Endoscopic Surgery of the Potential Anatomical Spaces

Edited by
Attilio Maria Farinon

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ENDOSCOPIC SURGERY OF THE POTENTIAL
ANATOMICAL SPACES

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“And it ought to be remebered that there is nothing more difficult to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things. Because the innovator has for enemies all those who have done well under the old conditions, and lukewarm defenders in those who may do well under the new.”

N. Machiavelli: The Prince (Chapter VI), 1531

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Foreword

"Anatomical potential spaces" is an attractive and no more abstract concept that offers new perspectives to a surgical world that is rapidily changing and becoming more complex.
Powerful new technologies demand our attention and testify that our clinical work and research are deeply influenced by surgical innovations. These latter dramatically modified approaches to treatment through the introduction of entirely new interventions such as minimally invasive surgical procedures, whose real appeal is represented by less invasiveness.
This constantly evolving research environment has gained large acceptance by surgeons accustomed to prompt adaptation to a new trend and inclined to nimble behaviour in the face of innovations. This behaviour, however, requires a rigorous control in order to lead to more reliable, evidence-based practice and to slow or halt the enthusiasm for some harmful or unhelpful treatments, especially if they are proven to be no better than standard procedures.
This particular area of concern has received our attention: to understand whether innovations should be considered as evolutionary variations on a standard procedure or the first stage of what should become recognized as a formal surgical research project.

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CHAPTER 1

ANATOMICAL SPACES

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For they inquire of the parts…but they inquire not of the secrecies of the passages.

Francis Bacon, The Advancement of Learning, 1605

Francis Bacon found many deficiencies in medical science and in particular in 'the inquiry which is made by anatomy'. Four hundred years later, there are areas still inadequately recognised by standard topographical and surgical anatomy, though most of these areas have in the past attracted transient and subsequently forgotten interest. One such area is a true passage of secrecy: the anatomy of the potential anatomical spaces.

THE SEMANTICS OF SPACES

Despite the conventions of common usage, space is no longer simply a three-dimensional, topographical concept. For Kant (Kemp Smith, 1933) space was not a concept at all, but a pure *a priori* intuition, something which had to be accepted for the rest of his system to work. The addition of the indefinite article – from 'space' to 'a space'- may change the concept completely. One wonders how such a change may be expressed in languages which lack such an article: context must suffice. Today, the meaning of 'space' depends upon the realm in which it is used. Architectural space is functional: its control, delimitation and envisaged usage determines the shape of structures built to enclose or reveal it (Lym, 1980). Postmodern space encompasses the geographical (Diprose and

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Ferrell, 1991), the cultural (Perec, 1997) and the social. Non-Euclidean mathematical space (Sutherland 1975) is a virtual, multi-eponymous and multidimensional wonderland within which special properties appear. Electronic virtual space (Shields 1996) has its own vocabulary: cyberspace and hyperspace have emerged. What does a space mean in the realm of surgical anatomy?

Anatomical space

It is interesting that the earliest reference given in the Oxford English Dictionary to 'space' used in the particular sense of "a void or empty place or part" is an anatomical one, though non-human, from 1888, referring to "interlamellar spaces" (OED, 1989). Yet Erasmus Wilson was already using the word in human anatomy 50 years earlier, describing the "anterior space" of the perineum (Wilson, 1838).

Anatomists have had difficulty with the definition and concept of anatomical space. It may be that alternative words will be found more accurate in expressing the anatomical entity. 'Cavity' has its own accepted meaning; 'interval' has been suggested (Stockwell 1999). 'Compartment' may be more accurate (Newell 1999).

What then is an anatomical space? What do you see and understand when you hear the phrases 'deep perineal space', 'palmar space', 'submandibular space'? Is the 'space' here the same sort as the epidural or the subphrenic? Do you see such a space as an actual three-dimensional gap? If an anatomical space is not the same as an anatomical cavity (synovial, peritoneal), what defines the difference? Is it only semantic?

Potential space

This term is commonly used to describe a space which is not evident until it is created by distension or by blunt dissection. Grodinsky and Holyoke (1938) refer to potential fascial spaces without prior definition of the term. Haines (1991) defined a "true potential space" as "one that may be created without disrupting the normal structure/functional integrity of the tissues involved in the creation of the space......[and which is] lined by a mesothelium which is normally covered by small amounts of a serous fluid". Haines also notes that such spaces "may be *repeatedly* created and obliterated without resulting in tissue damage or requiring tissue repair". The potential spaces considered in this book would not satisfy these strict criteria.

It could however be argued that *all* 'anatomical spaces' are artefactual, and that 'potential space' is both an abstract concept and an oxymoron. Is there any 'space' there at all before the dissector or the disease allows fluid (gaseous or liquid) to accumulate and thereby to separate tissue planes?

Connective tissue planes whose adjacent surfaces are normally connected by a thin layer of relatively sparse, loose areolar tissue are not strictly 'potential spaces' even though the surfaces may easily be separated. Such separation entails tissue damage, albeit minimal. In Quain's Anatomy, the buccopharyngeal fascia was described as "connected behind to the prevertebral fascia only by very loose areolar tissue, the meshes of which are readily distended by fluid, thus giving rise to the *so-called* retropharyngeal space. The loose tissue is continued without interruption along the oesophagus into the thorax, so that the *artificial cavity* may be extended downwards into the posterior mediastinum". (Thane 1894; author's emphases).

Normal, traditional 'spaces' unlined with mesothelium but having substantial contents, like the palmar and perineal 'spaces', may be more correctly described anatomically as compartments, but custom and everyday clinical usage prevail over pedantic accuracy.

HISTORICAL USAGE

Spaces in the dead

Having examined the semantics and accepted the pragmatic concept of an 'anatomical space', let us look at the history of the usage of the phrase.

It has been suggested that anatomical 'spaces' were first recognised and defined only in the preserved cadaver, and that the concepts of fascial planes and structural spaces were developed as a consequence of the definition and concomitant shrinkage of tissues provided by formalin fixation. It has been said that "..in many cases ..the over-enthusiasm with which the new techniques were adopted resulted in structures being 'discovered' that did not in fact exist" (Dobson, 1956). There may thus have been false extrapolations to the living situation.

The use of formaldehyde as an animal tissue fixative and preservative for microscopy was first described by Blum (1893), and soon developed in Germany for the preservation of dissecting-room cadavers. Arthur Keith presented the experience of its use at the London Hospital to the May 1896 meeting of the Anatomical Society of Great Britain and Ireland. Keith noted that such fixation improved the cleanliness of the dissection and the definition of fibrous membranes (Keith 1896). Tissue shrinkage and the consequent creation of artefactual 'spaces' were not mentioned.

In a study of spinal epidural anatomy, Hogan (1991) tried to preclude the effects of post-fixation shrinkage by examining large cryomicrotome sections of unembalmed cadavers. He found that large areas of the dura were directly in contact with the wall of the vertebral canal, and that the remaining areas were composed of segmentally compartmentalised fat. There was no 'space', fluid-filled or otherwise.

Such 'spaces' are much less readily visualised in the post-mortem (autopsy) room, where the unembalmed tissues have not shrunk away from each other. Pathologists find cavities and spaces made by disease and injury. These may be true, mesothelial-lined 'cavities', opened up by pathological accumulation of fluid, or they may be artefactual spaces, pathological cleavage planes (Haines 1991) created by haemorrhage or other forms of tissue disruption. Fully differentiated connective tissue retains the potentiality for cleavage and cavity formation (Williams et al., 1985). The occurrence of adventitious bursae and pseudarthroses bears this out. The latter forms of 'cavity' become lined with their own 'secondary mesothelium', as do cavities developing around foreign bodies. In the absence of such a lining, pathological cleavage planes and other pathological 'spaces' will be obliterated by the healing process.

So what were anatomists seeing before the use of formalin fixation became widespread? Erasmus Wilson (1857) describes the fasciae of the body in great detail. While he notes that the aponeurotic ('deep') fascia "assists the muscles in their action, by keeping up a tonic pressure on their surface; aids materially in the circulation of the fluids in opposition to the laws of gravity", nowhere does he refer to the concept of 'spaces' limited by the fascial planes which he describes. Gray (1858) similarly describes fascial topography and attachments without reference to the 'spaces' enclosed. Richet (1866) describes the fascia-bound compartments of the limbs as we understand them today, but uses the term *gaîne* which is usually translated into English as 'sheath'. In a long and detailed treatment of the fasciae of the neck, Richet again describes the compartments which they enclose, but this time uses the term *loge*. The same term is employed to describe the perineal 'spaces'.

Quain's Anatomy (Thane 1894) describes the 'suprasternal space' between the layers of the deep cervical fascia, but in the leg, though the fasciae are described in detail, there is no reference to a concept of compartments or 'spaces'.

Treves (1908) describes the intermuscular septa in the leg as 'forming a closed space which might become a definite and well localised cavity for pus'. Grodinsky and Holyoke (1938) suggest that the concept of fascial spaces dates back at least to Juvara (1870).

Spaces in the living

At operation, anatomical 'spaces' and 'planes' need to be opened up by dissection before their shape and extent can be demonstrated. The dissection may be blunt, as for 'true' cavities or for planes filled with loose areolar connective tissue. It may even consist only of the insertion of a finger or hand: for endoscopic procedures the 'body cavities' are opened up by the prior introduction of gas or saline. An active physical process is always required to separate adjacent tissues previously in contact with each other.

Can anatomical ‘spaces’ be demonstrated in the intact living subject by non-interventional techniques? Again, the problem is the meaning of the word ‘space’. Sargon et al. (1996) examined radiological ‘spaces’ in joints, on MRI of the knee. In only one place, half-way through the paper, does the word ‘space’ appear in quote marks. The authors acknowledge that they use the term ‘joint space’ to include (as the technique is MRI) both layers of cortical bone, as well as all non-osseous structures lying between the bone surfaces. In general terms it would seem that the ‘potential’ soft-tissue spaces can only be demonstrated non-interventionally by the relative radiodensity of their boundaries and contents.

SURGICAL ANATOMY OF THE POTENTIAL SPACES

Spaces and fasciae: the boundaries of the space and the relevant fascial planes

The surgeon must know what defines and limits the particular space. This includes the nature and topography of the tissues which form the ‘walls’ of the space. It is also of great importance to know whether surgical access may be required to structures which run in or lie on these walls.

In the neck and in the limbs, the spaces are bounded by fascial planes. Remembering that all fasciae are continuous and embryologically precede the contents of the spaces they limit, it may be useful to think in terms of a ‘fascial skeleton’. In the limbs, the concept perhaps originates with Xavier Bichat, and was developed by Richet (1866) as a ‘Fibrous System’. Bichat had earlier described ‘*aponévroses d’enveloppe générale et partielle*’. Richet mentions a collection of prosections by eminent French surgeons and anatomists, made specifically to demonstrate fascial compartments in the limbs, showing that: “the whole thickness of the limb between the encircling fascia and the bone is divided into as many fibrous compartments as there are muscles”. Later he recognises the fact that “in addition to the fascial coverings particular to each muscle, other fascial membranes are found which clearly separate…groups of muscles having similar functions, such as the peronei” (author’s translation).

Following Bichat, Richet also uses the term *cloison* to denote a fibrous partition-wall. In the same chapter, Richet gives possibly the earliest description of compartment syndrome, and in discussing its management gives the true and original meaning of *débridement*.

The concept of a fascial skeleton as a biomechanically functional system has been explored much more recently by Gerlach and Lierse (1990). Despite giving great detail of shape and fibre direction of all lower limb fasciae, the authors only mention in passing the fascial 'cavities' in which the muscles are contained.

The potential space and the surgical space

The true shape and size of the potential space must be known or demonstrable. It may not be necessary fully to distend the space in order to obtain adequate endoscopic access, but information about its dimensions from prior imaging may be helpful. It must also be known before distending and opening the space whether any anatomical structure is likely to pass through it and cross the field of view.

Is the space closed or open?

Richet (1866) described the continuity of the anatomical compartments via defects or foramina in the walls for the passage of nerves and vessels. Grodinsky and Holyoke (1938) describe multiple communications between potential fascial spaces in the head and neck. The surgical implications and possible use of such pathways have been recognised by Tucci et al (2000). The surgeon must know the landmarks which will enable such openings to be localised, entered and where necessary enlarged from within the space.

SURGICAL ACCESS

Opening or creating the space: techniques and consequences

An active physical process (dissection, distension or disease) is always required to separate the tissues and open up a potential space, so endoscopic access will require prior distension or creation of the 'space'. It will also be necessary to develop and refine methods of travelling between spaces via natural or surgically created pathways (Tucci et al 2000).

One of the major concerns relating to the exploration of potential spaces is the effect of the surgical intervention on the subsequent anatomy and function of the 'space'. In the absence of a 'mesothelial' lining (Haines 1991), loose and often sparse areolar tissue lies between fascial planes and may be said originally to 'occupy' the potential space. This areolar tissue allows movement to occur between the fascial planes. Surgical distension and dissection within the created space must cause an element, however minimal, of tissue damage. Adhesions may then develop and preclude repeated access to the same 'space'. It was part of Haines' (1991) definition of 'true' potential spaces that they "may be *repeatedly* created and obliterated without resulting in tissue damage or requiring tissue repair".

ANATOMICAL SPACES IN THE FUTURE

As we have seen, Bichat and Richet gave us the concept of the fascial skeleton in the 19th century. We are now seeing the recognition of the importance of the spaces enclosed, in the widest sense, by that skeleton. It is encouraging that anatomical spaces are now being given due regard in the design of computerised anatomical models (Mejino and Rosse 1999).

Historically the development of anatomical knowledge has both underpinned and run in parallel with that of the craft and science of surgery. Yet again, as recognised by Fontaine (2000), refinements in surgical technique are giving renewed life to a forgotten area of topographical anatomy – the anatomy of the hidden spaces. We are at last discovering the secrecies of the passages.

Some of the above material has been published in a review article by the author: Anatomical Spaces: a Review. Newell RLM Clinical Anatomy 12/1 © 1999 John Wiley and Sons, Inc.

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CHAPTER 2

RADIOLOGY OF THE ANATOMICAL COMPARTMENTS

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PREFACE

The study of the sectional anatomy of the human body goes back to the earliest days of systematic topographical anatomy. The beautiful drawings of the sagittal sections of the male and female trunk by Leonardo da Vinci (1452-1519), based on some 30 dissections, are examples of the use of body sections for the study of anatomy. These drawings anticipate modern techniques by several hundred years [1, 2].

The obstacle to detailed sectional anatomical studies was, of course, the problem of fixation of tissues during the cutting process.

The use of formalin as a preserving fluid was then introduced by Gerota in 1895 and it was soon found to be the method to obtain satisfactory sections of formalin hardened material.

The early years of the 20th century saw the publication of a number of atlases based on this technique.

It is always difficult to consider three dimension in the mind's eye, to be able to view the relationships of the viscera and fascial planes in transverse and vertical section helps to clarify the conventional appearances of the body's structure as seen in the operating theatre, in the dissecting room and in text books.

The introduction of modern imaging techniques, especially Ultrasound, Computed Tomography (CT) and Magnetic Resonance Imaging (MRI), has enormously expanded the already considerable importance of sectional anatomy.

The radiologist, neurologist, internist, chest physician and oncologist have now a clear idea of the relationships of the anatomical structures in transverse and vertical section, also helped by 3D imaging.

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Indeed, precise diagnosis, as well as the detailed planning of therapy and of interventional radiology, often depends on a correct cross-sectional approach [3].

COMPUTED TOMOGRAPHY (CT)

The technological advances that have occurred in the biomedical fields since the late 1980s have led to the diffusion of CT units with increasingly short scanning times [1-4].

The advent of spiral CT has represented a true breakthrough in clinical medicine.

This scanning technique, which is based on the continous transition of the patient and the simultaneous rotation of the tube-detector system, allows the acquisition of body volumes.

The advantages of this technique are:

– Optimisation of the X-ray tube: with the same energy load used in spiral CT, multislice can acquire large volumes of thin slices, or perform with multiphasic studies on large volumes without interrupting the scans.

– Improved temporal resolution: compared with spiral CT, multislice CT can acquire 4 slices (today even 16 slices per rotation and 32 slices per 1 second) per rotation; in other words, multislice CT covers a volume up to 8 times greater than spiral CT.

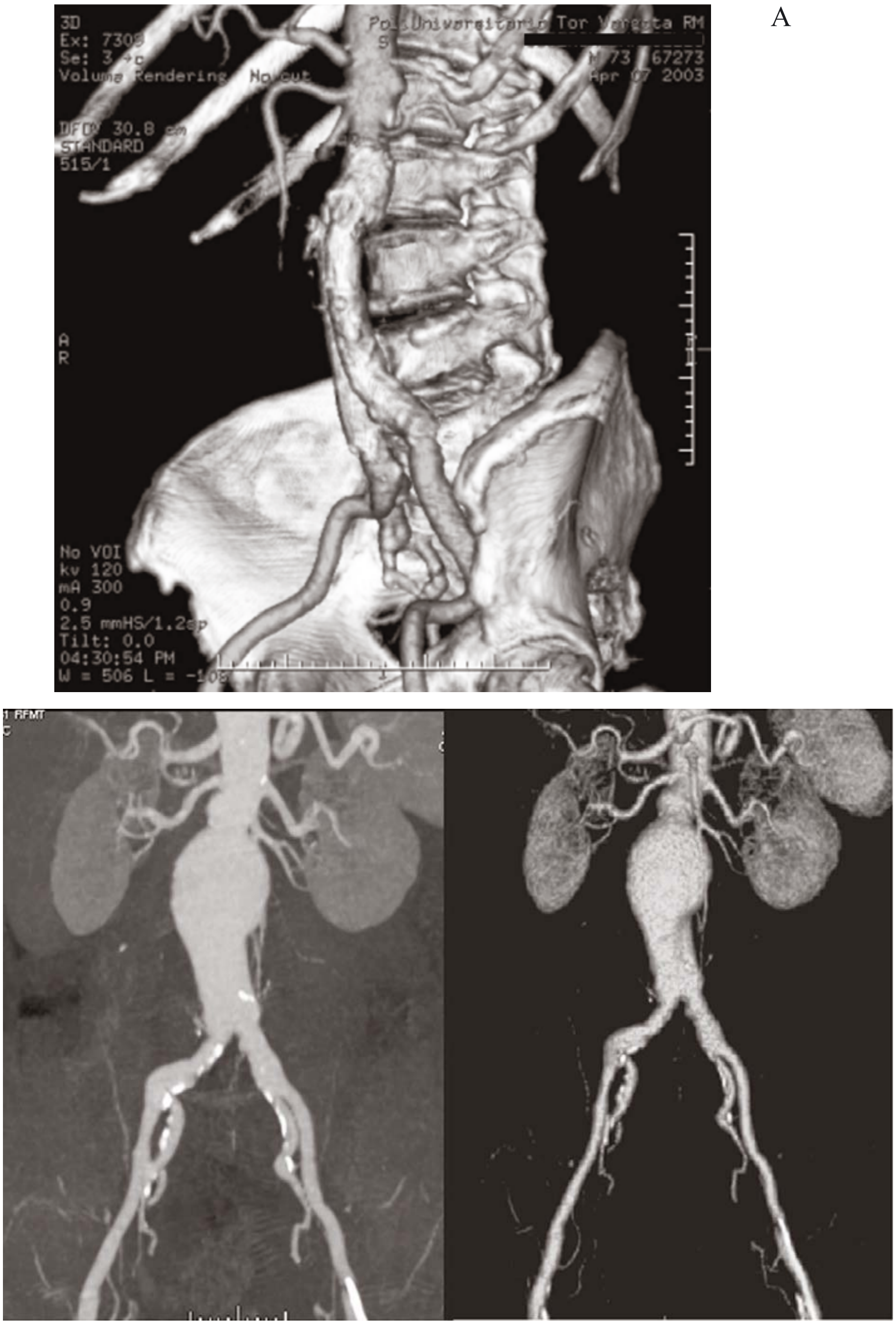
– Enhanced z-axis spatial resolution: the speed of multislice scanning allows one to cover large volumes with thin slices. With the aid of recostruction algorithms we can obtain a preserved slice profile and a noise reduction of 40%.

– Isotropic voxels: the possibility of acquiring very thin slices allows one to obtain voxels of the same size in the three spatial axes, with the appropiate recontruction FOV settings.

This advantage, combined with the possibility of back reformatting thin slices, affords high-quality 3D and multiplanar reconstructions, with excellent anatomical detail. (Fig. 1 - 2)

This is particularly useful in high-resolution applications, such as CT angiography of the circle of Willis pouch, in the study of pulmonary embolism, and CT angiography of the lower limbs, in musculo-skeletal applications (hand, hip, ankle), in the study of the ear and the facial bones.

A



B C

Figure1 Volume Rendering CT image of normal abdominal aorta (A).
Abdominal aortic aneurysm. MIP (B) and Volume Rendering CT (C) images.

Figure 2

Volume Rendering CT of the abdominal splanchnic and iliac arteries.

MAGNETIC RESONANCE IMAGING

The evolution of MRI to its present status has been gradual. A key milestone occurred when Lauterbur (1973) first revealed the imaging potential of MRI.

The physics of MRI is more complex than CT, even though the principles of picture elements (pixels) derived from volume elements (voxels) within the body are similar, along with the partial volume artefacts that can occur. Much of the competing and viewing software is similar; indeed many makes allow viewing of CT and MRI image on the same viewing console [2, 4].

The biggest and the more important component of an MRI system is the magnet.

The magnet of an MRI system is rated using a unit of measure known as a Tesla. Another unit of measure commonly used with magnets is the Gauss (1 Tesla = 10,000 Gauss). The magnets in use today in MRI are in the 0.5 T to 2.0 T range.

The fact that the MRI system does not use ionising radiation is a comfort to many patients, as is the fact that MRI contrast materials have a very low incidence of side effects.

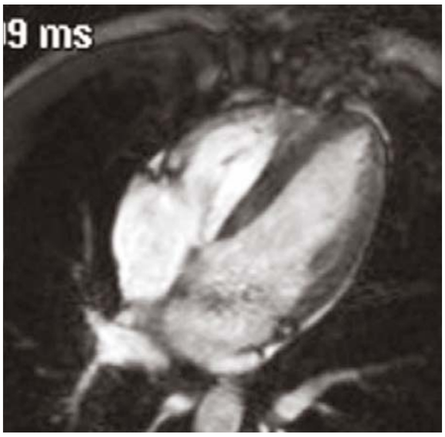
Another major advantage of MRI is its ability to image in any plane.

An MRI system can create axial images as well as images in the sagittal and coronal plane, or any degree in between, without the patient ever moving (fig.3).

Figure 3

Thoracic MRI: coronal (A), axial (B) and sagittal (C) planes.

A



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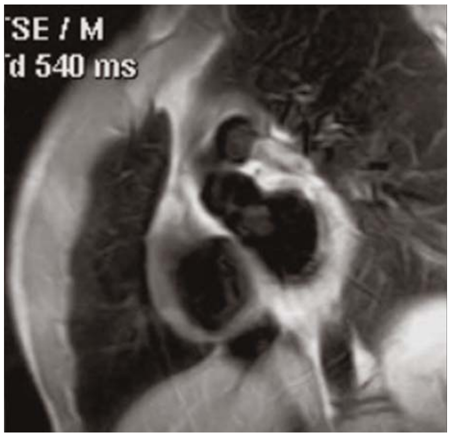


C

MRI is still in its infancy. MRI technology has been in widespread use for less than 20 years, compared with over 100 years for x-rays.

Recent technical advances in hardware and software have allowed the acquisition of MR images that are largely free of artifacts secondary to bowel peristalsis or respiratory motion; images providing excellent anatomical detail can now be obtained routinely. Fast sequences have reduced image acquisition time, thereby improving patient acceptance and allowing more efficient utilization of machine time. New three-dimensional sequences allow rapid image acquisition, reducing section misregistration and motion artifacts while improving multiplanar reformation [5].

THE NECK

The neck contains important communications between the head and the body, including air and food passages, major vessels and nerves and the spinal cord [4].

Its skeleton is primarily composed of the vertebral column. Anteriorly, the hyoid bone and laryngeal and tracheal cartilages support the aerodigestive spaces. These are suspended from the mandible and base of the skull by a system of muscles and ligaments.

Anteriorly, strap muscles connect the respiratory skeleton and sternum. There are also muscular attachments from the hyoid to the tongue, mandible, and styloid. The digastric muscle passes forward from the mastoid, attaches to the hyoid, then ascends to the anterior mandible (Fig. 4-5-6-7).

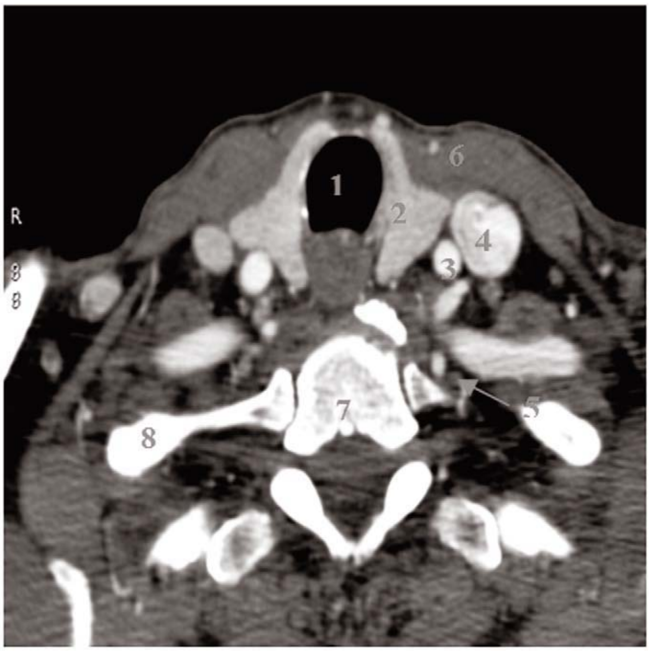


Figure 4 CT axial cervical section of neck region. Caudal level. 1 - Trachea; 2 - Left lateral lobe of the thyroid gland; 3 - Carotid Artery; 4 - Jugular vein; 5 - Vertebral vein and artery; 6 -Sternocleidomastoid; 7 - Vertebral body; 8 - Rib

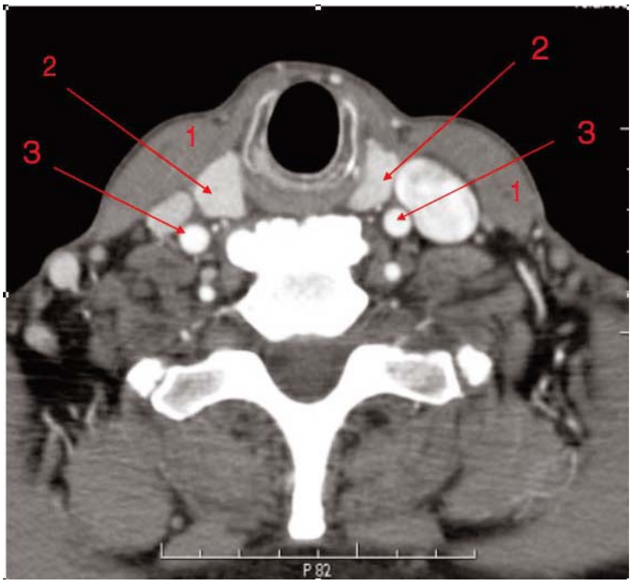


Figure 5 CT axial cervical section of neck region. Cranial level.
1 - Sternohyoid muscle; 2 - Left and right lobes of the the thyroid;
3 - Carotial arteries.

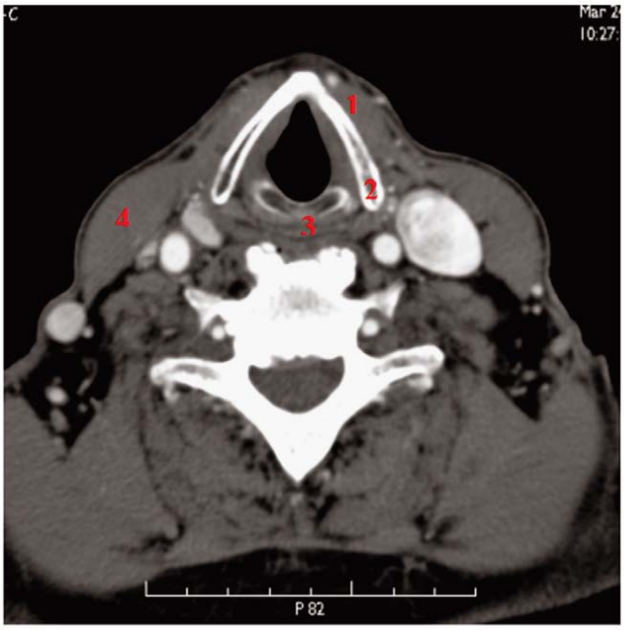


Figure 6 CT thin section through the lamina of the thyroid cartilage.
1 - Sternohyoid muscle; 2 - Lamina of the thyroid cartilage; 3 - Laringopharirynx;
4 - Sternocleidomastoid.

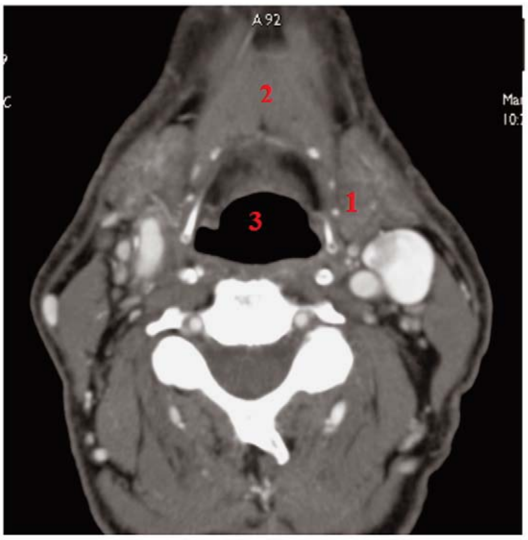
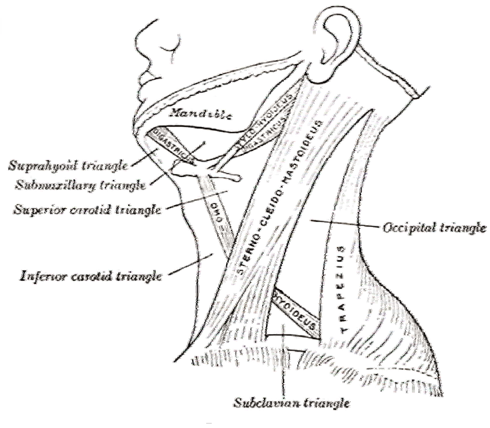


Figure 7 CT section through the mandible.
1 - Submandibular gland; 2 - Tongue; 3 - Oropharynx

The sternocleidomastoideus (SCM) divides the neck into anterior and posterior triangles (scheme 1). The posterior triangle is largely muscular. The anterior triangle, which contains most of the vital structures, can be divided into smaller triangles by muscles. The anterior and posterior bellies of the digastric form the submandibular triangle. The submental triangle is in the midline, between the anterior bellies. The vascular or carotid triangle is inferior to the digastric and hyoid.

The omohyoid is a small muscle, running at roughly 90 degrees to the SCM, from the hyoid to the scapula (Fig. 8 - 9).



Scheme 1 Anatomical triangles of muscular neck

Figure 8 Axial section through the mouth at the level of the upper alveolus.
1 - Masseteres, 2 - Ramus of mandible; 3 - Parotid glande; 4 - Medial pterygoid;
5 - Trapezius; 6 - Nasopharinx

Figure 9

Sagittal MRI of the neck:
1 - Body of hyoid bone
2 - Thyroid cartilage
3 - Arythenoid cartilage
4 - Lamina of cricoid cartilage
5 - Rynopharynx
6 - Oropharynx

THE MEDIASTINUM (INTERPLEURAL SPACE)

The mediastinum lies near the median sagittal plane of the chest between the right and left pleuræ. It extends from the sternum in front to the vertebral column behind, and contains all the thoracic viscera except the lungs. It may be divided for the purposes of description into two parts: an upper portion, above the upper level of the pericardium, which is named the superior mediastinum; and a lower portion, below the upper level of the pericardium. This lower portion is again subdivided into three parts: the anterior mediastinum, in front of the pericardium; the middle mediastinum, containing the pericardium and its contents; and the posterior mediastinum, behind the pericardium [6] (fig. 10-11 -12-13).

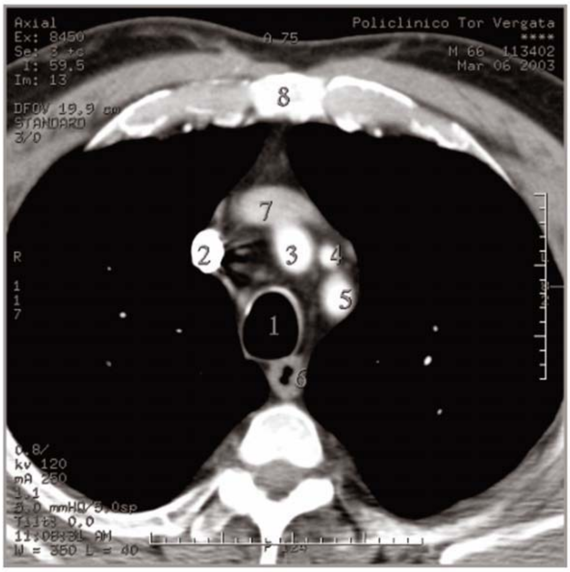


Figure 10 Axial CT section of the mediastinum:
1 - Trachea; 2 - Right brachiocephalic vein; 3 - Brachiocephalic artery; 4 - Left carotid artery; 5 - Left subclavian artery; 6 - Oesophagus; 7 - Left brachiocephalic vein; 8 - Manubrium of sterni

The Anterior Mediastinum - anterior wall is formed by the left transversus thoracis and the fifth, sixth, and seventh left costal cartilages. It contains a quantity of loose areolar tissue, some lymphatic vessels, which ascend from the convex surface of the liver, two or three anterior mediastinal lymph glands, and the small mediastinal branches of the internal mammary artery.

The Middle Mediastinum - is the broadest part of the interpleural space. It contains the heart enclosed in the pericardium, the ascending aorta, the lower half of the superior vena cava with the azygos vein opening into it, the bifurcation

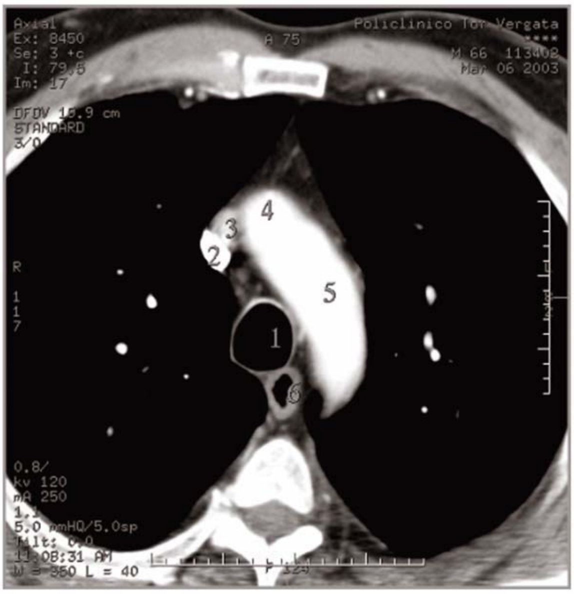


Figure 11 Axial CT section of the mediastinum
1 - Trachea; 2 - Right brachiocephalic vein; 3 - Left brachiocephalic vein;
4 - Brachiocephalic artery; 5 - Aortic arch; 6 - Oesophagus

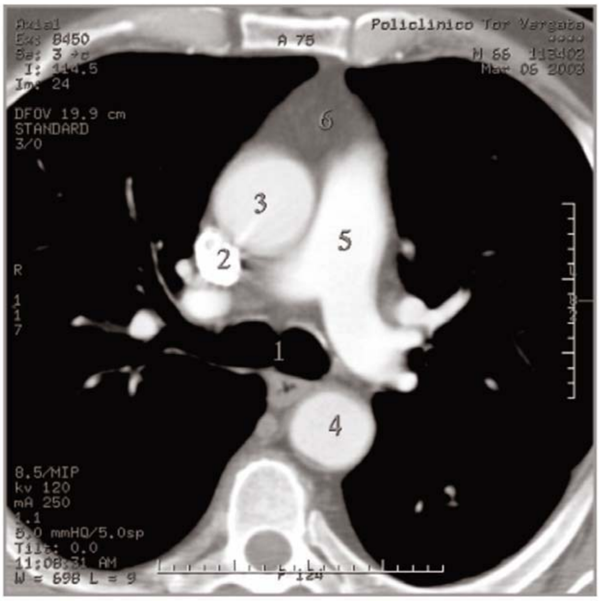


Figure 12 Axial CT section of the mediastinum
1 - Trachea bifurcation; 2 - Superior vena cava; 3 - Ascending Aorta;
4 - Descending Aorta; 5 - Pulmonary Artery; 6 - Fat

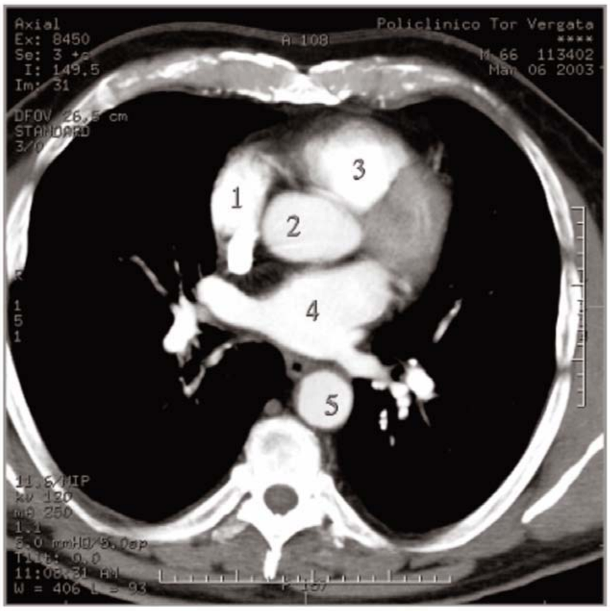
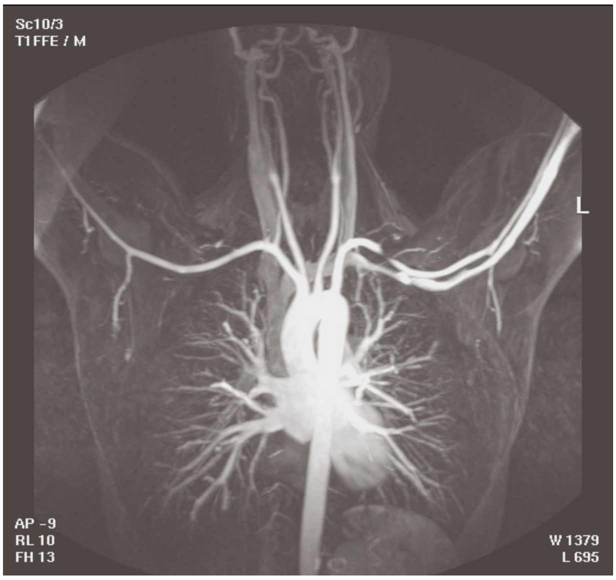
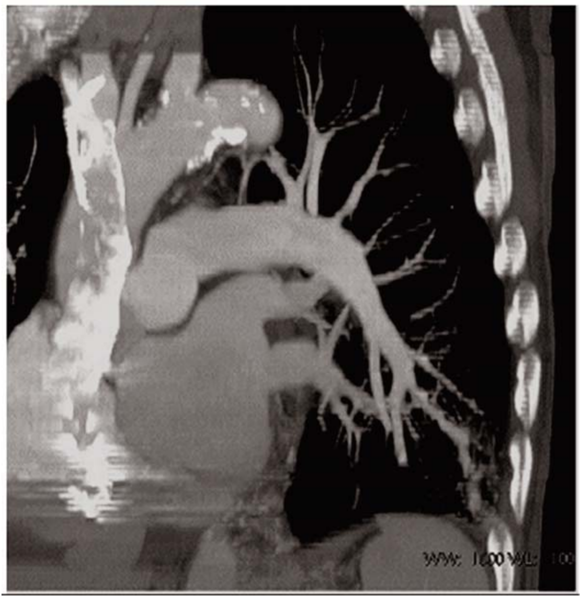


Figure 13 Axial CT section of the mediastinum
1 - Right Auricola; 2 - Ascending Aorta; 3 - Right Ventricle; 4 - Left Atrium;
5 - Descending Aorta

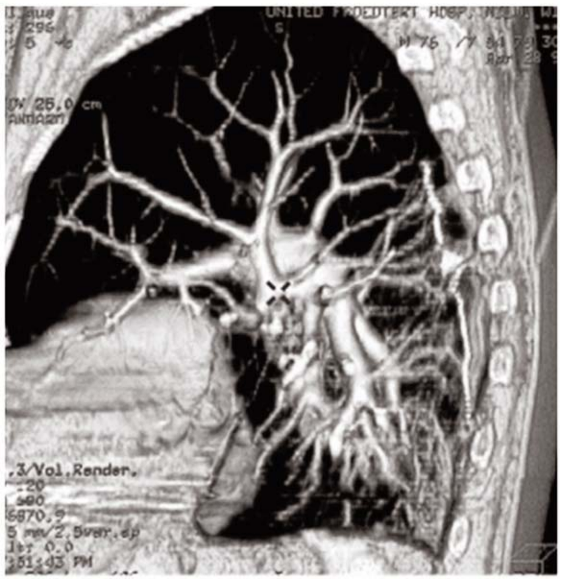
of the trachea and the two bronchi, the pulmonary artery dividing into its two branches, the right and left pulmonary veins, the phrenic nerves and some bronchial lymph glands (Fig. 14A - B - C).



A



B



C

Figure 14 MR Angiography with MIP algorithm of normal vascular anatomy of thoracic vessels (A). Sagittal CT MPR (B) and Volume Rendering (C).

The Posterior Mediastinum - is an irregular triangular space running parallel with the vertebral column; it is bounded in front by the pericardium above, and by the posterior surface of the diaphragm below, behind by the vertebral column from the lower border of the fourth to the twelfth thoracic vertebra, and on either side by the mediastinal pleura. It contains the thoracic part of the descending aorta, the azygos and the two hemiazygos veins, the vagus and splanchnic nerves, the esophagus, the thoracic duct and some lymph glands.

THE PLEURA

The pleura is a delicate serous membrane arranged in the form of a closed invaginated sac that invests each lung (Fig. 15-16). The pulmonary pleura covers the surface of the lung and dips into the fissures between its lobes. The parietal pleura is the rest of the membrane and lines the inner surface of the chest wall, covers the diaphragm and is reflected over the structures occupying the middle of the thorax.

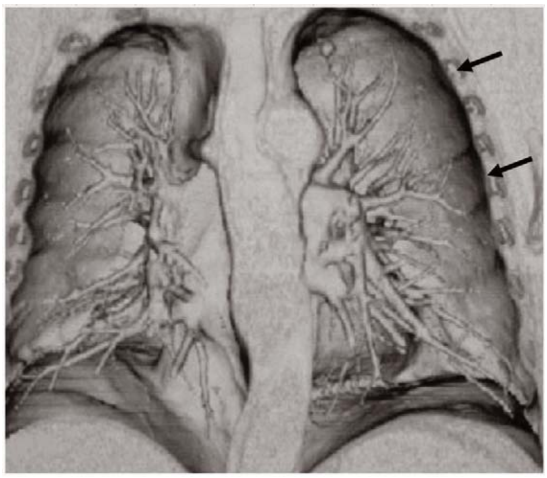


Figure 15

Volume Rendering coronal CT image of the thorax. Visceral pleura is well evident (arrows).

The two layers are continuous with one another around and below the root of the lung; in health they are in actual contact with one another, but the potential space between them is known as the pleural cavity. When the lung collapses or when air or fluid collects between the two layers, the cavity becomes apparent. The right and left pleural sacs are entirely separate from the mediastinum.

Reflections of the pleura start at the sternum, the pleura passes laterally and is reflected upon the sides of the bodies of the vertebræ.

From the vertebral column the pleura passes to the side of the pericardium; it then covers the back part of the root of the lung, from the lower border of which a triangular sheet descends vertically toward the diaphragm. This sheet is the posterior layer of a wide fold, known as the pulmonary ligament. From the back of the lung root, the pleura may be traced over the costal surface of the

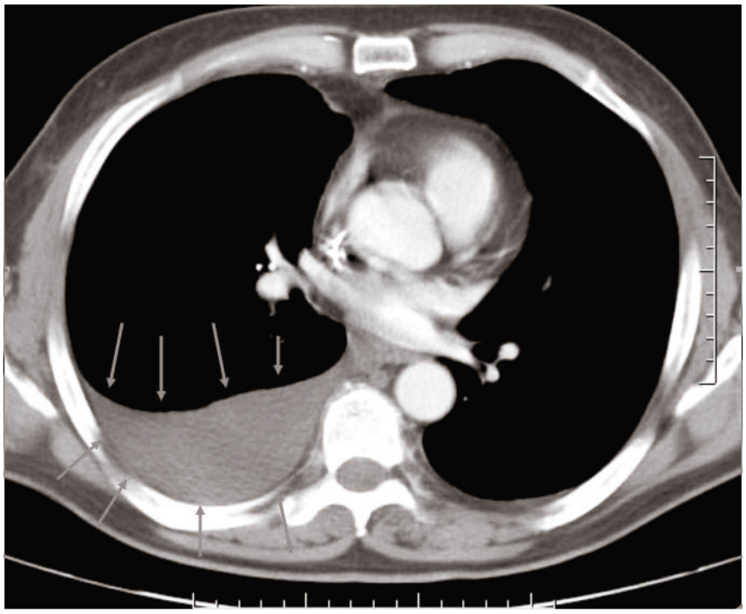


Figure 16 CT axial plane. The two pleural layers are visible in a case of effusion (arrows).

lung, the apex and base and also over the sides of the fissures between the lobes, on to its mediastinal surface and the front part of its root [4].

THE ABDOMEN

The abdomen is the largest cavity of the body. It has an oval shape, the extremities of the oval being directed upward and downward. The upper extremity is formed by the diaphragm, which extends like a dome over the abdomen, so that the cavity extends high into the bony thorax, reaching on the right side, in the mammary line, to the upper border of the fifth rib; on the left side it falls below this level by about 2.5 cm. The lower extremity is formed by the structures which clothe the inner surface of the bony pelvis, principally the Levator ani and coccygeus on either side (Fig. 17-18) [6].

The cavity is wider above than below, and measures more in the vertical than in the transverse axis.

It is artificially divided into two parts: an upper and larger part, the abdomen proper; and a lower and smaller part, the pelvis. These two cavities are not separated from each other but the border between them is marked by the superior aperture of the lesser pelvis.

The abdomen contains the greater part of the digestive tube; the liver, the pancreas, the spleen, the kidneys and the suprarenal glands (Fig. 19-20). Most

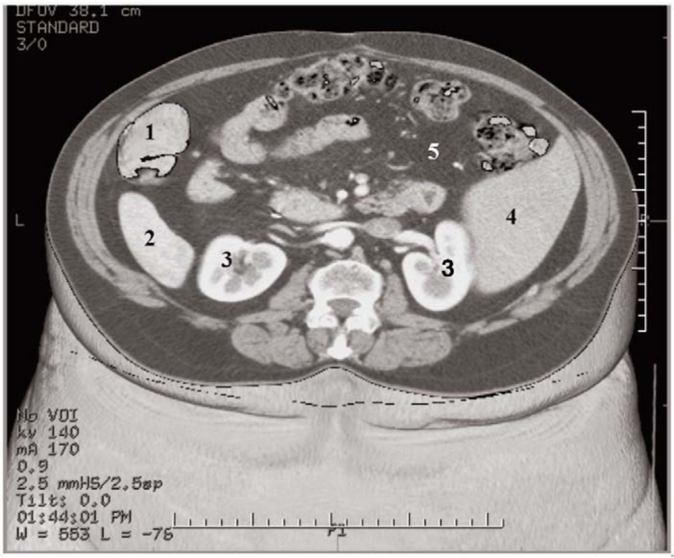


Figure 17 Axial Volume Rendering CT of abdomen.
1 - Colon; 2 - Liver; 3 - Kidneys; 4 - Spleen; 5 - Fat

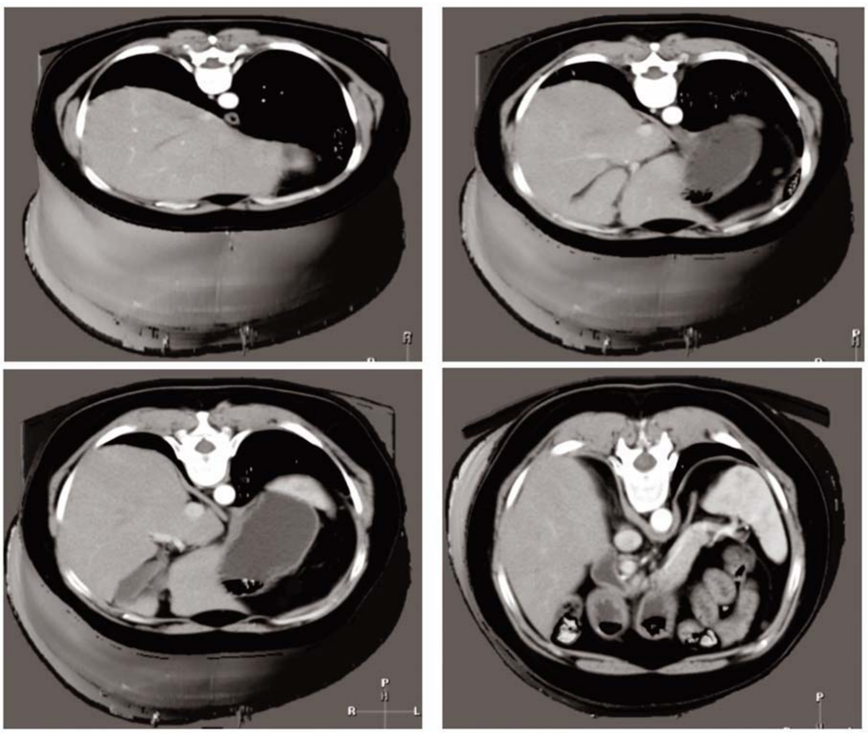


Figure 18 Multislice CT. Internal organs, as well as muscles and skin, are clearly visible on 3D CT abdominal reconstruction.

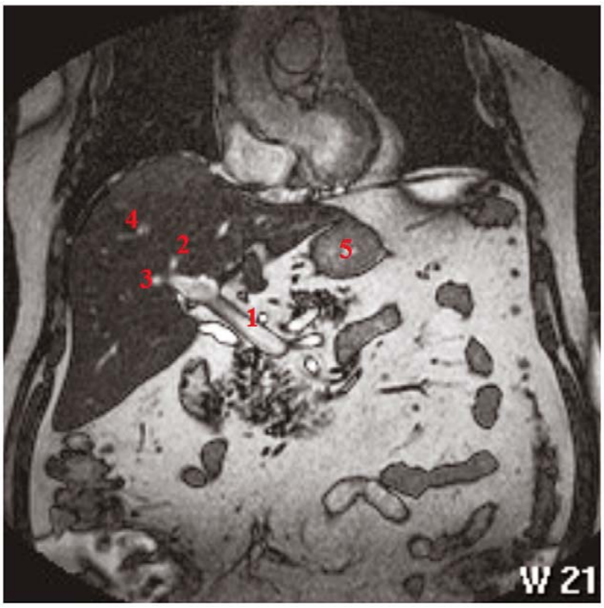


Figure 19 MR coronal imaging of the superior abdomen. Anterior plane.
1 - Portal vein; 2 - Left branch of portal vein; 3 - Right branch of portal vein;
4 - Liver; 5 - Stomach

Figure 20 MR coronal image of the superior abdomen. Posterior plane.
1 - Liver; 2- Kidneys; 3 - Spleen; 4 - Perirenal Fat;

of these structures, as well as the wall of the cavity in which they are contained, are more or less covered by an extensive and complicated serous membrane, the peritoneum.

THE PERITONEUM (TUNICA SEROSA)

The peritoneum is the largest serous membrane in the body and consists, in the male, of a closed sac, a part of which is applied against the abdominal parietes, while the remainder is reflected over the contained viscera. In the female, the peritoneum is not a closed sac, since the free ends of the uterine tubes open directly into the peritoneal cavity. The part which lines the parietes is named the parietal portion of the peritoneum; that which is reflected over the contained viscera constitutes the visceral portion of the peritoneum. The free surface of the membrane is smooth, covered by a layer of flattened mesothelium and lubricated by a small quantity of serous fluid. Hence the viscera can glide freely against the wall of the cavity or against one another with the least possible amount of friction. The attached surface is rough, being connected to the viscera and inner surface of the parietes by means of areolar tissue, termed the subserous areolar tissue. The parietal portion is loosely connected with the fascial lining of the abdomen and pelvis, but is more closely adherent to the under surface of the diaphragm and also in the middle line of the abdomen. The space between the parietal and visceral layers of the peritoneum is named the peritoneal cavity; but under normal conditions this cavity is merely a potential one, since the parietal and visceral layers are in contact. The peritoneal cavity gives off a large diverticulum, the omental bursa, which is situated behind the stomach and adjoining structures; the neck of communication between the cavity and the bursa is termed the epiploic foramen (foramen of Winslow). Formerly the main portion of the cavity was described as the greater, and the omental bursa as the lesser sac [7, 8].

Vertical Disposition of the Main Peritoneal Cavity (greater sac)

It is convenient to trace this from the back of the abdominal wall at the level of the umbilicus. On following the peritoneum upward from this level it is seen to be reflected around a fibrous cord, the ligamentum teres (obliterated umbilical vein),which reaches from the umbilicus to the under surface of the liver. This reflection forms a somewhat triangular fold, the falciform ligament of the liver, attaching the upper and anterior surfaces of the liver to the diaphragm and abdominal wall. With the exception of the line of attachment of this ligament, the peritoneum covers the whole of the under surface of the anterior part of the diaphragm and continues on from it to the upper surface of the right lobe of the liver as the superior layer of the coronary ligament and on to the upper surface of the left lobe as the superior layer of the left triangular ligament of the liver. Covering the upper and anterior surfaces of the liver, it is continued around its sharp margin on to the under surface, where it presents the following relations:

(a) It covers the under surface of the right lobe and is reflected from the back part of this on to the right suprarenal gland and upper extremity of the right kidney, forming in this situation the inferior layer of the coronary ligament; a special fold, the hepatorenal ligament, is frequently present between the inferior surface of the liver and the front of the kidney. From the kidney it is carried downward to the duodenum and right colic flexure and medialward in front of the inferior vena cava, where it is continuous with the posterior wall of the omental bursa. Between the two layers of the coronary ligament there is a large triangular surface of the liver devoid of peritoneal covering; this is named the bare area of the liver, and is attached to the diaphragm by areolar tissue. Toward the right margin of the liver the two layers of the coronary ligament gradually approach each other and ultimately fuse, to form a small, triangular fold connecting the right lobe of the liver to the diaphragm and named the right triangular ligament of the liver. The apex of the triangular bare area corresponds with the point of meeting of the two layers of the coronary ligament, its base with the fossa for the inferior vena cava.

(b) It covers the lower surface of the quadrate lobe, the under and lateral surfaces of the gall-bladder and the under surface and posterior border of the left lobe; it is then reflected from the upper surface of the left lobe to the diaphragm as the inferior layer of the left triangular ligament and from the porta of the liver and the fossa for the ductus venosus to the lesser cuvature of the stomach and the first 2.5 cm of the duodenum as the anterior layer of the hepatogastric and hepatoduodenal ligaments, which together constitute the lesser omentum. If this layer of the lesser omentum be followed to the right, it will be found to turn around the hepatic artery, bile duct and portal vein and become continuous with the anterior wall of the omental bursa, forming a free folded edge of the peritoneum. Traced downward, it covers the antero-superior surface of the stomach and the commencement of the duodenum and is carried down into a large free fold, known as the gastrocolic ligament or greater omentum. Reaching the free margin of this fold, it is reflected upward to cover the under and posterior surfaces of the transverse colon and thence to the posterior abdominal wall as the inferior layer of the transverse mesocolon. It reaches the abdominal wall at the head and anterior border of the pancreas, is then carried down over the lower part of the head and over the inferior surface of the pancreas on the superior mesenteric vessels and thence to the small intestine as the anterior layer of the mesentery. It encircles the intestine, and subsequently may be traced as the posterior layer of the mesentery, upward and backward to the abdominal wall. From this it sweeps down over the aorta into the pelvis, where it invests the sigmoid colon, its reduplication forming the sigmoid mesocolon. Leaving first the sides and then the front of the rectum, it is reflected on to the seminal vesicles and fundus of the urinary bladder and, after covering the upper surface of that viscus, is carried along the medial and lateral umbilical ligaments on to the back of the abdominal wall to the level from which a start was made.

THE RETROPERITONEUM

The retroperitoneum is an anatomical compartment contained between the posterior parietal peritoneum and the trasversalis fascia. It is limited, from below upward, by the under surface of diaphragm and, downward, is separated from the pelvis by iliac vessels (Fig. 21-22-23-24) [6, 7].

Laterally, the retroperitoneum is limited by the muscles of abdominal wall.

The model divides the retroperitoneum into three distinct compartments: posterior pararenal space, perirenal space and anterior pararenal space.

The posterior pararenal space contains only fat and is rarely the site of fluid collection.

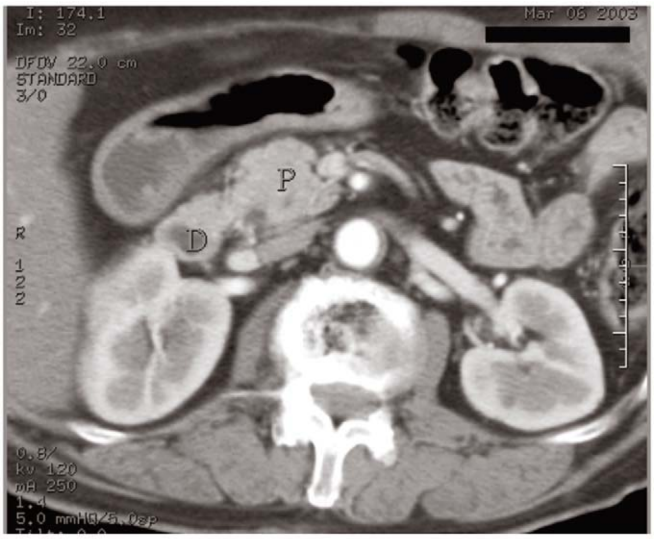


Figure 21 Axial CT. This section passes throught the body of the first lumbar vertebra. The kidneys are embedded in the perirenal fat. At the lateral border of the kidney, the two layers of the renal fascia are fused. D: duodenum; P: pancreas.

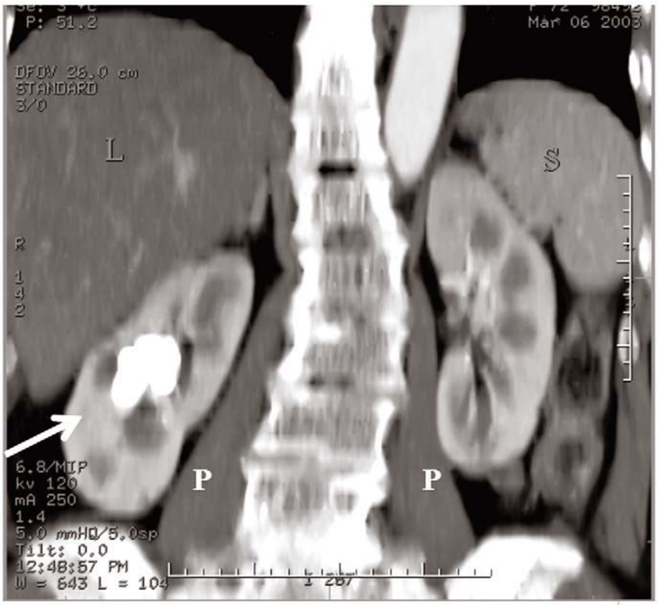


Figure 22 CT. Coronal plane.
Retroperitoneal kidneys (inside a litiasic image: point of arrow), liver and spleen.
Psoas muscles are visible on the left and on the right of the spine (P)

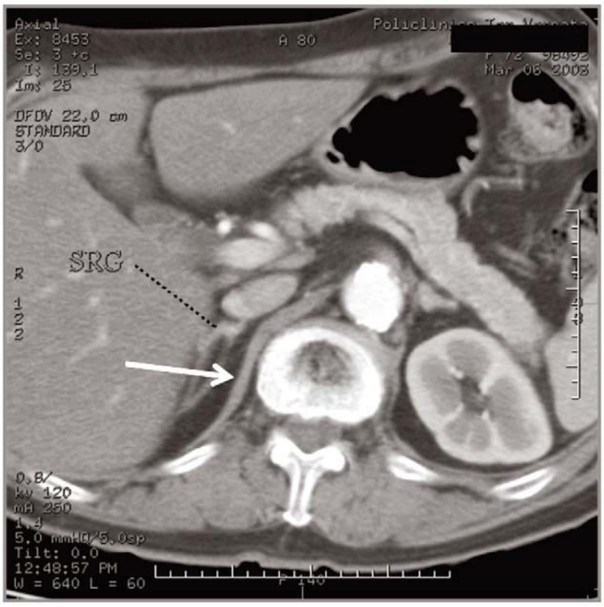


Figure 23 CT axial plane throught the XI thoracic vertebra. The adrenals (SRG) have a costant relationship with the diaphragmatic crura.
The right crus of the diaphragm (arrow) is often bulky.
The pancreas is clearly visible in the more anterior planes.

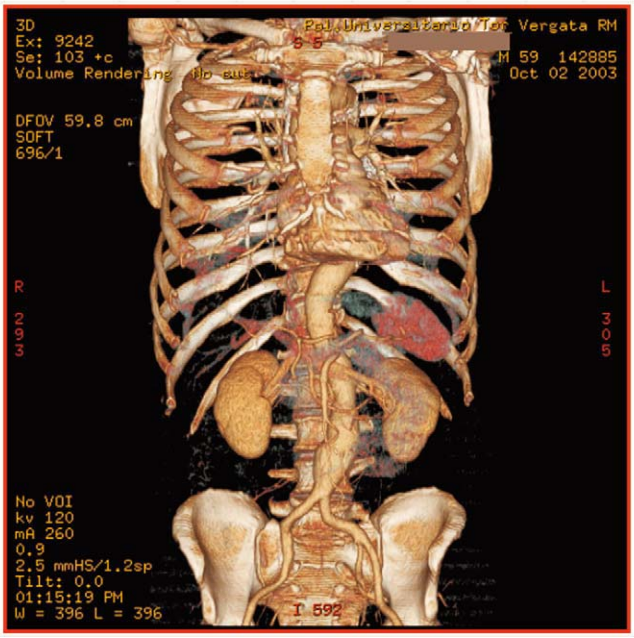


Figure 24 CT Volume Rendering. The Abdominal Aorta is visible until iliac bifurcation.

The two perirenal spaces contain the kidneys, renal pelvis and proximal ureters, adrenal glands, and perirenal fat (Fig. 25-26) [9, 10].

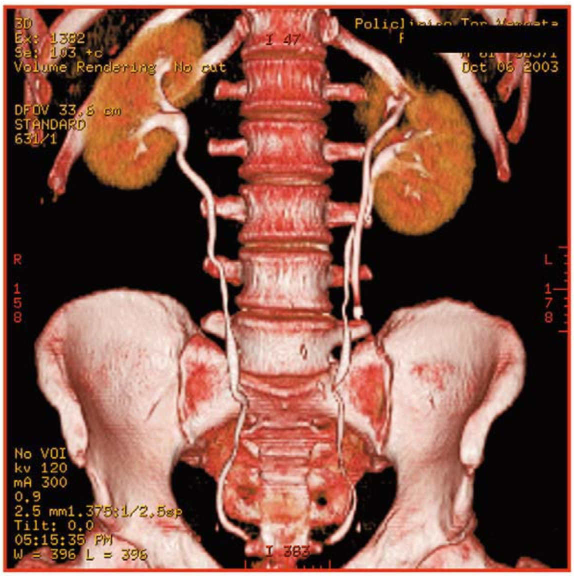


Figure 25 CT Volume Rendering. The kidneys and the urinary tract; on the left is visible the double district.

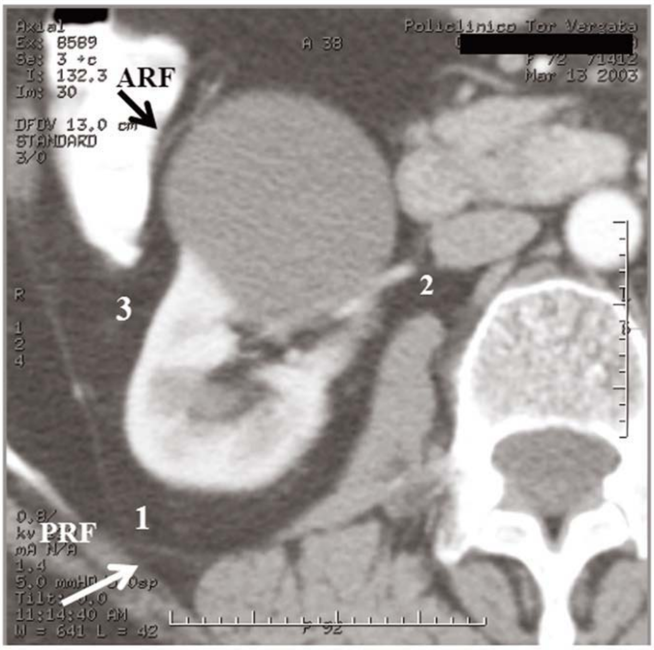


Figure 26

Perirenal spaces. Posterior and anterior renal fascia (ARF, PRF) (point of arrows).

1 - Posterior pararenal space;
2 - Perirenal space;
3 - Anterior pararenal space

The anterior pararenal space contains the retroperitoneal segments of the colon and duodenum, the pancreas and the root of the small intestinal mesentery (Fig. 27-28).

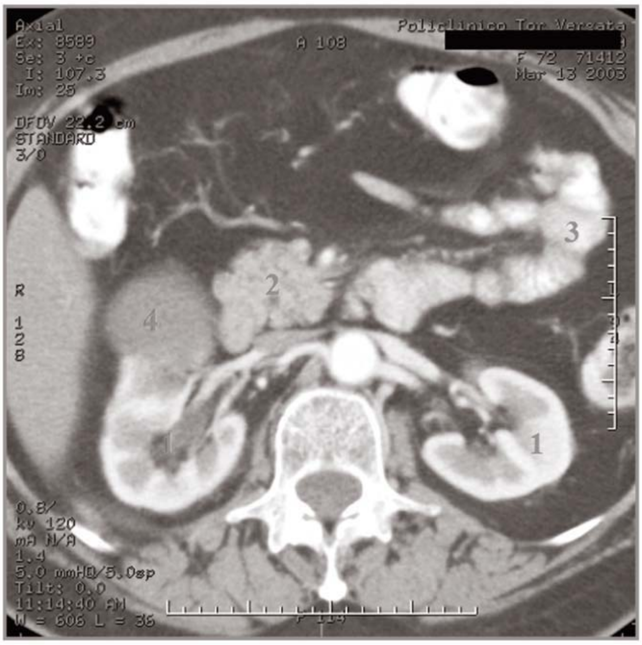


Figure 27

Axial plane throught the retroperitoneal structures.

1 - Kidneys;
2 - Head of the pancreas;
3 - Bowel loop;
4 - Cyst of right kidney

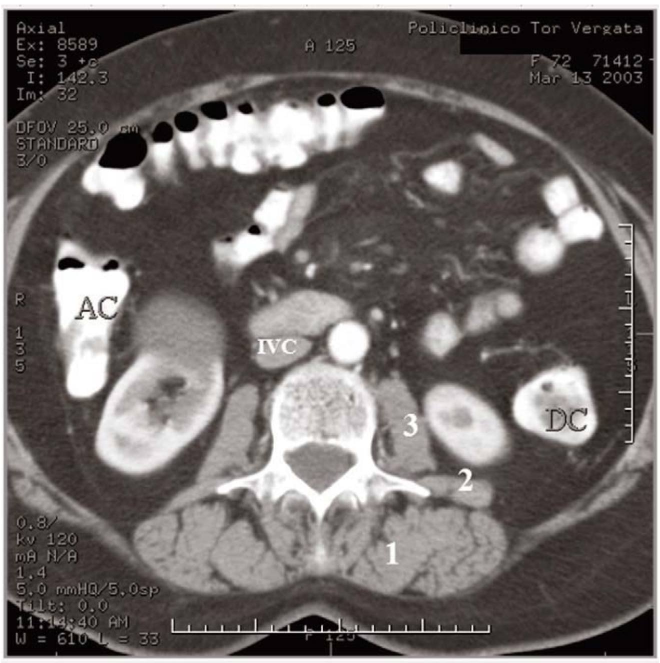


Figure 28 CT section passes throught the second and third lumbar vertebrae.
A - aorta; IVC - inferior vena cava; AC - ascending colon; DC - descending colon
1 - Erector spine; 2 - Quadratus lumborum; 3 - Psoas major

This compartmental model of the retroperitoneum has been successful because, in the majority of cases, it explains the distribution of fluid collection and the extension of pathologic processes within the abdomen.

The images in this chapter were obtained from the Department of Radiology, Tor Vergata Hospital, Rome, Italy.

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CHAPTER 3

SURGICAL ENDOSCOPIC ACCESS TO POTENTIAL ANATOMICAL SPACES: A MULTIDISCIPLINARY ISSUE

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In the seventies, diagnostic laparoscopy, endoscopy, ultrasounds, and later computed tomography, contributed deeply to modifying and renewing anatomical knowledge. Further improvements in imaging and video-assisted surgical techniques led us to reconsider diagnostic and therapeutical approaches. Consequently, laparoscopic surgery, as well as the diagnostic and therapeutical application of endoscopy in urological, digestive and tracheo-bronchial diseases, led to a better understanding of extraluminal (abdomen and thorax) and luminal (digestive tract, bronchial tree, bladder, etc.) anatomy. But, if we exclude anatomical cavities, we are still challenged by the potential or "virtual" spaces, those ones that have been traditionally described by Newell as "hidden" spaces [1].

The spread of video-assisted surgery and its application in the management of diseases involving organs or anatomical structures placed in the "potential" spaces, rendered the surgical anatomy of these spaces (neck, mediastinum, pre- and retroperitoneum, subfascial space of the leg, etc.) less abstract. Neverthless, it must be underlined that the relative anatomical notions, well codified by traditional anatomy but better defined by modern radiological imaging, are an important part of the time spent for the learning curve of the mini-invasive surgical approaches and should be refined by assessing the possibilities of transforming a virtual space to a "real cavity" (by gas insufflation or gasless procedures) in which exploration and operation is realistic. These issues are shared by different surgical specialities. Some of these are strictly connected with general surgical and surgical subspecialities activities and therefore, once more, this testifies to the fact that the video-assisted and endoscopic surgical offers "transversal" ways to explore anatomical spaces. In other words, this transversality is better understood if we consider the multidisciplinarity on which the approaches are based (Fig. 1).

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As recently stated by Meakins [2], "Surgery in all disciplines has been undergoing a revolution over the last decade as our refinement of surgical technique increases, driven by patient-centred outcomes, competition for patients

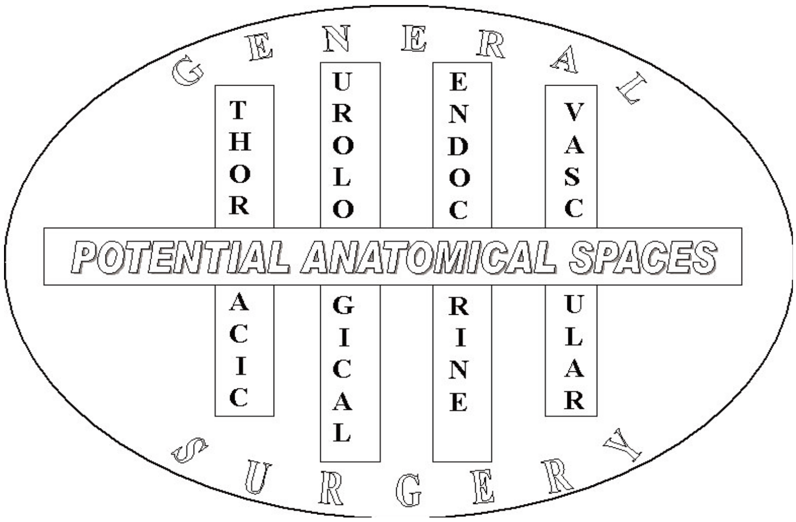

Figure 1 Explanation in the text

and new technology. Examples of patient-driven operative approaches can be seen in the estabilishment of laparoscopic cholecystectomy as the standard approach".

One of the problems in the introduction of a new surgical approach is how to get the best training in the interest of the patients and in the interest of the transmission of the lessons learned in the experimental and clinical settings (i.e. training and teaching).

Most of the problems we are facing in the video-assisted approach to the potential spaces have been in part overcome by other surgical specialistes (i.e. urologists, gynecologists, neurosurgeons, etc). For instance, since 1982 discoscopy has proved its value as a means of continous optical control of percutaneous intradiscal procedures [3].

In 1995 Zelko et al [4], demonstrated the safeness of laparoscopic lumbar discectomy, as an alternative to posterior microdiscectomy. Most of the contributions on the video-assisted approach to the retroperitoneum are due to the work of urologists [5, 6].

The endoscopic approach to the potential spaces or compartments is actually one of the abilities most required by general surgeons and this is demonstrated by the interest devoted to this field by leading researchers into videoasisted surgical techniques [7, 8].

It is of utmost importance to define the potential anatomical spaces and the differences in surgical approach to them and anatomical cavities.

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CHAPTER 4

TECHNICAL ASPECTS FOR ACCESS INTO THE NECK (MINIMALLY INVASIVE VIDEO-ASSISTED THYROIDECTOMY - MIVAT)

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SURGICAL ANATOMY

The thyroid consists of two lobes joined by an isthmus. The normal weight of the adult gland is around 20 gr. Each lobe has a conical shape and measures about 2 x 3 x 5 cm. The normal thyroid is dark wine red in color, soft and covered by a thin capsule.

The gland is situated in the lower aspect of the neck with the isthmus crossing the trachea at the level of the second and the third tracheal ring. The posterior suspensory ligament (Berry's ligament) attaches the gland to this structure.

The gland is covered by the strap muscles (sternohyoid and sternothyroid muscles), joined in the midline by the cervical linea alba (anterior fascia cervicalis). The medial aspect of each lobe lies over the larynx and the trachea. The esophagus is situated on the posteromedial aspect of the thyroid lobe, and the recurrent nerve runs more or less vertically along the tracheo-esophageal groove (see later). The superior poles are in contact with the inferior constrictor muscle and the posterior aspect of the cricothyroid muscle. The inferior pole usually reaches the fourth or the fifth tracheal ring. Often, a residual of the thyroglossal duct extends cranially from the isthmus and is variably developed (pyramidal lobe).

Blood supply – The gland receives its arterial blood supply from the superior and inferior thyroid arteries. The superior thyroid artery originates from the external carotid artery. It descends along the surface of the inferior constrictor of the pharynx and enters the upper pole of the thyroid on its antero-superior surface. In about 10% of cases a branch of this artery feeds the superior parathyroid gland. The external branch of the superior laryngeal nerve runs

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very close to the branches of the superior thyroid artery, but despite this relationship is quite variable (see later).

The inferior thyroid artery is a branch of the thyrocervical trunk: it passes superiorly behind the common carotid artery and jugular vein, towards the cricoid cartilage. At the level of the gland, the artery loops downward and medially and enters the middle aspect of the lobe. It divides into several terminal branches. This artery and its branches have a very close relationship with the inferior laryngeal nerve (see later). A branch of the inferior thyroid artery usually feeds the inferior parathyroid gland; in most cases the inferior thyroid artery also supplies the superior parathyroid gland. A lower thyroid artery (ima) is rarely present: it arises from the innominate artery and enters the isthmus.

The venous drainage is more variable than the arterial supply. The superior is closely related to the superior artery and drains into the internal jugular vein. Middle thyroid veins vary in number and pass from the lateral border of the lobe into the internal jugular vein. The inferior veins are separate from the inferior thyroid arteries and drain the inferior lobe into the internal jugular or innominate veins.

Lymphatic drainage – The lymphatic drainage of the thyroid is very extensive. The surgeon must consider two main zones of lymphatic drainage: central compartment (periglandular space) and lateral compartment. The carotid sheet separates the two compartments.

The central compartment includes the prelaryngeal, the pretracheal and paratracheal-esophageal groups. The anterior boundary of this compartment are strap muscles, but sometimes node metastases may be found along the linea alba just above the isthmus (Delphian nodes). This zone is the primary site of metastasis from thyroid carcinoma. Only tumors arising in the upper pole may metastasize directly to the lateral compartment, because of direct drainage. Large connections between the two compartments and the two sides are present.

Laryngeal nerves – As already described above, the external branch of the superior laryngeal nerve has close relationships with the superior thyroid vessels and the superior thyroid pole. The superior laryngeal nerve arises from the vagus and descends lying on the middle constrictor muscles. At this level it divides into external and internal branches. The external branch continues inferiorly and innervates the cricothyroid muscle. This muscle produces tension of the vocal cord: thus in case of lesions of this branch, high-pitched voice sounds may be compromised. In 6-18% of cases the external branch of the superior laryngeal nerve runs with or around the superior thyroid artery or its branches and is thus susceptible to lesion during surgical dissection. In almost 20% of cases it is not situated in the surgically accessible area around the superior pole of the thyroid gland and cannot be visualized during conventional surgery: thanks to the endoscope, a wider area can be viewed, both because of the optical magnification and the 30-degree angle, which allows exposure of the entire anterior surface of the cricothyroid muscle. Thus its preparation is easily achieved during video-assisted procedures (not less than 90% of cases according to our series) but, in case its course makes imaging impossible, the superior thyroid artery should be ligated selectively and very close to the capsule of the thyroid.

The inferior laryngeal nerve arises from the vagus and supplies all muscles of the larynx except the cricothyroid. On the right-hand side, the nerve passes behind the subclavian artery and hooks around it, running upwards towards the larynx. On the left-hand side, the nerve passes around the aortic arch. Both nerves run cranially and medially, towards the cricoid cartilage where it enters the larynx. The inferior laryngeal nerve is not a single strand but usually offers several branches (to the esophagus, trachea, thyroid) and anastomoses with other nervous structures (superior laryngeal nerve; sympathetic system, contralateral nerve). The relationship between the inferior thyroid artery and the inferior laryngeal nerve is very variable. It may pass anteriorly, posteriorly or between the branches of the artery. In less than one per cent of cases the nerve does not recur on the right side and it originates directly from the vagus on the neck and reaches the larynx running more or less transversely. This variant is determined by a vascular anomaly during embryonic development, resulting in an aberrant subclavian artery (arteria lusoria), originating directly from the aortic arch on the left of the left suclavian artery and passing transversely posterior to the esophagus. This anomaly is exceptional on the left side and requires situs viscerum inversus and vascular anomaly.

OPERATIVE TECHNIQUE (MINIMALLY INVASIVE, VIDEO-ASSISTED THYROIDECTOMY - MIVAT)

The patient lies in a supine position without neck hyperextension. The neck is prepared and draped in the conventional way. A steri-drape is used to cover the skin.

A 15-mm horizontal incision is performed 2 cm above the sternal notch (Fig. 1), subcutaneous fat and platysma are carefully dissected so as to avoid any minimal bleeding. The cervical linea alba is divided longitudinally as much as possible (3 - 4 cm). This is a critical point because it is necessary to incise the mid line on an absolutely bloodless plane: any minimal bleeding at this point prevents the surgeon from carrying out the procedure. The best way to localize it is to use an electro cauthery blade completely isolated until the very tip with a thin film of Tegaderm.

The strap muscles on the affected side are then gently retracted with one small retractor; a second retractor is placed directly on the thyroid lobe, which is retracted medially and lifted up. The dissection of the lobe from the strap

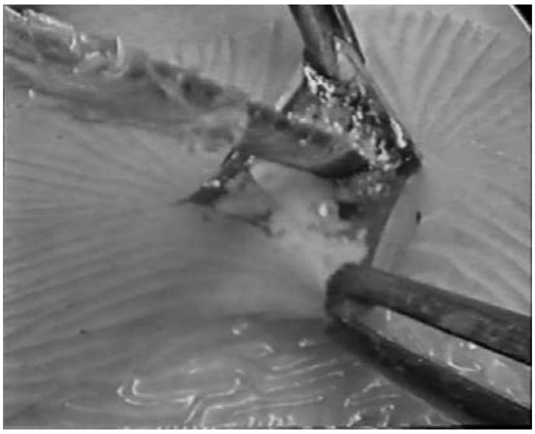

Figure 1

A skin incision (1,5 cm) is performed 2 cm above the sternal notch.

muscles is completely achieved through the skin incision by gentle retraction and using conventional instruments.

The two small retractors maintain the operative space. A 30° 5-mm endoscope is inserted through the skin incision. The dissection of the thyrotracheal groove is completed under endoscopic vision by using small (2 mm in diameter) instruments: atraumatic spatulas in different shapes, spatula shaped aspirator, ear-nose-throat forceps and scissors (Fig. 2).

Figure 2 Instrumentation for MIVAT

Washing and cleaning the operative field is very simple because there are not trocars in this procedure and water can be injected directly with the syringe: its aspiration can be greatly facilitated by the use of the spatula shaped aspirator. It allows one to keep on operating through the spatula and aspirating smoke and liquids without introducing extra instruments into the incision.

The first vessel to be ligated is the middle vein, when present, or the small veins between jugular vein and thyroid capsule. Haemostasis is achieved by means of small (3 mm) conventional vascular clips, applied by a reusable clip applier or by ultrasonic scissors (Harmonic Scalpel).

This step allows a better preparation of the thyrotracheal groove, where the recurrent nerve will be later searched for.

The next step is the ligature and section of the upper pedicle, which must be carefully prepared, until an optimal visualization of the different branches is achieved. The tip of the Harmonic scalpel must be carefully checked while ligating the upper pedicle: it reaches high temperatures which could damage the larynx and even the pharynx, if the tip is maintained too long on their wall.

The thyroid lobe is retracted downward by the retractor. After exposing the upper pole, the spatula is used to separate the larynx from the vessels and retract them laterally. The vessels are then selectively ligated by conventional vascular clips and or cut by harmonic scalpel.

The external branch of the superior laryngeal nerve can easily be identified during most of the procedures once the different components of the upper pedicle have been prepared.

After retracting medially and lifting up the thyroid lobe, the fascia can be opened by gentle spatula retraction. The recurrent laryngeal nerve generally appears at this point in time, lying in the thyrotracheal groove, posterior to the Zuckerkandl tuberculum (posterior lobe), which constitutes an important landmark in this step (Fig. 3)

Both parathyroid glands are also generally easily visualized thanks to the endoscope magnification. Their vascular supply is preserved by selective ligature of the branches of the inferior thyroid artery. During dissection, haemostasis is achieved by vascular clips or Harmonic Scalpel, when dealing with large vessels or small vessels close to the nerve. In this way, the recurrent nerve and the parathyroid glands are dissected and freed from the thyroid.

After removing the endoscope and the retractors, the surgeon carefully pulls out the upper portion of the gland using conventional forceps. A gentle traction over the lobe allows the complete exteriorization of the gland (Fig. 4).

Thyroid cysts are also a good indication for this procedure but they are often larger than 3.5 cm. Nonetheless, even cysts as large as 4 or 5 cm can be operated on this way as long as they are aspirated before pulling out the thyroid lobe

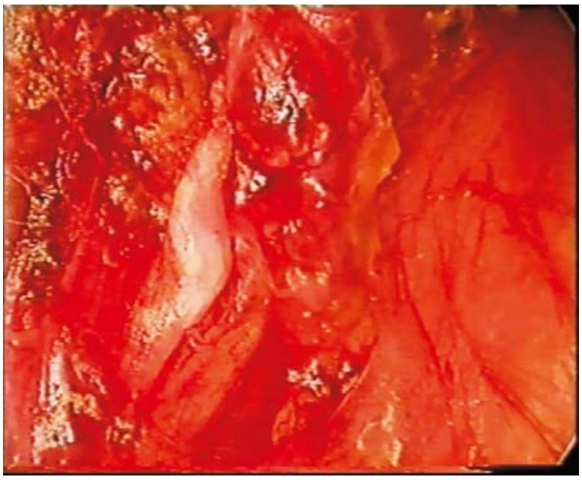

Figure 3

Recurrent laryngeal nerve is evident

from the skin incision. Emptying these cysts in fact results in a sharp decrease in their size so as to allow the lobe to be easily extracted.

The operation is now conducted as in open surgery under direct vision. The lobe is freed from the trachea by ligating the small vessels and dissecting the Berry ligament. It is very important to check the laryngeal nerve once again at this point in time, so as to avoid its injury before the final step.

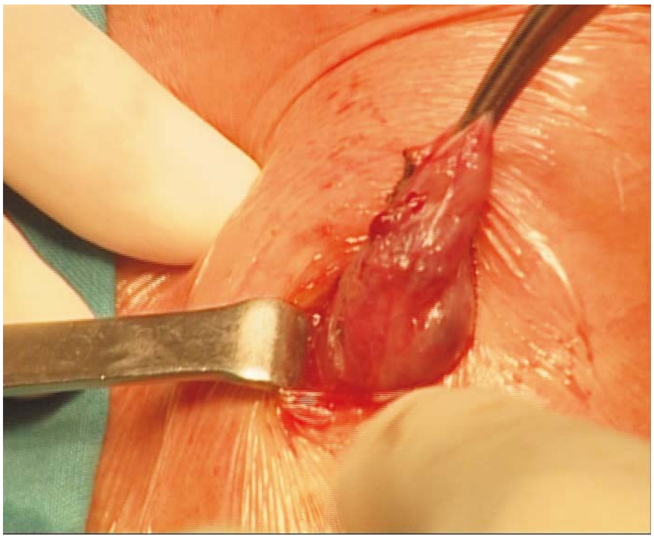

Figure 4

Thyroid lobe is exteriorized

The isthmus is then dissected from the trachea and divided. After completely exposing the trachea, the lobe is finally removed by the conventional open technique.

Drainage is not necessary. The space is filled with a haemostatic substance. The linea alba and platysma is sutured with reabsorbable sutures and the skin closed either by subcuticular suture or by skin glue (Fig. 5)

Figure 5

Skin suture is achieved by glue

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CHAPTER 5

VIDEO-ASSISTED THORACOSCOPIC ACCESS TO THE MEDIASTINUM

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SUMMMARY
Video-assisted Thoracic Surgery (VATS) is now routinely employed as a reliable diagnostic method for undetermined mediastinal masses and lymphadenopathy. It can also prove useful for lung and esophageal cancer staging due to the possibility of a comprehensive assessment of the pleural cavity, lung and mediastinum. Therapeutic VATS has been successfully applied to thymectomy, excision of small encapsulated anterior mediastinal tumours and posterior neurogenic tumours, management of benign esophageal conditions, pericardiectomy and pericardioscopy. Furthermore, VATS has also been employed in combination with laparotomy and cervicotomy to perform esophagectomy for esophageal cancer.
Despite a wide spectrum of potential applications, the surgeon's judgement must play a key role in deciding which procedure is best suited for adopting VATS. In fact, despite a shortened hospital stay and an easier patient acceptance of the procedure, VATS equipment is expensive, time in the operating room may be long and inadvertent intraoperative complications can be lifethreatening and difficult to manage promptly. For this reason, we believe that use of VATS in the management of mediastinal diseases should be never performed without adequate training, while, the advantages of using it for more complex therapeutic procedures will always require a careful comparison with those deriving from already validated open approaches.

INTRODUCTION

Continuing improvements in endoscopic instrumentation and the increasing experience with minimally invasive surgical techniques, have expanded the applications of video-assisted thoracic surgery (VATS) to disease processes of the mediastinum. This surgical modality is now routinely applied for establishing the diagnosis of indeterminate mediastinal masses and lymphadenopathy.

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In addition, the possibility to offer a wider access to mediastinal compartments than other methods such as anterior mediastinotomy and cervical mediastinoscopy, has also contributed to advocate the use of VATS for a more accurate staging of lung and esophageal cancer and lymphomas.

Therapeutic VATS has been successfully applied to thoracic sympathectomy, thymectomy for thymomatous and non-thymomatous myasthenia gravis, excision of mediastinal cysts or posterior mediastinal masses including neurogenic tumours and benign esophageal tumours. In addition, surgical management of descending purulent mediastinitis has also been advocated.

The surgical access can vary depending on the site of the disease process and the personal preference of the surgeon. Posterior-superior mediastinal masses are most often approached from the right pleural cavity, while left, right and substernal approaches have all been successfully employed to achieve access to the anterior mediastinum with advantages and disadvantages being advocated by proponents of each approach.

ANATOMY OF THE MEDIASTINUM

The thoracic space which lies between the two pleural cavities is defined mediastinum. Its limits are the thoracic inlet cephalad, the superior surface of the diaphragm caudad, the undersurface of the sternum ventrally and the anterior longitudinal spinal ligament dorsally.

Paravertebral areas and costovertebral sulci also have both been classically included amongst the mediastinal compartments, although they are not truly within the mediastinum.

According to an anatomo-surgical classification, the mediastinum can be divided in different compartments. Along a coronal plane, it can be divided in a superior and an inferior compartment with a division line passing through the carina. Along a sagittal plane, it can be divided in an anterior compartment bounded by the sternum anteriorly and the anterior margin of the trachea posteriorly; a middle or central compartment contained within the tracheal plane and a posterior mediastinum bounded by the posterior margin of the trachea anteriorly and the costovertebral sulci posteriorly. As a result, 6 compartments are anatomically outlined.

Anterior compartment. It can be divided in an anterior superior compartment containing the thymus gland, the great vessels, internal mammary vessels, lymph nodes, connective tissue and fat. Displaced parathyroid glands and true ectopic thyroid tissue may be also occasionally located in this compartment. An anterior inferior compartment is occupied by the heart.

Middle compartment. It entails a middle superior compartment with the trachea and the parathracheal lymphnodes, and a middle inferior compartment containing the main stem bronchi.

Posterior compartment. It is divided in a posterior superior compartment with the aortic arch, the esophagus the thoracic duct and the sympathetic chain. A posterior inferior compartment containing the descending aorta, the esophagus, the thoracic duct and the sympathetic chain.

APPROACH TO THYMIC ANOMALIES

Recently, VATS has been successfully applied to thymectomy. Typically, thymectomy has been advocated within an integrated surgical and medical management of nonthymomatous myasthenia gravis [1-6] although even small capsulated thymomas [7] and massive thymic hyperplasia [8] have been successfully excised by VATS. Proponents of VATS thymectomy are comfortable that it might associate the minimal surgical trauma of the transcervical approach and the excellent visualization of the anterior mediastinum of the trans-sternal approach. Also, VATS does not prevent an easy access to the lower cervical area, allowing for a complete removal of the superior thymic hornes. On the other hand, the cosmetically acceptable incisions and the enhanced magnification are recognized advantages of VATS over open approaches. VATS thymectomy has been performed by right [1, 2] or left approaches [3-5]. Advocates of the right approach assume that it allows a greater maneuverability of instrumentation in the wider right pleural cavity and easier identification of the left innominate vein due to the landmark of the superior vena cava [1]. Furthermore, VATS thymectomy has also been recently performed through an infrasternal approach with the aim of improving visualization of both phrenic nerves [9, 10]. We prefer the left-sided approach and the use of adjuvant pneumomediastinum to facilitate dissection maneuvers and enhance the completeness of thymectomy [2].

We believe that from the left the dissection is safer because the superior vena cava lies out of the surgical field, reducing the risk of an incidental lesion of this vessel. Furthermore, we carry out an extended removal of the perithymic fatty tissue, which in our experience is prevalent in the left pericardiophrenic angle and in the aorto-pulmonary window. We consider this step essential in achieving intentional extended thymectomy and we have found that the only limitation to the left approach relates to the presence of cardiomegalia that may limit exposure of the thymus [3].

The left VATS approach. To facilitate the dissection maneuvers and to shorten operative time, we perform adjuvant pneumomediastinum about 24 h before the operation. For this purpose, we introduce a Veress needle under local anesthesia at the level of the suprasternal notch, behind the posterior wall of the sternum. Afterwards, 400 to 600 mL of air is insufflated in a sterile way at a rate of 25 mL/min. Through this simple and safe maneuver, the thymus is progressively unglued from the surrounding structures (Fig. 1).

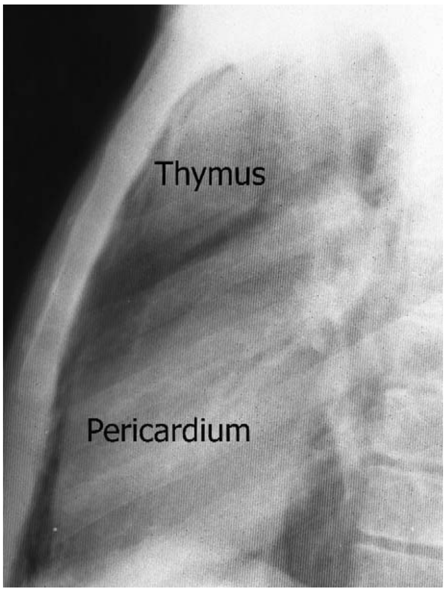

Figure 1

Pneumomediastinum is indicated by the presence of air in the anterior mediastinum at the lateral chest X-ray

At the operation, after double-lumen intubation, the patient is placed in a 45-degree off-center position and 4 flexible thoracoscopic trocars are inserted (Fig. 2).

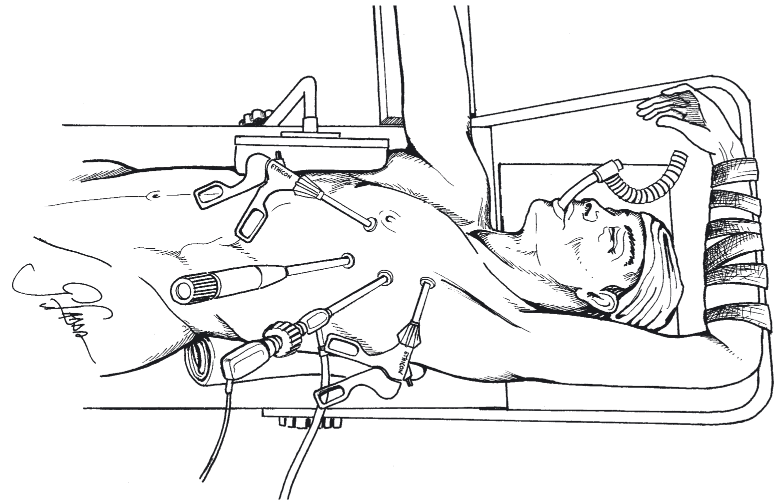

Figure 2 Patient positioning and surgical access for VATS thymectomy

The entire hemithorax is carefully explored with particular attention to aortic arch, subclavian artery, pericardium and phrenic nerve.

Dissection is begun inferiorly by incising the mediastinal pleura along the anterior border of the phrenic nerve. Because of the preoperative pneumomediastinum, the mediastinal adipose tissue is embedded with air and the thymus appears already partially separated from the pericardium and from the sternum. As a result the dissection proceeds more rapidly and easily, mainly by blunt maneuvers, with the aid of two pledgets.

All mediastinal tissue including fat is swept away from the phrenic nerve and the left inferior horn is dissected off the underlying pericardium. Afterwards, the gland is dissected off the retrosternal area beginning just below the internal mammary pedicle and continuing rightwards until the right mediastinal pleura is visualized and the right inferior horn is fully dissected up to the isthmus

The lower half of the gland is then retracted upward and the thymic veins, usually two or three, are identified, clipped and divided (Fig. 3). Subsequently, the dissection proceeds cephalad, superior to the innominate vein into the lower cervical area; the superior horns are progressively dissected free by blunt maneuvers with the aid of gentle traction applied downward on the thymus. In this way, even long and thin upper hornes can be dissected en bloc with the rest of the gland. The intact thymus is finally extracted in a retrieval bag through the most anterior port and examined to ensure that the whole gland has been removed. Subsequently, all mediastinal fat that is found in the pretracheal space, along the internal mammary pedicles, in the aorto-pulmonary window as well

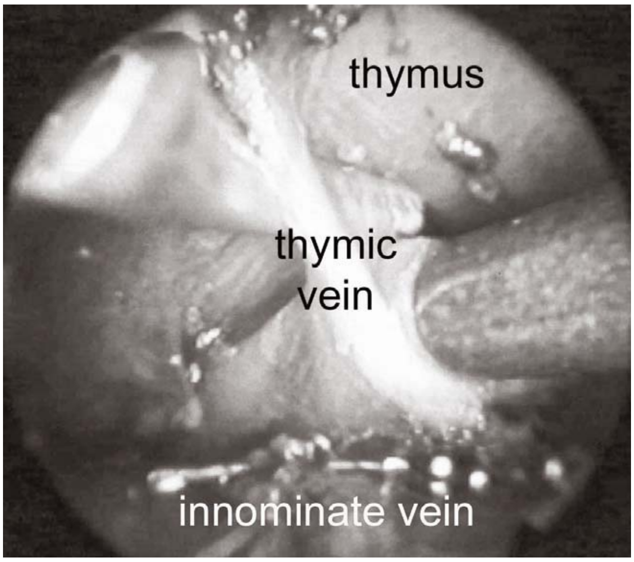

Figure 3

Magnified image of a thymic vein, which is being dissected free and interrupted.

as in the right and left pericardiophrenic angles, that may contain ectopic thymic tissue, is completely excised to accomplish an intentional extended thymectomy [3] (Fig. 4).

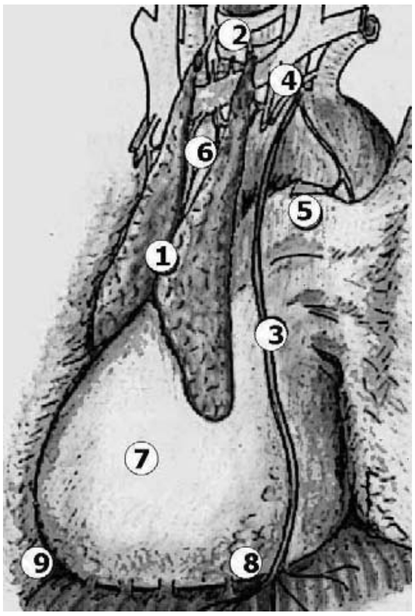

Figure 4

Schematic drawing of the sites, which are routinely dissected during intentional extended VATS thymectomy.
1)Thymus;
2) pretracheal fat;
3) left phrenic nerve;
4) mammary vessels;
5) aorto-pulmonary window;
6) retroinnominate area;
7) pericardium;
8) left and
9) right pericardiophrenic angle.

The right VATS approach. The patient is placed at a 30° off-center position and three 10 mm incisions are performed in the right infraaxillary area through the lateral ones. A 30° angled scope is placed through the middle incision and the grasping instrument and scissors. The dissection is begun at the inferior portion of the thymus gland, just anterior to the phrenic nerve. By a combination of sharp and blunt dissection, all anterior mediastinal tissue is dissected free off the pericardium. The mediastinal pleura is then incised in the retrosternal area and the anterior portion of the thymic gland is freed until the contralateral pleural sheet. The arterial blood supply to the thymus that arises from the internal thoracic artery is next interrupted with endoscopic clips. At this point the innominate vein can be identified and dissection proceeds along this vessel until the thymic veins entering the innominate vein can be identified and interrupted with clips. Finally, the dissection is carried cephalad to the innominate vein in the cervical area to dissect the superior thymic hornes. The fascial attachments of the thymic gland to the inferior portion of the thyroid gland are divided and thymectomy is completed [1].

The infrasternal VATS approach. This procedure can be performed under general anesthesia with [9] or without [10] double-lumen tube intubation. The patient is placed in the supine straddle position with the neck extended. An arc shaped incision of 3 cm is made just below the xiphoid process. The rectus abdominis muscle is divided and the xiphoid process is excised. A retractor is inserted beneath the lower part of the sternum to lift it. The infrasternal incision is used for insertion of a grasping forceps and ultrasonic coagulation shears. A 30° angled scope is inserted through a trocar placed below the surgical wound. The anterior mediastinal tissue, including the thymus, is progressively dissected free from the pericardium. The anterior mediastinal space is well visualized by pushing the ventilating lungs aside with a lung spatula or an andoscopic fan retractor. After that, the innominate and thymic veins are identified the latter are clipped and divided as in the other approaches. Other small feeding vessels can be divided with the Harmonic scalpel. Finally the thymus is dissected free in the cervical area and thymectomy is completed. Complete dissection of the lateral adipose tissue along both phrenic nerves is confirmed at the end of surgery [9].

APPROACH TO THE PERICARDIUM

Partial pericardiectomy can be performed for both diagnostic and therapeutic purposes in patients with malignant pericardial effusion. The procedure requires general anesthesia and a double-lumen endotracheal tube for single-lung ventilation. Pericardial fenestration can be performed by either left or right approaches, although whenever possible we prefer the right approach due to the wider operating room and the reduced risk of damaging a coronary artery branch. The patient is placed in lateral decubitus position and a three trocars access is employed. The pericardial sac is incised with the hook cautery and the opening is enlarged with the endoshears. All the pericardial fluid is aspirated and collected for cytological examination. Afterwards, one of the free margins of the pericardial wound is grasped and a pericardial segment is excised. In this way, subsequent closure of the pericardial opening and recurrence of fluid accumulation is avoided. Additional pericardial biopsies can be performed if required.

More recently, the thoracoscopic approach has been employed to perform video-assisted pericardioscopy to assess resectability of bulky non-small-cell lung cancer with suspicion of intrapericardial invasion of the pulmonary vessels [11]. For this procedure we use a three-trocars access and a 0° camera. After incision of the pericardial sac (Fig. 5) and aspiration of the pericardial fluid, a videobronchoscope is inserted through the most anterior port into the pericardial space (Fig. 6) to carefully examine the intrapericardial tract of the pulmonary artery and veins. If these vessels are free from neoplastic invasion (Fig. 7), thoracotomy is immediately carried out.

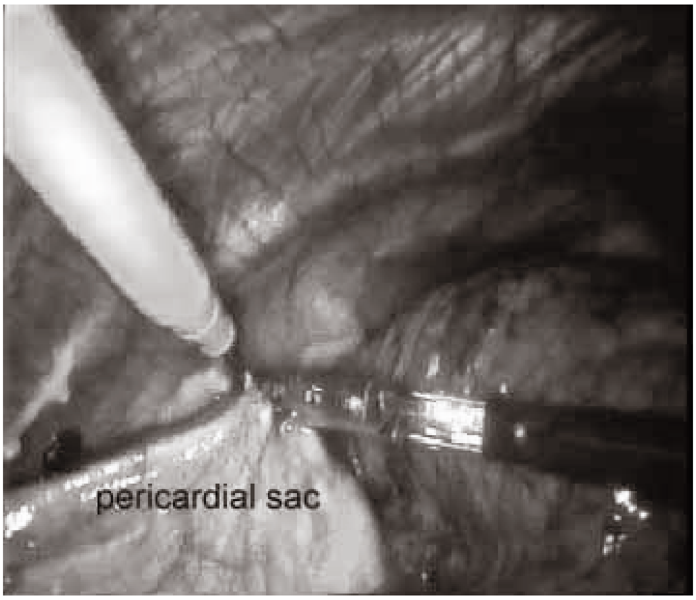

Figure 5. Operative view of the pericardial sac being incised by hook cautery.

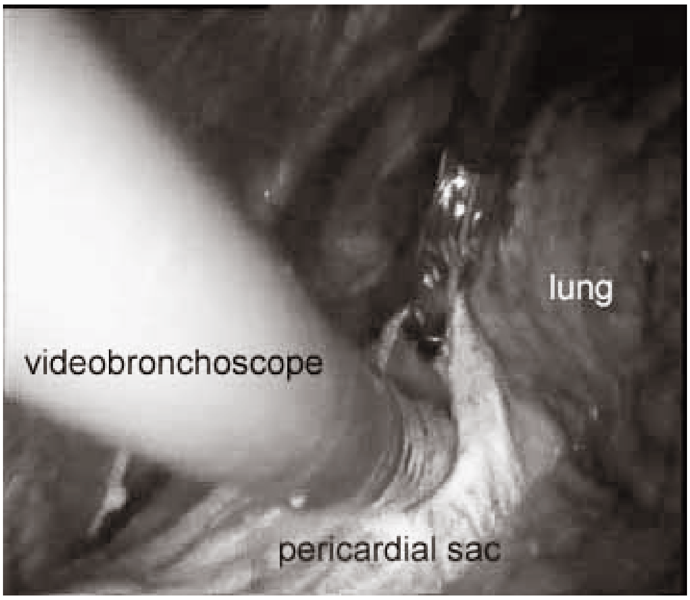

Figure 6. Videobronchoscopic examination of the intrapericardial tract of the pulmonary vessels.

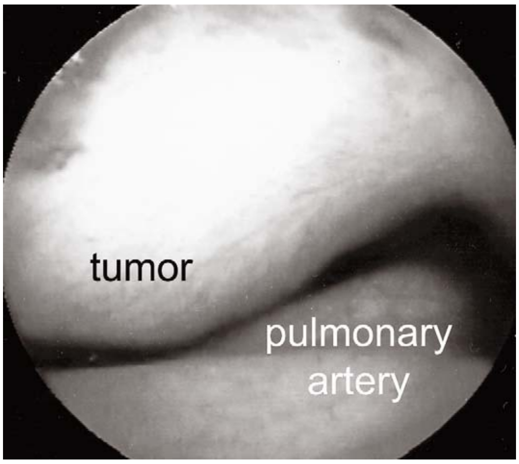

Figure 7

Intrapericardial view of the pulmonary artery, which is eventually found to be free from neoplastic invasion.

APPROACH TO MEDIASTINAL LYMPHADENOPATHY

Accurate clinical evaluation of the mediastinum is now possible due to the improved resolution of modern diagnostic radiographic modalities, including magnetic resonance imaging and helical computed tomography (CT). Transbronchial and CT-guided percutaneous needle biopsy can be effective in selected cases to confirm malignant cytology metastatic to mediastinal lymphnodes. However, a surgical biopsy is still required in many instances to establish a histologic diagnosis. Because of the access and visual limitations of cervical mediastinoscopy and anterior mediastinotomy, VATS techniques have been explored as an adjunctive modality to evaluate mediastinal lymphadenopathy, particularly when these are located out of the reach of the mediastinoscope or when a more comprehensive evaluation of the mediastinum is required and multiple sites within the mediastinum require biopsy. The focus of many of the reported experiences with VATS evaluation of mediastinal lymphadenopaty has been in the extended staging of potentially resectable lung cancer [12] and esophageal cancer [13, 14]. VATS is also useful in the evaluation of primary mediastinal lymphadenopathy associated with benign and malignant lymphoid conditions [15]. It can also easily provide sufficient tissue to establish the histologic diagnosis of benign or infectious diseases, including sarcoidosis and lymphoid hyperplasia. VATS avoids the more extensive and cosmetically unappealing anterior mediastinotomy incision and allows for immediate use of radiation therapy without the fear of detrimental wound healing problems. We currently routinely prefer VATS to anterior mediastinotomy for lymphadenopathies contained within the aorto-pulmonary window. However, we still prefer the anterior mediastinotomy approach for the diagnosis of large anterior mediastinal masses abutting the anterior chest wall. In these cases, a simple anterior incision is preferable to the complications surrounding double-lumen endotracheal intubation, especially when the trachea is compressed by a huge mediastinal mass.

Lymphadenopaty in aortopulmonary window. The dissection and sampling of lymphnodes and other pathologic processes in these locations have been safe, accurate and technically feasible. General anesthesia and double-lumen endotracheal intubation are required. For this VATS approach the patient is placed in right full lateral decubitus position, with the table rotated posteriorly to better expose the anterior part of the chest. The thoracoscope is usually introduced through the sixth ICS along the middle axillary line. Second and third ICS access sites are obtained through the fourth ICS in the auscultatory triangle and along the anterior axillary line for dissecting instruments and the endoscopic clip applier (Fig. 8). If necessary, an additional 5 mm port can be placed between the second and the third port, always through the fourth ICS so that the most posterior access can be employed to retract the lung with a fan retractor. A

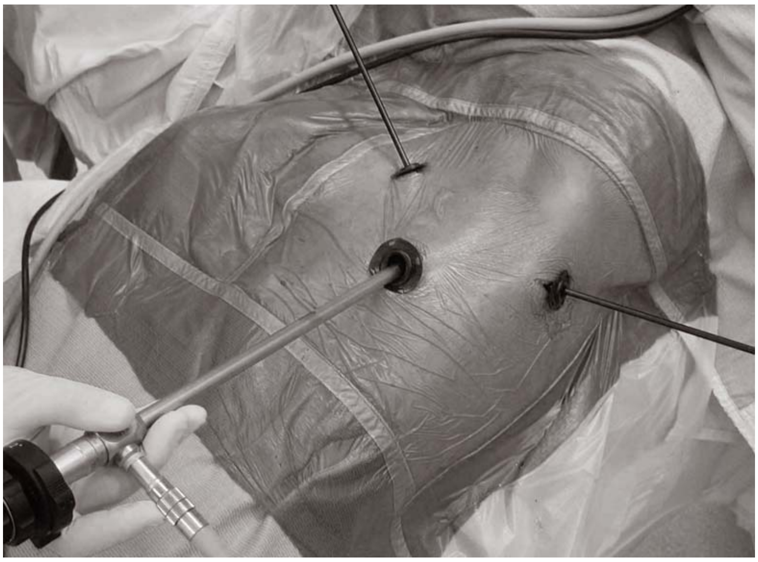

Figure 8 Operative view of VATS access for biopsy in the aorto-pulmonary window respecting the ideal triangular disposition of the camera and instrumentation.

nodal dissection with visibility superior to that obtained through the anterior mediastinotomy approach is consistently achieved (Fig. 9).

Lymphnode staging in lung cancer. VATS can be employed as an alternative to anterior mediastinotomy for the biopsy of lymphnodes in the aortopulmonary window (ascending aorta nodes and Botallo ligament nodes). In addition, it also allows access to paraesophageal and pulmonary ligament levels that are not reachable either by mediastinoscopy or by anterior medastinotomy. In selected

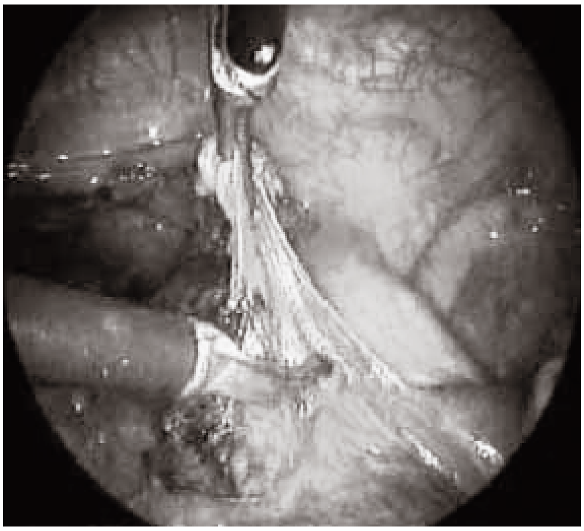

Figure 9

Operative view of lymph node biopsy in the aorto-pulmonary window.

cases, VATS can be performed in combination with video-assisted mediastinoscopy, either in staged or simultaneous fashion, for a more accurate lymphnode staging [16].

On the right side, VATS allows exploration of upper and lower paratracheal lymphnodes, subcarinal nodes, paraesophageal and pulmonary ligament nodes. An additional advantage of using VATS for mediastinal staging of lung cancer is the possibility to concomitantly assess the resectability of bulky tumours with radiologic suspicion of mediastinal invasion and to discover unsuspected pleural seedings, thus avoiding unnecessary thoracotomy.

Lymph nodes staging in esophageal cancer. Since lymphnode metastasis has been shown to represent an important prognosticator in esophageal cancer, VATS has been employed in combination with laparoscopy for staging of biopsy-proven esophageal cancer [13, 14]. Thoracoscopic lymphnodes staging is usually performed through a right approach and a three-trocar access that allows one to reach the right paratracheal nodes, the subcarinal nodes and most of the paraesophageal nodes. On the other hand, whenever noninvasive staging shows enlargement of the aortopulmonary window lymphnodes, a left-sided approach is preferred.

APPROACH TO BRONCHOGENIC CYSTS

Bronchogenic cysts are lined with ciliated, columnar epithelium and often contain mucous glands or cartilage in their walls. They are most commonly found in the middle mediastinum, although they may also be located in the posterior mediastinal compartment. They are often asymptomatic, being discovered incidentally. However, they may cause symptoms due to compression or irritation of adjacent structures and infection from communication with the tracheobronchiale tree. Preoperative evaluation includes a chest X-ray, which usually reveals a well circumscribed rounded density with or without signs of calcifications in the capsula. An air fluid level may be present if a communication with the gastrointestinal or respiratory tract does exist. An esophagogram may reveal distortion of the esophagus, while a CT scan can be useful to confirm the diagnosis and provide information about connections with the tracheobronchiale tree or the esophageal wall. Complete resection is the preferred management of these lesions. After positioning of the patient as previously described for similarly located lesions, proper exposure is achieved after division of thick adhesions which are frequently found in these instances. The cyst is than aspirated and its content is submitted for bacteria and fungi cultures. Subsequently, the cyst is grasped with a clamp and the mass is dissected away from the surrounding tissues. In most patients, the cyst can be removed in its entirety. Sometimes, however, the cyst is adherent to vascular structures, so that a small amount of its wall can be left in place to reduce risks of vascular injuries. In these cases, cauterization of the mucosal lining of the residual part of the cyst is recommended to avoid recurrence. The pleural cavity is then irrigated with antibiotic solution and 2 chest tubes are inserted into the pleural cavity [17].

APPROACH TO POSTERIOR NEUROGENIC TUMOURS

Posterior neurogenic tumours, including schwannomas, neurofibromas and ganglioneuromas, documented by magnetic resonance imaging and/or CT to be free of neural canal involvement, are ideally suited for VATS resection. Contraindications for the thoracoscopic approach include malignant histology, size greater than 6 cm, a low costodiaphragmatixc location and the presence of a spinal artery in close proximity to the tumour [18, 19]. As for other intrathoracic pathology, optimal instrument manipulation is achieved by inserting the trocars so that the lesion can be managed from an adequate distance. Thus, we usually approach posteriorly located lesions through a slightly anterior access site. We also rotate the operative table anteriorly to facilitate gravity assistance for the displacement of the lung. Most frequently, posterior neurogenic tumours are located in the superior costovertebral recess. In these cases, a 0° thoracoscope is introduced through the sixth intercostal space at the mid axillary line. A lung retractor is placed through the fifth intercostal space in the anterior axillary line, while two operating ports are placed in the fourth and third intercostal spaces through the anterior axillary line (Fig. 10).

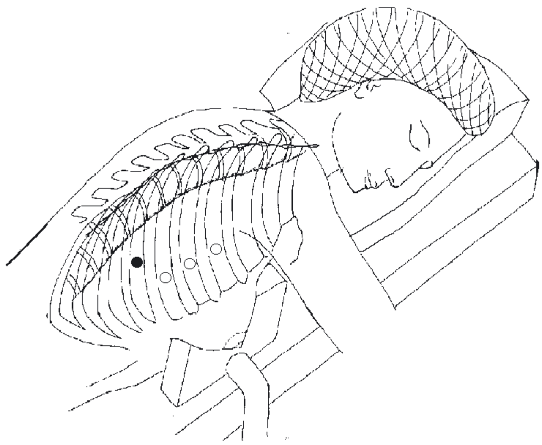

Figure 10.

Disposition of thoracoscopic ports for access to posterior mediastinal tumors. Filled in circle indicates the camera port. Open circles indicate ports for instrumentation.

Occasionally, it can be necessary to extend one of these incisions to facilitate tumour dissection and removal. When the tumour is excised, it is extracted from the chest through an endoscopic retrieval bag and a chest tube is placed in the posterior mediastinum.

APPROACH TO BENIGN ESOPHAGEAL ANOMALIES

A thoracoscopic approach can be safely used to treat several benign esophageal lesions the most common of which are leiomyomas. The approach to the upper and midesophagus is performed through the right pleural cavity, while that for lower thoracic esophagus and gastroesophageal junction is best accomplished from the left chest. The camera port is placed two intercostal spaces caudad to the lesion in the midaxillary line and two to three operating ports are placed following the usual triangular or diamond disposition. For lesions of the gastroesophageal junction, the trocar placement is reversed. For a typical midesophageal leiomyoma, a 10 mm 0° telescope is introduced into the right pleural cavity through the seventh intercostal space on the midaxillary line. Next, a fan retractor is inserted through the fifth intercostal space on the midclavicular line. Operating ports are placed through the fourth intercostal space on the posterior and the anterior axillary lines, respectively. A hydrostatic balloon dilator is inserted under endoscopic guidance and inflated to compress the tumour and thus facilitate its identification and enucleation. The mediastinal pleura is incised and the exposed esophagus bulges slightly into the wound. After the esophageal muscular layers are incised, the exposed tumour is separated bluntly from both the muscle and mucosal layers. Once the tumour has been excised, it is placed in an endoscopic specimen bag and removed through the most anterior port, the muscle layer is re-approximated with interrupted non-absorbable sutures to prevent pseudodiverticula formation. A single chest tube is placed in the posterior mediastinum close to the esophageal suture [20].

Other nonmalignant lesions of the esophagus, including duplication cysts and diverticula, can be treated using a similar approach. The preferred management of both these lesions is complete resection, which is best accomplished with an endoscopic stapler placed at the base of the lesion after incision of the esophageal muscle layers. Once again, suturing the muscle layer over the staple line. For esophageal diverticula, a concomitant myotomy distal to the pouch is usually performed thoracoscopically, to treat the underlying motor disorder and to prevent recurrence [17].

Recently, thoracoscopy-assisted esophagomiotomy has been performed in patients with esophageal achalasia by a combined 8 to 10 cm minithoracotomy sixth or seventh intercostal space and two 10-mm trocar ports placed through stab incisions inferior to the thoracotomy [21].

VATS ESOPHAGECTOMY

Esophagectomy represents the optimal treatment for localized esophageal cancer. The most effective surgical option is the three-holes esophagectomy, entailing a thoracotomy, a laparotomy and a cervicotomy access. This aggressive approach, however can be associated with significant morbidity and mortality. Avoiding the consequences of thoracotomy in fragile patients might be the first step toward the goal of reducing the esophagectomy-associated morbidity. Transhiatal esophagectomy is one alternative to thoracotomy but has the disadvantage inherent to the blind dissection involved. VATS has been proposed as a less invasive alternative aimed at allowing the dissection of the thoracic esophagus to be performed under direct vision without thoracotomy [22-24]. The operation is carried out in three stages. The first is the thoracoscopic mobilization of the esophagus. The second is the construction of the gastroplasty, which is carrried out through laparotomy incision, while the third stage is the creation of the cervical anastomosis between the esophagus and the gastric pull-through. The patient is placed in the left lateral decubitus position, tilted forward a little to facilitate exposure of the posterior mediastinum. Using double-lumen tube intubation, five trocars are inserted in the right side of the chest, one through the sixth intercostal space, two through the fourth, and two through the eight (Fig. 11). The posterior mediastinum is entered through two longitudinal incisions in the right mediastinal pleura, along the right sympathetic chain and the right wall of the trachea, respectively. The azygos arch is divided by endoscopic vascular stapler so that access to the

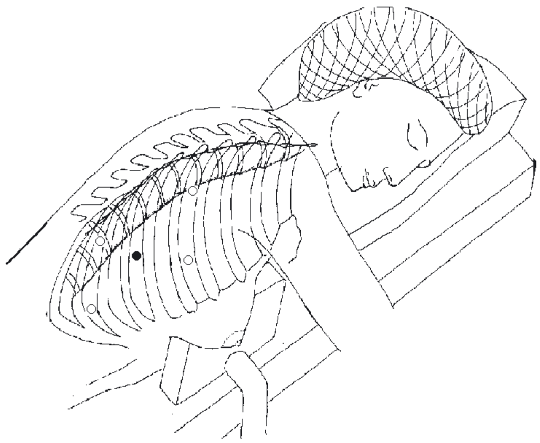

Figure 11

Disposition of thoracoscopic ports for access to the esophagus for VATS esophagectomy. Filled in circle indicates the camera port. Open circles indicate ports for instrumentation.

lower part of the trachea is achieved. The right vagus nerve is divided. The anterior aspect of the descending aorta is cleared up. This step requires careful identification and interruption of two or three esophageal arteries. The esophagus is progressively dissected free either below and above the tumour level and subsequently encircled with two vascular tapes to allow gentle traction and thus facilitate the completion of the esophageal mobilization. All periesophageal, subcarinal, and paratracheal lymphnodes are disected free either en bloc with the esophagus or separately [24].

Posteriorly, middle and upper mediastinal dissection lead to division of the left vagus nerve just below the left main bronchus. Once the dissection is completed, the esophageal bloc is eventually abandoned in the chest. The chest is drained by two chest tubes. The patient is then placed in the recumbent position for laparotomy and cervicotomy as for the standard three-holes approach.

APPROACH TO THE SYMPATHETIC CHAIN

Dorsal sympathectomy with VATS is usually performed for palmar and axillary hyperidrosis, although patients with reflex sympathetic dystrophy, peripheral vascular disease and Raynaud's syndrome can also benefit from the procedure [25, 26]. The recent development of miniaturized instrumentation and scope can now allow one to minimize the extent of the skin incisions resulting in excellent cosmetic results. In patients with palmar hyperidrosis, we perfom a bilateral surgical ablation of the sympathetic chain between T2 and T3 associated with resection of all visible side branches under sole loco-regional anesthesia. A percutaneous intercostals block is performed at the level of the thoracic incision for a maximum extension of 3 spaces by local injection of ropivacaine 7.5%, 4 mL for each intercostal space. Patients maintain spontaneous breathing throughout the procedure and supplementary oxygen is administered by means of a facemask as required. The patient is placed in the semi-prone position for each side, with the ipsilateral arm abducted and mild anti-Trendelenburg inclination. After additional local anesthesia with 10 mL of mepivacaine 2%, two 5 mm ports are placed respectively in the fourth intercostals space on the midaxillary line and the third intercostal space at the midaxillary line just anterior to the latissimus dorsi muscle (Fig. 12). The former being used to introduce a 5 mm telescope, while dissection is performed

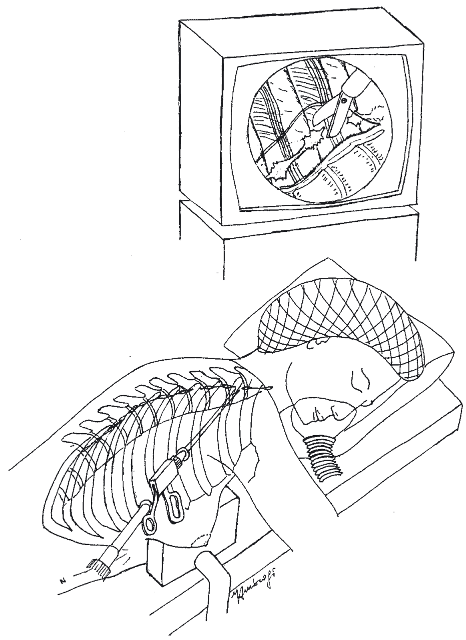

Figure 12 Patient positioning and instrument placement for dorsal thoracic sympathectomy

through the other port. The first side to be approached is always the right. The surgical technique consists in opening the parietal pleura, identifying the T2-T3 sympathetic chain and dividing by cautery communicating branches. Subsequent dissection at T2 level is always performed by scissors to avoid possible heat injury to the stellate ganglion, while T3 section is made on cautery. Careful dissection of accessory branches and the Kuntz nerve is performed to prevent relapses. A 10 Fr thoracic drain is inserted through the lower port and left in place in each pleural cavity for 2 to 3 hours.

APPROACH FOR MANAGEMENT OF ACUTE PURULENT MEDIASTINITIS

Acute mediastinitis is an extremely severe infection that can occur due to esophageal perforation, thoracic operation, oropharingeal infections or penetrating chest trauma. Overall mortality can be as high as 40%. Appropriate management require prompt diagnsosis and active surrgical intervention in addition to appropriate antibiotic therapy.

Accepted surgical approaches include anterior cervicotomy with or without subxiphoid incision, thoracotomy or even open window thoracostomy.

During the last few years, the expansion of the indications for VATS in mediastinal pathology have led to applying it to manage acute purulent mediastinitis [27]. The procedure can be performed by either a right or left approach. Under general anesthesia and with double-lumen tube intubation, the patient is placed in lateral decubitus position as for thoractomy and a two trocar access is usually employed. In fact, VATS allows excellent visualization of the whole pleural cavity. After evacuating blood clots, pus and fibrinous debris from the pleural cavity, it is possbile to explore the mediastinum and to drain mediastinal fluid collections.

CONCLUSIONS

VATS have proven its usefulness in dealing with pathology in the mediastinum compartments. The surgeon's judgement plays a key role in deciding which procedure is best suited for dealing with a particular lesion in any given patient in order to assure optimal management with fewer risks. The cost-effectiveness of these minimally invasive procedures compared with the analogous open procedures still remains to be determined. In fact, despite a shortened hospital stay and an easier patient acceptance of the procedure, the equipment is more expensive and time spent in the operating room may be longer. Nonetheless, there exists now sufficient evidence that for some disease processes, such as mediastinal biopsy in areas not reached by the mediastinoscope, nonthymomatous myasthenia, mediastinal cysts or benign posterior mediastinal tumours, VATS can undoubtedly offer some advantages over standard open approaches and could now be advocated as the technique of choice.

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CHAPTER 6

MINIMALLY INVASIVE ACCESS TO THE AXILLA

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Axillary dissection is presently considered to be the standard treatment for breast cancer. Our studies revealed that almost 80% of less than 2 cm breast tumor patients (T1,N0), who had clinically negative axillary node, had a negative hystological examination (pN0) after surgery. Tumor cells progressively spread to regional lymph nodes from first to third level; present skip-metastases in only 2% of cases. The number of involved nodes is related to breast cancer dimensions. According to recent literature, only 15% of 1 cm tumor breast cancer patients had axillary metastases, while 70% of 5 cm tumor breast cancer patients had node metastases. Lymph-node status is still the most important independent prognostic parameter [1,2,3,4], although other prognostic factors have been studied in order to avoid axillary dissection.

Axillary dissection is a high morbidity rate surgical procedure: it produces pain, paresthesies, seroma, lymphoedema, infection and arm disorders, according to different authors [4]. On the above considerations, since 1996 the sentinel lymph-node technique has been adopted as the experimental procedure intended to avoid axillary dissection in selected T1 clinically negative axillary node breast cancer patients [5,6]. To date, this procedure validity has been endorsed by both clinical and oncological evidence. This also enhances the importance of immunohistochemical and genetic amplification techniques in detecting lymph-node metastasis (Table 1) .

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Table 1 Accuracy in predicting axillary node status using immunohistochemical and genetic amplification techniques in detecting lymph-node metastasis

Study *	Study Population	Tumor Stage of Study Participans	Method Used (blue dye, radioactive tracer or combined technique)	Accuracy in Predicting Axillary Node Status Sensitivity %
Guenther et al [9]	145	All tumor stages	Blue dye alone	90.3%
Giuliano et al [10]	107	T1 or T2	Blue dye alone	100 %
Veronesi et al [6]	376	T1, T2, or T3	Radioactive tracer alone	93.3 %
Krag et al [5]	443	All tumor stages	Radioactive tracer alone	88.6 %
Borgstein et al [11]	130	T1, NO or T2, NO	Radioactive tracer alone	98.3%
Reuhl et al [12]	123	All tumor stages	Radioactive tracer alone	93%
Martin et al [13]	758	T1, NO or T2, NO	Combined technique	94.2%
Nwariaku et al [14]	119	All tumor stages	Combined technique	96.3 %
Doting et al [15]	136	T1, T2, T3, or T4	Combined technique	95 %

* Clinical Trials (non-randomized)

About 25% of negative nodes patients presented micrometastases after a more accurate specimen analysis. This finding is enough to modify the disease staging assessment and probably the patients' prognosis, thus raising a breast cancer micrometastases management problem. If preliminary results are confirmed, indication to sentinel node technique will be restricted to only 30-50% of T1 breast cancer patients. All other cases are to be treated by standard axillary dissection.

According to the U.S.A. National Cancer Institute guidelines for breast cancer, axillary lymph nodes staging should be considered a valuable aid in indicating prognosis and therapy. Most authors agree that axillary node dissection in case of clinically negative nodes is a necessary staging procedure. However, controversy exists as to the extent of the procedure because of the associated long-term morbidity (arm discomfort and swelling). Data suggest that the lymph node involvement level (I versus II versus III) does not add any independent prognostic information on the total number of positive axillary nodes [1] Therefore, the standard evaluation procedure usually envisages only a I and

II level dissection, thus removing a sufficient number of nodes (at least 6-10), while reducing the procedure's morbidity. Several research groups have tried to define a population of women having such a low nodal metastasis probability as to avoid axillary node biopsy. In these single institution case series, the prevalence of positive nodes in patients with T1a tumors ranged from 9% to 16%.[2; 3] In another series, the incidence of axillary node relapse in patients with T1a tumors treated without axillary node dissection was 2%.[4]

Since the axillary node status remains the most important outcome indicator in breast cancer patients, lymphnode staging is to be recommended in most patients with invasive breast cancer.

In an effort to decrease the morbidity of axillary lymphadenectomy while maintaining accurate staging, several studies have investigated lymphatic mapping and sentinel lymph node (SLN) biopsy in women with invasive breast cancer.[5, 6] The SLN is the first node in the lymphatic basin to receive primary lymphatic flow. Studies revealed that the drainage of detection compounds (such as technetium-labeled sulfur colloid, vital blue dye, or both) into the axilla, allows the identification of the SLN in 92% to 98% of patients [7, 8]. Detection compounds should be injected into the biopsy cavity or into the subareolar area or around the tumor. These preliminary reports demonstrate a 97.5% to 100% concordance between SLN biopsy and complete axillary lymph node dissection.[5, 6]

The reported false-negative rates (the number of patients with negative SLN biopsy divided by the number of patients with positive axillary nodes at the time of axillary node dissection) of SLN biopsy range from 0% to 10%. The success rate varies with the surgeon's experience and with the primary tumor characteristics. Studies have suggested the use of SLN biopsy only to T1 and T2 patients, without evidence of multifocal involvement, clinically positive lymph nodes, or prior chemotherapy (neoadjuvant). Before SLN may replace total axillary lymphadenectomy, randomized trials are needed in order to confirm that both procedures yield comparable survival rates. If axillary lymph nodes are affected by cancer, sentinel node biopsy will detect it in over 90% of cases, as reflected in the results of the nine non-randomized clinical trials listed below. However, only recurrent randomized controlled trials (such as the NSABP B-32 trial) can monitor patient's outcome in cases of sentinel node biopsy and of standard axillary lymph node dissection.

It is important to note that prior experience of the breast surgeon is critical to the success of sentinel node biopsy. Demand from patients for the procedure might outpace adequate physician training in some medical centers. Patients should always be assured that the physicians performing surgery and subsequent nodes analysis have adequate experience with the procedure.

In 1993, Suzanne et al. [16] first issued reports on the endoscopic approach for axyllary limphadenectomy in breast cancer. They were followed by others as Brun in 1998 [17]. The aims were:

a) to reduce procedure morbidity (pain, arm discomfort and oedema, shoulder restriction) [18; 19; 20], and

b) To give better aesthetic results by reducing axillary scarring while preserving the same oncologic radicality as the traditional open technique. The above aims were to be obtained through minimally invasive access, sufficient to perform adequate lymphnode dissection.

So far, studies concerning sentinel node biopsy appear very promising in avoiding a complete axillary lymphadenectomy in selected patients.

Unfortunately, today less then 50% of breast cancer patients can be treated by sentinel node biopsy alone.

Complete axillary dissection must be performed in the following cases:

– Patients with pre-operative clinically positive axyllary lymph nodes;

– Patients with positive sentinel node;

– Patients with multifocal or large breast cancer.

On the above considerations, we think that the time has not yet come to completely abandon axillary dissection as the local treatment and the prognostic parameter, with the exception of selected cases; it is still mandatory to try and reduce the morbidity of this surgical procedure. Seroma is definitely the most frequent axillary dissection complication and its management surely affects National Health Care costs. Many controversial solutions have been proposed to solve this problem. Some tried to act on the surgical technique; others on drains management, others again have evaluated the influence of postoperative physiotherapy timing on lymphatic complications of axillary dissection.

Another issue is nowadays important: the gold standard in breast cancer surgery is to achieve the best oncologic result combined with the best cosmetic and functional result possible.

For this reason, several studies have been carried out to reduce the anti-aesthetic effects of breast surgery. A new word has been created to describe a kind of surgery that can conjugate oncologic and reconstructive surgery: oncoplastic surgery.

The concept of oncoplastic surgery, first described by Audretsch [21], is based on the possibility to apply some plastic surgery techniques to breast oncological surgery. The possibility to perform breast conserving surgery without leaving anti-aesthetic scars and breast deformities is today achievable if performed by expert breast surgeons. [22, 23, 24]

Therefore, the use of minimally invasive surgery alone or in addition to open surgery (video-assisted), can be an important tool in the surgeon's hands.

ENDOSCOPIC AXILLARY SURGERY

As we have already mentioned, in this sentinel node biopsy world the need of a complete axillary dissection still remains valid. Apart from mastectomy cases, where the entity of breast demolition easily allows the performance of dissection cases of skin-sparing mastectomy, presently increasingly used in breast conserving surgery, still faces two situations where a complete axillary dissection is required:

– Clinically positive axillary nodes and
– Positive sentinel node, particularly when the sentinel node biopsy is performed in local anaesthesia before the lymphadenectomy.

In the above cases, the axillary dissection can be performed through the access way of the tumorectomy or with a separate incision in the axilla. This incision has to be three to four cm long it and needs a strong retraction of the pectoral muscles, resulting in post-operative pain and shoulder restriction.

The use of minimal invasive surgery can reduce the entity of the scar and the post-operative discomfort.

ANATOMICAL NOTES

The axilla comprises lymph nodes, nerves, large blood vessels, and muscles and it is adjacent to the upper ribs. Access to the axilla is necessary for lymph node sampling and excision to determine the cause, extent, and type of cancer or other diseases that affect the lymph nodes.

The axilla is the pyramidal area at the junction between the arm and the thorax. A knowledge of the neurovascular relationships within the axilla is of paramount importance to a clinician.

Boundaries of the axilla

The apex of pyramid points into the neck and lies between the 1st rib, the clavicle and the superior edge of the subscapularis muscle. The major vessels of the arm pass through the apex. (Fig. 1)

The *base* is formed by the skin of the armpit and the fascia extending from the arm to the thoracic wall.

The *anterior wall* is formed by pectoralis major and minor and the clavicle.

The *posterior wall* is composed of the subscapularis muscle on the costal surface of the scapula and more laterally, the muscles of the posterior axillary fold (teres major and latissimus dorsi).

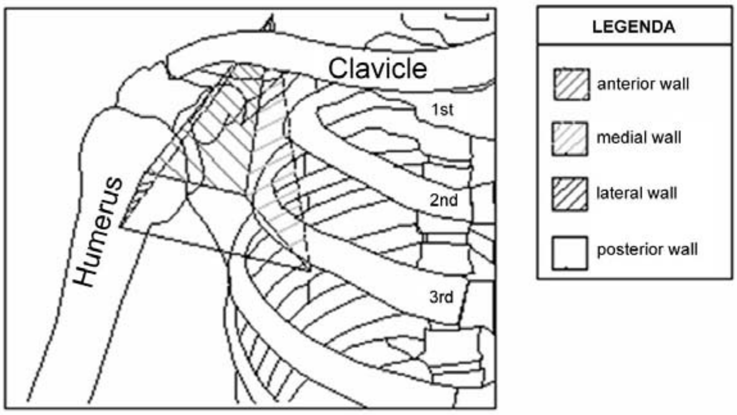

Figure 1 Boundaries of axilla

The *medial wall* is made up of serratus anterior muscle that covers the thoracic wall in this region (over 1st to 4th ribs and the associated intercostal muscles)

The *lateral wall* is narrow as the anterior and posterior walls converge laterally and is formed by the intertubercular groove of the humerus

Contents of the Axilla

The axilla has 4 main components: the axillary artery and vein, the lymph nodes and the brachial plexus with all its branches. The axillary artery, the brachial plexus, and the main branches of this plexus are enclosed in an axillary sheath (a sleeve of tough fascia). This sheath, the axillary vein, the groups of lymph nodes and the branches of all the major vessels and nerves are embedded in a large amount of tough fatty tissue, making anatomic and surgical dissection of the axilla challenging. (Fig. 2)

The axillary artery is a continuation of the subclavian artery and begins at the lateral border of 1st rib, passes posterior to pectoralis minor and ends at the inferior border of teres major to form the brachial artery. Branches of the axillary artery supply the muscles and joints of the shoulder and pectoral region and also part of the breast.

The axillary vein lies on the medial side of the axillary artery and collects blood from all parts and regions of the upper limb. It is the direct upward continuation of the basilic vein of the arm at the inferior border of teres major and ends at the lateral border of 1st rib to become the subclavian vein. The vein lies outside the axillary sheath.

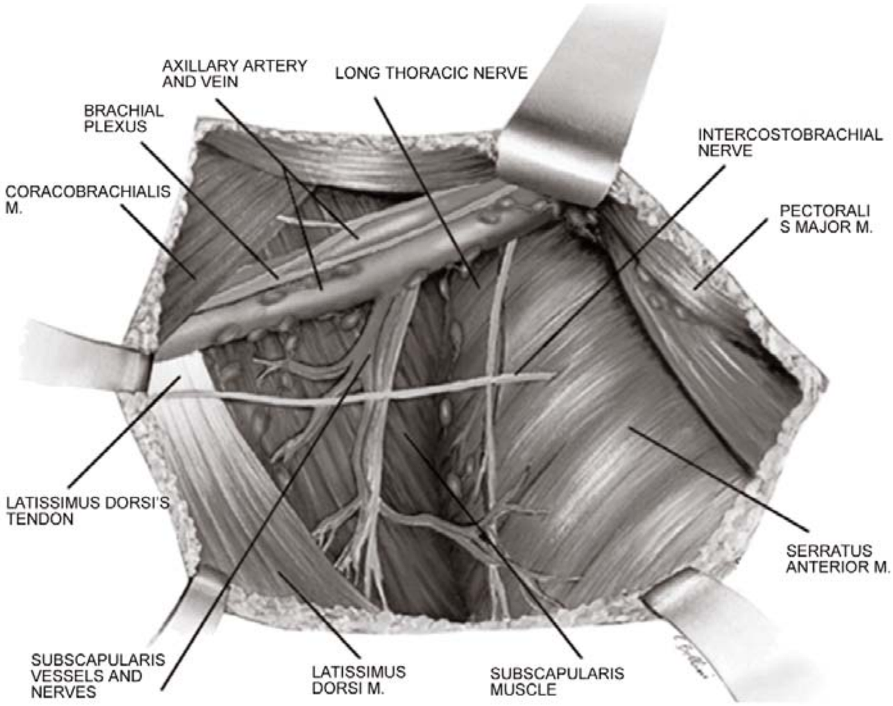

Figure 2 Axillary vessels, lymphatics and nerves

The brachial plexus is an ordered network of large nerves through which sensory and motor nerve supply is distributed to all structures in the upper limb. This plexus is formed by the union of the ventral rami of C5-C8 and T1 nerves. The cords of the plexus - medial, lateral and posterior - are named according to their relationship with the axillary artery.

Axillary Lymph Nodes: apical (subclavicular) group, central group, lateral group, anterior (pectoral) group, posterior (subscapular) group

SURGICAL OPTIONS

There are three surgical options in minimally invasive axillary dissection:

– Endoscopic lymphadenectomy, performed following liposuction of axillary fat [Suzanne (16); Kuhn (25)];
– Endoscopic lymphadenectomy by using CO2 insufflation in the axillary cavity or by using a balloon with [Winzer (26)], or without prior lipoaspiration [(Wilmot (27), Kamprath (28)]
– Video assisted axilloscopy in which the axillary access can be combined with a periareolar surgical approach used to perform the tumorectomy.

Endoscopic lymphadenectomy performed following liposuction of axillary fat (Suzanne; Kuhn)

The patient is placed in the common supine position.

Axilloscopy is prepared by prior lipoaspiration of the axillary fat. Before performing liposuction, a lipolytic solution (200-300 cc) is injected by a Verres needle into the axilla (composition of the solution: saline solution 250 ml, distilled water 250 ml, adrenalin 1:1000 1cc and xylocaine 1% 40ml) after 20 minutes, the dissolved axyllary fat is sucked out by using lipoaspiration.

A 5 mm trocar is then introduced into the same hole of the removed Verres needle and the axilla is insufflated using CO2 at 10 mm Hg pressure. The cavity can thus be viewed video endoscopically with a 5 mm diameter 30° endoscope. a 10 mm trocar is placed as far as possible above the camera trocar, medially, under direct vision, approaching the axillary vein and another 5 mm trocar, which serves as the working port, lateral to the camera trocar (Winzer; Kuhn).

Other authors describe the same technique using 2 mm trocars [Tagaya (29)].

The dissection is performed in the same way as the traditional technique by isolating the axillary vein and removing all the nodes. The long thoracic nerve, the thoraco-dorsal-neuro-vascular bundle and the intercostobrachial nerves are preserved. All nodes collected are then removed from the 10 mm incision and a suction drain is left in the axillary space.

Endoscopic lymphadenectomy by using CO2 insufflation in the axillary cavity with the use of a balloon

A 10 mm incision is made on the mid axillary line and a blunt dissection proceeds down to the lateral margin of the major pectoral muscle.

A pre-peritoneal distension balloon system is inserted into the dissected area and inflated to create a working space. The balloon is then removed and a 10 mm balloon trocar is placed to prevent air leakage and to maintain the working space. An axillary space is created by insufflation with CO2 at a pressure in the range of 6 to 10 mm Hg. A 30° endoscope is introduced through a 10 mm trocar and two 5 or 2 mm trocars (8 cm in length) are introduced at the cranial and caudal sides of the 10 mm trocar. Then the fat and lymphatic tissue is dissected from the medial side of the thoraco-acromial vessels towards the latissimus dorsi muscle, after identification of the axillary vein.

Video assisted axilloscopy in which the axillary access can be combined with a periareolar surgical approach used to perform the tumorectomy.

Complete (360°) or partial (180°) periareolar incision is performed in order to proceed to the tumorectomy, a large portion of the breast gland is detached from the skin and from the major pectoral muscle fascia. (Fig. 3).

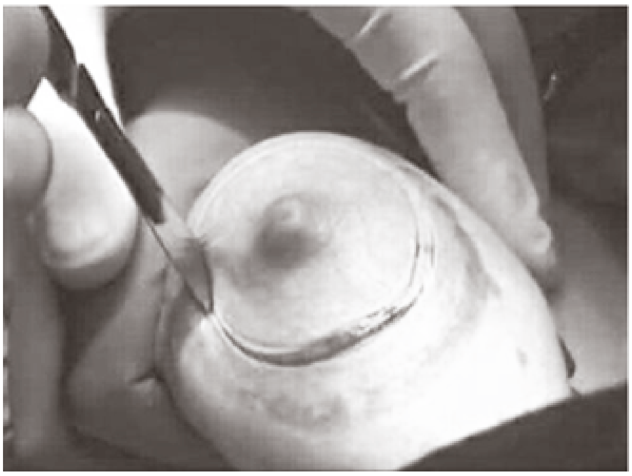

Figure 3

See text

After the remotion of the breast gland quadrant containing the cancer, the clavicopectoral fascia is opened by conventional surgery.

Two 5 mm trocars are introduced in the axilla, respectively one in the cranial side and caudally to the first. (Fig. 4)

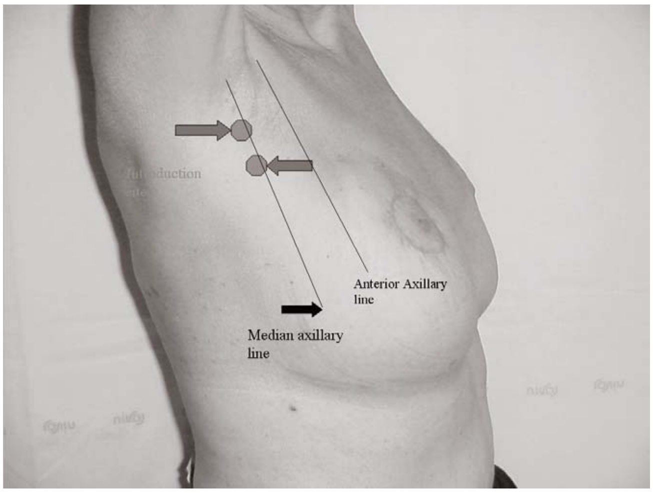

Figure 4

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A 30° endoscope is introduced through the periareolar incision, while the endoscopic instruments are introduced through the trocars. The space in the axilla is achieved by a gentle retraction of the pectoral muscle through a retractor inserted in the periareolar hole. (Fig. 5)

Figure 5

See text

Axillary dissection is performed in the same way as described previously and the axillary content is extracted through the periareolar hole. (Fig. 6)

This technique was first described by our group as an original technique in 2001 [30, 31]

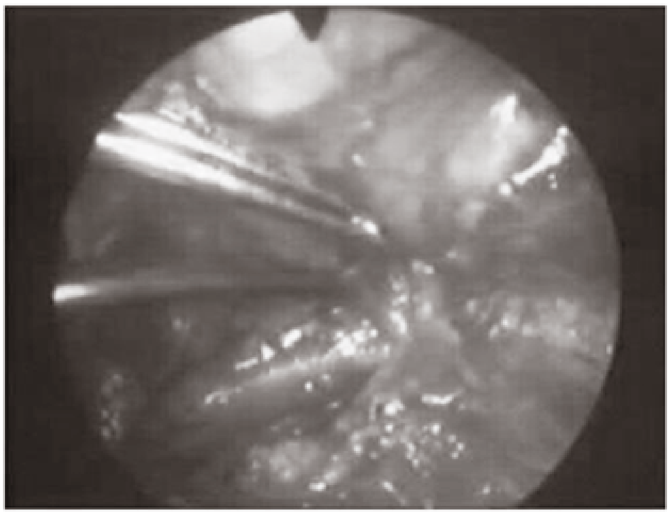

Figure 6

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RESULTS

Salvat [33] reported a randomized study comparing clinical and anatomo-pathological results of endoscopic axillary lymph node sampling with traditional surgical treatment, on 40 breast cancer patients, 20 of them undergoing open surgery and 20 undergoing axilloscopy.

Axilloscopy was perfomed through previous lipolysis of the axilla, as previously described, after insufflation at 8 mmHg pressure. The first datum is that the operation time in axilloscopy is aproximatively double that for traditional surgery (33 minutes versus 60 minutes). The number of nodes collected was almost the same (Endoscopy 12.9 vs surgery 11.7). The nodes collected by axilloscopy revealed a number of morphological lesions, partial or complete tearing of capsule, fragmentation, shearing, hemorrhage. In case of endoscopic treatment, the AA presented two cases of local relapse against 0 cases in traditional surgery. This event might be caused by node capsule rupture. There are no advantages in terms of seroma.

Kuhn et al. [33] performed axilloscopy through previous lipoaspiration in 53 breast cancer patients. The operating time ranged between 60 to 150 min. The average number of nodes collected was 17, the extent of postoperative lymphorrea and the seroma rate was the same as that of traditional surgery. Lymph node fragmentation appeared in 42% of cases. Damage of soft tissue was observed in 66% of patients; therefore AA concluded that lipoaspiration is not an atraumatic technique.

No substantial data about an improvement of shoulder-arm morbidity in axilloscopy compared to traditional open surgery are available. Kuehn et al. concluded that “endoscopic axillary dissection cannot yet be recommended in a daily clinical routine”.

Tagaya et al. [29] described endoscopic axillary lymphadenectomy on 5 breast cancer patients using needlescopic instruments (2mm). The procedure was performed without prior liposuction, in an avarage time of 105 min. No differences were reported about limphorrea or incidence of seroma compared to traditional surgery. The AA report better cosmetic results and a lower incidence of shoulder limitation.

Also Kamprath et al. [28] described axilloscopy in 33 patients without liposuction, in order to reduce side effects of the procedure in terms of tissue damage. Their results were similar to those described by others in terms of time length (average time 80 min.) and number of collected nodes. The lymphorrea and seroma incidence was also similar.

Cangiotti et al. [34] reported 15 patients treated by axilloscopy preceded by liposuction, where results were similar to those described by other authors.

Today, sentinel node biopsy is a popular procedure in breast cancer treatment, as we have mentioned. The use of this technique is also reported by comparing the traditional sentinel node biopsy to the endospic procedure. Sentinel node localization is obviously performed either by radiotracer or by blue dye.

Kocher et al. [35] first discussed the issue of the role of endoscopic limphadenectomy on the duration of the sentinel node procedure. Winzer [26] described the sentinel node biopsy by endoscopic procedure associated with radiotracer. Time of the operation ranged from 167 to 235 min. Results (only 4 cases) were disappointing, in our opinion: 2 cases were converted in open surgery and in one case did not detect the sentinel node. Also Kuenh [33] reported a preliminary study on 35 breast cancer patients where the sentinel node biopsy was performed by endospic procedure associated with lipolysis using blue dye. Sentinel node biopsy was followed in all cases by a complete axillary clearence, with an avarage number of 17 nodes removed.

Our experience [30; 31] suggests that in order to combine the best oncological result with the best cosmetic result, we take a total periareolar approach in conservative breast cancer surgery, when possible. In order to avoid an axillary scar when sentinel node positive biopsy requires complete axillary cleaning, we perform limphadenectomy by the same periareolar access. Sometimes, a combination of open surgical approach and video-assisted approaches can be useful. In these cases, the use of an endoscopic camera allows a better wiew and the use of two 5mm trocars inserted in the axilla is useful to perform the procedure. In this way, the duration is the same as that of traditional surgery (average time 30 min.). No liposuction or insufflation is needed. The axillary fat is removed "en bloc" with the nodes that are not isolated or damaged, as performed in open traditional surgery.

CONCLUSIONS

The use of endoscopic axillary lymphadenectomy in breast cancer was first proposed by Suzanne in 1993 [16]. Since this first report, only few studies have been performed. In particular, only one randomized study [33], on the long term oncologic effects of axilloscopy, refering to the incidence of local recurrences, is available. The use of the lipolytic technique, allowing for liposuction before endoscopic procedure, seems to be not adequately safe from an oncologic point of view. In all reports, this technique always implies damage to the nodes. Sometimes with the presence of neoplastic cells in the fluid collected by liposuction.

This is the reason why we recommend the liposuction technique.

Another issue is the operation time, which is longer in the endoscopic procedure than in traditional surgery, ranging from 60 to 235 minutes, versus the 30 minutes in traditional open surgery. This time length creates a serious problem in terms of costs and of anesthesia duration. No significant differences between open and endoscopic surgery of the axilla, in terms of limphorrea or seroma incidence, are reported. This is the same in terms of postoperative hospitalization.

As for shoulder limitations, no data demostrating better results from the endoscopic approach are available.

Only the extent of the axillary scar is reduced.

In conclusion, we think that quoting Kuhn [33], author of the most complete rewiew on the effectiveness of endoscopic axillary lymphadenectomy, is the best way to summarize the state of the art:

"… Although a definitive comparison between the two techniques (traditional and endoscopic) requires a prospective randomized trial, these data suggest that the endoscopic approach may reduce the overall morbidity of axillary lymph node dissection. The main critical issue in endoscopic surgery was the prolonged operating time, which could not be reduced to a reasonable length even after considerable experience. Endoscopic lymphadenectomy would be difficult to implement in daily clinical routine. Endoscopic axillary dissection cannot be recommended as a standard procedure for staging the axilla in breast cancer. Because of the uncertain oncological risk associated with the liposuction procedure, the endoscopic approach is restricted to small, probably node negative, cancers. For these patients, however, sentinel node biopsy represents an attractive alternative."

It is therefore our opinion that the use of endoscopic video-assisted procedures can be associated to traditional limphadenectomy surgery, when necessary, in order to minimize the axillary scar dimension. Again, endoscopic surgery should be considered a tool in surgeon's hands and not a totem.

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CHAPTER 7

VIDEO-ASSISTED APPROACH TO THE RETROPERITONEUM

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INTRODUCTION

The retroperitoneum is a part of the abdominal cavity located between the posterior parietal peritoneum and the posterior abdominal wall. The upper part extends to the hepatic peritoneal reflection, while the lower part goes to the extraperitoneal pelvic region. Although the interest of the urological community has increased greatly recently, only a few centres world-wide have adopted retroperitoneal laparoscopy as the standard surgical access for their patients as of yet. The lack of working space behind the peritoneum, as well as the difficulty in the orientation and in identifying the anatomical components within the virtual extraperitoneal space are the problems most frequently encountered by the surgeon who attempts to utilize the retroperitoneal laparoscopic access [1]. These concerns are often considered as deterrents for beginners or for surgeons who are not experts in video-assisted endourological techniques, in combination with the fear of any of the major operative complications that have been reported during urological laparoscopic procedures [2, 3]. Nevertheless, retroperitoneal laparoscopic procedures have been considered a safe and reliable surgical technique in several contributions published in the last few years, with results similar to the corresponding open procedures in terms of complication rates [4, 5]. Renal surgery and adrenal surgery have been demonstrated as reliable for a progressively large number of surgical indications, even for malignancies. Patient age is not considered a real problem anymore, as retroperitoneal laparoscopic procedures have been successfully reported in both elderly [6] and pediatric patients, even those younger than 1 year [7].

The question of whether laparoscopic surgery in the urogenital organs is better performed via a transperitoneal or via a retroperitoneal/extraperitoneal approach is still being debated. From a theoretical point of view, the concept of

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avoiding entering the peritoneal cavity is a well accepted principle in urology, for any surgical procedure being performed on extraperitoneal organs. Urologists are commonly confident with the flank position of the patient with the extra- or retroperitoneal open access. Retroperitoneal laparoscopy can therefore be converted to a retroperitoneal open procedure, if needed, without violation of the abdominal cavity. Another point in favour of retroperitoneal laparoscopy in renal surgery is that the renal vessels are directly and promptly controlled by this access, allowing the correct surgical procedure for radical nephrectomy in adult oncological diseases. Conversely, the lack of a wide working space and the difficult definition of anatomical landmarks represents the most significant problems that may be encountered using the retroperitoneal laparoscopic access.

RETROPERITONEAL ANATOMY

The retroperitoneal space contains fatty areolar tissue in which the abdominal aorta and its branches, the inferior vena cava and its roots, lymph nodes, nervous plexuses, the kidneys and adrenal glands, the renal pelvis, and the lumbar portion of the ureters are located. Furthermore, a portion of the pancreas and the second and third portion of the duodenum are also found there. Embryologically, these are intraperitoneal organs; subsequently they lost the posterior serosa, which joined with the posterior parietal peritoneum to become retroperitoneal organs and their anterior surface joined with the posterior parietal peritoneum. The retroperitoneal soft tissue is connected with the abdominal serous spaces through the mesenteric roots and the insertions of the ligaments [8].

RETROPERITONEAL WALLS

The anterior wall of the retroperitoneum is represented by the posterior parietal layer of the peritoneum.

The posterior wall of the retroperitoneum delimits the posterior wall of the abdominal cavity; there it consists of the bodies of the lumbar vertebrae and, on the side, of the ilio-psoas and quadratus lumborum muscles. The deep layer of the lumbodorsal aponeurosis and the transverse processes of the lumbar vertebrae represent a border between the retroperitoneal posterior wall and the lumbodorsal region (Fig. 1).

Superiorly, the retroperitoneal space extends to the 12th rib and down to the pelvic rim; on the side it reaches the quadratus lumborum muscle and the pelvic rim. The muscular layer is represented by the quadratus lumborum muscle and

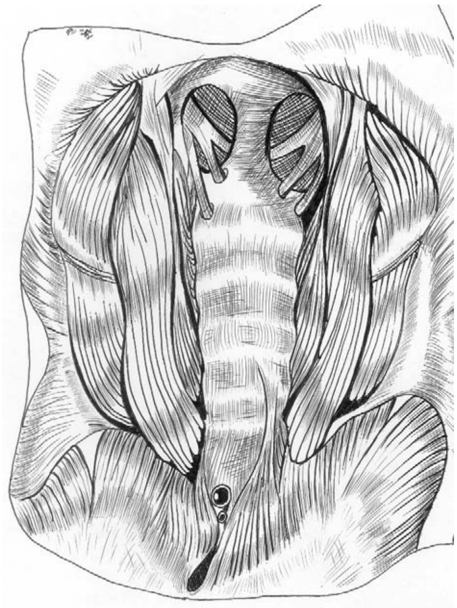

Figure 1

Frontal view of the retroperitoneal posterior wall. The *psoas magnum, iliac and quadratus lumborum muscles*, which represents the muscular layer of the wall are clearly evidenced

the iliopsoas muscle. The quadratus lumborum muscle is a square-shaped lamina placed between the 12th rib and the pelvic rim. Posteriorly, it connects with the deep layer of the lumbodorsal fascia; on the sides, the border of the quadratus lumborum muscle projects from the sacrolumbar muscular mass and joins with the aponeurosis of transverse muscle and the posterior border of the internal oblique muscle. On the upper part, the superior lumbar space of Grynfellt is circumscribed between the borders of quadratus lumborum and internal oblique muscles, the 12th rib and the inferolateral border of the serratus posteroinferior muscle.

The psoas magnum muscle and by the iliac muscle make up the ileopsoas muscle. The psoas magnum muscle originating from the transverse processes of lumbar vertebrae via its dorsal bundles and from the lateral surfaces of the bodies of D12 – L4 and the intervetebral disks via its ventral bundles. The muscles insert on the vertebrae by fibrous arches through the lumbar vessels and pass the sympathetic branches. The lumbar nerves proceed from the intervetebral spaces; their anterior branches are anastomosed under the muscular fascia, forming the lumbar plexus. At the promontorium level, the psoas magnum slopes down towards the pelvis, forming a groove for the femoral nerve with the iliac muscle. The terminal tendon passes through the lacuna musculorum up to the small trocanter of the femur. The iliac muscle, flat and triangularly shaped, lies on the iliac fossa, extending towards the coxo-femural articulation. Its bundles join with the psoas magnum muscle.

The muscle is separated from the retroperitoneal connective tissue by a thin fascia; its upper part is strengthened by the lateral lumbocostal tendineous arch of the diaphragm, which originates from L2 and the 12th rib. Sideways, it extends to the transverse fascia; medially, it passes on the psoas muscle. The lumbar portion of the psoas fascia is strengthened by the medial lumbocostal tendineous arch of the diaphragm; medially, the fascia is fixed to the vertebral column. The inferior part of the psoas fascia is known as the iliac fascia; it covers the iliac muscle, the iliac portion of the psoas magnum and forms the sheath for the external iliac vessels. It is fixed at the terminal line of the pelvis. The iliac fascia passes behind the inguinal ligament; at this point it is strengthened and its medial portion reaches the ileopectineal eminence, forming the ileopectineal fascia, which separates the lacuna vasorum from the lacuna musculorum.

The lateral walls of retroperitoneum are virtually absent, because they are represented by the flanks. In these areas the Petit's triangle, is located a lumbar triangularly shaped space bounded by the lateral edges of the latissimus dorsi muscle, the external oblique muscle and the iliac crest.

RETROPERITONEAL STRUCTURES

The abdominal aorta

The abdominal aorta reaches the retroperitoneum through the diaphragmatic aortic hiatus, passing along the anterior surfaces of the bodies of the lumbar vertebrae, lying on the anterior longitudinal ligament. At the L4 level, it is divided into the two common iliac arterie and ends with the medial sacral artery. The parietal branches of the aorta are distributed along the abdominal walls and are anastomosed with the intercostals arteries, the internal thoracic artery, the deep circumflex iliac arteries and the inferior epigastric artery. The aorta proceeds from the body of pancreas, the third portion of the duodenum, and the mesenteric root (Fig. 2).

The inferior vena cava

The inferior vena cava lies along the right side of the vertebral column; it starts at the confluence of the common iliac veins, at the L4 level. it passes behind the head of the pancreas and crosses the diaphragm through the caval diaphragmatic cavity. Interposed between the inferior vena cava and the posterior abdominal wall are the right sympathetic trunk, the lumbar vessels, the right renal vein and the right adrenal gland. Its tributary vessels are the inferior diaphragmatic veins, the lumbar veins (as parietal branches), the right gonadal veins and the hepatic veins (as visceral branches) (Fig. 3).

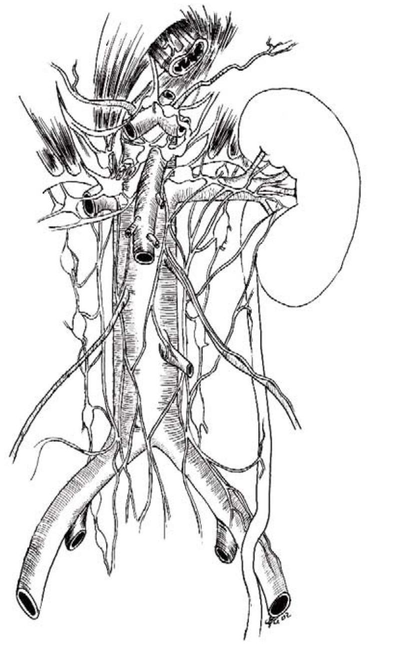

Figure 2 The abdominal aorta with its branches. The kidney, spleen and suprarenal irroration is represented

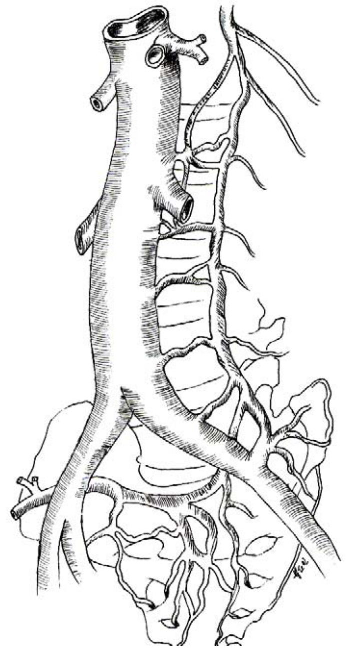

Figure 3 The inferior vena cava with its retroperitoneal-extraperitoneal roots

Other vessels

The common iliac artery proceeds inferolaterally towards the sacroiliac joint, where it divides into the internal and external iliac arteries. The right common iliac vein is behind the corresponding artery, while the left one is medially situated at the left common iliac artery and passes behind the right artery to reach the inferior vena cava. Its tributaries are the iliolumbar veins and the branches of the sacral venous plexus. The middle sacral vein reaches the left common iliac vein. The common iliac vessels pass along the medial border of the psoas magnum muscle; the muscular fascia forms a sheath, which contains the vessels and the internal iliac lymph nodes. Behind the common iliac vessels lie the lumbosacral nervous trunk, the obturator nerve, and the sympathetic trunk; the sympathetic branches of the abdominal aortic plexus lie in front of the vessels. In females, the ovarian vessels and their sympathetic nervous plexuses are present. The ureters pass over the vessels.

The external iliac artery passes laterally to the sacroiliac joint, under the inguinal ligament; the vein is situated behind and below the artery. Before the inguinal ligament the vas deferens in males and the roundish ligament in females crosses the vessels. The external iliac lymph nodes lie on the vessels, extending into the vascular sheath. The gonadal vessels, the lumbar vessels, the iliolumbar artery and the deep circumflex iliac arteries pass to the side of the spinal trunk. The gonadal arteries are accompanied by the gonadal veins, which drains the testes in males and the ovaries in females and also the ureteral, peritoneal and retroperitoneal vessels.

Usually, five lumbar arteries derive from the aorta; they pass under the psoas arches at the level of the lumbar vertebrae. The lumbar veins extend to the inferior vena cava; the left lumbar veins pass behind the aorta to reach the vena cava. Sideways the lumbar veins are connected by anastomoses, which are located behind the psoas muscle and in front of the transverse processes of the lumbar vertebrae, forming the ascending lumbar vein, which extends from the iliolumbar to the azygos and hemiazygos veins. The iliolumbar artery, deriving from the internal iliac artery, extends upward, behind the psoas muscle, where it gives off a lumbar branch, a spinal branch and an iliac trunk.

Nervous structures

The sympathetic lumbar trunks lie on the side of the spinal trunk; the right one is covered by the inferior vena cava and the left one by the aorta. From these trunks several branches are derived that form the celiac plexus; this is located in front of the aorta at the level of D11-D12, L1-L2. The celiac plexus covers the aorta, the celiac trunk and the superior mesenteric artery; to the side it gives off branches for the adrenal glands and the kidneys and inferior branches for the pancreas. It is covered by the peritoneum at the level of the posterior wall of the omental bursa. The celiac plexus is formed by several ganglia. The right one, semilunarly shaped, lies on the diaphragmatic right medial pillar; its left portion takes the celiac trunks of the posterior vagal nerve, while the right portion receives the splanchnic nerves, forming the nervous ansa of Wrisberg. The left celiac ganglion lies on the diaphragmatic left medial pillar: it gives off branches for the left adrenal vein and receives the left splanchnic nerve. The aortoabdominal plexus lies below the celiac plexus, in front of the aorta: it continues along the internal iliac arteries as the hypogastric plexus. The lumbar plexus is found between the muscular bundles of the psoas muscle.

Lymph nodes

The retroperitoneal lymph nodes are divided into four groups: left para-aortic, right para-aortic, pre-aortic and retro-aortic lymph nodes. The para-aortic lymph nodes are the most important in the lymphatic drainage of the kidney. The left kidney drains into four to five para-aortic lymph nodes located at the left side of the aorta, near the renal vein. The left para-aortic lymph nodes form a chain along the left aortic border: the upper lymph node lies at the level of the left diaphragmatic pillar and gives off several lymphatic branches, which reach the thoracic duct. The right para-aortic lymph nodes lie around the inferior vena cava: the pre-venous ones are below the renal veins and the retro-venous ones lie on the roots of the psoas muscle and the right diaphragmatic pillar.

Retroperitoneal spaces and organs

The renal space or renal loggia is formed by the anterior fibrous pre-renal fascia and a posterior one, known as Zuckerkandl fascia. The pre-renal fascia extends from the lateral border of the kidney to the anterior surface of the aorta and the inferior vena cava, where it joins the contralateral one. The pre-renal fascia is thickened by the Toldt lamina at the level of the right and left colon. The Zuckerkandl fascia lies behind the kidneys; it is separated from the transverse fascia via Gerota's adipose layer or para-renal adipose body. The Zuckerkandl fascia ends at the level of the lumbar vertebrae. The pre-renal and Zuckerkandl fascia are fixed to the diaphragm at the adrenal glands, whereas inferiorly, under the kidneys, they usually end in the retroperitoneal tissue. To the sides, behind the right and left colon, the pre-renal and Zuckerkandl fascias are joined with the so-called fascia lateroconalis, which divides the posterior para-renal space from the anterior one. The fascia lateroconalis joins the Toldt line and, sideways, closes the anterior para-renal space. The renal loggia contains Gerota's capsule, the adrenal gland and the kidney with its vascular pedicle and the renal pelvis. Gerota's capsule is an adipose layer, its posterior wall being thicker, which envelops the kidney and the adrenal gland; it is covered by the pre-renal and Zuckerkandl fascias.

The adrenal gland

The adrenal glands cover the upper poles of both the kidneys. The right one is triangle-shaped, with its anterior surface facing the liver and the inferior one facing the upper pole of the kidney and, usually, directly on the renal vascular pedicle. The posterior surface lies on the diaphragm. The left adrenal gland is smaller than the right; it faces the stomach anteriorly, the spleen sideways, the upper pole of the kidney and the diaphragm posteriorly and the pancreas and splenic vessels inferiorly.

The adrenal vessels are usually divided into three groups; the superior adrenal arteries, which arise from the inferior diaphragmatic artery, the middle adrenal artery, which arises usually from the aorta (sometimes from the renal artery or the celiac trunk) and the inferior adrenal artery, arising from the renal artery. The right adrenal vein is short and drains directly into the inferior vena cava, whereas the left one is longer and drains into the left renal vein.

The kidney

The kidneys are bean shaped; the left one extends from D11 to L2-L3, the right one from the 12th rib to L3. The renal axis is oblique so the upper poles are closer to the middle line, represented by the vertebral column and the great abdominal vessels. The right kidney faces the posterior surface of the right lobe of the liver. The posterolateral border of the liver extends to cover the right kidney posteriorly; moreover, the right hepatic triangular ligament, which joins the liver to the diaphragm, passes between the right renal hylum and the inferior vena cava. The inferior portion of the right kidney is covered by the right colon whereas the duodenum covers its hylum and the renal pelvis. The spleen is found medial to the left kidney, whereas its anterior surface faces the stomach and pancreas. The upper half of the left kidney and the upper third of the right one are intrathoracic; behind the upper poles of both the kidneys is the pleural fold, which lies on the periosteum of the 12th rib, thus limiting the percutaneous approach to the kidney at an inferior level. The middle inferior portion of both kidneys is found at the lumbar level and, with its posterior surface, lies on the quadratus lumborum muscle, in front of the 12th intercostal nerve and the iliohypogastric and ilioinguinal nerves. Sideways, this part of the renal posterior surface exceeds the lateral border of the quadratus lumborum muscle and faces the muscles of the abdominal lateral wall, at the level of the Grynfellt square and the Petit triangle.

The ureter

Three morphofunctional regions can be distinguished in the ureter: the uretero-pelvic junction, the intermediate tract and the vesicoureteric junction. The ureters are about 28 – 34 cm long; the left one, longer than the right, ends in the intermediate layer of the retroperitoneal fascia, joining the renal fascia and strongly adheres to the peritoneum. In males, the ureters pass along the middle part of the psoas muscle and the left colic artery and cross over the genitofemoral nerve. After crossing the common iliac artery, the ureter follows the path of the hypogastric artery, passing medially to the sciatic spine and crossing the vas deferens then reaching the bladder. In females, after the sciatic spine, the ureter passes behind the ovary, strongly connected with the ovarian suspending ligament, forming the posterior border of the ovarian fossa; it then enters the parametrium and passes along the uterosacral, cardinal and uterovesical ligaments.

INDICATIONS FOR RETROPERITONEAL LAPAROSCOPY

The last decade of the 20th century saw a rise in the laparoscopic activity in the urologic field: this assumption is the result of two events, represented by the publication of the first laparoscopic nephrectomy by Clayman et al. in 1991 and by the publication of the balloon technique of retroperitoneoscopy by Gaur in 1992 [9, 10]. Nevertheless, a gross disparity between the urological and non-urological (general surgery, gynaecology) laparoscopic practice still remains: one reason is that most urological laparoscopic procedures have a steep learning curve, more so if performed by the retroperitoneal approach. The other reason for the comparatively smaller number of laparoscopic urological procedures is that while the role of laparoscopy in gynecology and general surgery soon was established, its role for most urological procedures is still being debated [11].

Many retroperitoneoscopic procedures, such as renal biopsy, varicocelectomy, culposuspension, renal cyst decortication, nephropexy and pelvic lymphadenectomy, which were frequently performed earlier, have now been discontinued or are performed far less frequently. This is because either there are not many indications for these procedures or their long-term results are not satisfactory or other, less invasive, therapeutic procedures are available.

Retroperitoneoscopic urological procedures of proven value are represented by simple nephrectomy and adrenalectomy. The efficiency, safety and efficacy of retroperitoneoscopic simple nephrectomy is demonstrated in a recent series of 185 operations performed by Hemal et al.[12], who had a mean operative time of 100 min, an open conversion rate of 10.3% and a major complication rate of 3.78%. The efficacy of the retroperitoneoscopic adrenalectomy was shown in a series of 142 interventions by Waltz et al. [13], with a mean operative time of 101 min, success rate of 95% and no major complications. Comparing the results of retroperitoneoscopic and trans-peritoneal laparoscopic adrenalectomy, no difference in operative time, analgesic requirement, hospitalization and return to normal activity has been found. According to the literature the retroperitoneal approach should be preferred if one expects intraperitoneal adhesions. Furthermore, it was shown that the lateral retroperitoneoscopic approach is an equally effective, simple and safe procedure as the posterior retroperitoneoscopic approach.

Evolving retroperitoneoscopic urological procedures are represented by radical nephrectomy and nephroureterectomy, partial nephrectomy, ureterolithotomy, pyelolithotomy, live donor nephrectomy, radical prostatectomy and reconstructive procedures. Retroperitoneoscopic reconstructive surgery is being performed at many centers throughout the world, but it has not yet been widely accepted because of problems in laparoscopic suturing and manipulation due to space restrictions [11]. With regard to radical nephrectomy, the retroperitoneoscopic approach is gaining in popularity as an effective minimally invasive method for treatment of T1-T2N0M0 renal tumours up to 10 cm maximum diameter [11]. Recent studies by Gill et al. [14] have shown identical results with the open radical nephrectomy series and have also shown that T1-T2N0MO tumours, even as large as 12 cm, can be safely removed by the retroperitoneal approach.

In the radical nephroureterectomy, the most difficult part of the intervention is the dissection of the juxtavesical ureter and excision of the bladder cuff. Salomon et al. [15] propose a small iliac incision for distal ureterectomy and excision of the bladder cuff, while Igarshi et al. [16] use a gasless hand-assisted retroperitoneoscopic approach.

The much simpler nephron-sparing procedure is represented by retroperitoneal laparoscopic renal cryoablation: it seems to be a safe and effective alternative to partial nephrectomy but the long-term results are still outstanding [17].

The laparoscopic ureterolithotomy is useful only as salvage procedure as an alternative to open procedures in patients in whom ESWL and URS have failed; however the retroperitoneoscopic approach may be used as a primary procedure if the surgeon feels that the chances of failure with URS or ESWL could be high due to size of the stone or cohexisting ureteral anomaly [18]. For the retroperitoneoscopic pyelolithotomy, there are actually not many indications but the procedure should have priority in a selected group of patients with large stones.

The live donor nephrectomy performed via retroperitoneoscopy presents problems, essentially related to the limited space. A hand-assisted standard retroperitoneoscopic live donor nephrectomy has also recently been proposed [11].

Lastly, the radical prostatectomy, usually performed via transperitoneal laparoscopy in many centers, represents a new field of training; Bollens et al. were the first to perform it retroperitoneoscopically (42 procedures with a mean operative time of 317 min) [19].

INDICATIONS FOR RETROPERITONEAL LAPAROSCOPY IN PÆDIATRICS

Even now, children represent a critical group of patients in employing laparoscopic urological procedures, except for cases of nonpalpable testes, ovarian pathology in gilrs and, lastly, the internal genitalia examination of intersexual patients. The question of the advantages and limitations of retroperitoneoscopy in paediatric urology is still debated if compared with well-standardised open surgery. Considering the largest number of paediatric urologic operations are carried out in early childhood and in infancy, the clinical use and the need for laparoscopic approaches may seem smaller in paediatric patients than in the adult. Limitations of retroperitoneal laparoscopic procedures in paediatric subjects compared with adult subjects are first represented by a higher rate of reconstructive rather than ablative procedures in childhood and by the lack of working space in retroperitoneoscopy. Furthermore, there is no adequate laparoscopic instrumentation for the young child [20].

A few indications are now well established and will probably represent the new gold standard for the paediatric urological centers where retroperitoneal laparoscopic procedures are currently available. For renal surgery, nephrectomy and nephroureterectomy for benign disease, upper pole or lower pole heminephrectomy in double systems, renal biopsy and cyst marsupialization can be performed through a retroperitoneal laparoscopic access as a valid alternative to the standardised open procedures. Several controversial indications for retroperitoneoscopy have been proposed in the last few years. Dismembered pyeloplasty for uretero-pelvic junction obstruction has been mostly performed via the transperitoneal approach in adult patients; a critical point is represented by the lack of working space in the retroperitoneal approach in infancy. Rare indications for ureterolithotomy and pyelolithotomy in paediatrics are reported: lastly, the spermatic vessel obliteration for varicocele represents a controversial indication in paediatric urology, because of the high cost-benefit ratio.

A relative contraindication for retroperitoneal laparoscopic procedures is any previous retroperitoneoscopic laparoscopy, as well as the presence of dense retroperitoneal fibrosis, as a result of local phlogistic processes. Like adult patients, moderate obesity could increase the difficulty in identifying anatomical structures in the retroperitoneal space.

RETROPERITONEAL LAPAROSCOPIC ACCESS

The laparoscopic approach has been applied to a wide variety of procedures in the field of urology; most of the procedures described have been based on the traditional transperitoneal approach. Well-defined organ systems and a relative paucity of intraperitoneal fat allow for the rapid identification of landmarks. Instilled gas expands the space in a predictable manner to allow for optimal visualization. In contrast, in traditional open urologic surgery, most urogenital organs are approached through a retroperitoneal access. However, it is technically difficult to develop a consistent working space in the retroperitoneum, which is occupied by areolar and fatty tissues. Adhesions have been associated with postoperative pain, bowel obstruction and difficulty in performing subsequent surgical procedures. The posterior peritoneum is attached to the body wall by delicate and dense fibrous bands, which can restrict the ability of simple insufflation to create this working space [21].

TECHNIQUES

The patient is placed in the lateral decubitus position with the table flexed and the kidney rest extended close to the skin. Additionally, a rolled towel can be placed between the operating table and the patient, to maximize the space between the 12th rib and the iliac crest; the patient is then secured on the operating table with roll tape (Fig. 4).

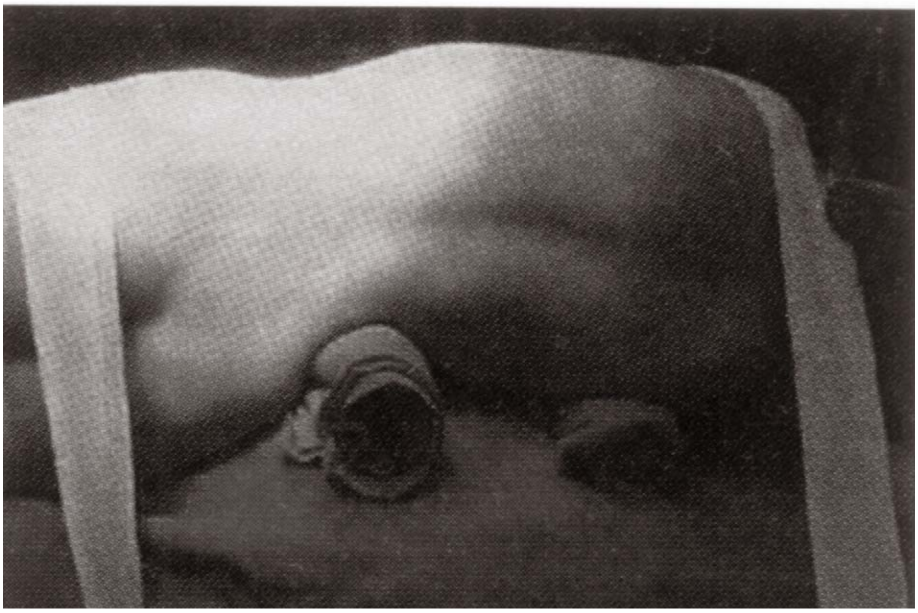

Figure 4

Veress needle technique

Following retrograde placement of a ureteral occlusion balloon catheter, the patient is placed prone on a table with fluoroscopy capability. The collecting system of the affected kidney is opacified by injecting contrast dye through the ureteral catheter. At the inferior lumbar triangle or Petit's triangle, bounded by the latissimus dorsi, external oblique muscle and iliac crest, a small skin incision is made and the Veress needle is introduced perpendicularly for a distance of 3-4 cm. The needle is advanced under direct fluoroscopic control until the horizontal plane of the kidney; the tip of the needle should now reside within Gerota's fascia and just below the lower pole of the kidney. Insufflation with CO2 is begun with the pressure set at 15 mmHg and, initially, at least 2l/min of insufflation in the retroperitoneum is necessary.

Balloon technique

A 1.5- to 2-cm skin incision is created below the tip of the 12th rib and the flank muscle fibers are bluntly separated. The retroperitoneum is reached by piercing the anterior toracolumbar fascia; finger dissection of the retroperitoneum is performed in the cephalic direction, remaining anterior to the psoas magnum muscle and posterior to the Gerota's fascia to create a space for placement of the balloon dilator (Fig. 5). The most common dissecting balloon device is fashioned from the middle finger of a sterile number 8 surgical glove and tied to the end of a 14 Fr red rubber catheter. The balloon device is inserted into the retroperitoneum and gradually distended with normal saline, according to the individual patient's body. The balloon is kept inflated for 5 min to facilitate hemostasis. Alternatively, balloon devices are made using condoms, whole surgical gloves, party balloons, a Foley catheter, saline distension

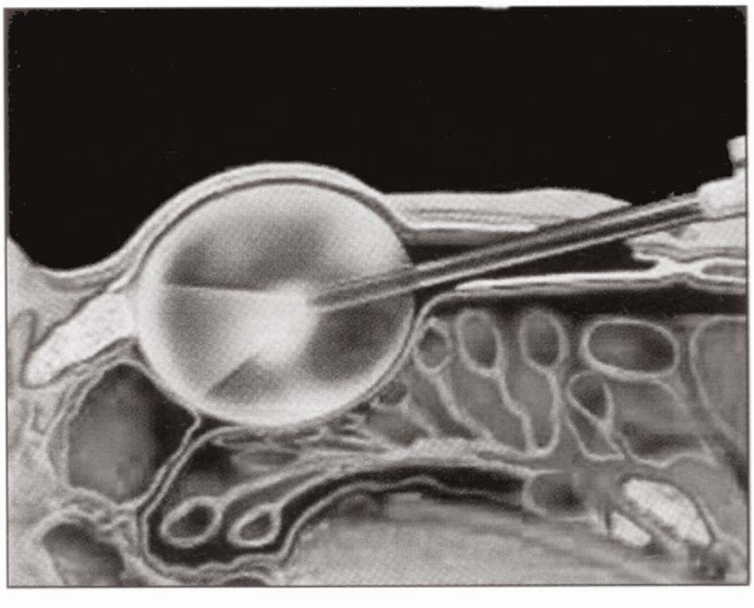

Figure 5 Ballon system to provide a rapid access and maintenance of the retroperitoneal space under direct visualization. Air inflation is continued until adequate space is created, then the device is removed.

balloons, and nephroscope balloon devices. Balloon dilation in pararenal fat, between the psoas magnum muscle posteriorly and Gerota's fascia anteriorly, effectively displaces the kidney anteromedially and expedites direct access to the posterior aspect of the renal hylum and adjacent great vessel [22].

Blunt finger dissection

A 15 to 18-mm incision is made in the Petit's triangle. A tunnel is created down to the retroperitoneal space by blunt dissection. This tunnel is dilated until an index finger can be inserted to push the retroperitoneum forward, thus creating a retroperitoneal cavity. Finger dissection continues in the space between the lumbar aponeurosis and Gerota's fascia and secondary trocars are inserted under laparoscopic guidance [22]. Additional working space is created by gas insufflation dissection aided by a swinging movement of the laparoscope, which allows blunt dissection of the loose perirenal tissue.

Direct vision technique

The patient is secured in the standard flank position , and the operating table flexed to allow the surgeon to find Petit's triangle. A 12-mm incision is made within this area and a laparoscopic visual trocar is advanced directly into the retroperitoneum under direct vision. Penetration of the Scarpa's fascia (the most superficial subcutaneous connective layer which continues at the perineal level as Colles fascia), the flank muscle and lumbodorsal fascia can subsequently be felt and seen in some patients.

Access for retroperitoneal laparoscopic adrenalectomy

Being the adrenal glands on the upper poles of the kidneys, the access is located in a superior part of the Petit's triangle, at the level of the angle formed by the latissimus dorsi muscle and the external oblique muscle. At this level lie the tips of the 11th and 12th ribs. The space posterior to Gerota's capsule is accessed by displacing the capsule anteriorly to the peritoneum. With the patient in a lateral recumbent position, a 2-cm incision is made along the lower border of the tip of the 11th rib and the end of the 12th; the shears are placed perpendicular to the patient and are gently pushed inside to dissect the muscle planes without tearing them. The scissors are open when passing through the various planes and then closed when they are pushed deeper. The muscle planes are thus progressively dissected. The surgeon can clearly feel that the retroperitoneal space has been accessed [23].

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CHAPTER 8

EXTRAPERITONEAL VIDEO-ASSISTED APPROACH TO THE ABDOMINAL AORTA

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INTRODUCTION

Laparoscopic surgery decreases morbidity by minimizing tissue trauma. But the nature and type of complications change compared to those incurred when, for example, aortic surgery is done transabdominally or through an open retroperitoneal incision. Exposure of the abdominal aorta laparoscopically should facilitate the contemplated surgical procedure. Knowledge of the surface anatomy and its relationship to underlying structures is essential in planning laparoscopic retroperitoneal procedures. Successful laparoscopic surgery in the retroperitoneum depends on the prevention of injury to vital structures.

This chapter describes a technique supported by substantial clinical experience (Castronuovo). A number of techniques have been proposed for extraperitoneal video-assisted exposure in the performance of laparoscopic aortic surgery. (Dion, Kline, Alimi)

DESCRIPTION OF TECHNIQUE

Preparation of the patient for laparoscopic aortic surgery includes preoperative CT scanning and angiography to exclude patients with an inappropriate anatomy, such as renal abnormalities, an aortic neck of less than one cm and visceral arterial abnormalities requiring surgical treatment.

The patient is positioned in a modified right lateral decubitus position similar to that used in the open the retroperitoneal approach for thoracoabdominal aneurysmectomy. Should conversion from video-assisted aneurysmectomy be

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required, this is readily accomplished without the need for re-positioning the patient. Gel pads and suction beanbag are used to aid in the positioning of the patient and reduce pressure points. The left arm is padded and elevated on a rest above the head. A kidney rest is not used (Fig. 1).

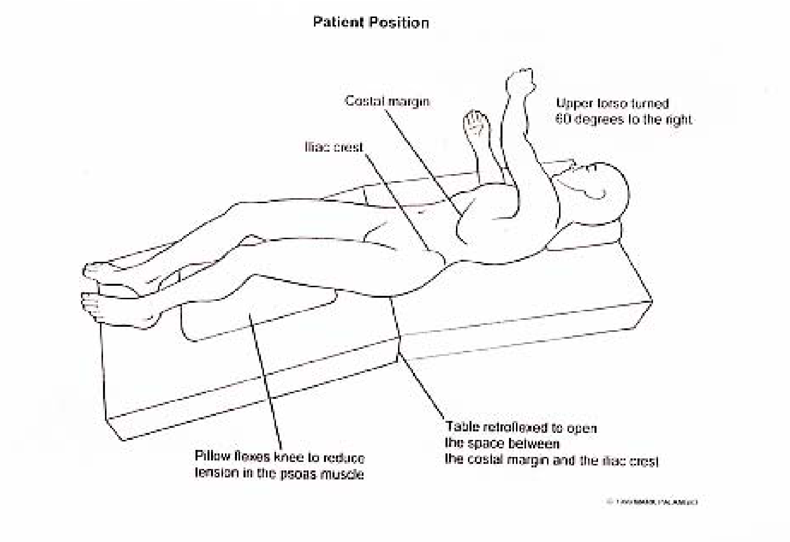

Figure 1. Modified right lateral decubitus position of the patient for laparoscopic-assisted abdominal aortic aneurysmectomy.

Initial retroperitoneal access is gained through an incision of 1.5cm in the left flank, just posterior to the anterior axillary line, midway between the costal margin and the iliac crest (Fig. 2). The muscles are split in the direction of their

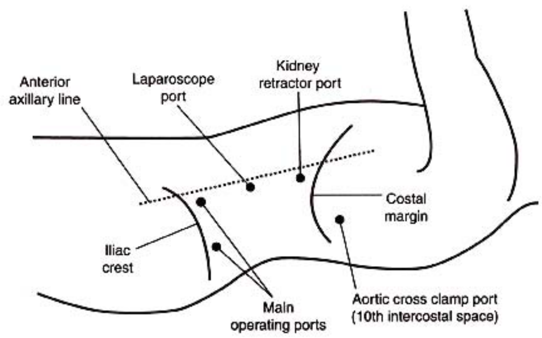

Figure 2 The five operation ports for the laparoscopic portion of the procedure. (The laparoscopic port and the kidney retractor port are connected for the open portion of the procedure, when the laparoscope is redirected through the counter incision made to expose the right external iliac or femoral artery.)

fibers and finger dissection is used to carry the incision to the psoas muscle. At this point, a balloon dissector (OMS-PDBAS2, Origin Medsystems, Menlo Park, CA) is inserted through a laparoscopic port. With visualization of the genitofemoral nerve on the surface of the psoas muscle and the ureter medially, the balloon is removed and the retroperitoneum is insufflated with CO_2 to a maximum pressure of 15mmHg.

The insertion of subsequent trocars is carried out under videoscopic observation. The main operating ports are inserted next, followed by insertion of the left kidney retraction port and the aortic cross-clamp port.

The two operating laparoscopic trocar ports are placed above the iliac crest. A 15mm port is placed in the original left flank incision and is used for the camera and laparoscopic stapling devices [Laparoscopic T.A. 30 (iliac) and T.A. 60 (aorta), U.S. Surgical Corp., Norwalk, CT]. A kidney retraction port is placed below the costal margin in the anterior axillary line. The aortic cross clamp is introduced via a puncture wound in the tenth intercostal space in the posterior axillary line.

We prefer a laparoscopic aortic clamp with a single action jaw (#9909-912-13 Scanlan International, St. Paul, MN), but a variety of clamps are available (MicroFrance, Saint-Aubain le Monial, France). The common iliac arteries are stapled with the Endo TA stapling device prior to placement of the aortic cross clamp to minimize the risk of distal embolization. Lumbar and other side branches originating from the aortic aneurysm sac can be identified and clipped laparoscopically. Post procedure peritoneoscopy is performed through a supraumbilical port to examine the bowel and spleen.

Vascular dissection is begun at the level of the common iliac artery with identification of the ureter. Both right and left common iliac artery are dissected circumferentially, care being taken to avoid injury to the iliac veins (Fig. 3). Attention is then turned superiorly and the left kidney is mobilized, rotated, and held medially with an inflatable laparoscopic retractor (Extra Hand, Guidant, Menlo Park, California).

The juxtarenal portion of the aorta and aneurysm neck are dissected (Fig. 4). This portion of the dissection requires clipping and division of the lumbar tributary of the left renal vein. After identification of the left renal artery, the proximal 2cm of the aneurysm is freed (Fig. 5).

Right and left oblique abdominal incisions are made to expose the external iliac arteries retroperitoneally or groin incisions are made for femoral anastomosis if iliac occlusive disease is present. The left incision is used to carry the graft retroperitoneally, within a plastic tube, to the aorta for the proximal anastomosis. A Penrose drain is led from the right incision to the area of aortic dissection and is used to carry the right limb of the aortic graft to the distal anastomotic site.

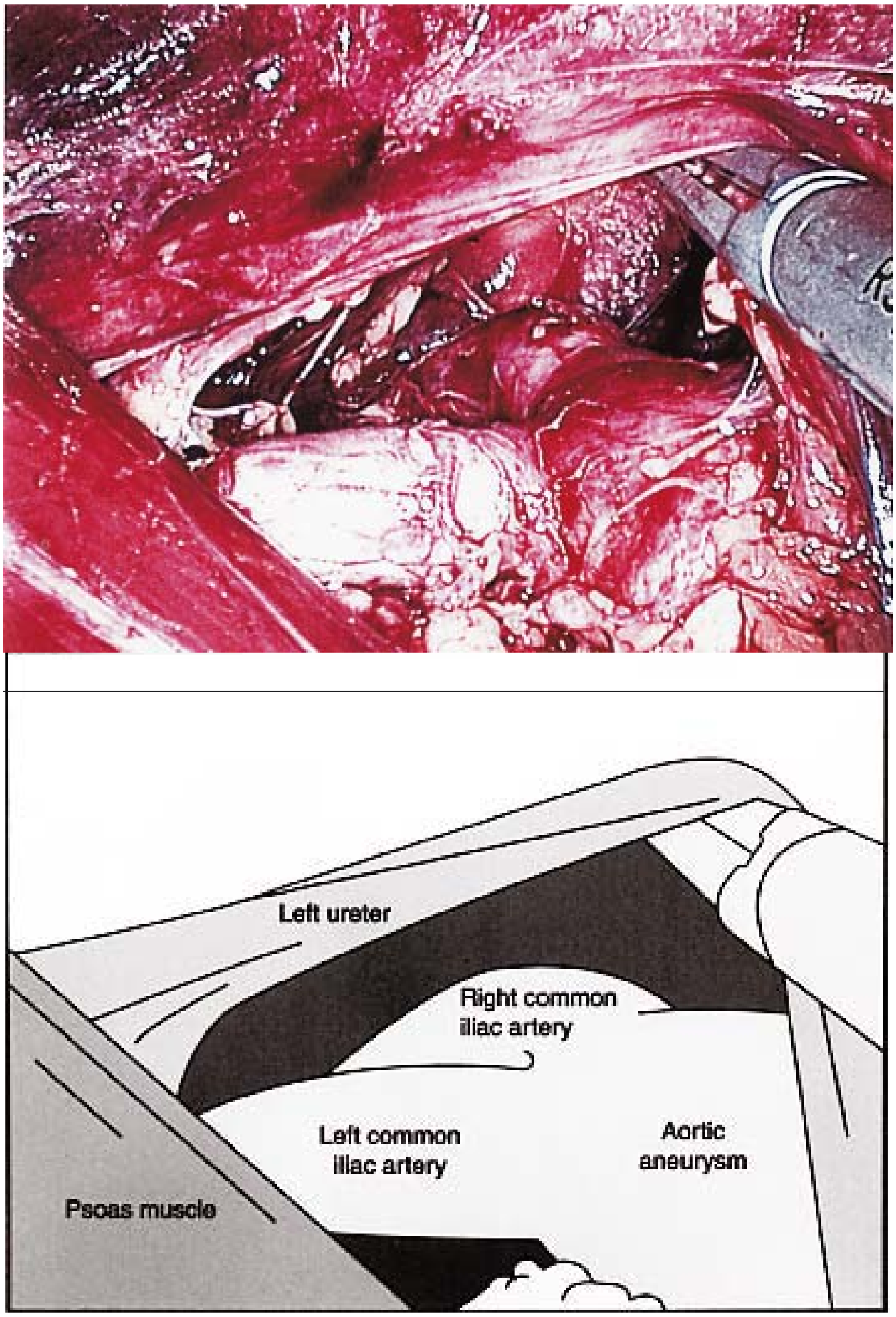

Figure 3 The five operation ports for the laparoscopic portion of the procedure. (The laparoscopic port and the kidney retractor port are connected for the open portion of the procedure, when the laparoscope is redirected through the counter incision made to expose the right external iliac or femoral artery.)

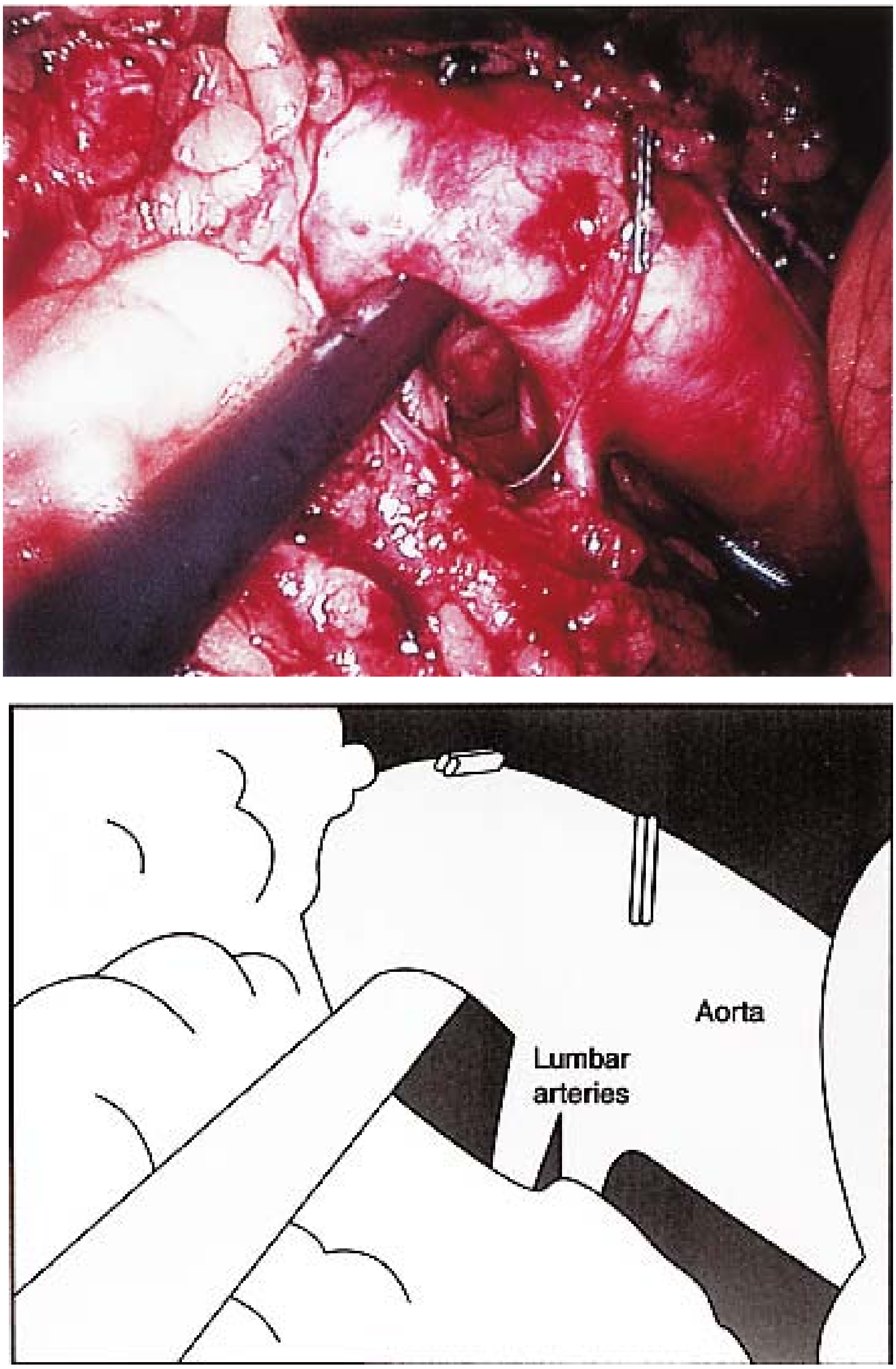

Figure 4 Laparoscopic exposure of the aortic neck; the proximal aorta is to the right in the photograph.

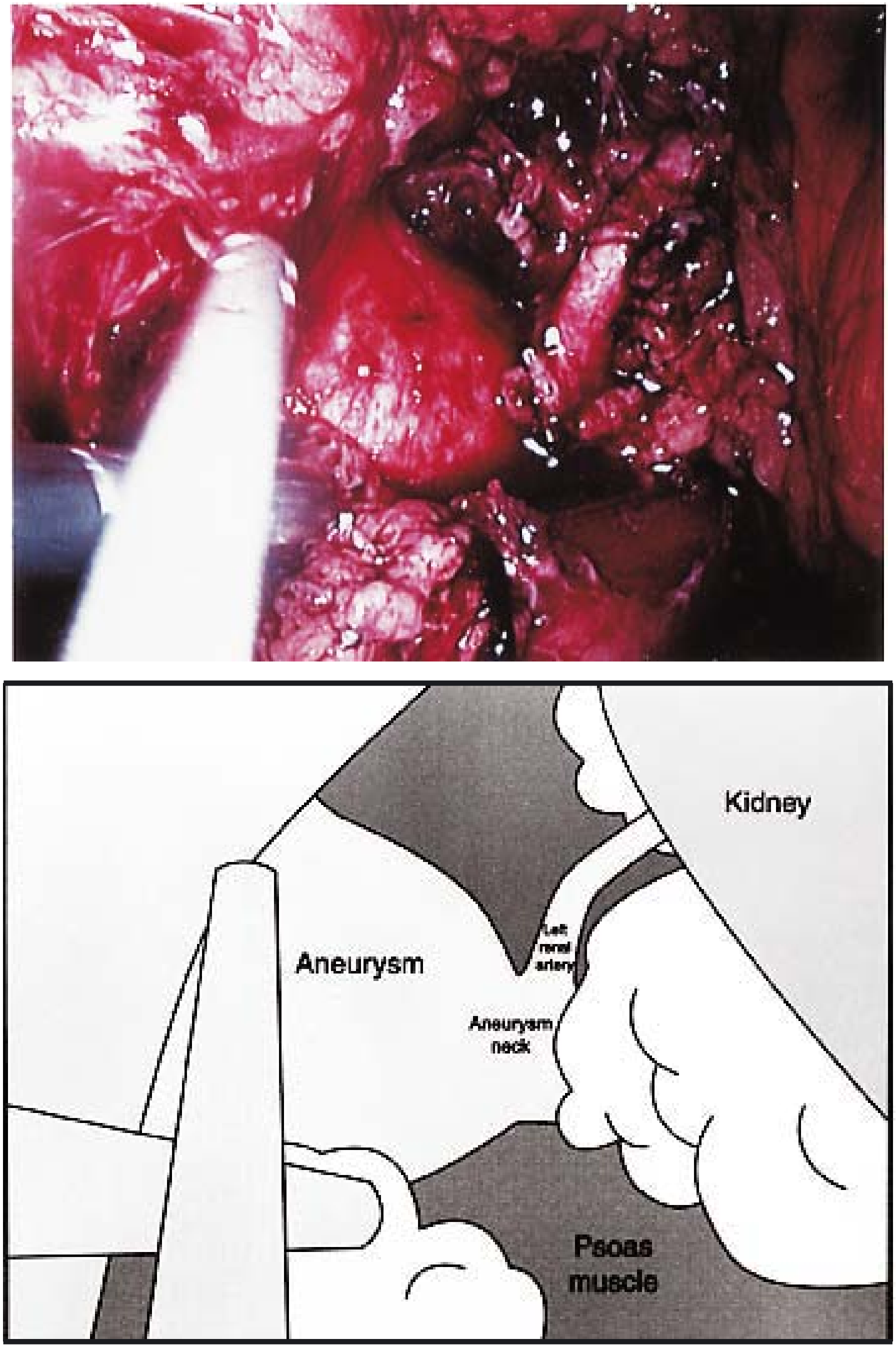

Figure 5 Juxtarenal aorta and left renal artery, as seen laparoscopically before cross clamping.

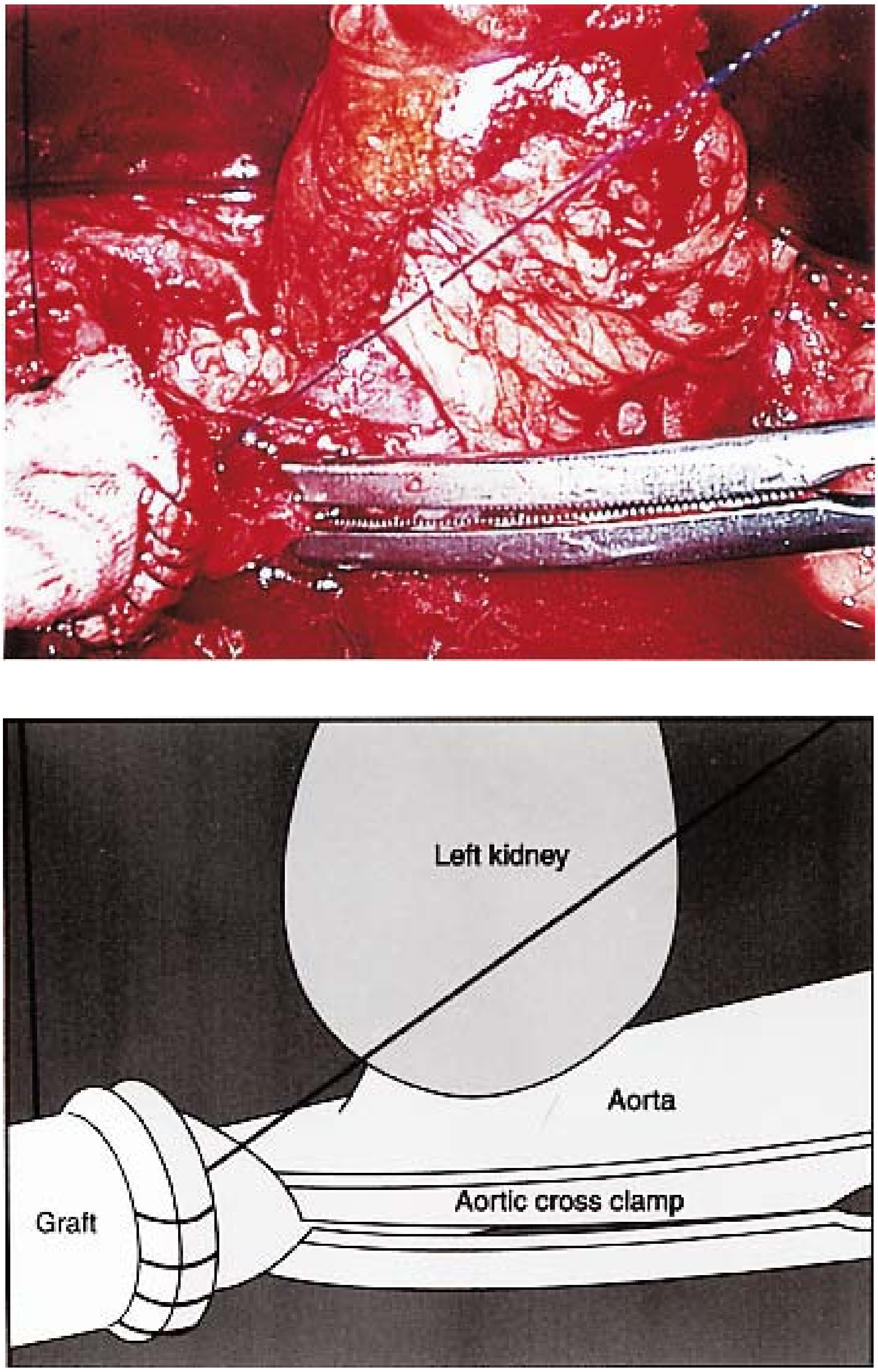

Figure 6 Proximal anastomosis carried out with laparoscopic visualization.

After the stapling of the common iliac arteries and the application of the cross clamp to the aortic neck, the aneurysm sac becomes floppy and can be easily and safely maneuvered to seek and ligate any remaining lumbar branches.

The aneurysm sac is partially opened and evacuated. Continued bleeding from the aneurysm sac beyond the usual initial flash of blood is indicative of a missed lumbar branch, which should be sought out and clipped. A portion of the aneurysm adjacent to the neck maybe excised to facilitate sewing of the proximal anastomosis. The remaining collapsed sac is closed with a laparoscopic T.A. 60 stapling device (U.S. Surgical Corp., Norwalk, CT).

We have found that excising a portion of the aortic sac near the neck greatly facilitates the laparoscopic suturing required for the proximal aorta to graft anastomosis, especially when the aneurysm sac is very large or buckled to the left.

Early in our experience, the aortic anastomosis was performed with interrupted mattress sutures because this technique lends itself to laparoscopic suturing and thus can be performed with the retroperitoneum insufflated.

The lengthy nature of this technique has led us to recommend that the anastomosis be carried out in running fashion with laparoscopic visualization, using standard instruments through a small incision created by connecting the laparoscopic and kidney retraction ports, this results in a three to four cm incision (Fig. 6).

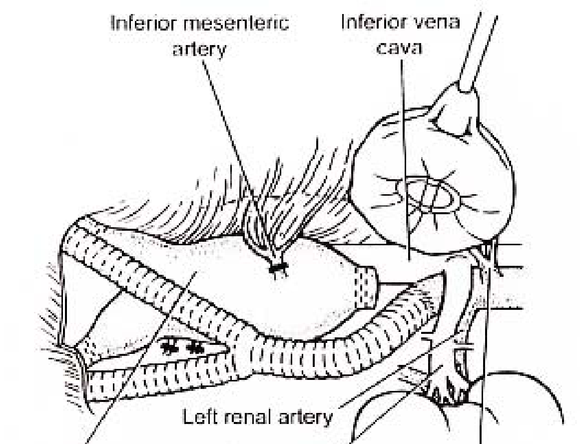

Figure 7 Schematic representation of the completed laparoscopic-assisted portion of the procedure. Distal anastomoses of the graft are carried out subsequently through counter incisions performed at the femoral or external iliac level.

This phase of the procedure is gasless, i.e., the retroperitoneum is deflated and the laparoscope is reinserted through the trocar site just anterior to the left iliac crest to visualize the anastomosis laparoscopically.

In the future, autosuture devices currently under development will permit anastomosis of the graft to the aorta entirely via a laparoscopic port.

Figure seven shows the laparoscopic assisted portion of the procedure completed. Distal anastomoses were performed to the femoral or external iliac arteries through counter incisions over these vessels. Patients were routinely heparinized before aortic cross clamping. At the conclusion of the procedure, absence of blood flow within the aneurysm sac was documented intraoperatively with an ultrasound probe, or alternatively the sac was opened to confirm there was no flow within it and then sutured closed.

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CHAPTER 9

TOTAL EXTRAPERITONEAL APPROACH (TEP) FOR INGUINAL HERNIA REPAIR

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INTRODUCTION

Inguinal hernioplasty had undergone a gradual evolution over the last century: in the beginning the techniques developed were traditional anterior surgical approaches (Bassini, Halsted and McVay). In 1970 surgeons began to use prosthetic material in hernia repair to eliminate tension (Trabucco), since then the inguinal hernioplasty technique has significantly changed. Stoppa and Wantz [1] applied the mesh to the posterior wall of the groin, developing a new way to approach the hernia repair. The introduction of laparoscopy and the development of new instruments and skills made surgeons further consider the posterior approach for inguinal hernioplasty. The interest in this new technique began in 1990, shortly after the introduction of laparoscopic cholecystectomy: the early pioneers modified the posterior technique, trying to duplicate the steps for the laparoscopic approach but due to inadequate dissection and repair of the entire floor of the groin, recurrence rates of early laparoscopic repair were high. Once it was realized that the laparoscopic technique had to mimic the open posterior mesh repair, the recurrence rate fell below 1% [2].

Most laparoscopic surgeons used the transabdominal properitoneal approach (TAPP) to the inguinal hernia [3, 4]: this technique is more friendly to the laparoscopist because it requires a laparoscopic exposure the extraperitoneal space entering into the peritoneal space. Although the TAPP has now been recognized as a successful technique, a total extraperitoneal approach (TEP) potentially offers some advantages: above all elimination of the complications related to violating the peritoneal cavity in order to reach the extraperitoneal space [5]. Moreover, this technique shortens operative time and allows the easy placement of a large properitoneal mesh in case of bilateral

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hernias. The TEP approach also seems to be indicated in the treatment of bilateral hernia repairs, because it requires minimal further dissection [2, 3, 6]. At the beginning, the extraperitoneal space dissection might seem difficult but with the initial use of balloon dissectors the exposure will become more easy and safe. The complications related to the TAPP technique are mostly eliminated and the operative time is reduced, although in special circumstances the TAPP approach or open anterior repair are still preferred [3, 7]. After the TEP technique, the patient has a rapid return to normal activities, an exceptional cosmetic and an excellent long-term results for both primary and recurrent hernia.

CHOICE OF APPROACH

When a surgeon evaluates a patient for an inguinal hernia repair, it is important that he is skilled in the open technique and both the TAPP and TEP approaches, in order to offer each patient the appropriate treatment. In general, patients with unitaleral hernia that are not candidates to a general anesthesia can be treated with an open approach under local anesthesia [3]. Several centres have reported a laparoscopic treatment (TEP) in local anesthesia [8, 9] but patients have a lower compliance during the procedure. For these reasons laparoscopic inguinal repair should be reserved for patients willing to udergo general anesthesia. Even the patient's age influences the choice of hernioplasty technique. Generally, the laparoscopic approach is particularly suitable for adults who need to go back quickly to their normal activities. In case of incarcerated inguinal hernia, with the help of the laparoscopic procedure, it is possible to explore the contents of the hernia sac and the status of incarcerated structures with accuracy [10]. At the same time, it is safe and usually easy to reduce these organs. Faced with an incarcerated hernia, it is very dangerous to use the balloon dissector to develop the extraperitoneal space for a TEP procedure, because you can cause injuries to the incarcerated organs (omentum, small bowel, bladder). Another relative contraindication is the presence of previous surgical pelvic or abdominal treatment, pelvic irradiation or the presence of infection. In case of a female patient with abdominal pain related with an inguinal hernia, the TAPP procedure should be the gold standard in order to differentiate other possible causes of pain, such as endometriosis: in these circumstances the surgeon first performs a diagnostic laparoscopy and then a TAPP repair. Again, during a TEP repair of recurrent indirect hernias, the complete dissection of the indirect sac might be extremely difficult and conversion into the TAPP approach should be considered. More generally, it is up to the surgeon's experience to choose which endoscopic treatment to use.

Anatomy

The inferior epigastric vessels are the main landmark to recognize inguinal hernia sites: a direct hernia occurs through a weakness of the transversalis fascia medial to those vessels. On the contrary an indirect hernia occurs through the internal abdominal ring, lateral to the inferior epigastric vessels. The genesis of a femoral hernia comes from a tissue laxity under the inguinal ligament medial to the femoral vein.

To create an extraperitoneal space it is necessary to perfectly know the anatomy of the anterior abdominal wall from its posterior view. Below the umbilicus the arcuate line starts: it is the place were the posterior sheath of the rectum muscle ends and the peritoneum is directly in contact with it. In this space, the surgeon has to create the preperitoneal pneumoperitoneum.

During the dissection the surgeon must pay attention to the dangerous areas, the triangle of pain and the triangle of doom: the first area is delimitated laterally by the reflection of the peritoneum on the anterior abdominal wall an medially by the spermatic vessels. In this area the ilio-inguinal and genito-femoral nerves proceed towards the inner inguinal ring and they can remain entrapped during mesh fixation. The triangle of doom is located immediately superior to the peritoneum reflection into the anterior abdominal wall. Laterally, it is delimited by the spermatic vessels and medially by the deferens duct: in this area there are potential risks of great vessel injury.

Preoperative preparation

Informed written consent should be obtained by the operating surgeon from all patients, following a discussion of risks and potential benefits, including the possibility that the TEP approach might be converted into TAPP or open procedure.

A monodose administration of antibiotics before surgery is advisable. The urinary bladder must be completely empty.

OR setting

The patient is positioned in a supine position, with both arms along the body side. Sterile drapes are located exposing the iliac crests bilaterally, the pubic region and the umbilicus. We usually work with the help of two monitors positioned at the patient's feet, one for the surgeon and the other for the assistant. If a left hernia side is performed, the surgeon stands on the opposite side and looks at the left monitor, whereas the assistant stands on the left and looks at the right monitor. In case of a right hernia the position of the team is reversed; for bilateral hernia, the surgeon should change sides or remain on the patient's left side. The scrub nurse is always to the left of the patient.

Equipment

At the beginning of our experience a blunt dissection was done in order to open the extraperitoneal space from the sub-umbilical incision but with the advent of the balloon tipped trocar the maneuver is usually made using this instrument. The dissecting balloon is surely safer than the gentle dissecting technique, because you can open the extraperitoneal space under direct endoscopic vision. A 30° 10 mm optics is generally used at our institution and is preferred over the 0° because it offers a better view of the inguinal region. Unipolar electro-coagulation connected with a 5 mm scissor is generally used to perform the dissection.

OPERATIVE TECHNIQUE

Dissection

The procedure starts with an 11 mm skin incision below the umbilicus, left sided for left hernia repair and right sided for right hernias (Fig. 1). The linea

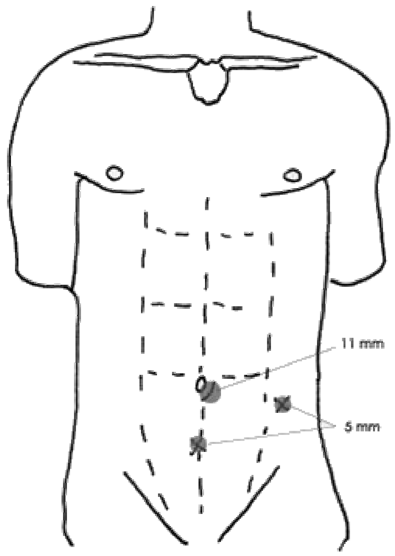

Figure 1

alba is exposed and the anterior sheath of the rectus muscle is opened, extending the incision on the hernia side. The two branches of the rectus muscle are exposed and retracted laterally and a canal between the rectus muscle and the posterior sheath is created until the arcuate line, where the muscle is directly in contact with the peritoneum. In the following stage the dissecting balloon is inserted and it must be direct medially on the midline towards the pubic symphysis (Fig. 2). This maneuver can be done under manual control on the

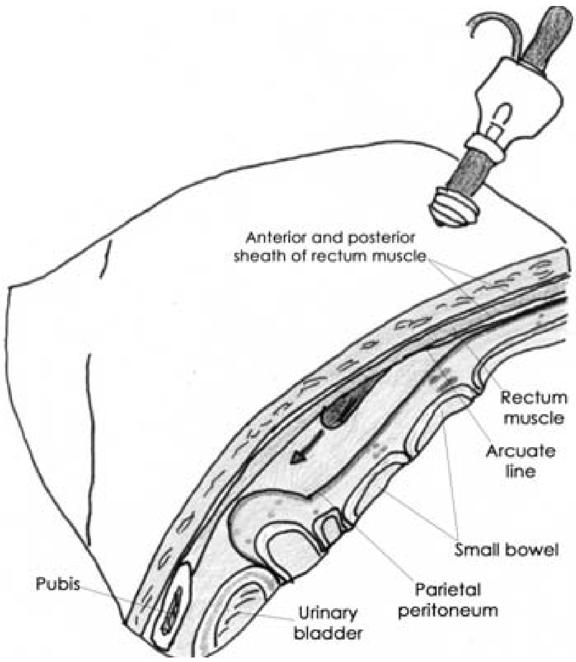

Figure 2

anterior abdominal wall. The balloon is then positioned posterior to the anterior edge of the pubic symphysis and inflated under endoscopic control (Fig. 3). During this phase the left hand of the surgeon guides the inflation and the position of the hernia side of the balloon. After inflating, the bulb is removed and the device is slowly deflated under visual control, to quickly recognize occasional bleeding from the anterior abdominal wall.

To prevent gas loss, a purse string suture is placed around the skin incision at the trocar's side. The dissection with the balloon tipped trocar is more easy and safe also for surgeons who are not familiar with this technique. The device allows the creation of a maximum work space because it ensures an appropriate seal, preventing gas loss. The laparoscope is next inserted and the preperitoneal space inflated with CO_2 (12mm/Hg) under visual control. The surgeon must check inside with the scope before inflating that the trocar in positioned in the

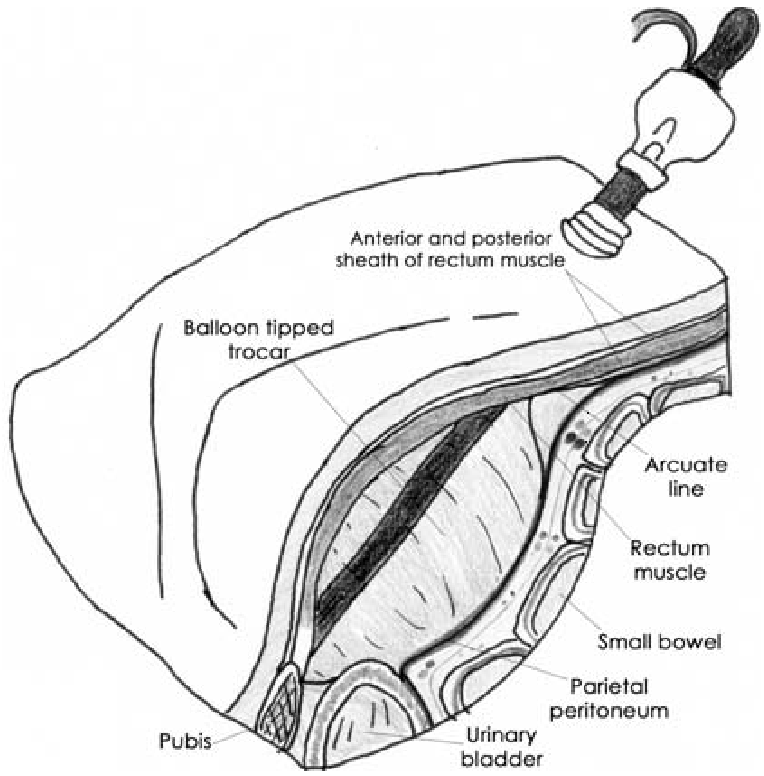

Figure 3

correct plane and for occasional injuries. A second 5 mm trocar is placed as close as possible to the first trocar on the midline under visual control. The internal view shows medially the pubic synphisys, inferiorly the urinary bladder, laterally the peritoneum reflection and the epigastric vessels and up the rectum muscle. A blunt dissection starts medially, the inferior edge of the pubis is completely isolated for 3 cm and the bladder is gentle pulled down to the pubis bone. Then the lateral dissection starts laterally and superior to the internal ring without dissecting it at this stage. The peritoneum is dissected down dorsally until the peritoneal edge and the transverse abdominis muscle are completely exposed at the superior iliac spine. The lateral dissection creates the space for a third trocar placement in hernia side's iliac fossa: a 5 mm trocar is placed. With the help of two operative instruments, bimanual dissection using a 5 mm grasper and 5 mm scissors, the peritoneal edge is found until the psoas muscle comes into view. The next stage is to dissect with the help of a grasper and scissors the tissue above the internal ring. The peritoneum is slowly dissected down looking for the epigastric vessels and the deferens duct: the triangles of doom and of pain are other important landmarks that must be respected during this stage. The dissection of an indirect hernia sac starts by following the peritoneum on the lateral side of the internal ring. The peritoneum of the sac is grasped cranially and it must be freed completely until the edge of the sac comes into view, detaching down the funicular elements with a blunt dissector. When the sac is very long or descending into the scrotum, the complete dissection may be very difficult and traumatic: many surgeons open the superior-lateral edge of the peritoneum and from this point, after identifying the funicular structures, the sac can be transected by diathermy. When dissecting a direct hernia, the weakness of transversalis fascia can be discovered medially to the inner inguinal ring and reduced by application of a stapler device on the superior pubic ramus. In case of controlateral occult hernia, TEP technique is more effective than the TAPP approach because the inspection of the preperitoneal space of the pubic area is more complete.

Preparation of Mesh

A prolene mesh (15 cm long and 13 cm high) is prepared for this procedure: a horizontal landmark may be drawn in order to facilitate its orientation during the fixation (Fig. 4). The mesh is inserted blindly, closed around a 5 mm grasper through the 11 mm trocar after removing the optics and then placed in its correct position under visual control with the help of two graspers. The rounded

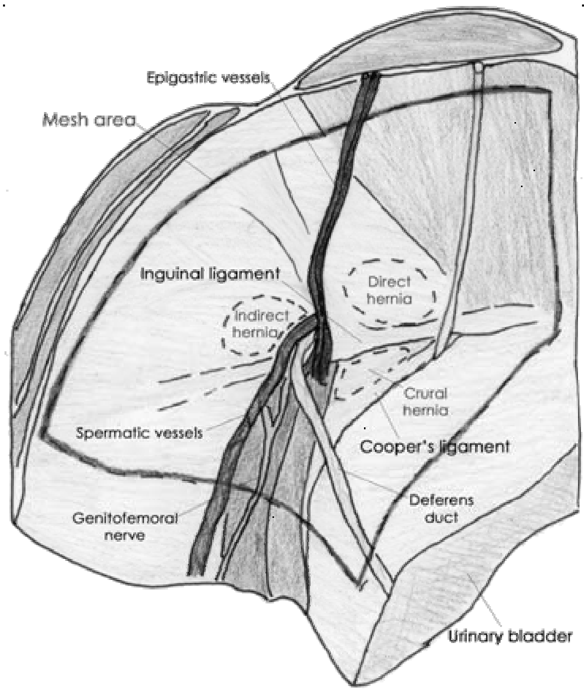

Figure 4

mesh must be spread medially to laterally and positioned with its inferior line attached to the inferior edge of the dissected peritoneum, particularly in order to cover all possible hernia sites [11]. We usually fix the mesh with a 5 mm helical stapling device at the abdominal wall. This avoids migration of the prosthesis and early recurrence. Some surgeons do not stabilize the mesh fearing nerve entrapment, but this risk is negligible if the fixation is done respecting the epigastric vessels, the triangle of doom and that of pain. The first spiral is usually placed into the pubic branch and Cooper's ligament. This step stabilizes the mesh medially and allows the surgeon to spread the prosthesis laterally into the inguinal region. It is mandatory to feel the bone under the stapler to eliminate the risk of damage of the iliac vein: It is also important to respect an unusual vein branch, named "corona mortis", located in 30% of people over the pubic bone. The next series of spirals are placed on the transversalis fascia up to the epigastric vessels and again attached laterally at the abdominal wall under the anterior iliac spine. After that, a slow deflation of extraperitoneal space allows the mesh to hold the position without any fold and the procedure is over. We usually close the muscle rectum sheath of the 11 mm trocar incision with an interrupted absorbable suture and the skin is approximated with glue after infiltrating the trocars access with local anesthetics.

Postoperative care

In general, the patient is discharged from hospital 24 hours after the end of the procedure without any particular therapy and returns to normal activities and work in less than one week.

Complications

Unfortunately, there are some postoperative complications that are most related to the laparoscopic approach, for example the development of seromas is common, but often they resolve spontaneously: on the contrary they must be drained with a sterile aspiration. Persistent pain is another problem related to the injuries of ilio-inguinal, genitor-femoral or femoro-cutaneous nerves but most these nevralgias will disappear in a few months [12, 13].

Some patients present CO_2 entrapped in the scrotum or in the subcuticular space of the inferior abdomen, but these problems resolve spontaneously in 2 days. Recurrences of hernia after the TEP approach are rare if the technique is done following the technical tips and are probably related to incomplete mesh fixation, incomplete dissection of the inguinal sac on the internal ring or peritoneum lateral dissection and sometimes related to an inadequate mesh size [14-16].

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CHAPTER 10

VIDEO-ASSISTED ACCESS TO THE SUBFASCIAL SPACE OF THE LEG

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Summary
Minimally invasive surgery, involving tiny incisions and the use of scopes or computers to visualize the operative area, has rapidly gained popularity because of the reduced pain, reduced stress and shorter recovery periods it provides for patients.
The evolution of endoscopic techniques has led to the development of a promising minimally invasive surgical alternative: endoscopic interruption of perforating veins. This technique permits access to the subfascial space of the leg and the rapid, direct exposure, identification, and interruption of the perforating vein system through small incisions that are remote from the region of the compromised tissue.
Since the modern general surgeon should be able to explore endoscopically, to make working space and to operate into the potential anatomical spaces, subfascial endoscopic perforator surgery may be a useful technique to gain the expertize necessary to achieve skill in approaching an anatomical compartment (i.e., the subfascial space of the leg) in a minimally invasive fashion.

INTRODUCTION

Minimally invasive surgery, involving tiny incisions and the use of scopes to visualize the operative area, has rapidly gained popularity because of the reduced pain, reduced stress and shorter recovery periods it provides for patients. Even in chronic venous insufficiency (CVI) of the legs the possibility to enter the subfascial space has made it possible to treat incompetent perforators veins under direct control.

The evolution of endoscopic techniques has led to the development of a promising minimally invasive surgical alternative: endoscopic interruption of perforating veins. This technique permits access to the subfascial space of the

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leg and the rapid, direct exposure, identification and interruption of the perforating vein system through small incisions that are remote from the region of compromised tissue.

Incompetent perforating veins (IPVs) in the medial compartment of the calf are believed to be a major cause of varicose veins in the leg. Cockett and Linton originally described the location of these veins connecting the deep venous system to posterior arch veins and the long saphenous veins, respectively [1, 2]. Direct surgical ligation of IPV has been reported to effectively treat severe chronic venous insufficiency (CVI) but is associated with significant morbidity [3]. Therefore, the need for an incision site remote from the area of ulcerative damage and a desire for direct visual control of the operative field led to the development of video-assisted techniques for IPV interruption. These techniques utilize fiberoptics and rigid endoscopic instruments [4]. Some surgeons use a single-port approach to subfascial endoscopic perforator surgery (SEPS), while others use two-ports. Skills that permit competence and mastery in video-assisted procedures are not directly derivative from skills used in open surgery. To become familiar with these methods and the enabling the instrumentation requires anatomical knowledge and practice in appropriate models. The known training models of SEPS are the animal ones described by Kolata in 1997 [5] and the SEPS simulator described by us in 2001 [6].

SURGICAL ANATOMY

Since the subfascial endoscopic perforator surgery (SEPS) has become popular in recent years there is the need to renew knowledge on the surgical anatomy of the subfascial space of the leg. This to enable one to explore endoscopically, to make working space and to operate in this particular compartment.

This minimally invasive technique achieves the same hemodynamic results as those obtained with the classic Linton operation but wound complications are reported to be significantly less and the duration of hospitalization is much shorter [7].

In the calf, the superficial and the deep venous system are separated from each other by the deep fascia. The perforator veins (PVs), drain blood from the superficial veins to the deep system. In the leg, major superficial veins are the greater and lesser saphenous veins and the posterior arch vein. The greater saphenous vein ascends anteriorally to the medial malleolus and crosses the tibia at the border of the distal and middle third of the calf. It then ascends medially to the knee [8]. The posterior arch vein (Leonardo's vein) drains a fine network below the medial ankle, ascends on the lower medial half of the leg and joins the greater saphenous vein below the knee.

The lesser saphenous vein ascends on the posterolateral side of the leg and joins the popliteal vein, most frequently in the proximal popliteal fossa.

Paired deep veins in the calf include the anterior and posterior tibial veins and the peroneal veins. They accompany the main leg arteries.

The posterior tibial veins run between the edges of the flexor digitorum longus and tibialis posterior muscles, penetrate the soleus close to its bony adherence and continue in the popliteal vein after union with the peroneal and the anterior tibial veins [9].

Linton [10] underlined that there are six to eight communicating veins connecting the superficial veins with the posterior tibial veins and that half of them were located in the distal third of the leg. He defined the site of one group of communicating veins 6 cm from the sole, posterior to the medial malleolus. Linton used the term "communicating veins" to describe the main venous trunks that connect the superficial system with the deep venous system; and any vein, small or large, that penetrated the deep fascia, he called a "perforating"vein.

Sherman [11], in a review of the literature on anatomic dissection, found groups of medial direct PVs at 13.5 cm and 18.5 cm from the sole and at 2 cm and 1 cm posterior to the medial border of the tibia, respectively. He observed that paratibial PVs consistently occurred at 24 cm, 30 cm, 35 cm, and 40 cm from the sole of the foot (Fig. 1). Another frequently occurring group of PVs was also identified behind the medial malleolus, at 5 to 10 cm. Sherman also observed the fact that lower PVs, like those at 13.5 cm and at 18.5 cm, connect the secondary tributaries of the greater saphenous vein with the deep veins.

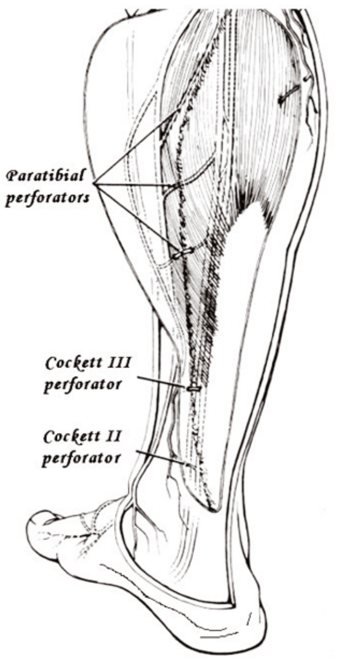


Figure 1 Medial perforator of the leg. From Mozes et al (18), modified.

Cockett [12] described three direct PVs (ankle perforators) that connect the posterior arch vein with the posterior tibial veins. The lowest perforator was found behind the medial malleolus and the middle PV was four finger-breadths above that. The upper, most consistently present PVs were nearly halfway up the leg, just posterior to the bony margin of the tibia. Later, May [13] named these the Cockett I, II, and III PVs, starting the numbering from distal to proximal. Cockett described a fourth direct PV located at the level of the tibial tuberosity that connects the greater saphenous vein to the popliteal vein (Boyd's perforator) [14]. O'Donnell et al. [15] studied the accuracy of ultrasonographic and venographic localization of incompetent PVs and compared the results of these diagnostic tests with intraoperative findings. They confirmed that the most common occurrence of incompetent PVs was between 10 cm and 15 cm from the medial ankle. In a recent study based on intraoperative confirmation of the location of PVs, Fischer [16] found a random distribution for incompetent PVs. He also emphasized that medial PVs occur in a 3-cm wide "lane" rather than along a line (Linton's line) [17, 18].

During SEPS, the endoscope is inserted through the deep fascia (also called the lamina superficialis of the deep fascia [10]) into the superficial posterior compartment [17]. Mozes et al. [18] showed in their anatomical studies that sixty-three percent of the perforators (including all indirect muscle PVs) were accessible from the superficial posterior compartment. They also demonstrated that 68% of the Cockett II and 16% of the Cockett III perforators were not accessible from this compartment. These PVs were located either in the deep posterior compartment or within a duplication of the deep fascia between the superficial and deep posterior compartments (Fig 2, A,B,C). In fact, Linton [2, 10] also mentioned the need for posterior deep compartment fasciotomy to access all perforators located in this area.

Mozes et al showed also that seventy-five percent of the paratibial perforators were not accessible from the superficial posterior compartment. These veins were hidden from view by the insertion of the soleus on the tibia, or they were located between the periosteum of the tibia and the deep fascia of the superficial posterior compartment. To access these paratibial perforators, Linton suggested the detachment of the soleus from the tibia. In our experience the division of paratibial perforators can usually be accomplished without risk to neurovascular structures.

Then, two thirds of the medial direct PVs are accessible for endoscopic division from the superficial posterior compartment. Division of incompetent paratibial PVs, however, frequently requires detachment of the soleus inserting on the tibia and incision of the paratibial deep fascia. To access the lower Cockett perforators, incision of the fascia of the deep posterior compartment is also frequently needed. Many clinical cases with SEPS have demonstrated that there are fewer complications with this technique in contrast to open surgery [19, 20].

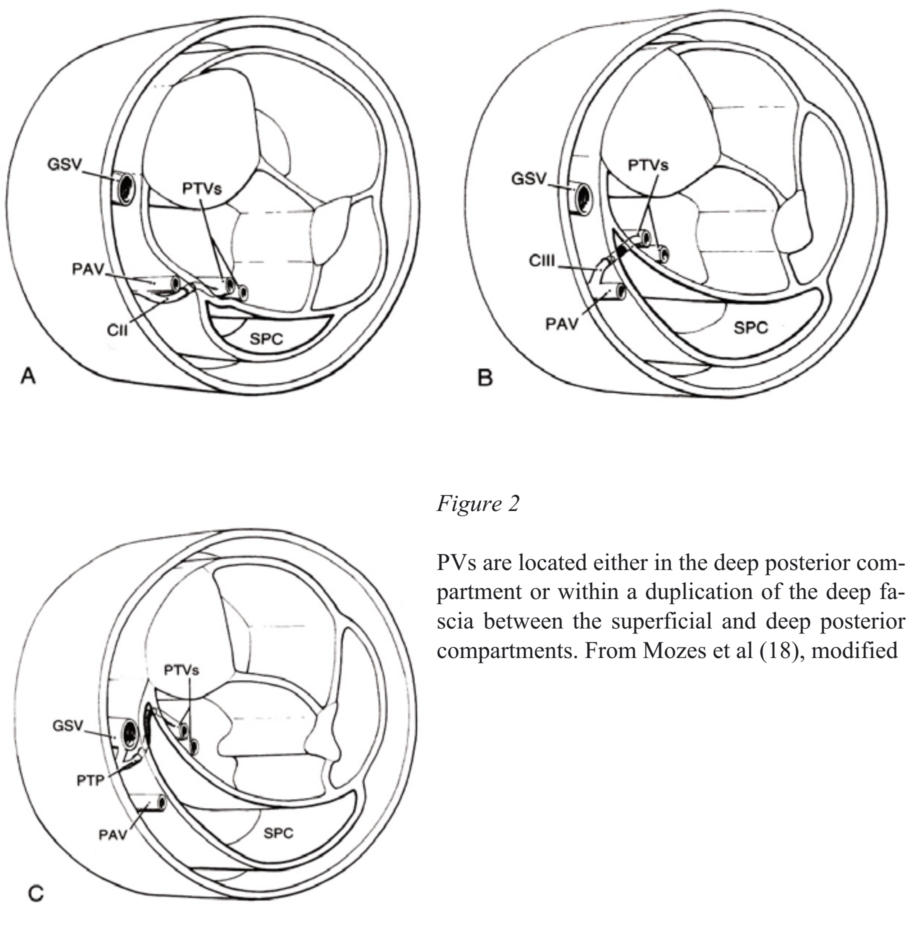


Figure 2

PVs are located either in the deep posterior compartment or within a duplication of the deep fascia between the superficial and deep posterior compartments. From Mozes et al (18), modified

SURGICAL TECHNIQUES

In the reported series [21,22], SEPS was performed under general or spinal anaesthesia, making the procedure less suitable for a day-case surgery. With the use of the sciatic-femoral blockade as a sole anesthetic technique, minimization of hemodynamic effects can be obtained and provision of long-lasting postoperative analgesia associated with early deambulation.

As previously underlined, two different techniques are currently used to approach the subfascial space of the leg in order to perform SEPS: the single port technique and the dual port technique. We will describe both techniques.

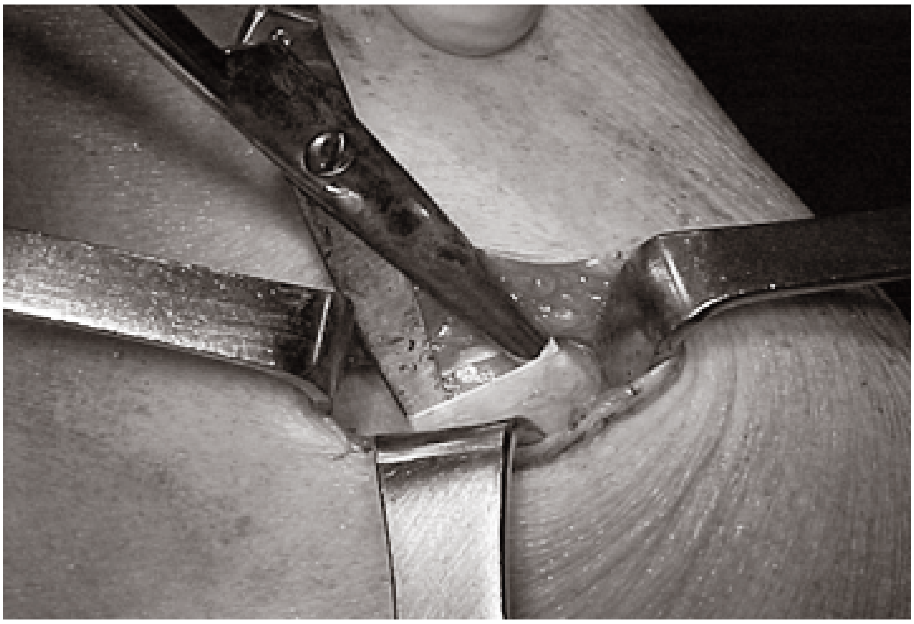
Single port technique

Hauer [23] was the first to introduce an endoscopic technique for the division of perforator veins. His work was soon followed by that of other investigators, using different types of endoscopes, mediastinoscopes, bronchoscopes, or arthroscopes to perform the surgery with direct vision through a single incision made in the proximal calf. In this single port approach, standard endoscopic instruments are used in combination with an operative channel integrated within the instrument.

Under general or loco-regional anaesthesia, the patient is placed supine and the whole limb and groin prepared and draped in the usual manner . Some surgeons use a sterile tourniquet placed above the knee and inflated above arterial pressure after exsanguination to work in a bloodless environment.

We perform SEPS without exsanguination with the pneumatic tourniquet since we abandoned the procedure currently applied to establish a bloodless field. A small single-stab skin incision (3.5 cm) is made at the medial side of the calf below the knee (Fig. 3). The subfascial plane is established by using finger dissection (Fig. 4 A, B). We employ a gasless technique. The operating 30° telescope (STORZ SEPS Endoscope; STORZ Tuttlingen, Germany), which has a lifting handle and a single 5-mm operating port, is inserted into the

Figure 3 A small single stab skin incision is made at the medial side of the calf below the knee.



A

B

Figure 4 The fascia is opened (A) and the subfascial plane is established by using finger dissection (B).

subfascial plane. A 5-mm clamp coagulator ultrasonic scalpel (Ethicon, Cinncinnati, Ohio, USA) is inserted via the operating port. The ultrasonic scalpel is set at a frequency of 55.5 KHz. We use power settings at level 3 and 5. The perforating veins are then identified and transected under direct vision.

After the intervention, the legs are treated with compressive bandages and the patients are allowed to walk as soon as they feel able to do so.

Dual port technique

The limb may be exsanguinated with an Esmarque bandage and a thigh tourniquet is inflated to 300 mmHg to provide a bloodless field but even with this technique we do not employ exanguination of the limb. Two endoscopic ports (a 10 mm and 5 mm port), are placed in the subfascial space in the calf through two small skin incisions made remotely from the area of ulceration (the first at the same site of the single port technique, the second, 5 mm port, below and laterally to the optic port) (Fig. 5). A space-maker balloon (Fig 6) is inflated in the subfascial space to improve access and carbon dioxide is insufflated to facilitate dissection (Fig. 7). The incompetent perforating veins are coagulated

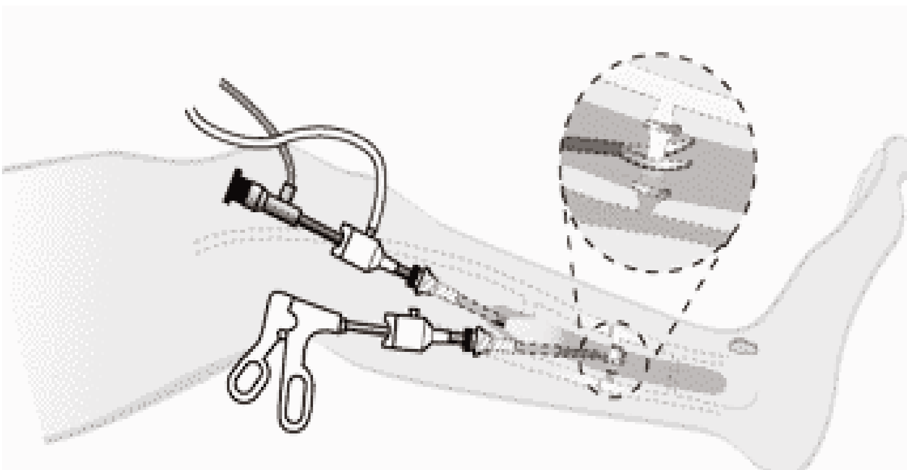


Figure 5 The optic port is placed below the knee, the second (operative trocar) below and laterally to the optic port.

and divided with a 5-mm clamp coagulator ultrasonic scalpel (Ethicon, Cinncinnati, Ohio, USA). Division of all paratibial perforators requires fasciotomy of the deep posterior compartment.

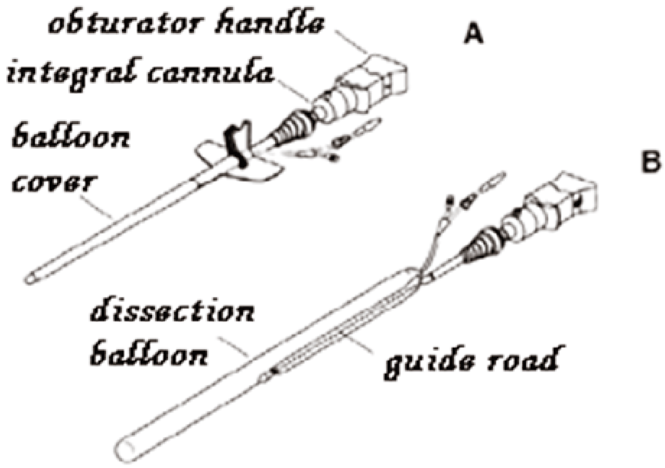


Figure 6 The space-maker balloon (A) is inflated (B) in the subfascial space

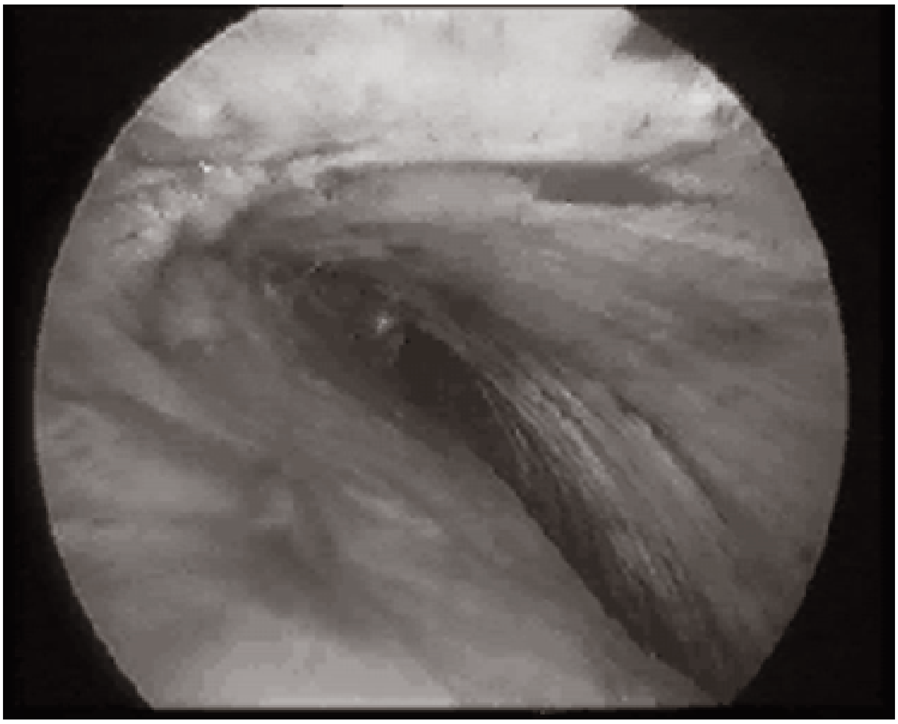


Figure 7 Subfascial space of the leg.

CONCLUSIONS

Interest in SEPS increasing. Surgeons may not be familiar with these endoscopic methods and instrumentation used for video-assisted access to the subfascial space of the leg. To become familiar with these methods and the enabling instrumentation requires practice on appropriate models and deep knowledge of the anatomy of the subfascial compartment of the leg [5, 6].

In conclusion, long before the advent of video-assisted surgery, surgeons have used planes of dissection to avoid injury to vital structures and reduce bleeding. Increasingly, modern surgeons are able to develop these same planes and spaces using minimal access techniques. Such spaces are likely to be small and difficult areas to work in. There is a trade off between the use of large spaces such as the peritoneal cavity and the more difficult potential spaces. Technology designed for intraperitoneal laparoscopic surgey may not be appropriate to the potential spaces and new technology needs to be developed – e.g. balloon dilators – although this results in considerable cost increases. Anatomical teaching may also need to be rethought.

It seems to us that the modern general surgeon should be able to explore endoscopically, to make working space and to operate, in these spaces. SEPS may be a useful technique to gain the expertise necessary to achieve skill in approaching a compartment in a minimally invasive fashion.

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CHAPTER 11

NEW TECHNOLOGIES IN MINIMALLY INVASIVE SURGERY

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INTRODUCTION

Advances in technology continue at a rapid pace and affect all aspects of life: medicine is no exception. Minimally Invasive Surgery (MIS) is, by its own nature, a highly technological speciality of surgical practice.

During the last few years, the development of new instruments and new technologies have allowed one to perform complex procedures that in the past were not considered suitable for this kind of surgery. The aim of this paper is to review some of these advances and the impact they are having on the management of different surgical problems.

OPERATING THEATRES

Since they were developed for open, traditional, surgical procedures, the design of current operating theatres is not suitable for MIS. Surgeons have no immediate control of all devices and the power output of the used systems; instruments are carried on bulky trollies and accidental activation of electrocautery, video displays, insufflators etc., may generate serious danger. Furthermore, trolley-mounted display systems do not provide an optimal view of the surgical fields and surgeons have to maintain abnormal postures during the procedure, compromising both the overall performance and their personal health.

New, specifically designed operating theatres, (featuring suspended monitors, touch-screen control, 3D video system, robotic surgery instrumentation etc) are now available on the market. Many of these new theatres also integrate

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a video communication system for telementoring and distant learning via broadband connection (fig. 1).

Figure 1 Surgical Theatre specifically designed for MIS

THREE-DIMENSIONAL VIDEO SYSTEMS

Stereoscopic viewing (3D), is able to provide perception of space and depth and is mandatory when precise and fast complex manipulations are needed, as in MIS.

To date, the most common used 3D systems depend on rapid time-sequential imaging obtained by two cameras: these systems are based on the physiological phenomenon of retinal persistence (after image). Both channels alternate with sufficient speed (50-60 Hz) to avoid almost completely detection of the flicker by the human eye. Sequential switching between the two eyes is necessary to ensure that the correct image (left and right) falls on the corresponding retina: this is achieved by wearing special glasses that act as alternating shutters to each eye. Unfortunately, one of the main problems with these glasses is loss of brightness and colour degradation.

Although the use of 3D-systems potentially could provide improved visual information for spatial manipulations and they have shown their benefits in non-medical as well as some medical applications, nevertheless, the real benefit of 3D-visualisation systems in surgery is still controversial.

HEAD-MOUNTED DISPLAY

In the usual setting for minimally invasive surgery, the video displays are placed distant from the surgeons who have to look straight ahead (most of the time bending the neck) while the hands are operating lower down: this is a very unusual situation for the human brain, which is used to looking and moving in the same direction. Furthermore, "visual noise" created by theatre staff and operating lights may add difficulties and interfere with the surgeon's concentration.

A head-mounted display (HMD) allows the surgeon to have an undisturbed view of the screen, potentially improving the performance of a specific task. The image on the screen appears directly in front of the surgeon, without any obstructions and visual noises. Several head-mounted displays have been produced but to date, there is still no real evidence that support real clinical benefits. The need to wear the visual unit makes its use cumbersome and tiring, increasing overall fatigue. Furthermore, using HMD, all the instruments have to be positioned and extracted by the assistant since the surgeon's view is restricted to the operating field.

ULTRASONIC SYSTEMS

Ultrasonic dissectors are based on of high frequency vibration (with a frequency between 20 and 60 Khz) of the instrument's tip, generated by a transducer that is able to transform the electric signal into mechanical motion. This effect can create either dissection or coagulation or both, depending on frequency the used.

All ultrasonic dissectors comprise an electrical generator, piezoelectric transducer and dissection instrument. The hand piece, incorporating the transducer and dissection instrument, is connected to the generator by an electrical cable; the ferroelectric ceramic crystals of the transducer vibrate (expand and contract rapidly) and produce ultrasound waves. The frequency (Hz) of the vibration depends by the extent of polarisation of the crystals. The vibrations generated by the piezoelectric transducer are conducted via a metal rod to the tip of the instrument. An efficient system transmits most of the vibration energy to the tip of the instrument with little heating of the shaft.

Ultrasonic Dissector Systems

Using low frequency (25kHz) waves, ultrasonic devices can be used as dissectors that cannot cut fibrous organised structures (arteries, veins, etc) and cause very little, if any, collateral damage.

Their main characteristic is that they do not coagulate or cut directly but they cleave cells with a high water content by a process called “cavitation”. The waves cause vaporization of intracellular water by forming vacuoles, which then resonate with the vibrating tip of the instrument, leading to implosion of the cell.

Fat and parechymatous cells contain more water that connective tissue, thus the cavitational effects cause their fragmentation, while it keeps intact structures containing significant amounts of collagens, such as vessels and nerves (fig. 2).

Figure 2 Ultrasonic dissector during liver resection

The advantage of ultrasonic dissection for division of the hepatic parenchyma during open laparoscopic liver surgery has been well established since once bile ducts and blood vessels are skeletonized by the probe, these can be safely clipped, ligated or coagulated depending on their size. The combined use of argon (see ahead) coagulation and the ultrasonic probe results in virtually bloodless division of the hepatic parenchyma.

As the ultrasonic probe does not cut peritoneal membranes and fascial layers (low water content), Glisson’s capsule of the liver has to be incised by the electrosurgical knife before ultrasonic division of the hepatic parenchyma commences.

Ultrasonic Coagulating-Dissection Systems

More recently, ultrasonic systems have been used at a higher vibrating rate (up to 55.5 kHz), leading to a cutting and coagulating effect at the tissue-instrument interface.

High-power ultrasonic dissectors are widely used for both laparoscopic and open surgical interventions because of their efficiency in coagulation and cutting, reducing the number of required instruments and therefore reducing operating time. The high operating frequency delivers energy to the tissue, causing important heating, deformation and friction effects at the "instrument-tissue" interface.

Cutting is due to high speed frictional deformation coupled with linear compression of the tissue performed by the surgeon's hand, as well as the power setting, tissue tension and the blade sharpness: in this way, although several devices are present on the market, they can all change power settings and rotate the tip in order to use a sharper and smoother blade.

The main advantages of ultrasonic coagulating-dissecting systems in comparison to standard electrosurgical devices are:

– Control and precision over cutting and coagulation
– Minimal lateral thermal tissue damage
– Multifunctional instruments
– Less tissue sticking
– Less smoke formation
– No neuromuscular stimulation
– No electrical energy to or through patient

Although very efficient, high power ultrasonic dissectors can cause collateral tissue damage, especially when used at maximum power, since the cavitational effect is magnified by the higher vibrating energy (fig. 3) as well as lateral thermal spread.

It has been demonstrated that the use of high-power dissection for more than 5 seconds may create a significant lateral cavitational effect as well lateral heat that could lead to histological damage to the surrounding organs (vessels, bowel etc.) (fig. 4).

VESSEL SEALING DEVICES

Among the vessel sealing devices, one of the most important, effective and innovative instruments is represented by the LigaSure™. This is an electrothermal bipolar vessel sealer, developed as an alternative to suture ligatures, hemoclips, staplers and ultrasonic coagulators, for vessel closure and tissue bundles.

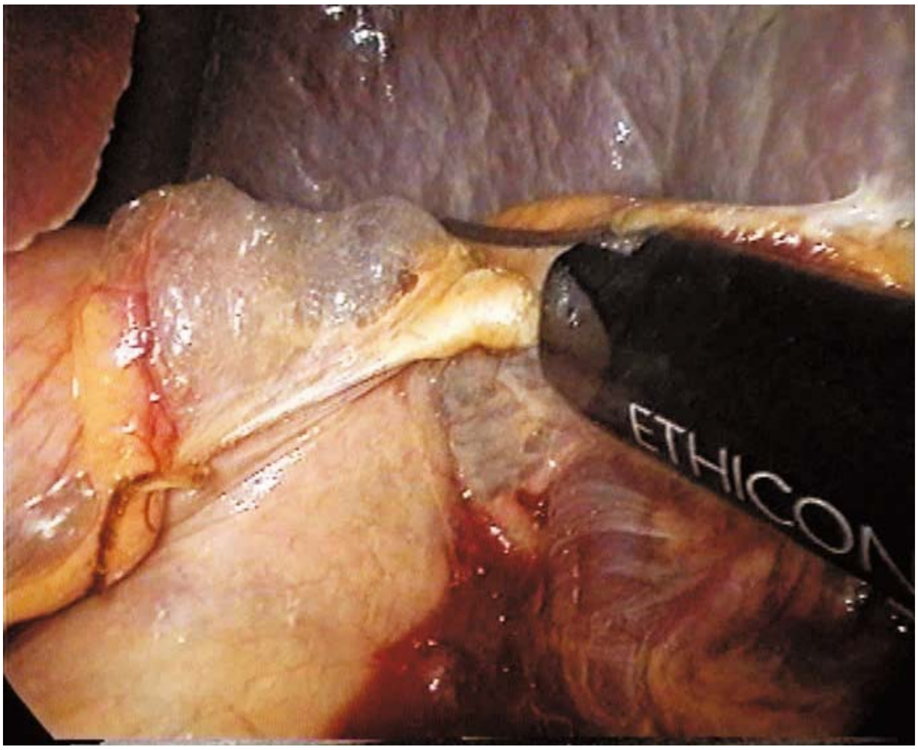

Figure 3 Lateral cavitational effect during the use of high-energy ultrasonic dissection

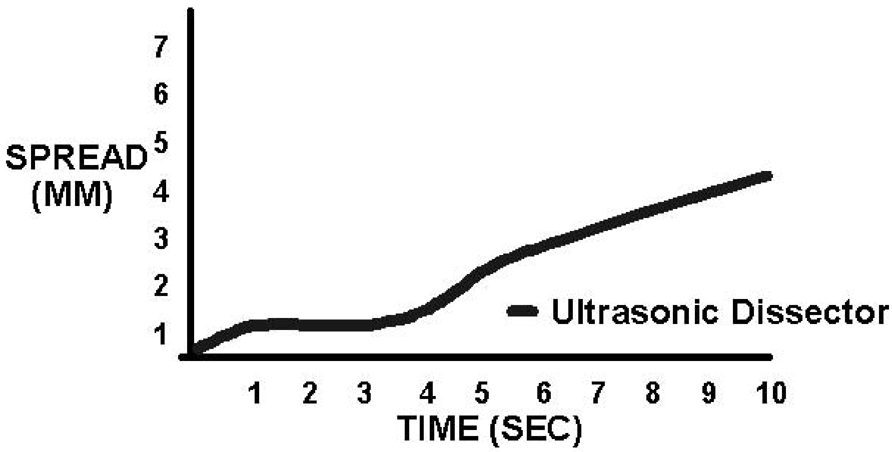

Figure 4 Lateral spread using ultrasonic dissector

LigaSure™ is able to seal vessels up to 7 mm in diameter by denaturing the collagen and elastin within the vessel's wall and surrounding connective tissue. The seal mechanism uses the body's collagen to actually change the nature of the vessel walls to obliterate the lumen (fig. 5).

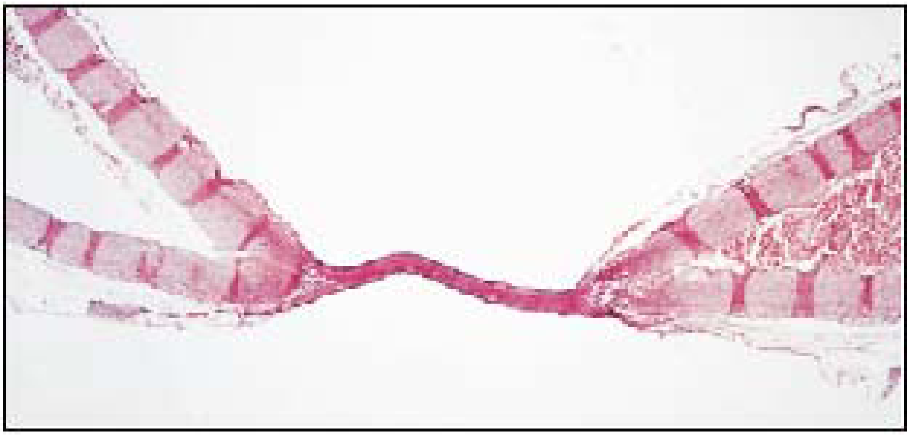

Figure 5 Coagulating effect of Ligasure™ under the microscope

This instrument is equipped with a feedback-controlled generator that allows a precise amount of energy delivery while the vessel wall and tissue bundle is held in opposition. As a consequence, this instrument is easy to use even with a limited learning curve.

LigaSure™ can be considered a multifunctional device since it can be used for blunt dissection, grasping, dividing and coagulation: this feature is extremely important during MIS procedures, since it reduces the number of instruments required for each procedure.

Furthermore, the risk of thermal lateral spread of energy is absent since the current is applied between the two jaws and the posterior one is coated and insulated.

In comparison with standard electrocautery or ultrasonic coagulating-dissector devices, LigaSure™ generates only little smoke and/or tissue spray, allowing an optimal view during use, expecially during the MIS procedure.

ION PLASMA COAGULATING SYSTEMS

Ion plasma coagulation systems are based on a "field (plasma)" of ions of an inert gas (usually argon: ABC) to deliver a high temperature electrical current directed, as a highly focused beam, to the target. The ABC uses a gentle flow of inert non-inflammable argon gas, instead of the conventional medium of air used by the electrosurgery, to conduct radiofrequency current to the target tissue. The radiofrequency forms arc tunnels in tissue and vessels of less than 3 mm diameter; through this arcing process the ABC distributes energy in a more homogeneous pattern than the electrocautery, thus resulting in an eschar of more uniform depth and allowing coagulation within the vessel wall. The temperature resulting from the ABC cauterization does not exceed 1100^{o}C. This is due to the cooling effect of the argon gas stream and to the blockade of radiofrequency energy conduction into the tissues once the eschar forms.

Since argon is a chemically and physiologically inert gas, the oxygen availability at the site of desiccation is reduced, resulting in less carbonization and smoke production. This last effect is particularly useful when performing laparoscopic and thoracoscopic surgery, where the use of standard electrocautery usually results in large amounts of smoke that can obscure the view of the surgical field through the optics. Furthermore, the argon gas clears blood from the surface of the target tissue, allowing better localization of the bleeding site and preventing the formation of a non-adherent eschar. All of these effects result in a well-delineated eschar that covers the surface of the target tissue and remains firmly attached to it (fig. 6).

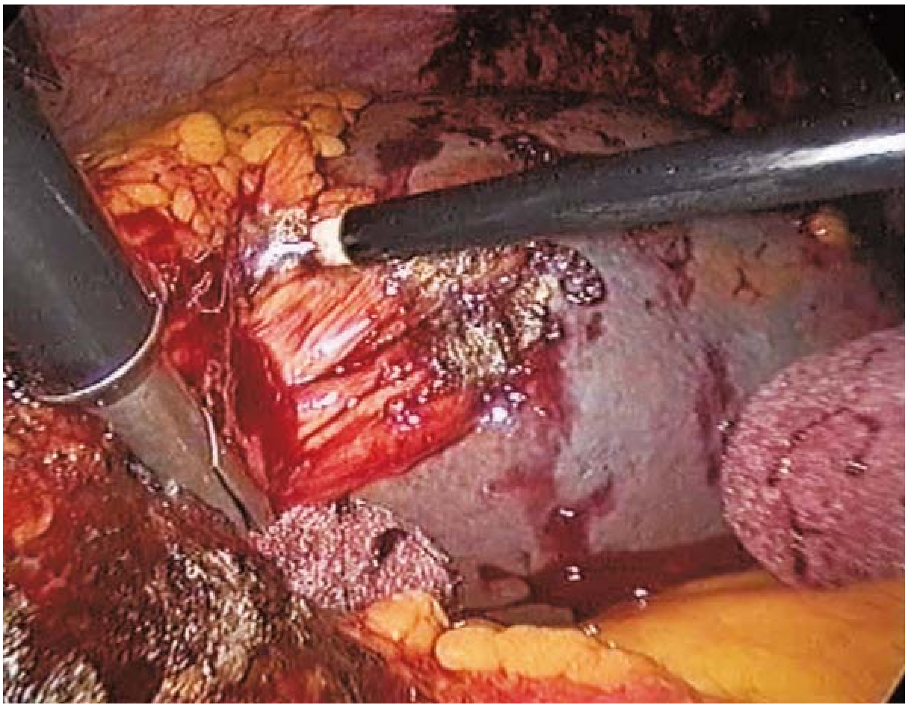

Figure 6 Coagulating effect of Ligasure™

Although developed more than 10 years ago, argon plasma coagulation has several application fields both in open surgery, MIS and interventional flexible endoscopy.

RADIOFREQUENCY TISSUE ABLATION (RFTA)

RFA (also known as radiofrequency thermal ablation, RFTA) is a recently developed thermo-ablative technique that induces temperature changes by utilising high-frequency, alternating current applied via an electrode(s) placed within the tissue to generate ionic agitation and, thereby, creating localised frictional heat: tissue surrounding the electrode generates localised areas of coagulative necrosis and tissue desiccation.

The radiofrequency energy radiates from the individual electrodes into the adjacent tissue and, as a consequence, the energy level and thus the heating effect, dissipates rapidly at an increasing distance from the electrodes.

RFA can be applied percutaneously, laparoscopically (fig. 7) or during open surgery in order to destroy neoplastic tissue. There is also evidence that tumor cells are relatively more sensitive to heat than normal cells and that temperatures above 60^{o}C have a rapid cytotoxic effect through protein coagulation.

Figure 7 Laparoscopic RFA of a large liver metastases

RFA of tumors has been widely used with excellent results, as non-surgical treatment of liver tumors and initial experience has been developed for lung, kidney and breast cancer.

RADIOFRENQUENCY COAGULATING SYSTEMS

The thermal effect generated by the ionic agitation caused by a radiofrequency generator system can be also used as coagulating technique.

The Tissuelink™ dissecting sealer is a new coagulating device that allows the surgeon to obtain an effective superficial coagulative effect also in highly vascularised organs such as liver, pancreas or kidney (Figure 8).

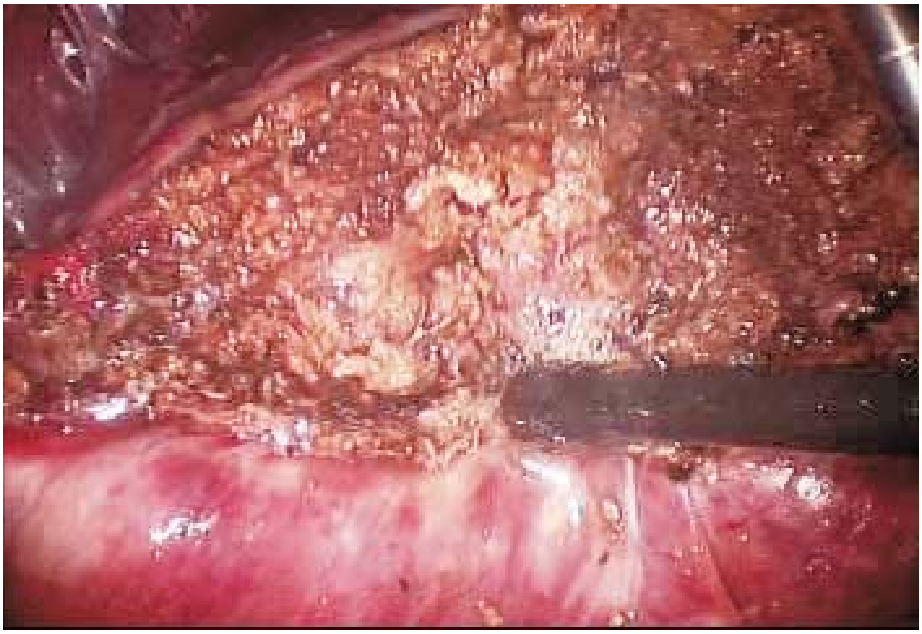

Figure 8 The use of Tissuelink™ for bleeding control during liver resection

With Tissuelink™ technology the heating effect is enhanced by realising that saline solution increased ionic concentration around the tissue and, as a direct effect, generates higher, coagulating temperatures by molecular changes in the collagen, causing it to shrink and seal blood vessels and tissue.

Coagulating radiofrequency can be used to control bleeding as well as to prevent it, by application of the energy before dissection of the tissue.

COBLATION TM TECHNOLOGY

CoblationTM is an innovative technology that could replace the extreme heat of laser and standard electro surgery with a gentle heating of the tissues that causes physical reduction and shrinkage of the target area.

CoblationTM occurs when the tip of the probe is merged in a saline gel, as a conductive medium and placed over the tissue. Upon applying a sufficiently high voltage difference between the probe and the tissues, the electrically conducting fluid is converted into an ionized vapor layer known as “plasma”. As a result of the voltage gradient across the plasma layer, charged particles are accelerated towards the tissue and, once a sufficiently high voltage gradient is generated, these particles gain adequate energy to cause dissociation of the molecular bonds within the tissue structure and, as a consequence, tissue destruction confined to the surface layer of the target tissue, while producing minimal necrosis of collateral tissue.

This same technology, when operated in sub-ablation mode, is also capable of producing hemostasis in larger vessels as well as tissue contraction. In contrast with laser or standard electrosurgery, which causes significant thermal damage, CoblationTM is based on a “non-thermal” mechanism.

Possible clinical application fields for CoblationTM technology are hepatic, pancreatic, urologic and thoracic surgery.

MICROWAVE COAGULATION THERAPY (MCT)

MCT is based on the conversion of energy to heat to destroy tissue via a high frequency alternating electromagnetic wave. This effect is reached by placing an electrode into the lesion under ultrasound guidance and applying microwaves that cause water molecules to polarise with the alternating electromagnetic wave and generating heat and coagulating necrosis with haemostasis.

MCT has been mainly used in selected cases such as treatment of inoperable liver tumors, although its use has been replaced by RFA.

FOCUSED ULTRASOUND TISSUE ABLATION

During focused ultrasound tissue ablation, a special transducer directs sound waves focused from a large area to a single point, through the skin and into the body.

The focused sound waves do not create heat along the way, but only at the focal point. The condensed energy at the focal point is used to rapidly raise the temperature in a small region inside the body: within 10 seconds, the tissue in the focal region reaches a temperature that causes irreversible cell death.

The ultrasound application can also be performed under MRI guidance in order to identify the target area in extreme detail. Possible applications of focused ultrasound tissue ablation are hepatic, breast, lung and kidney tumor.

ELECTRO/SONOPORATION

Electro/Sonoporation is a technique that uses the cavitation of microscopic spheres or bubbles (5-10 microns in diameter) to produce transient, non-lethal, increased porosity in cell membranes that allows large molecules which otherwise would be excluded access to the interior of the cell.

Bubble cavitation is mediated by the application of diagnostic ultrasound waves and an electric field: this technique has the potential to offer highly selective drug targeting as well gene therapy for the treatment of different tumors.

VIRTUAL REALITY

Virtual reality (VR) as described by Dr. Joseph Rosen, is a computer generated technology, which allows information to be displayed in a simulated but “lifelike” environment.

The use of virtual realty in medical-surgical practice can be summarized in the following fields:

- **EDUCATION**: Virtual patients can be used to create an environment for learning the human anatomy. The advantage of a virtual patient over traditional dissection would be that the exercises can be easily reversed, allowing the models to be repeatedly taken apart and examined from multiple points of view
- **SIMULATION FOR SURGICAL TRAINING**: Virtual reality can teach surgeons new procedures and determine their level of competence before they operate on patients. It can also allow the trainee to practice a skill several times as a refresher course (fig. 9).
- **TELEMEDICINE**: Telemedicine is a system of electronically communicating data from one site to a distant site. Virtual telemedicine can enhance telemedicine by superimposing data that is patient-specific directly onto that patient
- **TELEPRESENCE SURGERY**: The performance of surgical procedures where the patient and the surgeon are in different locations. Experimental

and also few clinical procedures have already been performed with success, although several technical problems have been encountered.

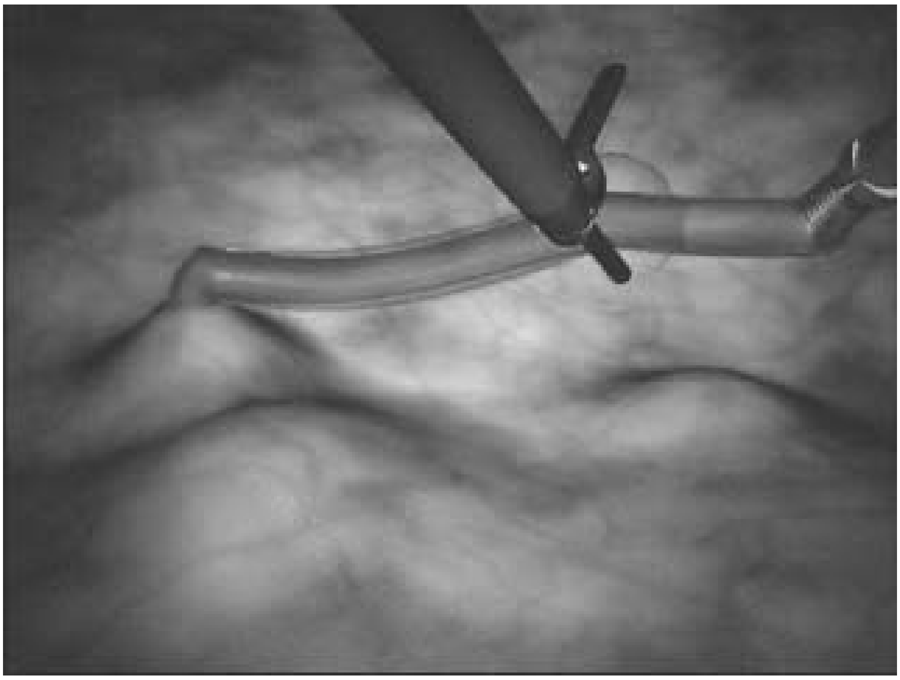

Figure 9 Virtual reality training in MIS

CONCLUSIONS

Minimally Invasive Surgery has always been "technology-dependent" and in the last few years several new, promising technologies have been proposed in order to reduce operative time and perform more complex procedures.

The safety, efficacy, and costs of potentially important new technology is essential to evaluate but not impede the timely development or use of the new treatment. Nevertheless, it is equally important to establish the real benefit and safety of any new procedure before it is widely used on patients.

Finally, surgeons have to be educated in the safe use of these technologies and fully aware of any potential danger.

Every time a new procedure or a new instrument is used, a severe evidence-based, independent evaluation has to be performed, focusing on safety, efficacy and real need. The assessment process may range from carefully monitored observational studies with evaluation, to controlled clinical trials.

Once this phase is concluded, before diffusion into clinical practice, a full education program for surgeons as well as a full evaluation of their knowledge should be recommended.

Acquisition of new technical skills and the development of appropriate support facilities as well periodic monitoring of outcomes (audit) represent the final phase before the new technology can be used.

Widespread application of new technologies must be continuously assessed and compared with alternative therapies to ensure appropriateness and cost-effectiveness through outcome studies.

We therefore report the following "Guidelines for Evaluation of Credentials of Individuals for the Purpose of Awarding Surgical Privileges in New Technologies" published by the American College of Surgeons:

– The surgeon must be a member in good standing of the department or service from which privileges are to be recommended.
– A defined educational program in the technology, including didactic and practical elements, must be completed and documented either as a postresidency course of instruction or as a component of an approved residency program.
– The surgeon must be qualified, experienced and knowledgeable in the management of the diseases for which the technology is applied – for example, laparoscopic instrumentation should be applied by surgeons with abdominal or pelvic surgical experience and credentials.
– The qualifications of the surgeon to apply the new technology must be assessed by a surgeon who is qualified and experienced in the technology and should result in a written recommendation to the department or service head. In the case of a resident trained in the technology during residency, recommendation by the program director is acceptable.

Maintenance of skills should be documented through periodic outcomes assessment and evaluation, in association with the regular renewal of surgical privileges.

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