the *Lig. vertebropleurale* can be seen. The length of this *ligament* is 22.14 mm and its greatest width is 1.45 mm. The spinal nerve of D1 emerges underneath it. This structure can be designated as the *Lig. costopleurale*. The *M. scalenus medius* is well-developed and its fibres merge with the *pleural dome.*

	Lig. vertebro-pleurale	Lig. transverso-pleurale	Lig. costo-pleurale	M. scalenus minimus	M. scalenus anterior	M. scale-nus medius
Right	0	0	0	0	1	1
Left	1	0	1	0	0	1

Table 3: *Results of the second dissection*

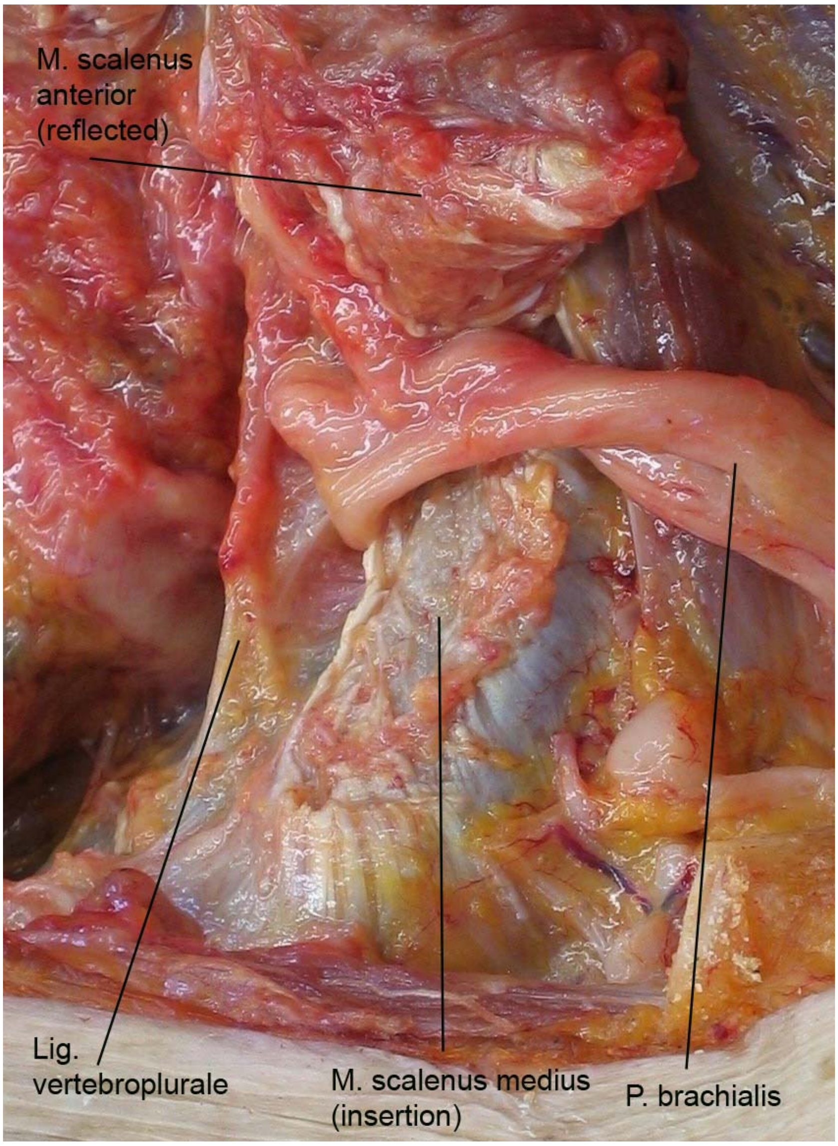

Figure 30: *The pleural dome on the left side with a well-developed vertebropleu-ral ligament. Also the broad attachment of the M. scalenus medius on the first rib is interesting.*

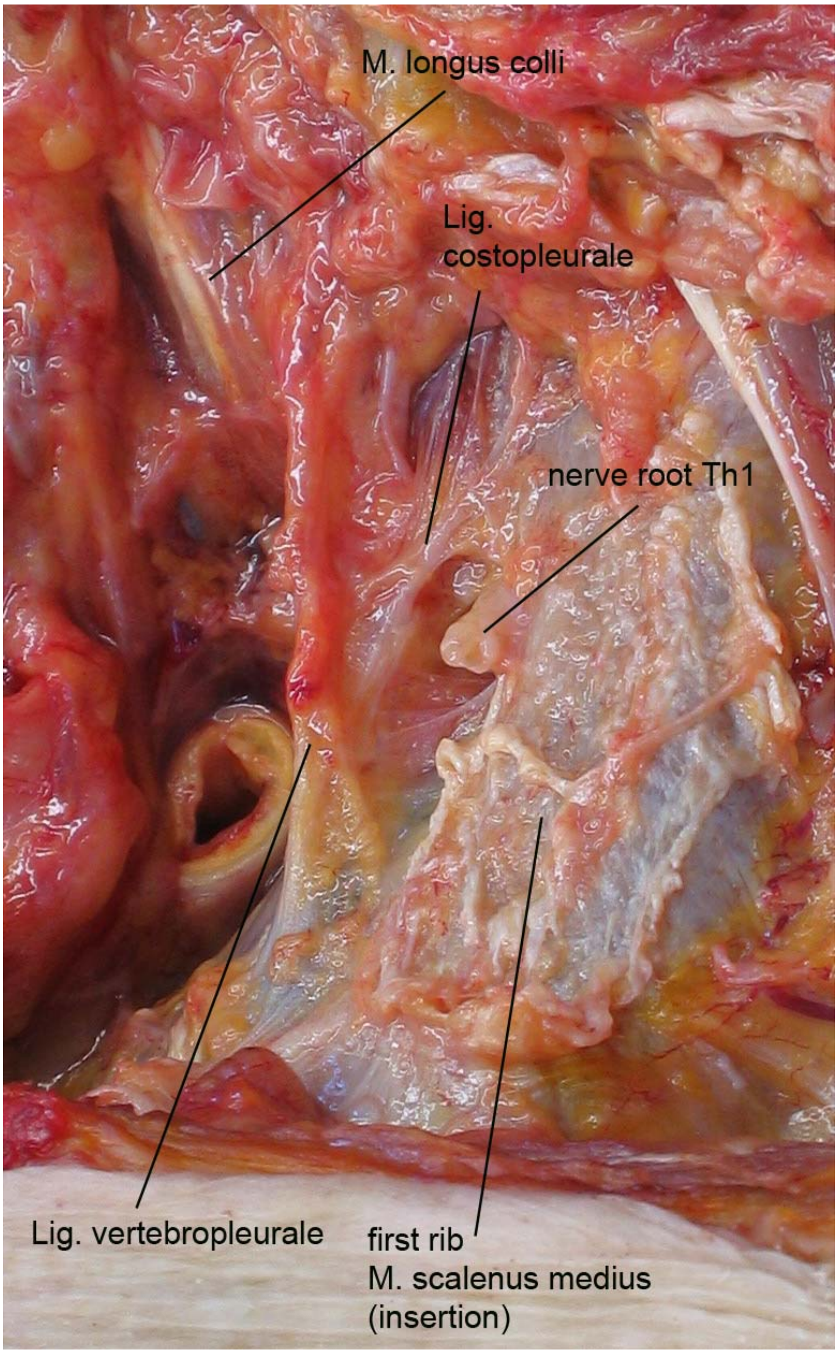

Figure 31: *The pleural dome of the left side. Besides the vertebropleural ligament also a costopleural ligament is visible. It originates from the first rib and merges with the region of the insertion of the Ligamentum vertebropleurale. Underneath the Lig. Costopleurale the severed root of the nerve of D1 can be seen.*

Figure 32: *The measurement of the Lig. vertebropleurale on the left side. It was carried out with an electrical slide calliper. Nevertheless some inaccuracy is possible in the length measurement due to the elasticity of the tissue.*

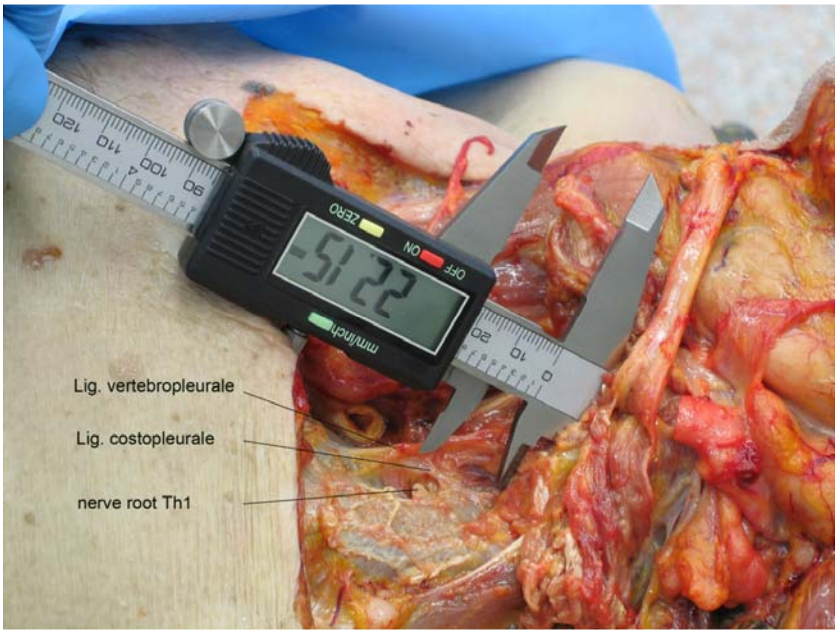

Figure 33: *The measurement of the Lig. costopleurale on the left side*

8.3 Dissection three

General remarks:

Embalmed male body

Right side:

On the right side the posterior scalene gap offers enough space for the *brachial plexus*. Once the *M. scalenus anterior* and *brachial plexus* have been cut and removed, the *M. scalenus minimus* behind them is exposed. The *M. scalenus minimus* is well-developed and has a strong attachment on the internal surface of the first rib. Its insertion merges with the whole *pleural dome*. The *pleural dome* presents as relatively compact layer of connective tissue whose fibres run in all directions. Increasingly connective tissue-like strands of fibres can be seen on the dorsal region of the *pleural dome*. The *M. scalenus medius* is well-developed and sends fibres into the *pleural dome*. No *ligament* structure can be detected.

Left side:

Also on the left side a *M. scalenus minimus* is present. It has a broad partially muscular, partially tendinous insertion onto the *pleural dome*. In comparison with the right side the *A. subclavia* and the *P. brachialis* on the left are more strongly connected with the *pleural dome* through strong connective tissue. The *M. scalenus anterior* is only weakly developed and inserts only onto the first rib. The *M. scalenus medius* has a broad attachment on the first rib and also sends fibres into the *pleural dome*. No *ligaments* can be discerned.

	Lig. vertebro-pleurale	**Lig. transverso-pleurale**	**Lig. costo-pleurale**	**M. scalenus minimus**	**M. scalenus anterior**	**M. scalenus medius**
Right	**0**	**0**	**0**	**1**	**0**	**1**
Left	**0**	**0**	**0**	**1**	**0**	**1**

Table 4: *Results of the third dissection*

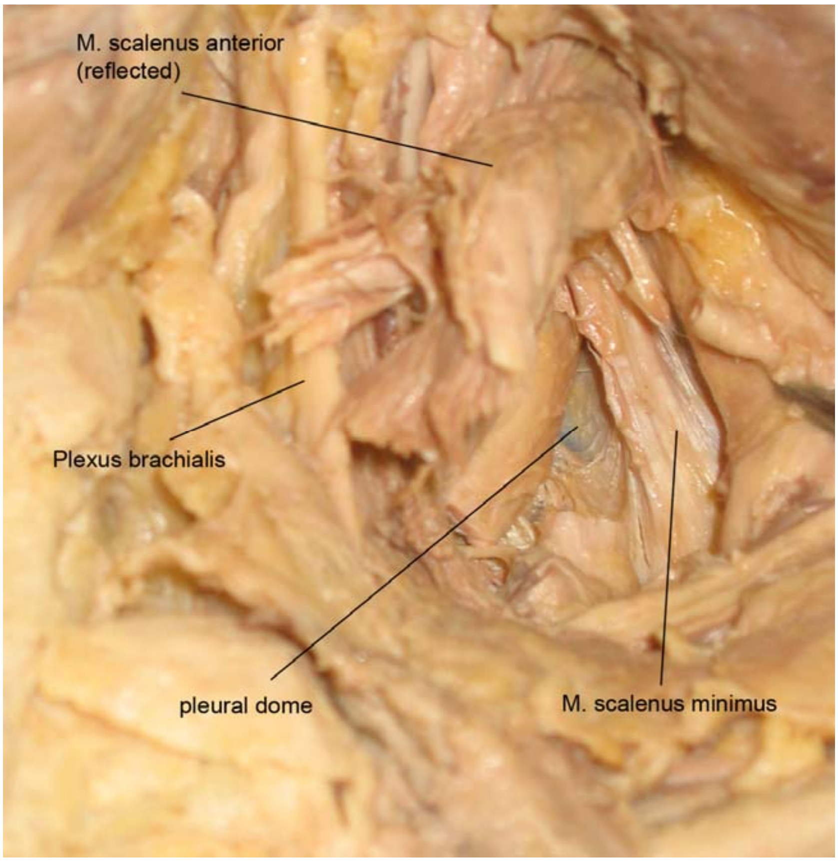

Figure 34: *The pleural dome on the right side with a well-developed M. scalenus minimus. The muscular portion is quite distinct.*

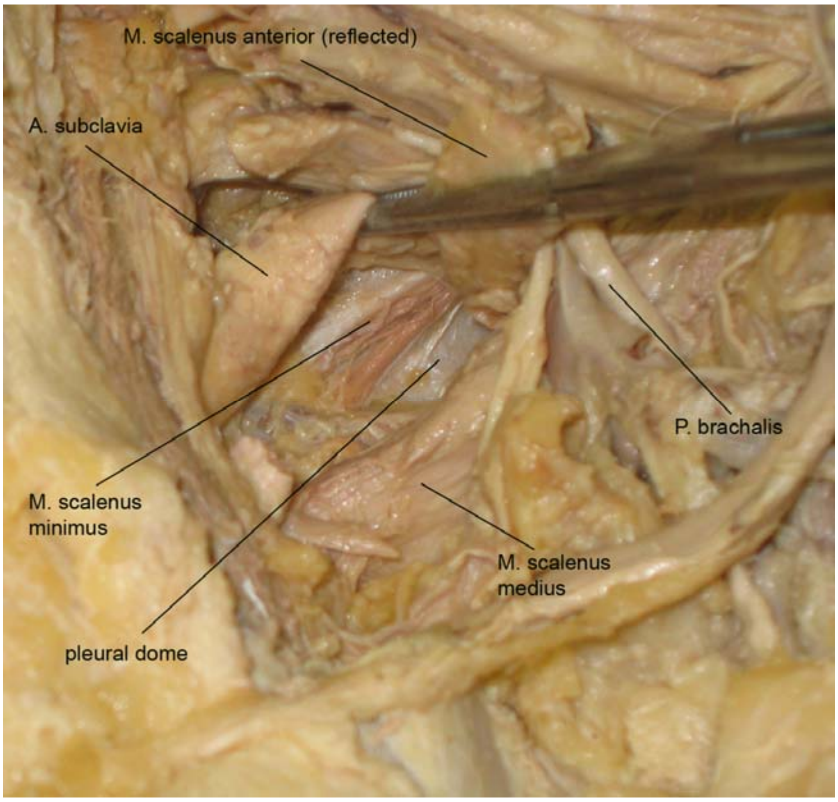

Figure 35: *The pleural dome on the left side. The M. scalenus minimus on this side is less developed. On the margins of the muscle tendinous portions are clearly visible. If the preparation is not done precisely enough, there is the risk that the muscular portion is removed and that could give the impression that there is a ligament.*

8.4 Dissection four

General remarks:

Embalmed male body

Right side:

The *M. scalenus anterior* on the right side is well-developed. It sends fibres into the *pleural dome*. The posterior scalene gap leaves enough space for the *A. subclavia* and *brachial plexus*. The *A. subclavia* is connected with the *pleural dome* through plenty of connective tissue. The *M. scalenus medius* is well-developed. It has a broad attachment in the posterior region of the arch of the first rib and merges with the *pleural dome* with its broad insertion. Neither a *ligament* nor a *M. scalenus minimus* can be detected.

Left side:

After the *M. scalenus anterior* has been cut at its insertion it is reflected to expose the *pleural dome* behind. On this side a *M. scalenus minimus* can be discerned. It inserts onto the first rib and also sends fibres into the *pleural dome*. The insertion onto the first rib is small. The muscle itself is well-developed and can be clearly recognized as muscular structure. The *pleural dome* is covered by connective tissue. In contrast to the right side the *A. subclavia* is less strongly connected with the *pleural dome*. The *M. scalenus medius* is less developed and sends hardly any fibres into the *pleural dome*.

	Lig. vertebro-pleurale	**Lig. transverso-pleurale**	**Lig. costo-pleurale**	**M. scalenus minimus**	**M. scalenus anterior**	**M. scale-nus medius**
Right	**0**	**0**	**0**	**0**	**1**	**1**
Left	**0**	**0**	**0**	**1**	**0**	**1**

Table 5: *Results of the fourth dissection*

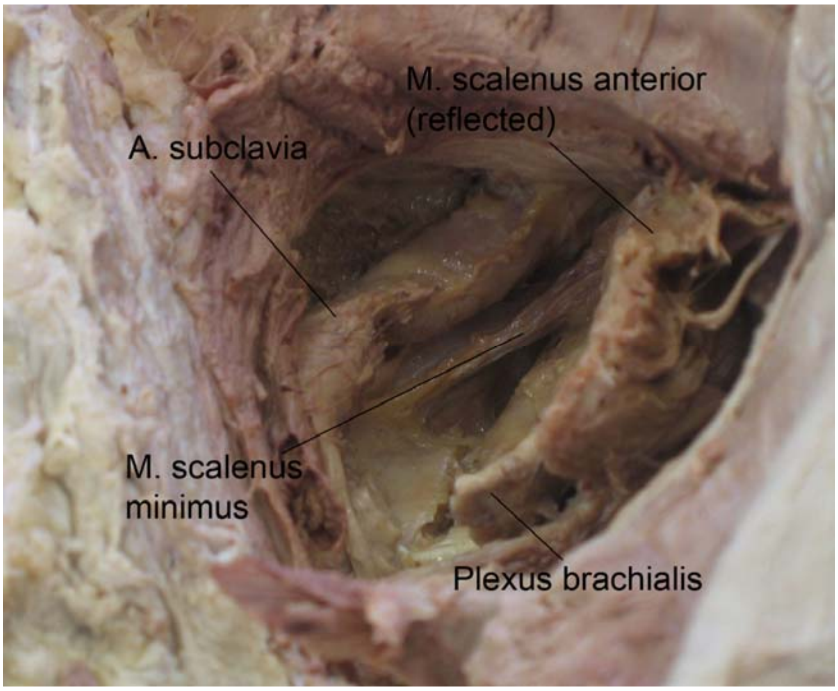

Figure 36: *The pleural dome on the left side. A M. scalenenus minimus is visible. Its muscular portion is well-developed. Abundant connective tissue is present in the region of the pleural dome.*

8.5 Dissection five

General remarks:

Embalmed female body

Right side:

A relatively weakly developed *M. scalenus anterior* can be seen on this side. In general the region of the *pleural dome* is quite narrow. The superficial portion of the *brachial plexus* can easily pass through the posterior scalene gap but the deeper portion lies quite tightly between the *A. subclavia* and the *M. scalenus medius.* The *A. subclavia* lies on the *pleural dome* and is connected with it through loose connective tissue. Like the whole muscle also the insertion of the *M. scalenus anterior* is weakly developed. The insertion of the *M. scalenus medius* is relatively broad and covers a large part of the posterior arch of the rib. It also sends fibres into the *pleural dome*. No *ligament* or *M. scalenus minimus* is visible.

Left side:

The situation on the left side is quite similar to that on the right. Also on the left the *M. scalenus medius* sends fibres into the *pleural dome*. The *A. subclavia* on this side is connected with the *pleural dome* through loose connective tissue. The *pleural dome* appears shiny and is covered by connective tissue. Neither a *ligament* nor a *M. scalenus minimus* are visible. Overall the body presents quite symmetrical.

	Lig. vertebro-pleurale	**Lig. transverso-pleurale**	**Lig. costo-pleurale**	**M. scalenus minimus**	**M. scalenus anterior**	**M. scale-nus medius**
Right	**0**	**0**	**0**	**0**	**0**	**1**
Left	**0**	**0**	**0**	**0**	**0**	**1**

Table 6: *Results of the fifth dissection*

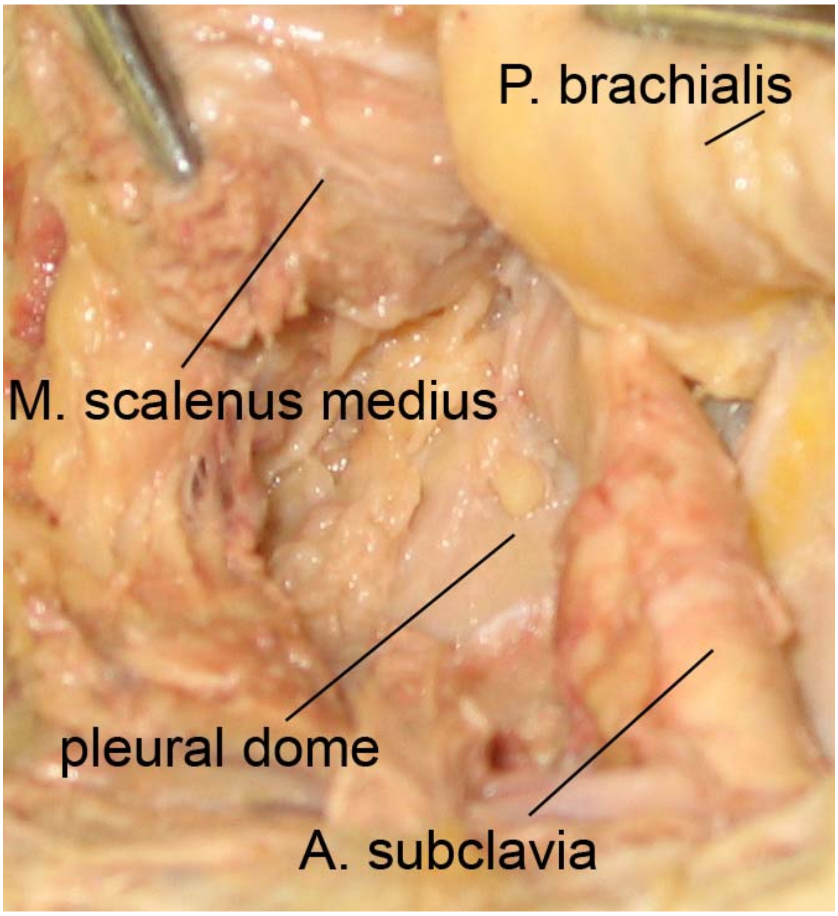

Figure 37: *The pleural dome on the right side. Fibres of the M. scalenenus medius that reach into the posterior region of the pleural dome can be seen. Also the connective tissue cover is clearly visible.*

8.6 Dissection six

General remarks:

Embalmed female body

Right side:

The *M. scalenus anterior* is not very well-developed but some of its fibres connect it with the *pleural dome.* On this side a well-developed *M. scalenus medius* can be recognized, which does not send any fibres into the *pleural dome*. After the *brachial plexus* has been cut at the level of the first rib, it is reflected to expose a connective tissue-like structure behind it, in the vicinity of the insertion of the *M. scalenus medius*. This structure has a length of 27.31 mm and a breadth of 1.5 mm. It originates from the posterior region of the first rib and sends fibres into the *pleural dome*. According to its position it seems to be the *Lig. costopleurale*. No *M. scalenus minimus* and no *Lig. vertebropleurale* could be detected.

Left side:

In contrast to the right side no *ligament* could be found on the left. Like in the body of the previous dissection the fascia of the *pleural dome* is strongly covered by connective tissue. Both the *M. scalenus anterior* and the *M. scalenus medius* send fibres towards the *pleural dome*. Also the *A. subclavia* adheres more strongly to the *pleural dome*. The *M. scalenus anterior* is only little developed, but the *M. scalenus medius* is well-developed. No *M. scalenus minimus* and no *Lig. vertebropleurale* could be detected.

	Lig. vertebro-pleurale	**Lig. transverso-pleurale**	**Lig. costo-pleurale**	**M. scalenus minimus**	**M. scalenus anterior**	**M. scale-nus medius**
Right	**0**	**0**	**1**	**0**	**1**	**1**
Left	**0**	**0**	**0**	**0**	**0**	**1**

Table 7: *Results of the sixth dissection*

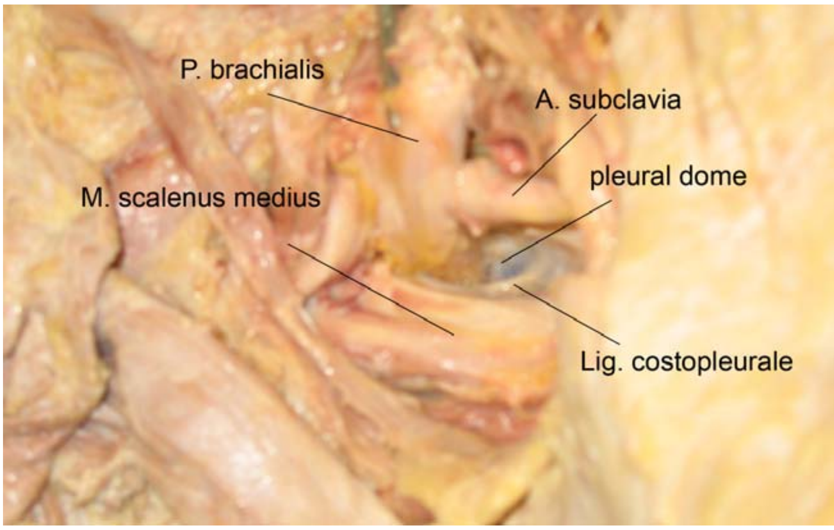

Figure 38: *The pleural dome on the right side. The costopleural ligament is clearly visible. From the posterior region of the rib the ligament extends also to the pleural dome.*

8.7 Dissection seven

General remarks:

Embalmed female body

Right side:

The *M. scalenus anterior* is well-developed and attaches onto the first rib and also sends some fibres into the *pleural dome*. The posterior scalene gap leaves enough space for the *A. subclavia* and the *P. brachialis.* In the region of the posterior arch of the first rib the *M. scalenus medius* merges with the *pleural dome.* The *M. scalenus anterior* has been cut and lifted. Behind it the *pleural dome* appears as a uniform layer of connective tissue. Neither *ligaments* nor a *M. scalenus minimus* can be recognized.

Left side:

The left side presents quite similar to the right. Also on the left side the *M. scalenus anterior* and *M. scalenus medius* are well-developed. Both send fibres into the *pleural dome*. The *pleural dome* presents as uniform layer of connective tissue. *Ligaments* or a *M. scalenus minimus* are absent.

	Lig. verte-bropleurale	**Lig. transverso-pleurale**	**Lig. costopleurale**	**M. scalenus minimus**	**M. scale-nus ante-rior**	**M. scale-nus me-dius**
Right	**0**	**0**	**0**	**0**	**1**	**1**
Left	**0**	**0**	**0**	**0**	**1**	**1**

Table 8: *Results of the seventh dissection*

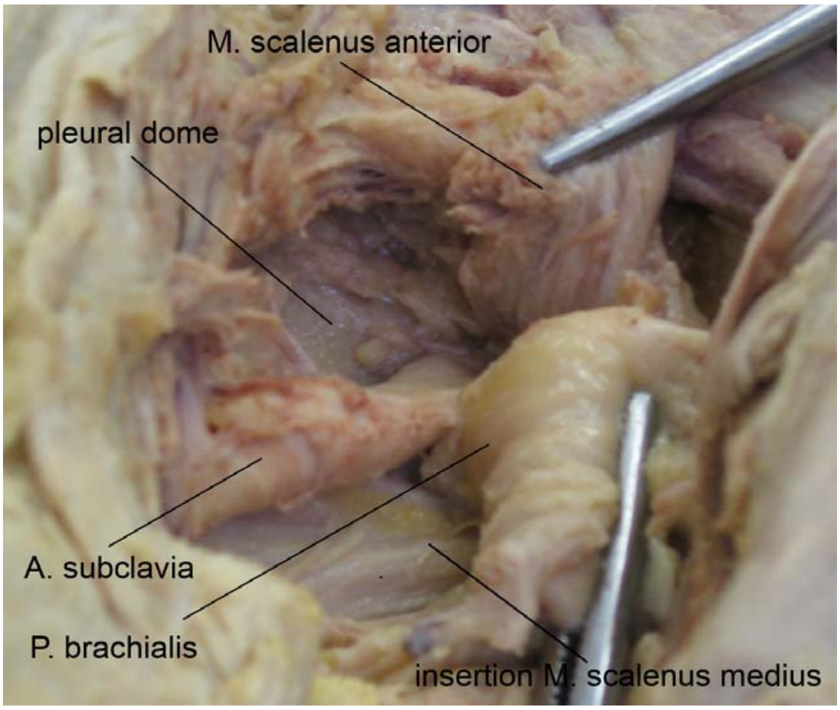

Figure 39: *The pleural dome on the left side. The pleural dome displays a quite thick and compact layer of connective tissue*

8.8 Dissection eight

General remarks:

Embalmed male body

Right side:

Both the *M. scalenus anterior* and the *M. scalenus medius* are well-developed, but only the *M. scalenus medius* sends fibres towards the *pleural dome*. Connective tissue adheres strongly to the whole region of the *pleural dome* and the *A. subclavia* can hardly be separated from it. The same holds for the *P. brachialis* because its fascial envelop has a strong insertion onto the *pleural dome*. After the *P. brachialis* and the *A. subclavia* have been detached from the *pleural dome*, the *pleural dome* becomes visible. Neither a *M. scalenus minimus* nor a *ligament* can be detected.

Left side:

The *A. subclavia* runs in a very flat arch over the *pleural dome*. In comparison with the other side the attachment of the *A. subclavia* and the *P. brachialis* is less developed. After removal of the *M. scalenus anterior* a *M. scalenus minimus* can be seen. It inserts broadly onto the *pleural dome* and also has a small insertion onto the internal surface of the first rib. The *M. scalenus medius* is well- developed and sends fibres into the *pleural dome*.

	Lig. vertebro-pleurale	**Lig. transverso-pleurale**	**Lig. costo-pleurale**	**M. scalenus minimus**	**M. scalenus anterior**	**M. scalenus medius**
Right	**0**	**0**	**0**	**0**	**0**	**1**
Left	**0**	**0**	**0**	**1**	**0**	**1**

Table 9: *Results of the eighth dissection*

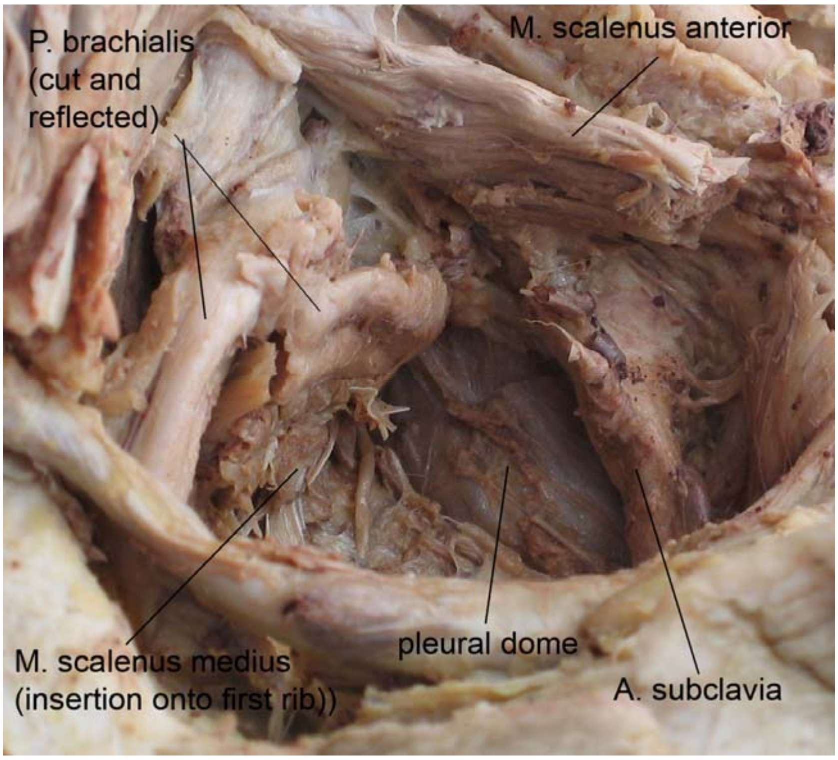

Figure 40: *The pleural dome on the right side.*

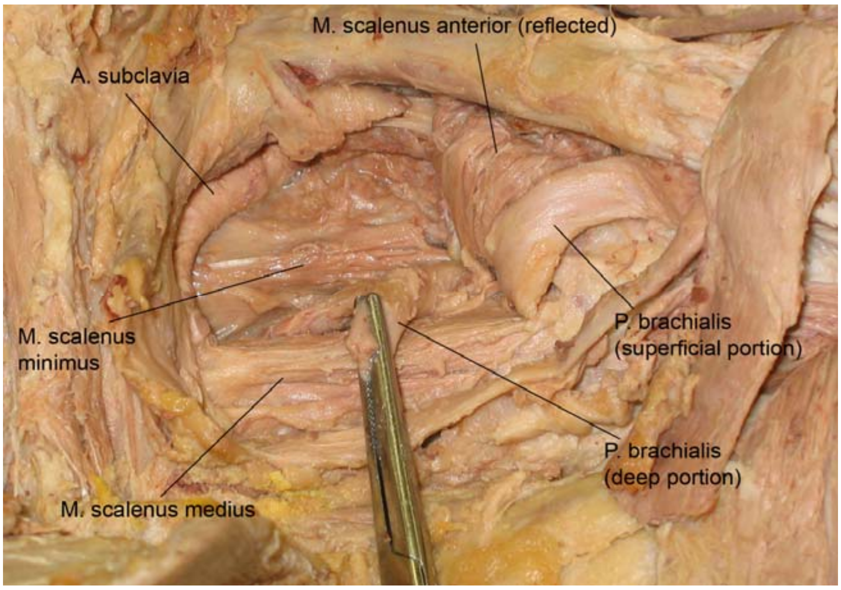

Figure 41: *The pleural dome on the left side. The muscular portion of the M. scalenus minimus is well-developed. The pleural dome is noticeably covered by connective tissue.*

8.9 Dissection nine

General remarks:

Embalmed female body

Right side:

On this side the *M. scalenus anterior* and also the *M. scalenus medius* are well-developed. Both send fibres into the *pleural dome* but this connection is quite delicate. The *M. scalenus anterior* was cut and reflected. The *P. brachialis* has been cut and removed. The *A. subclavia* was pushed inferiorly. This exposes a delicate but independent structure with a breadth of 2.12mm and a length of 44.28mm. It originates at the vertebral body of C7 and attaches onto the *pleural dome*. Given its path and location the structure can be identified as *Lig. vertebropleurale*. Neither a *M. scalenus minimus* nor other ligamentous structures could be detected.

Left side:

The *M. scalenus anterior* is well-developed and sends fibres into the *pleural dome*. The *A. subclavia* and the *P. brachialis* are connected with the *pleural dome* through connective tissue. The *M. scalenus medius* is well-developed. It is bifurcated and a tendinous portion runs to the *pleural dome* as well as to the first rib. The main portion of the muscle, which is quite well-developed, runs directly to the first rib. The portion that branches off the muscle is no independent ligament since it has a clear connection to the *M. scalenus medius*. After the *M. scalenus medius* has been removed the posterior part of the *pleural dome* is visible. It is covered with connective tissue but no *ligament is* discernable. Also the anterior region of the *pleural dome* is covered by connective tissue. There are no *ligaments* and no *M. scalenus minimus.*

	Lig. vertebro-pleurale	**Lig. transverso-pleurale**	**Lig. costo-pleurale**	**M. scalenus minimus**	**M. scalenus anterior**	**M. scale-nus medius**
Right	**1**	**0**	**0**	**0**	**1**	**1**
Left	**0**	**0**	**0**	**0**	**1**	**1**

Table 10: *Results of the ninth dissection*

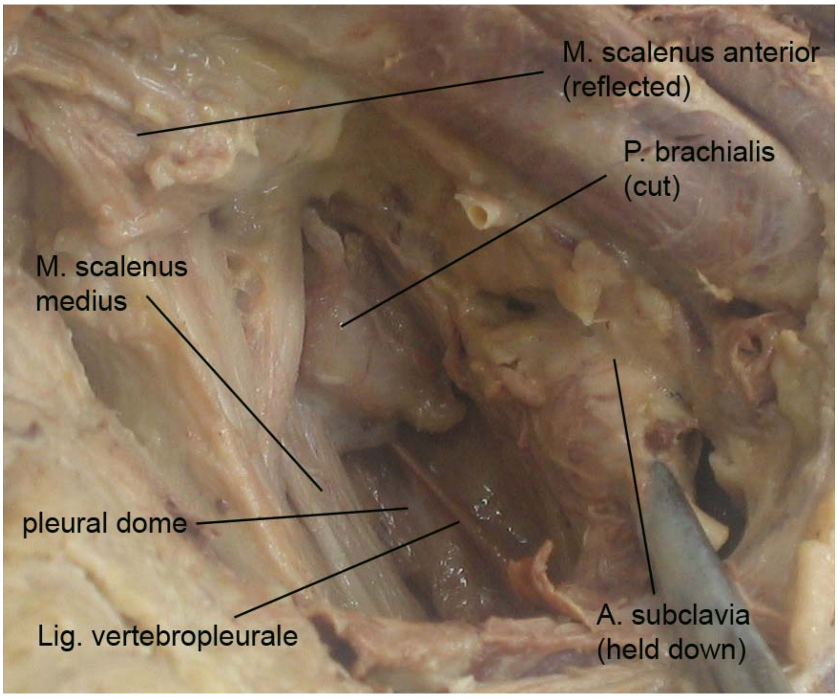

Figure 42: *The pleural dome on the right side. The Ligamentum vertebropleurale is only weakly developed but can be recognized as ligament. The attachment on the pleural dome is small.*

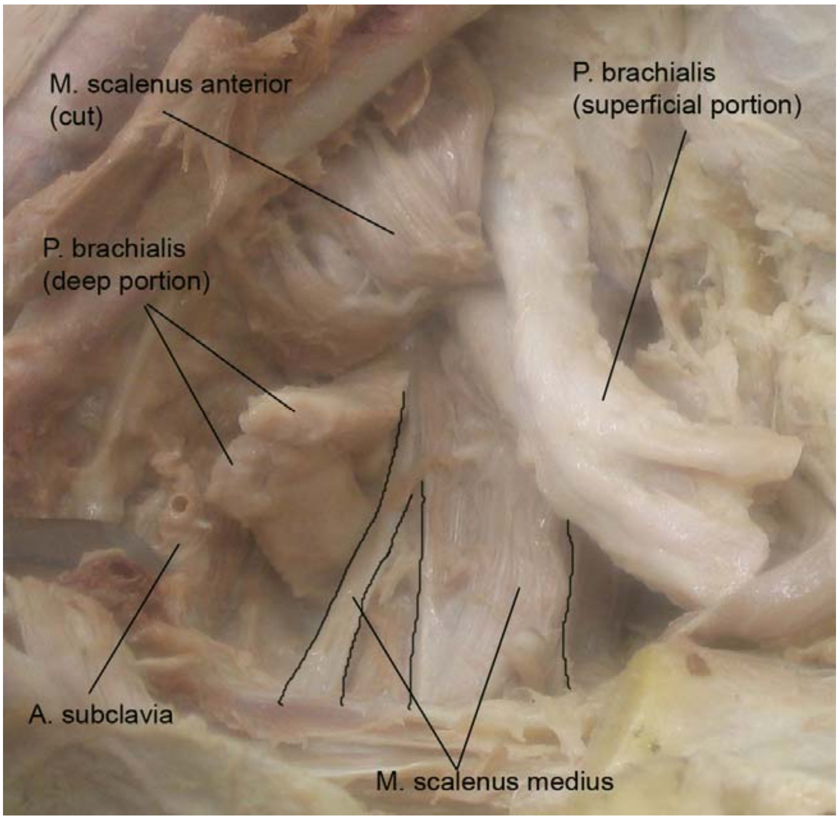

Figure 43: *The pleural dome on the left side. The bifurcation of the M. scalenus medius, which attaches onto and merges with the pleural dome, is clearly visible.*

8.10 Dissection ten

General remarks:

Embalmed male body

Right side:

Both the *M. scalenus anterior* and the *M. scalenus medius* are well-developed. Both have a broad insertion onto the first rib and send fibres into the *pleural dome*. The posterior scalene gap offers enough space for the *brachial plexus*. The *M. scalenus anterior* has been cut and lifted. Also the *M. scalenus medius* is removed. The *brachial plexus* is shifted laterally while the *A. subclavia* is pushed slightly caudally. This exposes the *pleural dome*. Neither a *ligament* nor a *M. scalenus minimus* is visible. The *pleural dome* presents as uniform layer of connective tissue.

Left side:

Also on the left side the *M. scalenus anterior* and *M. scalenenus medius* are well-developed and send fibres into the *pleural dome*. On this side the *A. subclavia* and the *P. brachialis* have been detached from the *pleural dome*. This causes gaps in the connective tissue layer. Also on this side no *ligament* or *M. scalenus minimus* could be detected.

	Lig. vertebro-pleurale	Lig. transverso-pleurale	Lig. costo-pleurale	M. scalenus minimus	M. scalenus anterior	M. scale-nus medius
Right	0	0	0	0	1	1
Left	0	0	0	0	1	1

Table 11: *Results of the tenth dissection*

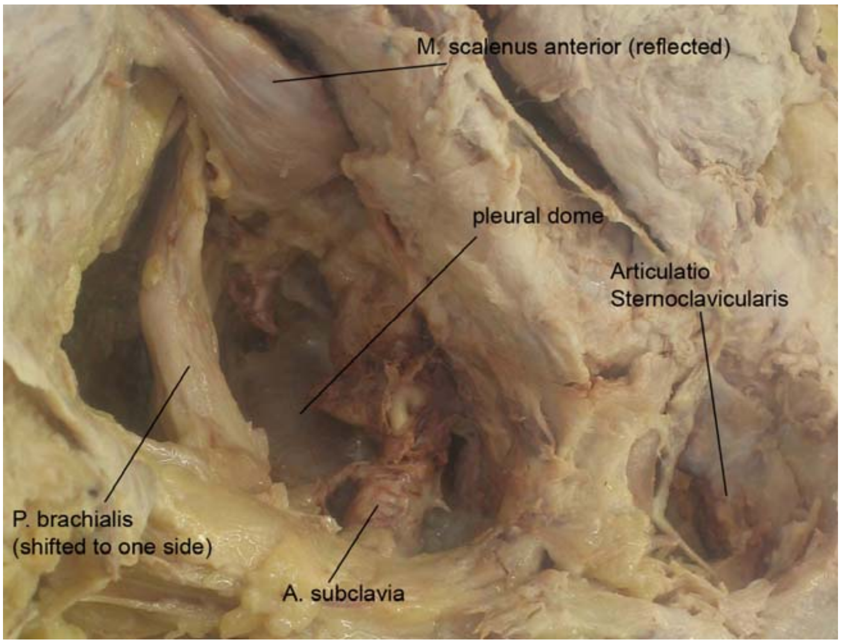

Figure 44: *The pleural dome on the right side. The size of the SC joint (Articulatio sternoclavicularis) is quite impressive on this picture.*

8.11 Dissection eleven

General remarks:

Embalmed male body

Right side:

The *M. scalenus anterior* and *M. scalenus medius* are well-developed. Both send fibres into the *pleural dome.* The *A. subclavia* and the *P. brachialis* are closely connected with the *pleural dome* through connective tissue. After the *M. scalenus anterior* and *M. scalenus medius* have been removed, the *A. subclavia* and *P. brachialis* are removed as well. The *pleural dome* presents as usual. It displays connective tissue fibres running in all directions. Neither a *ligament* nor a *M. scalenus minimus* are visible.

Left side:

The *M. scalenus anterior* and *M. scalenus medius* are well-developed and also on this side connected with the *pleural dome* through fibres. There is a connective tissue-like connection between the *A. subclavia* and the *P. brachialis*. In addition, the *A. subclavia* is strongly attached to the *pleural dome* by connective tissue. The *M. scalenus anterior* is cut at its insertion and then removed. After removal of the *M. scalenus anterior* a *M. scalenus minimus* becomes visible. Its tendinous insertion has the same diameter as its muscular portion. No *ligament* could be detected.

	Lig. vertebro-pleurale	**Lig. transverso-pleurale**	**Lig. costo-pleurale**	**M. scalenus minimus**	**M. scalenus anterior**	**M. scale-nus medius**
Right	**0**	**0**	**0**	**0**	**1**	**1**
Left	**0**	**0**	**0**	**1**	**1**	**1**

Table 12: *Results of the eleventh dissection*

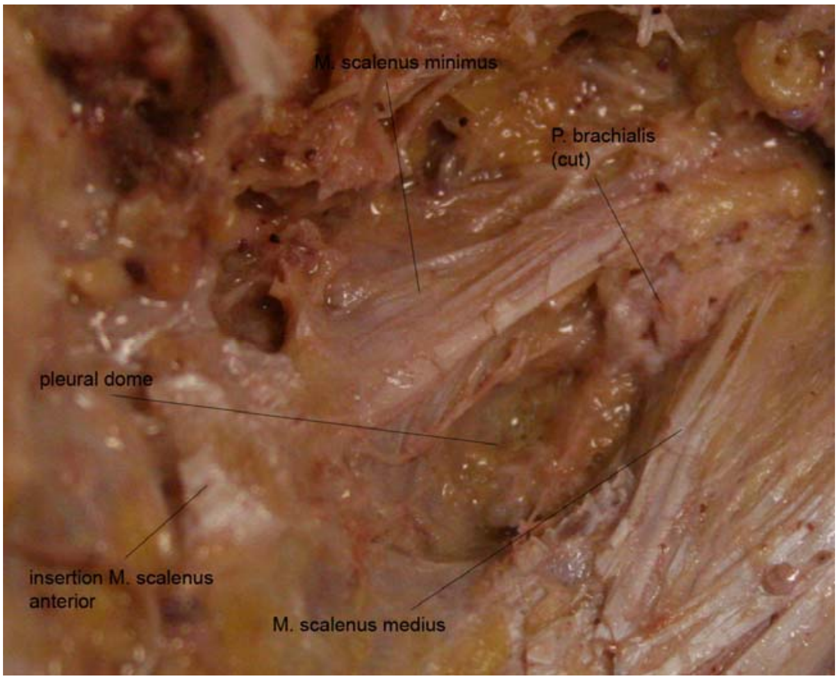

Figure 45: *The pleural dome on the left side where the M. scalenus minimus is well-developed. The proportion of its tendinous and muscular portions is quite balanced.*

8.12 Dissection twelve

General remarks:

Embalmed male body

Right side:

The *M. scalenus anterior* and *M. scalenus medius* are well-developed. After both structures have been cut they are pushed to one side. Then the *A. subclavia* and the *P. brachialis* are cut to expose the *pleural dome*. Neither a *ligament* nor a *M. scalenus minimus* are visible. The *pleural dome* appears uniform. Also at the sites where the *A. subclavia* and the *P. brachialis* were resting on it no noteworthy gap can be seen. The *M. scalenus anterior* and the *M. scalenus medius* send fibres into the *pleural dome* in the vicinity of their insertion.

Left side:

Basically the left side presents similar to the right one. Also on the left side no *ligament* or *M. scalenus minimus* could be detected. The *pleural dome* is compact and covered by connective tissue. The *M. scalenus anterior* and the *M. scalenus medius* send fibres into the *pleural dome*.

	Lig. vertebro-pleurale	**Lig. transverso-pleurale**	**Lig. costo-pleurale**	**M. scalenus minimus**	**M. scalenus anterior**	**M. scale-nus medius**
Right	**0**	**0**	**0**	**0**	**1**	**1**
Left	**0**	**0**	**0**	**0**	**1**	**1**

Table 13: *Results of the twelfth dissection*

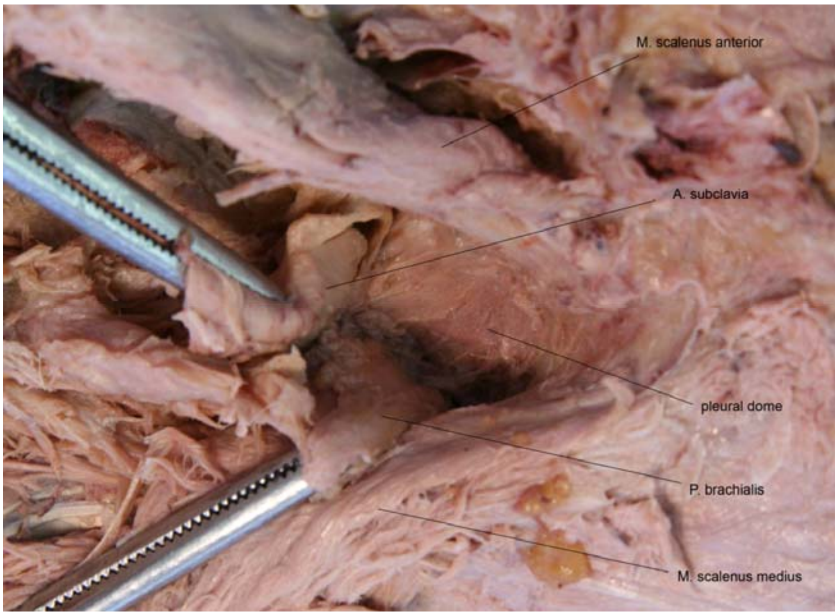

Figure 46: *The pleural dome on the right side. It presents with a compact connective tissue cover.*

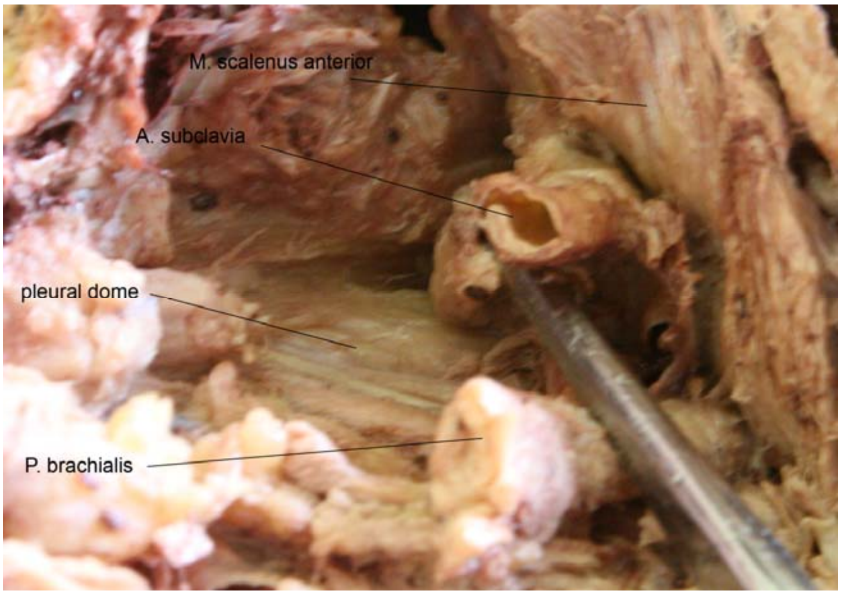

Figure 47: *The pleural dome on the left side. Also here a uniform connective tissue layer can be seen.*

8.13 Dissection thirteen

General remarks:

Non-embalmed male body

Right side:

The *M. scalenus anterior* is well-developed and strong and sends fibres into the *pleural dome*. Also the *M. scalenus medius* is well-developed and has a broad insertion onto the *pleural dome*. Like the *brachial plexus* the *A. subclavia* is connected with the *pleural dome* through connective tissue. No fibres can be detected on the *pleural dome* whose direction would suggest the presence of a *ligament.* Also no *M. scalenus minimus* could be detected.

Left side:

Also on the left side the *A. subclavia* and *P. brachialis* are closely connected with the *pleural dome* through connective tissue. The *pleural dome* is thin and shiny; the connective tissue does not have any particular direction of fibres. Both the *M. scalenus anterior* and *M. scalenus medius* send fibres towards the direction of the *pleural dome*. Neither a *ligament* nor a *M. scalenus minimus* are visible.

	Lig. vertebro-pleurale	Lig. transverso-pleurale	Lig. costo-pleurale	M. scalenus minimus	M. scalenus anterior	M. scalenus medius
Right	0	0	0	0	1	1
Left	0	0	0	0	1	1

Table 14: *Results of the thirteenth dissection*

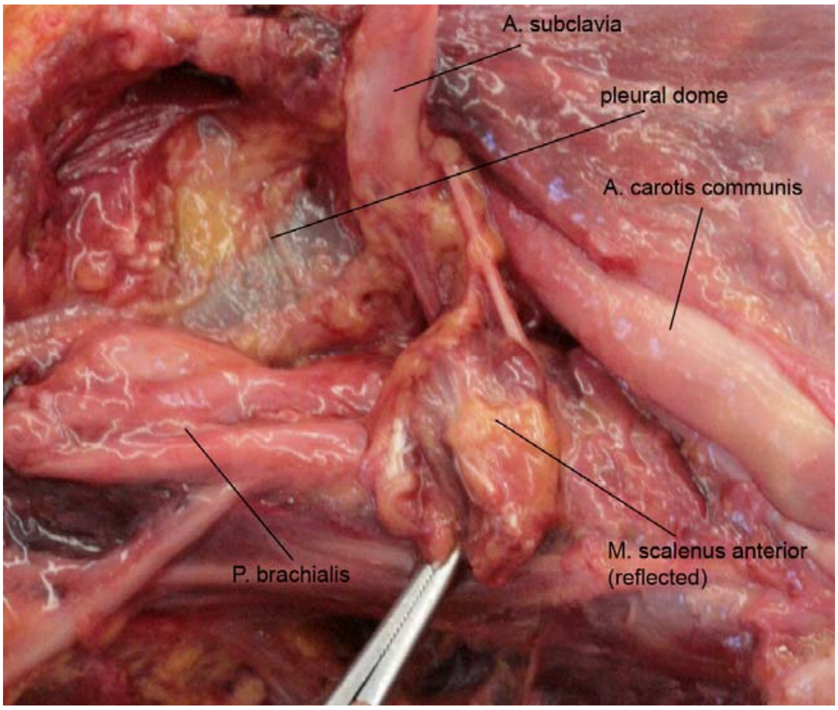

Figure 48: *The pleural dome on the right side*

8.14 Dissection fourteen

General remarks:

Non-embalmed male body

Right side:

The posterior scalene gap is quite narrow. Both the *brachial plexus* and the *A. subclavia* are crowded by the *M. scalenus anterior* and *M. scalenus medius*. The *A. subclavia* adheres tightly to the *pleural dome.* The removal of the *A. subclavia* leaves a true hole in the connective tissue that covers the *pleural dome*. The *M. scalenus anterior* has a broad insertion onto the *pleural dome*. The *M. scalenus medius* is well-developed, attaches onto the first rib but sends hardly any fibres into the *pleural dome*. Neither a *M. scalenus minimus* nor a *ligament* can be recognized. Both the *A. subclavia* and the *brachial plexus* are tightly connected with the *pleural dome*. The structure that has the strongest connection with the *pleural dome* is the *M. scalenus anterior.*

Left side:

Similar to the right side, the *M. scalenus anterior* and *M. scalenus medius* on the left are well-developed. The posterior scalene gap is quite narrow Thus there is not much space for the *brachial plexus* and the *A. subclavia*. After removal of the *M. scalenus anterior*, which has a broad insertion onto the *pleural dome*, as well as the *A. subclavia* and *brachial plexus* the typical shiny surface of the *pleural dome* is visible. Neither a *ligament* nor a *M. scalenus minimus* are present. The *M. scalenus medius* sends hardly any fibres into the *pleural dome*. The insertion of the *M. scalenus anterior* onto the *pleural dome* was not removed in order to illustrate the size of the attachment.

	Lig. vertebro-pleurale	**Lig. transverso-pleurale**	**Lig. costo-pleurale**	**M. scalenus minimus**	**M. scalenus anterior**	**M. scale-nus medius**
Right	**0**	**0**	**0**	**0**	**1**	**1**
Left	**0**	**0**	**0**	**0**	**1**	**1**

Table 15: *Results of the fourteenth dissection*

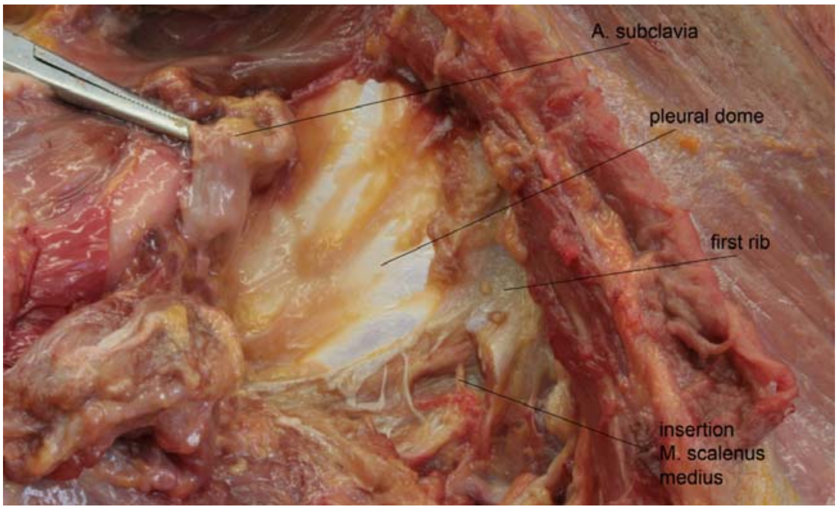

Figure 49: *The pleural dome on the right side. The delicate and shine spots are the sites where the P. brachialis and A. subclavia have been removed from the pleural dome. This illustrates a problem: to expose the suspension of the pleural dome structures that participate in the system have to be removed.*

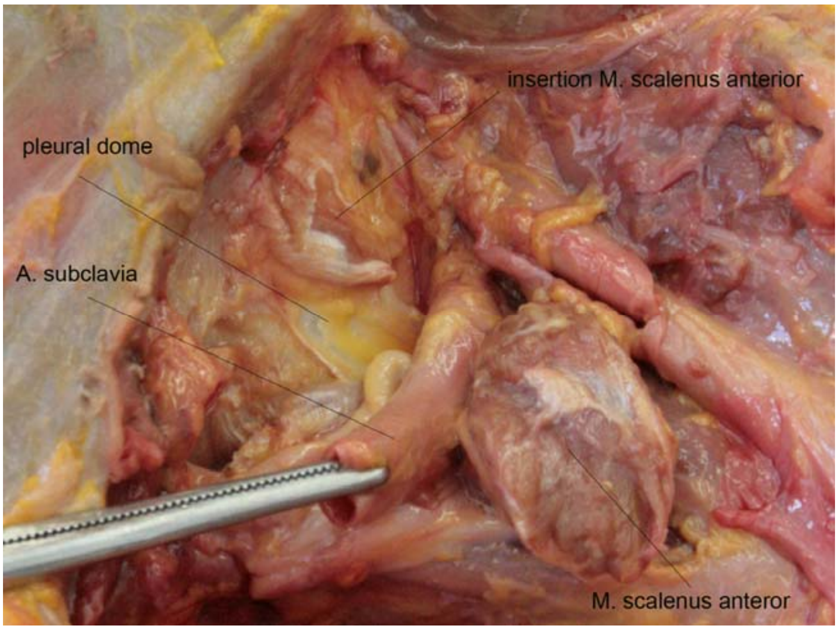

Figure 50: *The pleural dome on the left side. The broad insertion of the M. scalenus anterior onto the pleural dome is quite noteworthy.*

8.15 Dissection fifteen

General remarks:

Non-embalmed male body; pronounced adiposity

Right side:

The *M. scalenus anterior* and *M. scalenus medius* are well-developed and insert onto the first rib. Neither of those muscles sends fibres into the *pleural dome*. After removal of the *A. subclavia* and *P. brachialis* the *pleural dome* is exposed and presents as uniform layer that contains inclusions of fatty tissue. Neither a *ligament* nor a *M. scalenus minimus* are recognizable.

Left side:

Also the left *M. scalenus anterior* and *M. scalenus minimus* are well-developed. Both muscles insert onto the first rib without sending any fibres into the *pleural dome*. After removal of the *A. subclavia* and *brachial plexus* the *pleural dome* presents quite similar to the right side. Fatty tissue is embedded in the connective tissue. No *ligament* attaches onto the *pleural dome*. Also no *M. scalenus minimus* can be detected.

	Lig. vertebro-pleurale	**Lig. transverso-pleurale**	**Lig. costo-pleurale**	**M. scalenus minimus**	**M. scalenus anterior**	**M. scale-nus medius**
Right	**0**	**0**	**0**	**0**	**0**	**0**
Left	**0**	**0**	**0**	**0**	**0**	**0**

Table 16: *Results of the fifteenth dissection*

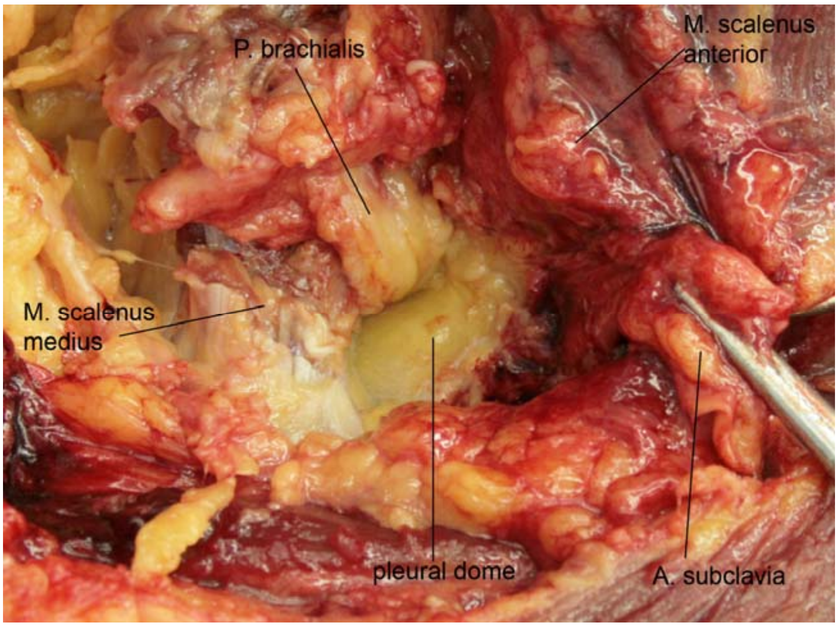

Figure 51: *The pleural dome on the right side. The picture shows the layer of connective tissue that overlays the pleural dome and is interspersed with fatty tissue.*

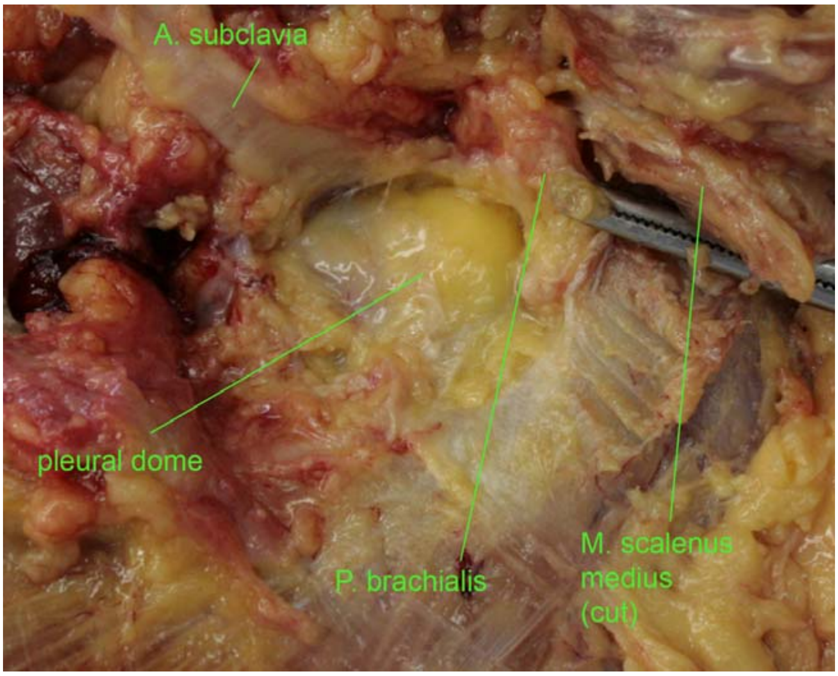

Figure 52: *The pleural dome on the left side. Also here the fatty tissue can be well recognized. Good visibility also of the insertion of the M. scalenus medius onto the first rib.*

8.16 Dissection sixteen

General remarks:

Non-embalmed male body; to gain a better impression of the suspension of the *pleural dome* the parietal layer of the *pleura* was detached from the *Fascia endothoracica* and the connective tissue dome was photographed from the inside. (cf. Fig. 55, 56)

Right side:

The *M. scalenus anterior* and *M. scalenus medius* are well-developed. Both insert onto the first rib and do not send any fibres towards the *pleural dome*. The *A. subclavia* and *P. brachialis* can be easily removed from the *pleural dome*. After removal of all structures the *pleural dome* is well visible. Neither a *ligament* nor a *M. scalenus minimus* can be recognized.

Left side:

Also the left *M. scalenus anterior* and *M. scalenus medius* are well-developed and insert onto the first rib. No muscle fibres run towards the *pleural dome*. After removal of the *A. subclavia* and *P. brachialis* a weakly developed muscle becomes visible. It sends fibres into the *pleural dome*. This muscle is the *M. scalenus minimus*. There are no *ligaments*.

	Lig. vertebro-pleurale	**Lig. transverso-pleurale**	**Lig. costo-pleurale**	**M. scalenus minimus**	**M. scalenus anterior**	**M. scalenus medius**
Right	**0**	**0**	**0**	**0**	**0**	**0**
Left	**0**	**0**	**0**	**1**	**0**	**0**

Table 17: *Results of the sixteenth dissection*

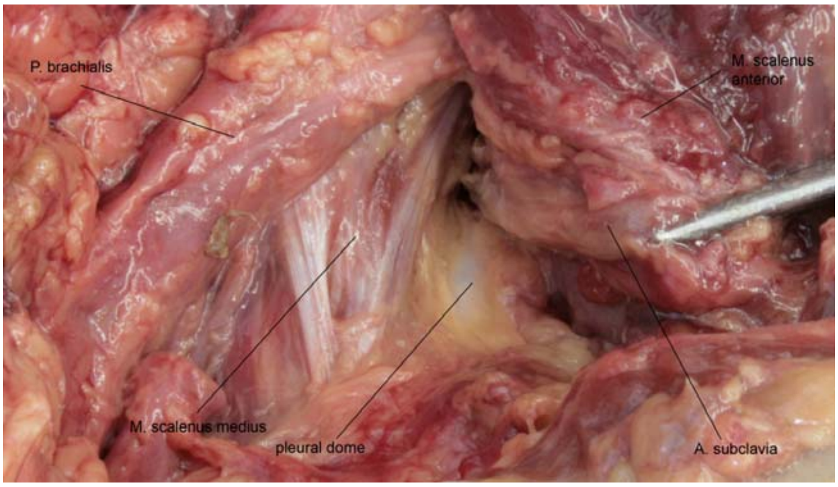

Figure 53: *The pleural dome on the right side. The extremely well-developed M. scalenus medius is quite impressive.*

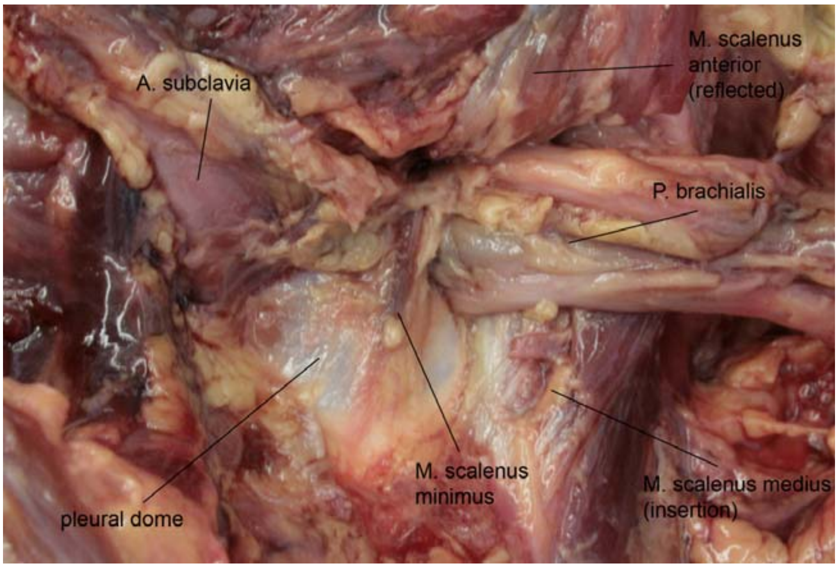

Figure 54: *The pleural dome on the left side. A weakly developed M. scalenus minimus can be recognized which has a broad insertion onto the pleural dome.*

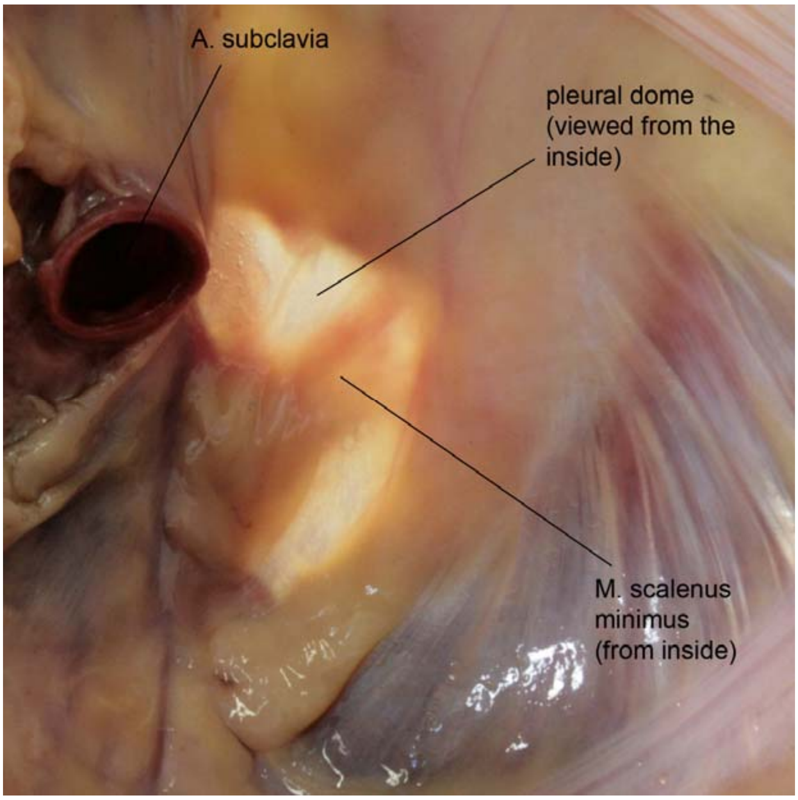

Figure 55: *The left pleural dome viewed from the inside. The parietal pleura and the Fascia endothoracica span the superior thoracic aperture. The M. scalenus minimus shows through theses structures.*

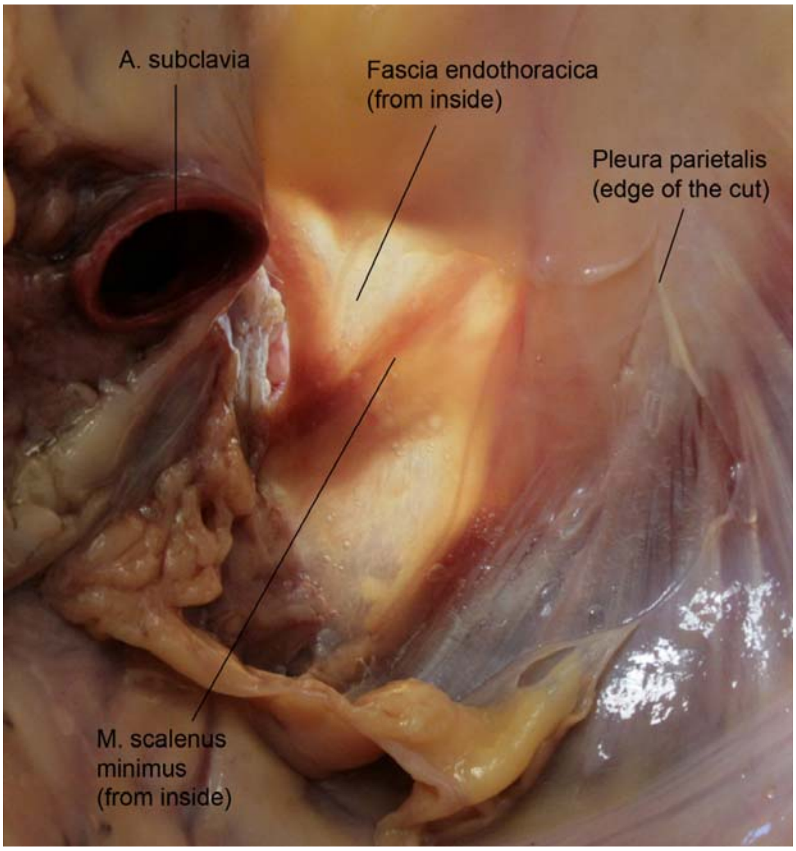

Figure 56: *The left pleural dome viewed from the inside. The parietal pleura has been removed from the whole region of the pleural dome. The edge of the cut can be seen very well. What is left is the extremely thin layer of the Fascia endothoracica.*

8.17 Dissection seventeen

General remarks:

Non-embalmed male body

Right side:

The *M. scalenus anterior* is only weakly developed and sends fibres into the *pleural dome*. The posterior scalene gap is very narrow. Both the *A. subclavia* and the *brachial plexus* are crowded by the two scalene muscles. The *A. subclavia* and the *brachial plexus* are connected with the *pleural dome* through connective tissue. The *M. scalenus medius* is well-developed and merges with the *pleural dome*. On this side the *pleural dome* is covered with a delicate layer of connective tissue. Neither a *M. scalenus minimus* nor *ligaments* are visible.

Left side:

The *M. scalenus anterior* is weakly developed and merges with the *pleural dome*. After removal of the *M. scalenus anterior* the *A. subclavia* is exposed. Like the *brachial plexus* the artery has been cut and detached from the *pleural dome*. Together with the *M. scalenus anterior* the structures were shifted medially. The *M. scalenus medius* does not have a uniform appearance. Its bundles are fanned out. The most external bundle has been removed which exposes another more internal bundle that inserts onto the internal surface of the first rib and also sends fibres into the *pleural dome*. The *pleural dome* is covered with a delicate layer of connective tissue. Neither a *M. scalenus minimus* nor a *ligament* can be detected.

	Lig. vertebro-pleurale	**Lig. transverso-pleurale**	**Lig. costo-pleurale**	**M. scalenus minimus**	**M. scalenus anterior**	**M. scale-nus medius**
Right	**0**	**0**	**0**	**0**	**1**	**1**
Left	**0**	**0**	**0**	**0**	**1**	**1**

Table 18: *Results of the seventeenth dissection*

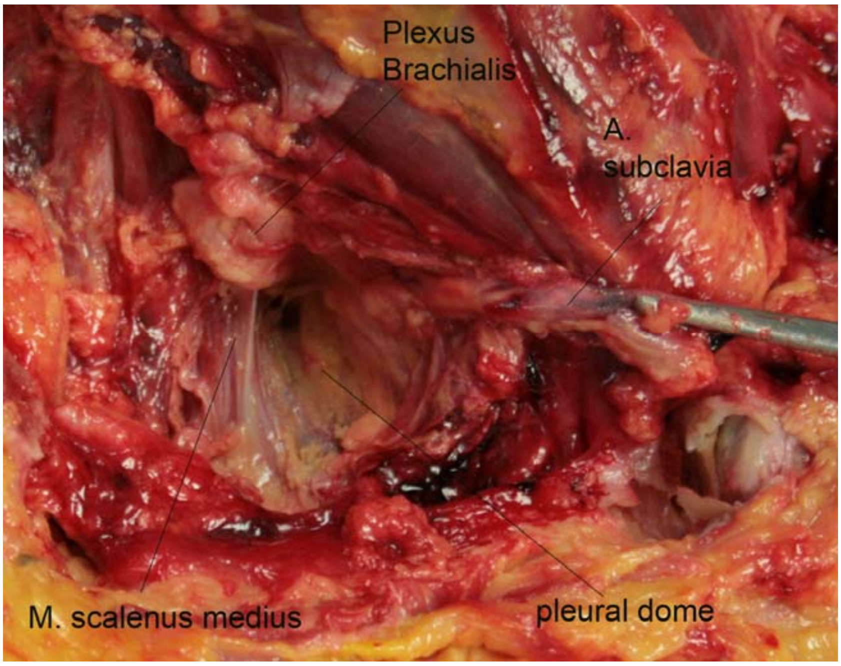

Figure 57: *The pleural dome on the right side*

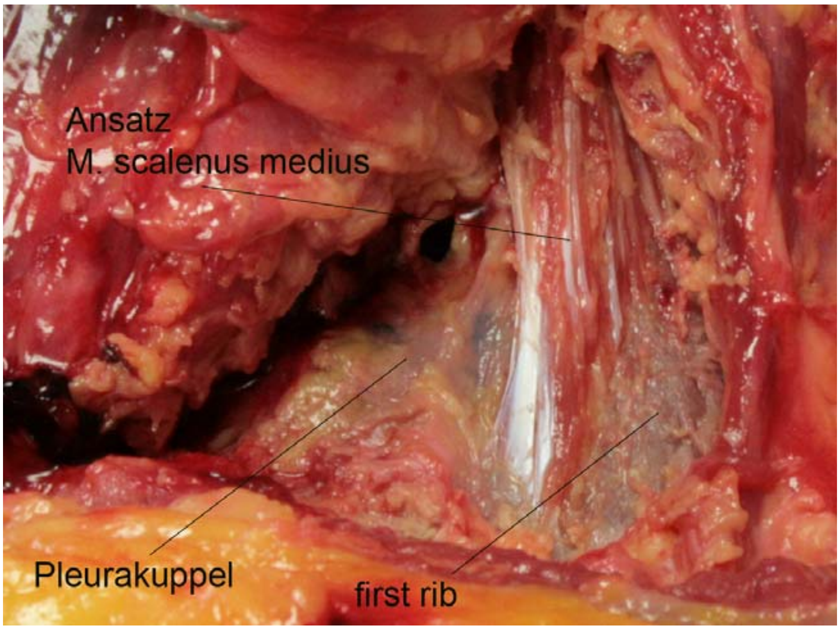

Figure 58: *The pleural dome on the left side. The external portion of the insertion of the M. scalenus medius onto the first rib has been removed. The insertion onto the internal surface of the first rib and onto the pleural dome is exposed.*

8.18 Dissection eighteen

General remarks:

Non-embalmed female body; adiposity

Right side:

The *M. scalenus anterior* is weakly developed and merges with the *pleural dome*. The *A. subclavia* and *brachial plexus* are strongly connected with the *pleural dome* through connective tissue. Removal of those structures exposes the *pleural dome*. On the right side less fatty tissue can be observed than on the left side. The *M. scalenus medius* is well-developed and broadly inserts onto the first rib. It has no attachment on the *pleural dome*. Neither *ligaments* nor a *M. scalenus minimus* are visible.

Left side:

The *M. scalenus anterior* is only weakly developed and like on the opposite side inserts onto the *pleural dome.* The *M. scalenus medius* is well-developed and also sends fibres into the *pleural dome*. Both the *brachial plexus* and the *A. subclavia* could be easily removed from the *pleural dome*. The *pleural dome* is covered by connective tissue. The dispersion of fatty tissue can be well recognized. Neither *ligaments* nor a *M. scalenus minimus* are present.

	Lig. vertebro-pleurale	**Lig. transverso-pleurale**	**Lig. costo-pleurale**	**M. scalenus minimus**	**M. scalenus anterior**	**M. scalenus medius**
Right	**0**	**0**	**0**	**0**	**1**	**0**
Left	**0**	**0**	**0**	**0**	**1**	**1**

Table 19: *Results of the eighteenth dissection*

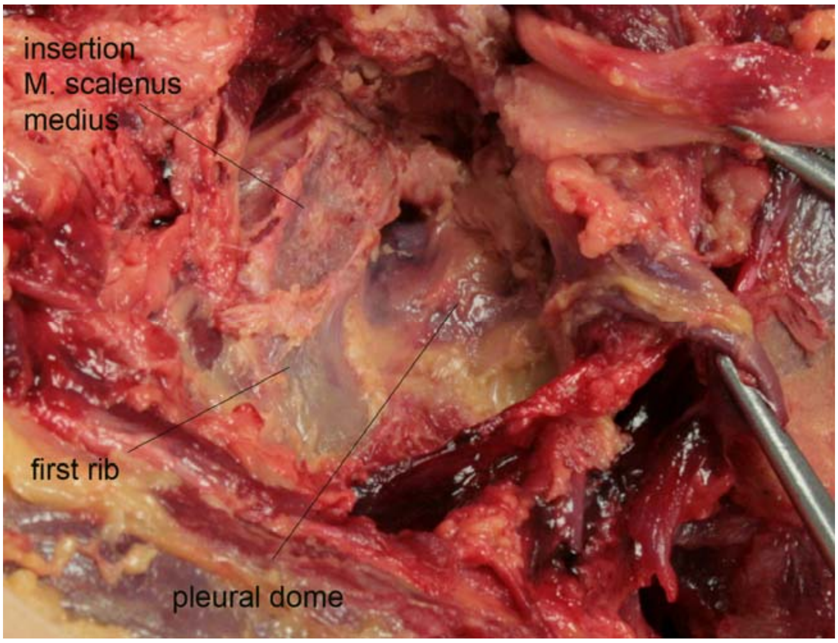

Figure 59: *The pleural dome on the right side. The insertion of the M. scalenus medius onto the first rib is clearly visible.*

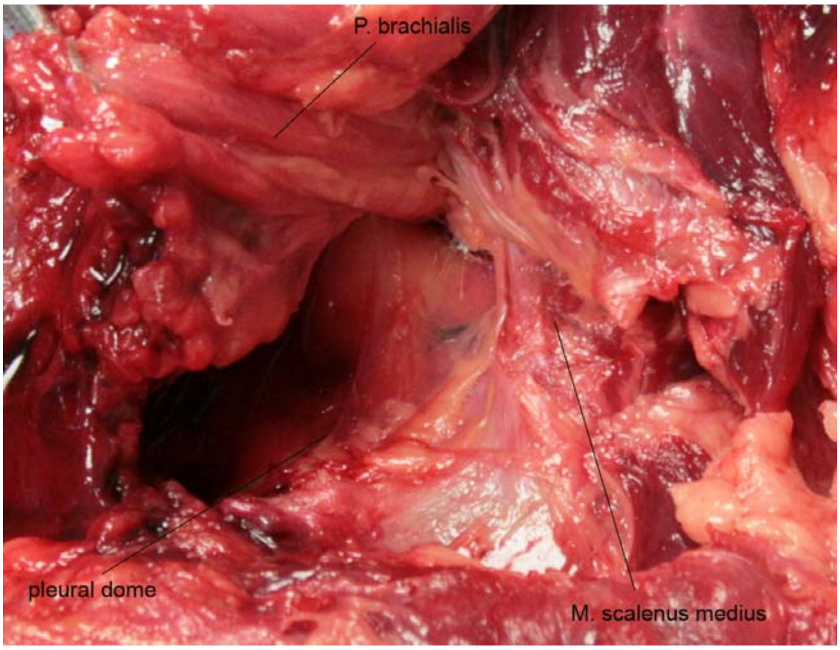

Figure 60: *The pleural dome on the left side. The picture shows the insertion of the M. scalenus medius onto the pleural dome.*

8.19 Dissection nineteen

General remarks:

The body is male and has not been embalmed. The particularity of this preparation is that the tissue of the lungs is clearly visible. It can be recognized how far the apex of the lung reaches beyond the first rib. It is only possible to see this because the cadaver was frozen and at the moment of dissection the internal organs were still in a frozen state. Thus the lung did not collapse like it would normally do when air enters into the pleural gap.

Right side:

The *M. scalenus anterior* is well-developed and does not send any fibres towards the *pleural dome*. The *M. scalenus medius* has a broad insertion onto the first rib and also clearly inserts into the *pleural dome.* Removal of the *A. subclavia* and *brachial plexus* exposes the *pleural dome*. It is very delicate in this case. Neither a *ligament* nor a *M. scalenus minimus* are visible. The *M. scalenus medius* which is broadly fanned out and has a clear insertion onto the *pleural dome* is very interesting.

Left side:

Also on this side the *M. scalenus anterior* is well-developed but in contrast to the right side the left muscle sends fibres into the *pleural dome*. The *A. subclavia* and *P. brachialis* can be easily removed from the *pleural dome*. Like on the other side the *M. scalenus medius* is fanned out broadly and inserts onto the first rib. It also merges with the posterior portion of the *pleural dome*. The *pleural dome* is very delicate and covered only by little connective tissue. Neither a *ligament* nor a *M. scalenus minimus* are present.

	Lig. vertebro-pleurale	**Lig. transverso-pleurale**	**Lig. costo-pleurale**	**M. scalenus minimus**	**M. scalenus anterior**	**M. scalenus medius**
Right	**0**	**0**	**0**	**0**	**0**	**1**
Left	**0**	**0**	**0**	**0**	**1**	**1**

Table 20: *Results of the nineteenth dissection*

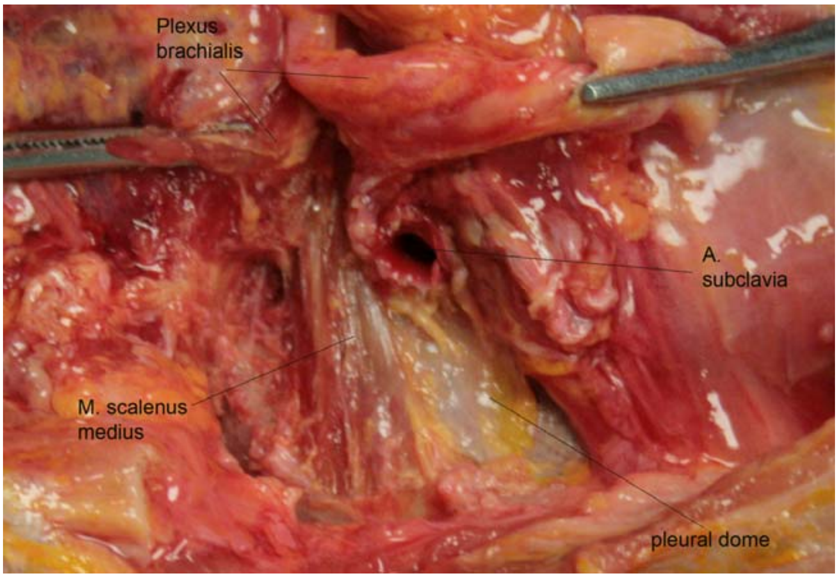

Figure 61: *The pleural dome on the right side which can be recognized as thin shiny layer.*

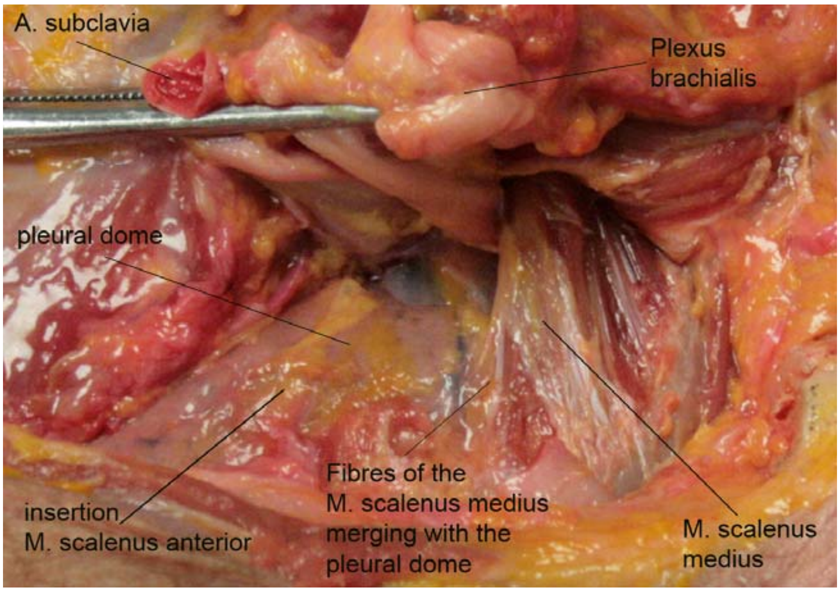

Figure 62: *The pleural dome on the left side. The picture illustrates the insertion of the M. scalenus medius onto the pleural dome.*

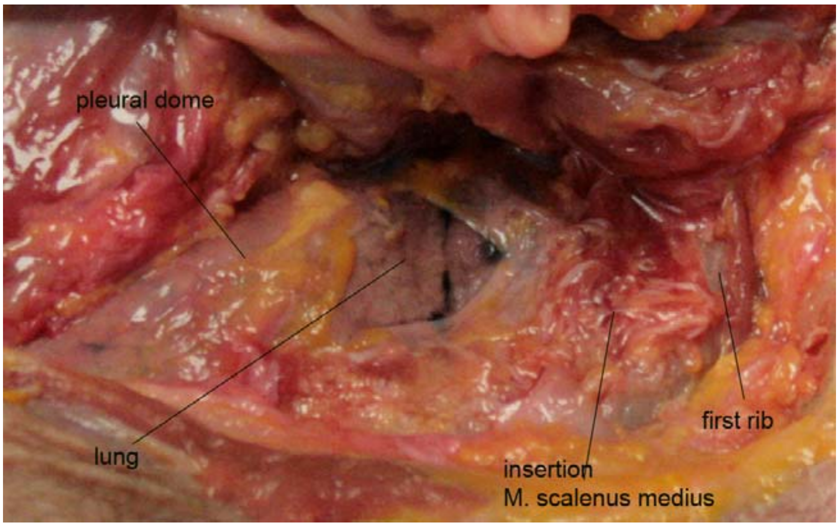

Figure 63: *The pleural dome on the left side. The pleural dome has been opened to expose the tissue of the lung. This is only possible because the lung is still frozen. If this was not the case, the lung would have collapsed after the pleura had been opened.*

8.20 Dissection twenty

General remarks:

Embalmed male body

Right side:

The *M. scalenus anterior* is only weakly developed and inserts onto the first rib. It sends fibres towards the *pleural dome*. The *M. scalenus medius* is well-developed and inserts onto the first rib and also sends fibres into the *pleural dome*. After the removal of the *A. subclavia* and the *P. brachialis* a structure with a length of 35.39 mm and a breadth of 3.36 mm is exposed. It originates at the transverse process of C7 and inserts onto the *pleural dome*. This structure is the *Lig. transversopleurale.* The *pleural dome* is covered by connective tissue.

Left side:

The *M. scalenus anterior* is weakly developed and inserts only onto the first rib. The *M. scalenus medius* has a broad insertion onto the first rib and also sends fibres into the *pleural dome*. Removal of the *A. subclavia* and *P. brachialis* exposes a well-developed *M. scalenus minimus* which has a broad insertion onto the *pleural dome* and also attaches onto the internal surface of the first rib. No other *ligament* could be detected.

	Lig. vertebro-pleurale	**Lig. transverso-pleurale**	**Lig. costo-pleurale**	**M. scalenus minimus**	**M. scalenus anterior**	**M. scale-nus medius**
Right	**0**	**1**	**0**	**0**	**1**	**1**
Left	**0**	**0**	**0**	**1**	**0**	**1**

Table 21: *Results of the twentieth dissection*

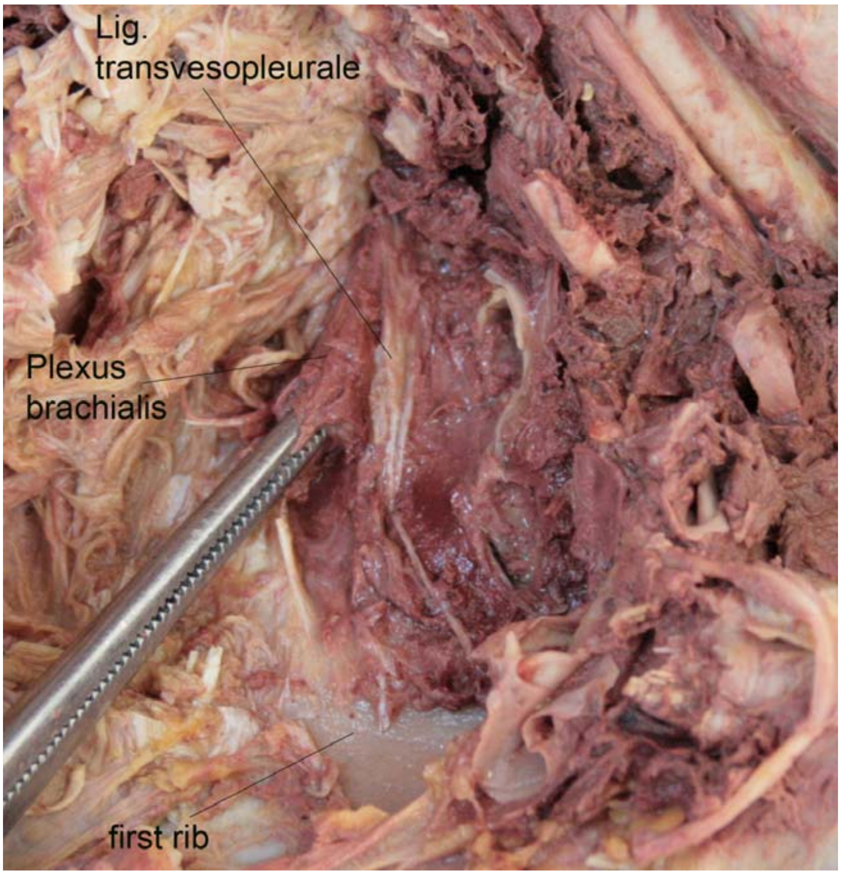

Figure 64: *The pleural dome on the right side. A Ligamentum transversopleurale can be detected. It originates at the transverse process of C7 and merges with the pleural dome.*

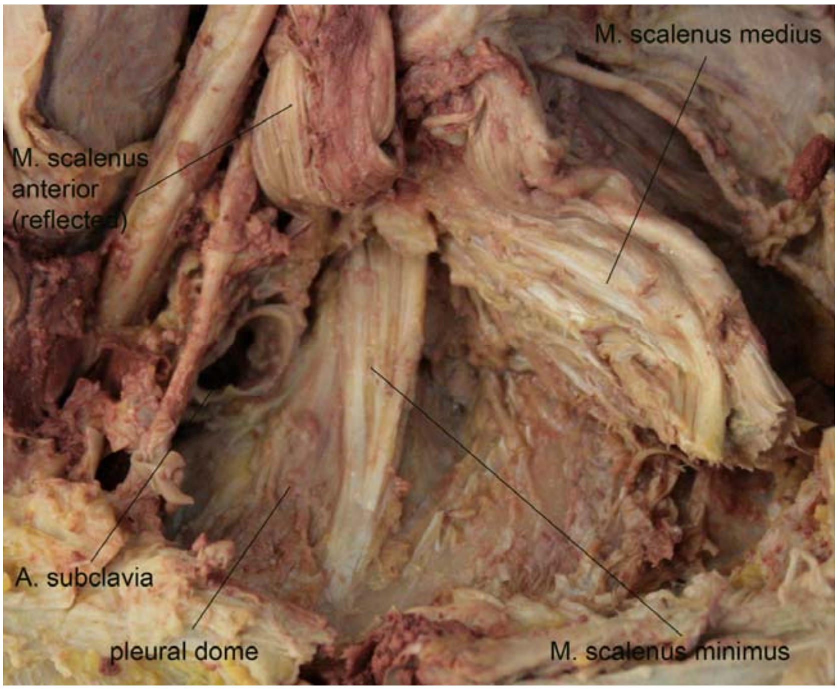

Figure 65: *The pleural dome on the left side. It presents a well-developed M. scalenus minimus which has a broad insertion onto the pleural dome and also has a small insertion onto the first rib.*

9 The results of the statistical analysis

9.1 Data Evaluation

Descriptive Statistic

Observed and relative frequencies of the findings (identified = "yes"/ not identified = "no") will be tabularized and graphically displayed for each state of preservation ("embalmed"/ "not embalmed"). Additionally, 95%-confidence intervals (95%CI) for unknown relative frequency of occurrence of the anatomic structures and unknown variance will be calculated. Under the presumption, that samples characterize the population adequately, these 95%-confidence intervals describe the range of relative frequencies of findings. The actual percentage of findings will be observed within in 95% of all samples drawn from the total population. That means, in only 5% of such samples, percentages exceeding the limits, will be found.

Statistical tests

In order to visualize possible artifacts which might be caused by preservation, mean percentage of the finding of the anatomic structures will be compared by statistical tests with the finding as the dependent variable (identified/ not identified) and the preservation state (embalmed/ not embalmed) as the independent variable.

With regard to the data characteristics, χ^2-tests will be used. Precondition for Pearson's χ^2-tests, which are most common for nominal data of this kind, is, that expected frequencies of < 5 are calculated for less than 20% of the individual cells and that no individual observed frequency is lower than one. Since these criteria are not met in most of the data sets, results of Fisher's exact test, for that these assumptions do not apply to, will be considered, instead.

Level of significance is chosen with $\alpha = 0.05$ and tests will be performed two-tailed.

Software used for the evaluation is SPSS® 12.0.0.

9.2 The statistical analysis concerning the detected ligaments

Ligamentum vertebropleurale

The number of findings of the *Ligamentum vertebropleurale* is summarized in *Fig. 66*.

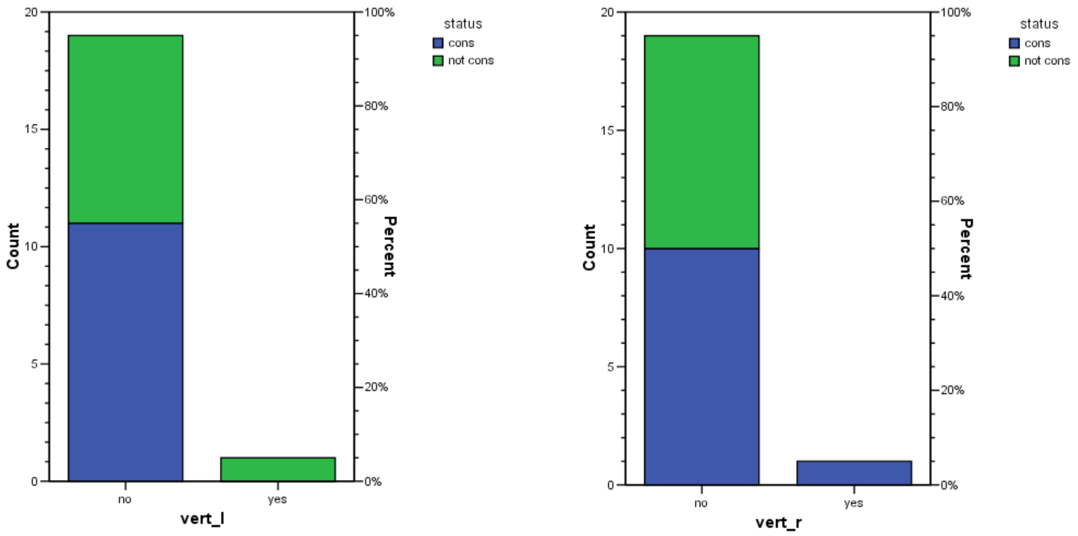

Fig. 66: *Each Ligamentum vertebropleurale, the left and the right, could be observed only once, each.*

In the following two tables, results are contrasted, in how many of the embalmed and not embalmed dissections, the *Ligamentum vertebropleurale* could be identified (left *Ligamentum vertebropleurale*: Table 2222, right one: Table 233).

Lig. vertebropleurale left		emb	not emb	total
n	No	11	8	19
	Yes	0	1	1
%	no	100	88.9	95.0
	yes	0	11.1	5.0
95% CI	yes	0.0 - 25.9%	2.0 - 43.5%	0.9 - 23.6%

Table 22: *Numbers of the findings of the left Ligamentum vertebropleurale in embalmed ("emb"), not embalmed dissections ("not emb") and in total.*

The left *Lig. vertebropleurale* could be identified in only one (“not embalmed”) of 20 dissections (rel. frequency: 5%, 95%CI: 0.9% - 23.6%). That means, in 95% of all samples, the left *Lig. vertebropleurale* can be identified in 1% to 24% of the sample dissections.

There is no significant difference between embalmed and not embalmed dissections in the number of finding the left *Lig. vertebropleurale* (χ^2 = 1.287 und p = 0.26). Fisher's exact test results in p = 0.45. That means, no significant differences can be observed by means of this test either.

Lig. vertebropleurale right		emb	not emb	total
n	no	10	9	19
	yes	1	0	1
%	no	90.9	100	95.0
	yes	9.1	0	5.0
95% CI	yes	1.6 - 37.7%	0.0 - 29.9%	0.9 - 23.6%

Table 23: *Numbers of the findings of the right Ligamentum vertebropleurale in embalmed ("emb"), not embalmed dissections ("not emb") and in total.*

Also the right *Lig. vertebropleurale* could be identified in only one (in this case embalmed) dissection of 20 (rel. frequency: 5%, 95%CI: 0.9% - 23.6%). That means, in 95% of all samples, the right *Lig. vertebropleurale* can be identified in 1% to 24% of the sample dissections.

There is no significant difference between embalmed and not embalmed dissections in the number of finding the right *Lig. vertebropleurale* (χ^2 = 0.861 und p = 0.35). Fisher's exact test results in p = 1.00. That means, no significant differences can be observed by means of this test either.

Ligamentum transversopleurale

The number of findings of the *Ligamentum transversopleurale* is summarized in *Fig. 67*.

No observations at all.

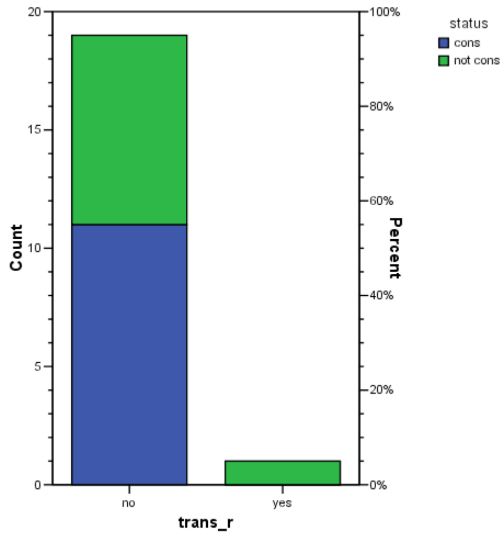

Fig. 67: *The left Ligamentum transversopleurale could not be identified in any of the 20 sample dissection, the right Ligamentum transversopleurale only once*

In the following two tables, results are contrasted, in how many of the embalmed and not embalmed dissections, the *Ligamentum transversopleurale* could be identified (incidence of left *Ligamentum transversopleurale* is listed in Table 24, and incidence of right *Ligamentum transversopleurale* is listed in Table 25).

Lig. transversopleurale left		emb	not emb	total
N	no	11	9	20
	yes	0	0	0
%	no	100	100	100
	yes	0	0	0
95% CI	yes	0.0 - 25.9%	0.0 - 29.9%	0.0 - 16.1%

Table 24: *Numbers of the findings of the left Ligamentum transversopleurale in embalmed ("emb"), not embalmed dissections ("not emb") and in total.*

The existence of the left *Lig. transversopleurale* could not be proved in any of the 20 dissections (95%CI: 0.0%-16.1%). Thus, no test could be performed.

Lig. transversopleurale right		emb	not emb	total
N	no	11	8	19
	yes	0	1	1
%	no	100	88.9	95.0
	yes	0	11.1	5.0
95% CI	yes	0.0 - 25.9%	2.0 - 43.5%	0.9 - 23.6%

Table 25: *Numbers of the findings of the right Ligamentum transversopleurale in embalmed ("emb"), not embalmed dissections ("not emb") and in total.*

Also the right *Lig. transversopleurale* was identified in only one (in this case, not embalmed) dissection of 20 (rel. frequency: 5%, 95%CI: 0.9% - 23.6%). That means, in 95% of all samples, the right *Lig. transversopleurale* can be identified in 1% to 24% of the sample dissections.

There is no significant difference between embalmed and not embalmed dissections in the number of finding the right *Lig. transversopleurale* ($\chi^2 = 1.287$ und $p = 0.26$). Fisher's exact test results in $p = 0.45$. That means, no significant differences can be observed by means of this test either.

Ligamentum costopleurale

The number of findings of the *Ligamentum costopleurale* is summarized in *Fig. 68*.

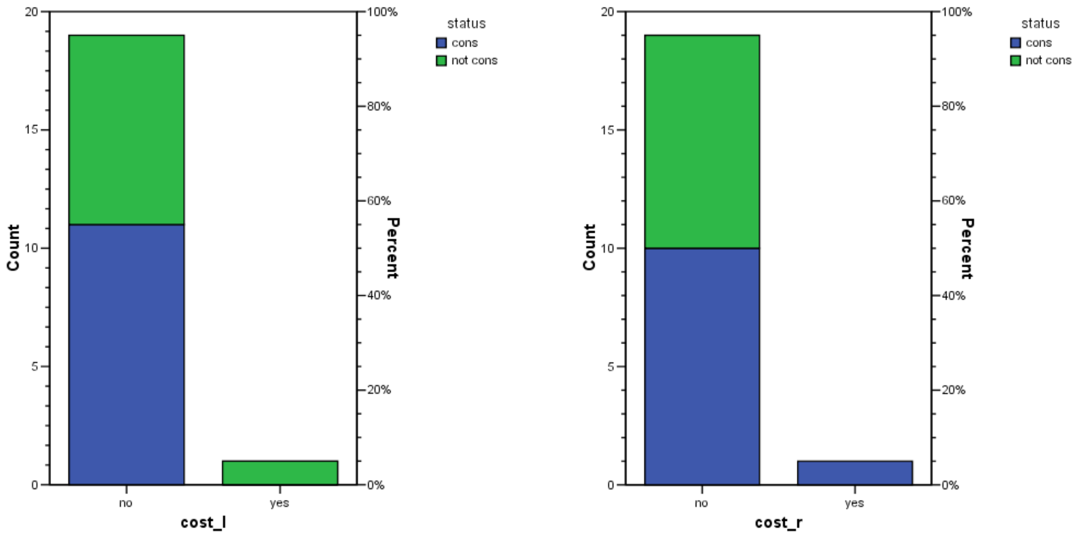

Fig. 68: *The left and right Ligamentum costopleurale could only be observed once respectively.*

In the following two tables, results are contrasted, in how many of the embalmed and not embalmed dissections, the *Ligamentum costopleurale* could be identified (left *Ligamentum costopleurale*: Table 26, right one: Table 27).

Lig. costopleurale left		emb	not emb	total
n	no	11	8	19
	yes	0	1	1
%	no	100	88.9	95.0
	yes	0	11.1	5.0
95% CI	yes	0.0 - 25.9%	2.0 - 43.5%	0.9 - 23.6%

Table 26: *Numbers of the findings of the left Ligamentum costopleurale in embalmed ("emb"), not embalmed dissections ("not emb") and in total.*

The left *Lig. costopleurale* could be identified only in one (not embalmed) of 20 dissections (rel. frequency: 5%, 95%CI: 0.9% - 23.6%). That means, in 95% of all samples, the left *Lig. costopleurale* can be identified in 1% to 24% of the sample dissections.

There is no significant difference between embalmed and not embalmed dissections in the number of finding the left *Lig. costopleurale* (χ^2 = 1.287 and p = 0.26). Fisher's exact test results in p = 0.45. That means, no significant differences can be observed by means of this test either.

Lig. costopleurale right		emb	not emb	total
n	no	10	9	19
	yes	1	0	1
%	no	90.9	100	95.0
	yes	9.1	0	5.0
95% CI	yes	1.6 - 37.7%	0.0 - 29.9%	0.9 - 23.6%

Table 27: *Numbers of the findings of the right Ligamentum costopleurale in embalmed ("emb"), not embalmed dissections ("not emb") and in total.*

Also the right *Lig. costopleurale* could be identified only in one (in this case not embalmed) dissection of 20 (rel. frequency: 5%, 95%CI: 0.9% - 23.6%). That means, in 95% of all samples, the right *Lig. costopleurale* can be identified in 1% to 24% of the sample dissections..

There is no significant difference between embalmed and not embalmed dissections in the number of finding the right *Lig. costopleurale* (χ^2 = 0.861 und p = 0.35). Fisher's exact test results in p = 1.00. That means, no significant differences can be observed by means of this test either.

9.3 The statistical analysis concerning the detected muscles

Musculus scalenus minor

The observations of insertions of the *Musculus scalenus minor* are summarized in *Fig. 69*.

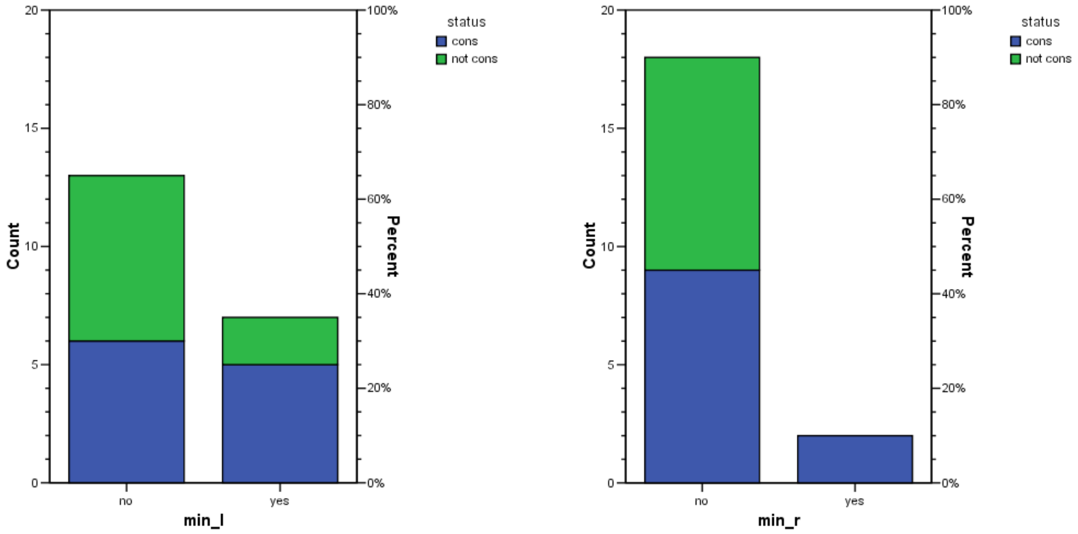

Fig. 69: *The left Musculus scalenus minor could be observed more often than the right one. Additionally, it could be identified more frequently in embalmed dissections.*

In the following two tables, results are contrasted, in how many of the embalmed and not embalmed dissections, the *Musculus scalenus min.* could be observed (left *Musculus scalenus min.* in Table 28 and right one in Table 29).

M. scalenenus min. left		emb	not emb	Total
n	no	6	7	13
	yes	5	2	7
%	no	54.5	77.8	65.0
	yes	45.5	22.2	35.0
95% CI	yes	21.3 - 72.0%	6.3 - 54.7%	18 - 57%

Table 28: *Numbers of the findings of the left Musculus scalenus min. in embalmed ("emb"), in*

not embalmed dissections ("not emb") and in total.

The left *m. scalenus min.* could be observed in seven of 20 dissections (rel. frequency: 35%, 95%CI: 18% - 57%). That means, in 95% of all samples, the left *m. scalenus min.* can be identified in 18% to 57% of the sample dissections.

Also in this case, no significant difference between embalmed and not embalmed dissections could be observed ($\chi^2 = 1.174$ und $p = 0.28$). Fisher's exact test results in $p = 0.37$. That means, no significant differences can be observed by means of this test either.

m. scalenenus min. Right		emb	not emb	total
n	No	9	9	18
	yes	2	0	2
%	no	81.8	100	90.0
	yes	18.2	0	10.0
95% CI	yes	5.1 - 47.7%	0.0 - 29.9%	3 - 30%

Table 29: *Numbers of the findings of the right Musculus scalenus min. in embalmed ("emb"), in not embalmed dissections ("not emb") and in total.*

The right *Musculus scalenus min.* could be observed in only two (embalmed) dissections of 20 (rel. frequency: 10%, 95%CI: 3% - 30%). That means, in 95% of all samples, the right *Musculus scalenus min.* can be identified in 3% to 30% of the sample dissections

There is no significant difference between embalmed and not embalmed dissections in the number of finding insertions of the right *Musculus scalenus min.* ($\chi^2 = 1.818$ and $p = 0.18$). Fisher's exact test results in $p = 0.48$. That means, no significant differences can be observed by means of this test, either.

Musculus scalenus anterior

The observations of insertions of the *Musculus scalenus anterior* are summarized in *Fig. 70*.

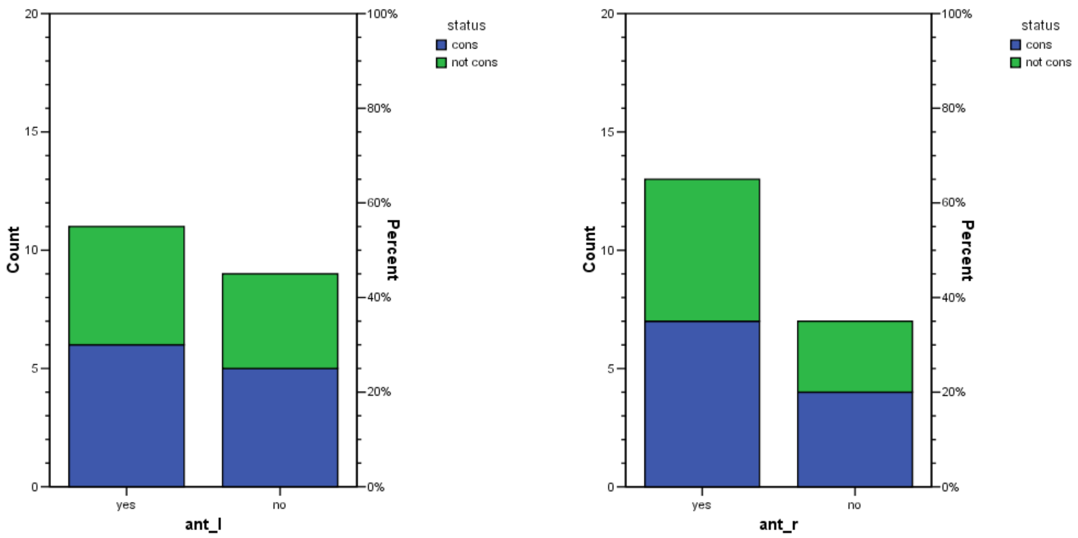

Fig. 70: *Insertions of the right Musculus scalenus anterior could be observed more often, than insertions of the left one, independently from preservation status.*

In the following two tables, results are contrasted, in how many of the embalmed and not embalmed dissections, an insertion of the *Musculus scalenus ant.* onto the *pleural dome* could be observed (left *Musculus scalenus ant.* are listed in Table 30 and the right *Musculus scalenus ant.* is listed in Table .

m. scalenenus ant. left		emb	not emb	total
n	no	5	4	9
	yes	6	5	11
%	no	45.5	44.4	45.0
	yes	54.5	55.6	55.0
95% CI	yes	28.0 - 78.7%	26.7 - 81.1%	34 - 74%

Table 30: *Numbers of the findings of insertion of the left Musculus scalenus ant. into the pleural dome in embalmed ("emb"), in not embalmed dissections ("not emb") and in total.*

Insertion of the *left m. scalenus ant.* could be observed in 11 of 20 dissections (rel. frequency: 55%, 95%CI: 34% - 74%). That means, in 95% of all samples, insertions of the left *m. scalenus ant.* can be identified in 34% to 74% of the sample dissections .

Also in this case, no significant difference between embalmed and not embalmed dissections could be observed (χ^2 = 0.002 und p = 0.96). Fisher's exact test results in p = 1.00. That means, no significant differences can be observed by means of this test, either.

m. scalenenus ant. right		emb	not emb	total
n	no	4	3	7
	yes	7	6	13
%	no	36.4	33.3	35.0
	yes	63.6	66.7	65.0
95% CI	yes	35.4 - 84.8%	35.4 - 87.9%	43 - 82%

Table 31: *Numbers of the findings of insertion of the right Musculus scalenus ant. into the pleural dome in embalmed ("emb"), in not embalmed dissections ("not emb") and in total.*

Insertion of the right *Musculus scalenus ant.* could be observed in 13 (embalmed as well as not embalmed) dissections of 20 (rel. frequency: 65%, 95%CI: 43% - 82%). That means, in 95% of all samples, insertions of the right *Musculus scalenus ant.* can be identified in 43% to 82% of the sample dissections.

There is no significant difference between embalmed and not embalmed dissections in the number of finding insertions of the right *Musculus scalenus ant.* (χ^2 = 0.20 und p = 0.89). Fisher's exact test results in p = 1.00. That means, no significant differences can be observed by means of this test either.

Musculus scalenus medius

The observations of insertions of the *Musculus scalenus medius* are summarized in *Fig. 71*.

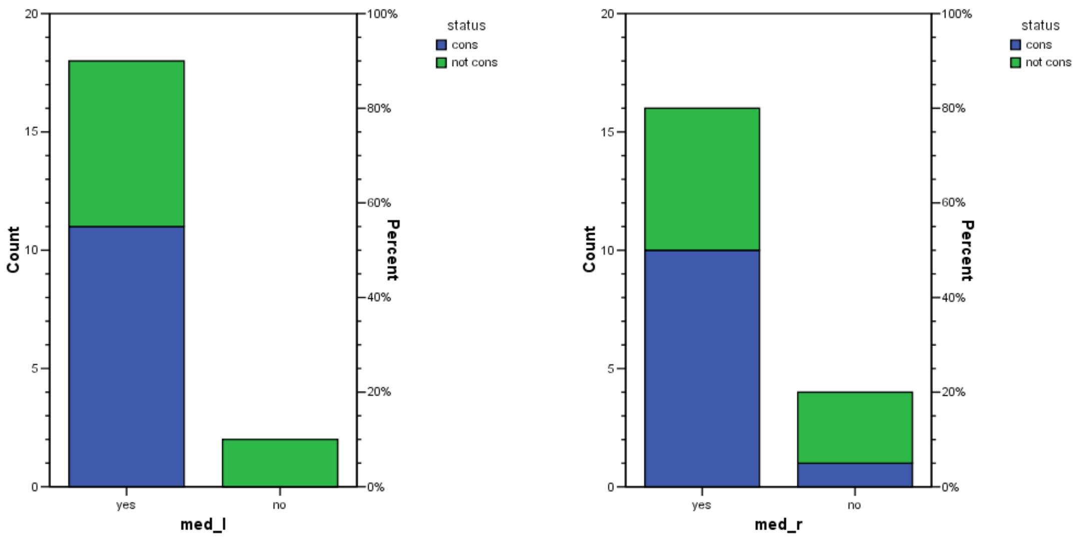

Fig. 71: *Insertions of the left Musculus scalenus medius could be observed more often, than insertions of the right one. In not embalmed dissections, negative results are more frequent.*

In the following two tables, results are contrasted, in how many of the embalmed and not embalmed dissections, an insertion of the *Musculus scalenus med.* onto the *pleural dome* ribs could be observed (left *Musculus scalenus med.* in Table 32 and the right *Musculus scalenus med.* in Table 33).

m. scalenus med. left		emb	not emb	total
n	no	0	2	2
	yes	11	7	18
%	no	0	22.2	10.0
	yes	100	77.8	90.0
95% CI	yes	74.1 - 100.0%	45.3 - 93.7%	70 - 97%

Table 32: *Numbers of the findings of insertion of the left Musculus scalenus med. into the pleural dome in embalmed ("emb"), in not embalmed dissections ("not emb") and in total.*

Insertions of the left *m. scalenus med.* could be observed in 18 of 20 dissections (rel. frequency: 90%, 95%CI: 70% - 97%). That means, in 95% of all samples, insertions of the left *m. scalenus med.* can be identified in 70% to 97% of the sample dissections.

Also in this case, no significant difference between embalmed and not embalmed dissections could be observed (χ^2 = 2.716 und p = 0.10). Fisher's exact test results in p = 0.19. That means, no significant differences can be observed by means of this test either.

m. scalenenus med. right		emb	not emb	total
n	no	1	3	4
	yes	10	6	16
%	no	9.1	33.3	20.0
	yes	90.9	66.7	80.0
95% CI	yes	62.3 - 98.4%	35.4 - 87.9%	58 - 92%

Table 33: *Numbers of the findings of insertion of the right Musculus scalenus med. onto the first and second rib in embalmed ("emb"), in not embalmed dissections ("not emb") and in total.*

Insertion of the right *Musculus scalenus med.* could be observed in 16 (embalmed as well as not embalmed) dissections of 20 (rel. frequency: 80%, 95%CI: 58% - 92%). That means, in 95% of all samples, insertions of the right *Musculus scalenus med.* can be identified in 58% to 92% of the sample dissections.

There is no significant difference between embalmed and not embalmed dissections in the number of finding ob insertions of the right *Musculus scalenus med.* (χ^2 = 1.818 und p = 0.18). Fisher's exact test results in p = 0.29. That means, no significant differences can be observed by means of this test either.

9.4 Summary

The Ligaments

The right and left *Ligamentum vertebropleurale*, the right and left *Ligamentum costopleurale*, as well as the right *Ligamentum transversopleurale* respectively, could be identified in only one of 20 dissections (5%). According to the 95%-confidence intervals, in 95% of all samples, these structures can be observed in 1% - 24% of the dissections of these samples (cfFig. 72).

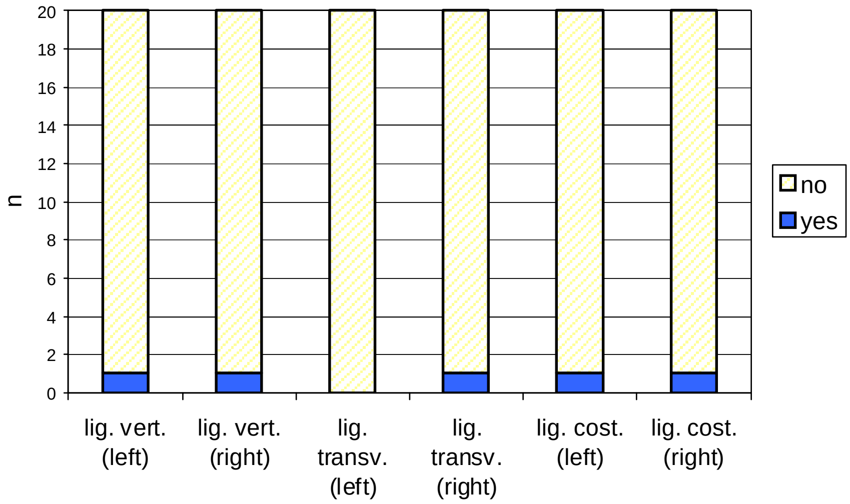

Fig. 72: *Observations of the individual Ligaments.*

The left *Ligamentum transversopleurale* could not be identified in any of the 20 dissections. According to the 95%-confidence intervals, in 95% of all samples, this structure can be observed in maximum 16% of the dissections of these samples.

The Muscles

The observations of insertions of the scalene muscles are summarized in *Fig. 73*.

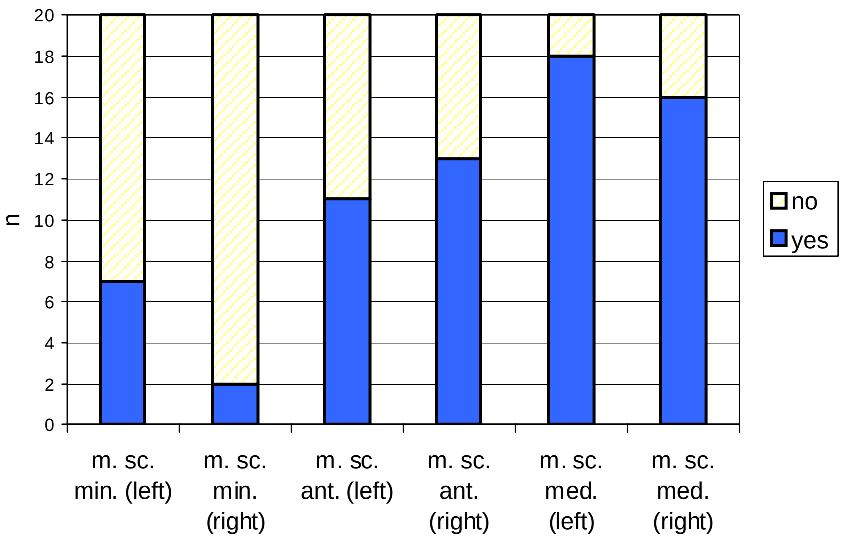

Fig. 73: *Observations of insertions of the scalene muscles.*

An insertion of the left *Musculus scalenus minimus* could be observed in seven of 20 dissections (35%), the insertion of the right *scalenus minimus* in two (10%). According to the 95%-confidence intervals, in 95% of all samples, an insertion of the left muscle can be observed in 18% - 57% of the dissections of these samples, an insertion of the right muscle in 3% - 30% of the dissections.

An insertion of the left *Musculus scalenus ant*. could be observed in 11 of 20 dissections (55%), the insertion of the right *anterior scalene muscle* in 13 (65%). According to the 95%-confidence intervals, in 95% of all samples, an insertion of the left muscle can be observed in 34% - 74% of the dissections of these samples, an insertion of the right muscle in 43% - 82% of the dissections.

Insertions of the left *Musculus scalenus med.* could be observed most often (18 of 20 dissections, 90%). According to the 95%-confidence interval, in 95% of all samples, an insertion of the left muscle can be observed in 70% - 97% of the dissections of these samples. The right *Musculus scalenus med.* could be observed in 16 of the 20 dissections (80%). According to the 95%-confidence interval, in 95% of all samples, an insertion of the left muscle can be observed in 58% - 92% of the dissections of these samples.

Influences by Preparation

No significant influences by artefacts, which might be caused by preservation of the dissections, can be observed on the number of findings of the examined anatomic structures.

10 Discussion

10.1 Discussion of the methodology applied in the statistical analysis

Statistical Evaluation

Sample size is low and thus confidence intervals are wide. Especially, in the cases, when they are calculated for only one or even no single observation, these limits cannot be guaranteed and have to be interpreted as estimations.

Low sample size and data characteristics additionally influence the results of χ^2-tests: Pearson's χ^2-tests are inappropriate, because expected frequencies are <5 and/or observed frequency is lower than one for at least one cell. Since these assumptions do not apply to Fisher's exact tests, they were used for evaluation.

10.2 Discussion of the results

The summary of chapter 9 shows that especially the group of the scalene muscles contributes to the build-up of the *pleural dome.* If the *M. scalenus minimus* is present it has an important influence on the *pleural dome.*

Most frequently the *M. scalenus medius* sends fibres into the *pleural dome.* However, the size of this connection can vary considerably. It ranges from only a few fibres that merge with the *pleural dome* (cf. 8.11 dissection eleven) to a portion of the muscle that branches off to merge with the *pleural dome* (cf. 8.9 dissection nine). The assumption that the *Fascia suprapleuralis* could be the end tendon of the *M. scalenus medius* (Shah 2005, cf. chapter 4.4) could not be confirmed.

Also the *M. scalenus anterior* often has a connection with the *pleural dome*, but its influence on the *pleural dome* is much less important in comparison with the *M. scalenus medius.* Concerning the size of connection with the *pleural dome* it is similar to the *M. scalenus medius*.

The *ligaments* of the *pleural dome* play a minor role. On average they are present in 1% to 24% of the cases, i.e. this is the range of probability that one *ligament* is present.

The probability that all three *ligaments* are present (as described in the osteopathic literature) is approximately zero. Thus the statements in the osteopathic literature, which give the impression that the *ligaments* of the *pleural dome* are constant structures, may be regarded as misleading. (In addition, it has to be pointed out that in the osteopathic literature any form of reference concerning the presence of these *ligaments* in the body and in how many cases they are actually present is lacking) The individual techniques that are described for treating these *ligaments* thus have to be considered with the utmost reservation because the probability to really treat a *ligament* with them is very small.

Assumptions found in the anatomical literature describing the ligaments of the *pleural dome* as inconsistent structures (Zuckerkandl 1876 cf. chapter 4.5) and explaining that the development of these *ligaments* can vary very much (Hafferl 1939 cf. chapter 4.5) could be confirmed. Zuckerkandl is the only author in the anatomical literature who indicates how often these *ligaments* can be found in the body. Concerning the *Lig. costopleurale* the frequency indicated by Zuckerkandl figured within the statistical range that could be found in this study. With regard to the *Lig. costo-pleuro-vertebrale* (*Lig. vertebropleurale*) the frequency deviates increasingly upward.

Zuckerkandl's (1876 cf. chapter 4.5) and Merkel's (1899 cf. chapter 4.4) statements concerning the presence of a *Lig. vertebropleurale* (or *Lig. costo-pleuro-vertebrale*) to replace the *M. scalenus minimus* could not be confirmed. None of the cadavers examined in this study where a *M. scalenus minimus* was found on one side had a *Lig. vertebropleurale* on the other side.

Another finding of this study was that it did not make any difference whether the cadavers were embalmed or not. In both groups the *ligaments* could be detected equally often or rather equally infrequently.

The results of this study give reason to reconsider the osteopathic techniques that are applied for theses structures. Even though the application of the techniques can have satisfying effects, the explanation that the *ligaments* are treated with these techniques simply has to be considered as wrong in most of the cases.

The results of the 15th dissection, where neither ligaments nor muscles sending fibres into the pleural dome could be found, and the results of the 16th dissection, where only a M. scalenus minimus could be found on one side but no ligaments or other muscles attaching onto the pleural dome, give reason to investigate the suspension of the pleural dome in more detail.

Further anatomical studies in this direction are definitely required. Also anatomy courses in the dissection room can help answer many questions. If structures like the visceral *ligaments* or the so-called *diaphragm* of the *thoracic inlet* could be observed in dissection preparations many discussions would be superfluous. Or to put it in the words of Still:

"I had printed books, but went back to the great book of nature as a chief study." (Still 2000 page 84)

With that the circle closes and all that is left to do is to refer to the introduction which points out the importance of anatomy in osteopathy (cf. chapter 2.2).

11 Annex

11.1 List of figures:

Fig. 13: ZUCKERKANDL, E. (1876): Beitrag zur deskriptiven und topographischen Anatomie des unteren Halsdreiecks. Z. Anat. Page 54-69, Page 69

Fig. 14: ZUCKERKANDL, E. (1876): Beitrag zur deskriptiven und topographischen Anatomie des unteren Halsdreiecks. Z. Anat. Page 54-69, Page 69

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Fig. 18: BRIZON, CASTAING (1989) Les feuillets d`anatomie .Pour la préparation des concours hospitaliers et des examens de la faculté de médicine. Bd 14 Thorax Paris : Maloine. In Ligner 1998 „unveröffentl. Skript“

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Fig.45-47: SCHEITERBAUER, F. (2007): Laboratories of Anatomical Enlightment Inc. in Boulder/Colorado. All cadaver images are the property of Labratories for Anatomical Enlightment the Cadaver images are not to be reproduces in any way. To do so is both unlawful and ethically unacceptable

Fig. 48-65: SCHEITERBAUER, F. (2007): Anatomisches Institut Wien

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11.3 List of tables

11.4 List of abbreviations

A.,Aa	Arteria,ae	artery, arteries
Art	Articulatio	joint, articulation
C	cervical (cervical vertebra)	
M,Mm	Muskulus,I	muscle, muscles
N	Nervus	nerve
Lig	Ligamentum,a	ligament
Pl	Plexus	
Proc	Processus	process
Th	thoracic (D = dorsal vertebra)	
V.,Vae	Vena,ae	vein, veins