Abdominal Wall Surgery
Abdominal Wall Surgery

How Reimbursement Systems Can Change Surgical Evolution
Over 100 years ago, Edoardo Bassini, a great pride of Italian surgery, asked whether it was still necessary to argue about hernia surgery. Actually, since Hippocrates until now, doctors have argued and debated about this topic and certainly will do so in the next decades.

In the last 30 years, during the progression of my personal academic, scientific and professional activities, I have had the honour and responsibility of the leadership of the European Hernia Society, a great society involving world-renowned key opinion leaders in hernia surgery that accounts for the largest part of the surgery carried out all over the world.

Hand in hand with this scientific expansion, technological and material evolution has been such as to merge the interest of patients, companies, media and especially surgeons. And of course, all this represented a real challenge for the health organizations in terms of cost/benefit ratio.

The fundamental objective in the surgery of the abdominal wall is the “restitutio ad integrum”, that is to say a reconstruction as natural as possible, achieving at the same time a perfect repair in the different districts, and a relapse rate as low as possible, trying of course to control the expenses.

But today, there is something new: the concept of “Quality of life” (QOL) has become more and more important and appears in the most serious series as an essential item, whose measurement is requested to the individual patient after surgery; essentially, post-operative comfort for the recovery of normal life and work habits, in some cases the improvement of sports performances, and finally the natural cosmetic appearance are no more considered as collateral objectives but rather as essential ones.

For this reason, the concept of tailor-made surgery has been gradually developed, and, together with the acquisition of our international guidelines, it must permeate the training and the daily activity of surgeons who want to dedicate their professional life to this exciting journey.

This book has been realized thanks to the collaboration between surgeons and economists: Prof. Elio Borgonovi is a world-renowned expert in health administration and management and president of CERGAS, Bocconi University, Milan. Dr. Dalila Patrizia Greco is a surgeon who, as many other colleagues, has been challenged for years with the objective—as the same time difficult and beautiful—of obtaining the maximum satisfaction for her patients. She is also a great expert in management and
administration, this following the virtuous path of super-specialization: the book I have the honour of presenting is the “summa” of their professional dedication.

I wish them and their collaborators the best of success with this book that has to be recommended for all individuals interested in abdominal wall surgery.

Milan, Italy

Giampiero Campanelli
Past President of European Hernia Society
Preface

One of the main critical issues concerning health protection in modern systems is the development of parallel worlds unable to speak and understand each other: medical doctors, healthcare professionals, managers and policy-makers.

Doctors are focused on the development of scientific knowledge, clinical procedures and techniques and on the relationship with patients. Managers are focused on the functioning of hospitals and other structures delivering healthcare services and on their organization and financial balance. Policy-makers are focused on the identification of general rules concerning professionals and structures and on resource allocation.

The purpose of this book is to contribute to overcoming these crucial issues; it stems from the fruitful collaboration of the Editors, who come, respectively, from the world of abdominal wall surgery and from the world of management and health policies protection systems. This preface is written adopting the “narrative approach”, which is gradually growing in different research fields.

The cultural exchange started about 30 years ago when Elio Borgonovi launched a master in economy and management (Ippocrate) addressed to medical doctors and healthcare administrative professionals at SDA Bocconi (School of Management). Health managers were the main audience, since clinicians’ activity was not yet affected by the lack of resources, a problem that they have been facing in the last decades. At that time, Dalila Patrizia Greco, young surgeon, was already interested in abdominal wall surgery and in new models of care, such as Day Surgery, which was considered a way to contain spending, at the same time increasing the quality of service. She was convinced that in order to introduce a change, it was necessary to prove its benefits. The performance schemes adopted at that time were simple and simplistic. Efficiency was emphasized independently from the clinical outcomes and from the perceived quality from the patient’s point of view.

In a way, it was considered that new methods were automatically granting better solutions to patients’ need, and hospital managers were focused on the comparison between direct costs of inpatient versus outpatient surgery.

The young surgeon was convinced of the need to overcome this gap. She considered Ippocrate programme as the best place to start a dialogue not only among researchers and teachers but also among people with heterogeneous professional experiences. She believed that everyone could bring a different perspective in the analysis of the reality.
On the other hand, for an academic interested in economy and management, the discussion with someone facing the requirements of the new medicine was both challenging and useful. CERGAS and SDA were in fact adopting a bottom-up approach (beginning from a problem to define actions and rules finalized to solve it) that required a debate with front-line professionals to propose realistic and feasible changes.

It was a fruitful meeting, which allowed them to exchange views on health system and helped them to deal with the difficulties involved in the healthcare system change. Several meetings, congresses and exchanges followed, enriching them and helping surgeons to learn those management skills which were, at that point, imperative.

The career development of the surgeon took her on the European Hernia Society quality board, whose aim is to investigate the topics of a better surgical performance and the possibility of developing tools to implement it. Different conditions are essential to improve quality: surgeon’s skills, a well-organized system that allows to build multidisciplinary teams and the availability of resources to acquire good and appropriate technology.

The board has always claimed that abdominal wall surgery is penalized by inadequate reimbursement systems worldwide, above all by systems that require the so-called “silos” financing (reimbursement of the single procedure/performance). To be effective, abdominal wall surgery must produce advantages in terms of functional recovery, in particular, reducing risk factors for recurrence and complications, but these aspects are not considered by the “silos” reimbursement systems.

The board decided to study the consequences of the economy of the abdominal wall surgery evolution. A phone call and a series of meetings between the surgeon and the economist led to plan a conference where the surgeons had the task of explaining in simple terms what abdominal wall surgery is (in the collective imagination, it generally means only inguinal hernia), while the economists had the task of explaining to surgeons the functioning of complex organizations and how costs are determined.

The conference was held under the auspices of the EHS quality board and of the group of Italian surgeons who practise wall surgery and are affiliated with EHS (ISHAWS), and it took place in the prestigious headquarters of SDA Bocconi in January 2017.

During the conference, the delegates proposed to continue the discussion between surgeons and economists, and they thought to realize this through a book that would strengthen the communication channels between the two worlds.

It is difficult, if not impossible, for economists and management scholars to understand the differences between the various methods and surgical techniques and for surgeons to understand sophisticated aspects of economic analysis.

However, it was considered possible to identify a common ground that, avoiding the most technical aspects of both fields, allowed to communicate and think together about the improvement of this area of surgery.

In some cases, we found it interesting to exchange roles, planning contributions in which surgeons talk about organizational aspects, criteria and requirements of
high specialization reference centres, while economists and management scholars deal with the correlation between costs and benefits of medical research, clinical evidence and health outcomes. This dialogue has later become a three-way discussion, since it was considered useful, or even necessary, to involve users and patients’ associations, to represent the essential voice of people to whom the services are addressed.

Many different readers could be enriched from reading this book: surgeons can benefit from the knowledge of management principles, gaining incentives to find suitable solutions to overcome the restrictions, thus considering management as an opportunity, and not as an obstacle to their professional development and the adoption of advanced technologies. Economists and management scholars can be helped to better understand the complexity of abdominal wall surgery that, like other areas of health protection, has its distinctive features, different from other services. Users and patients’ associations may receive a help to raise awareness about the cost impact of increasingly effective interventions.

To maintain a health system based on the principles of universality, solidarity and impartiality, patients must realize that any right involving an economic interest, such as health protection, can be concretely met also through their responsibility in the prevention and the adoption of behaviours leading to a fast recovery after surgery.

It was certainly a great effort to coordinate many people with different skills, but our hope is to have opened a new way, to have proposed a model for collaboration valid also for other areas of health protection. We thank everyone for accepting this challenge and for their collaboration.

Milan, Italy

Dalila Patrizia Greco
Elio Borgonovi
Contents

1 The Evolution of Surgery .................................................. 1
   Elio Borgonovi and Dalila Patrizia Greco

Part I Abdominal Wall

2 Anatomy of the Abdominal Wall ....................................... 9
   Cesare Stabilini and Ezio Gianetta

3 Clusters of Pathology and Interventions ............................ 21
   Pier Luigi Ipponi and Diego Cuccurullo

4 Unit of Wall Surgery ..................................................... 37
   Francesco Gossetti, Linda D’Amore, Francesca Ceci, Lucia Bambi,
   Elena Annesi, and Paolo Negro

5 Organization and Certification of Abdominal Wall Surgery .... 43
   Carla Rognoni

6 Biomaterials in Abdominal Wall Surgery .............................. 51
   Dalila Patrizia Greco and Claudia Abbati

7 Care Settings .............................................................. 63
   Dalila Patrizia Greco and Claudia Abbati

8 Preventing Incisional Hernias: Closure of Abdominal Wall,
   Follow-Up in Abdominal Surgery ...................................... 71
   Cesare Stabilini, Linda D’Amore, Elena Annesi, Lucia Bambi,
   Paolo Negro, and Francesco Gossetti

Part II Economics

9 State-of-the-Art of Abdominal Wall Surgery in Italy:
   Coding, Reimbursement, Hospitalisations and Expenditure
   for Surgical Meshes ...................................................... 87
   Maria Caterina Cavallo, Giuditta Callea, and Rosanna Tarricone
## Contents

10 Presurgical Hidden Costs: Imaging, Assessment Clinic .......................... 105  
Cristiano Sgrazzutti, Ilaria Vicentin, Alessandra Coppola,  
and Angelo Vanzulli

11 Post-Surgical Hidden Cost: Neuralgia ........................................................ 117  
Paolo Notaro, Paolo Bocchi, Nicola Ladiana, and Claudia Abbati

12 Post-surgical Hidden Costs: Infections ...................................................... 127  
Massimo Puoti, Dalila Patrizia Greco, Marco Merli,  
and Claudia Abbati

13 Basic Principles of Health Technology Assessment,  
Economic Evaluation, and Costing of Healthcare Programs .............. 141  
Rosanna Tarricone and Aleksandra Torbica

14 Economic Modeling and Budget Impact Analysis  
in Abdominal Surgery: The Case of Mesh ............................................ 157  
Carla Rognoni

Part III  Outcomes

15 How to Measure Outcomes in Surgery ..................................................... 169  
Graziano Pernazza and Enrico Pernazza

16 Present and Future of EBM in Inguinal Hernia Repair  
and Abdominal Wall Reconstruction ..................................................... 183  
Umberto Bracale, Giovanni Merola, Cesare Stabilini, Maurizio  
Sodo, and Giuseppe Cavallaro

17 Health Technology Assessment in Abdominal Wall Surgery ........ 191  
Valentina Beretta, Michele Tringali, and Antonio Marioni

Part IV  Future Perspectives

18 Stakeholders’ Opinion ................................................................. 201  
Diego Orlando Freri

19 Evolution of Abdominal Wall Surgery  
in Non-developed Countries ................................................................. 207  
Giampiero Campanelli, Piero Giovanni Bruni, Marta Cavalli,  
and Francesca Martina Lombardo

20 How Social Patterns Affect the Development of Science  
and Medicine ................................................................. 213  
Ivan Cavicchi

Part V  Conclusions

21 Ferrying to the Future ................................................................. 231  
Elio Borgonovi and Dalila Patrizia Greco
The Evolution of Surgery

Elio Borgonovi and Dalila Patrizia Greco

The term surgery derives from the Greek words χέρι (hand) and ἔργον (work). However, it is likely that surgical techniques first appeared before other medical practices. Indeed, there are archeological findings dating back to the Paleolithic which suggest that some sort of surgical activity was already being carried out, such as trepanning. Furthermore, there is evidence that the Egyptians were capable of performing highly specialized surgical techniques, with doctors benefiting from the anatomical knowledge of embalmers. The first regulation of the medical profession dates back to the Old Kingdom, whereas the world’s oldest depiction of a surgical procedure—a circumcision—can be found at the entrance to the temple in Memphis. The first example of regulating the practice of physicians and surgeons can be attributed to some of the laws found in the Code of Hammurabi (1792–1759 BC), which provided for both monetary sanctions and corporal punishment in the event of medical errors.

In Europe, the “Hippocratic oath” was credited with bringing the medical practice out of the realm of magic and religion. The text attributed to Hippocrates (who lived in Greece around 450 BC) represents the first code of conduct for the medical profession, as well as the first time a distinction was made between physicians and surgeons. Indeed, the latter were held in lower regard than the former, but they were the only ones who could physically operate on patients.

After the barbarian invasions, medicine regressed during the Middle Ages. At that point, the practice was largely based on Greek and Roman texts that had escaped...
destruction and which were now conserved in monasteries, making it the prerogative of monks, who also provided healthcare and took in patients. The Hippocratic distinction between physicians and surgeons still existed, with the former treating what were considered to be internal problems and the latter operating on external manifestations of disease. Surgeons mostly performed manual work, and indeed they were often described as *practici*, but they were not necessarily poorly educated people. Those with less training were the so-called barber-surgeons, who generally performed bloodletting, treated wounds or carried out simple operations. The famed medical school in Salerno (*Schola Medica Salernitana*) enjoyed its first period of splendor against this backdrop, towards the end of the eleventh century. Lastly, there were the so-called charlatans, commoners who lacked any formal training and who would provide mostly ineffective remedies at a lower price than licensed physicians.

As the study of human anatomy progressed, so too did surgery. Indeed, autopsies carried out during the Middle Ages began to explore anatomy in addition to discovering the cause of death. In any case, only with the revival of classical and humanist studies in the Renaissance would the study of the human body come to be recognized as an essential aid to surgery. In the sixteenth century, surgery was elevated to a higher social and scientific status, achieving the same recognition reserved for medicine. This was mainly thanks to the efforts of two major historical figures: Paracelsus and Ambroise Paré. The latter was a member of the barber-surgeon guild, but at the same time he worked at the Hôtel-Dieu in Paris, which was the area’s main hospital. Paré started working as a surgeon in the French army, specializing in gunshot wounds. During the Damvillers campaign of 1552, he would perform the first ligation of arteries during a leg amputation. The introduction of firearms would have a significant impact on military surgery, leading to the development of revolutionary techniques and new ways of treating the wounded.

That same period was also witness to an important evolution in the regulation and supervision of the profession. Indeed, in 1540, two English guilds which up to that point had been separate—the barbers and the surgeons—were united to form a single Corporation (though each would retain its own coat of arms). The new charter not only addressed the quality and duration of training, but also established that surgeons could not perform the tasks of barbers, and that barbers would limit their practice to pulling teeth (the Corporation would be dissolved in 1745, leading to the formation of the independent Corporation of Surgeons; that body would then become the Royal College of Surgeons in 1843, which still exists today). A new decree in 1629 prohibited anyone from practicing medical professions unless they had been specifically licensed to do so following an examination conducted by four examiners, two of whom were to be master barber-surgeons.

As the Enlightenment unfolded and new ideas blossomed in all fields of human knowledge, surgery too came to be recognized as an independent medical discipline. Specialized texts written by renowned surgeons began to circulate, and the first scientific societies dedicated specifically to surgery were established, such as
the Académie de Chirurgie in Paris (1731) and the Royal College of Surgeons in London (1800). Over the course of these centuries, surgeons, barber-surgeons, and military surgeons would achieve different degrees of social status, with some recognized as learned surgeons and others as untrained practitioners who learned on the job. In any case, the three categories would unite towards the end of the eighteenth century in most areas, and indeed French surgery was transformed from a craft guild to a liberal guild in 1750.

These developments would eventually reach North America as well, albeit a bit later on. While initially there were not so many physicians and professional surgeons in America, the great medical schools of the future would soon be founded at America’s oldest universities, such as the University of Pennsylvania School of Medicine in 1765 and Harvard Medical School. In his Discourse upon the Institution of Medical School in America of 1765, John Morgan, the co-founder of the University of Pennsylvania School of Medicine, made a conceptual distinction between the practice of physic, surgery, and pharmacy.

Surgery was radically transformed towards the middle of the nineteenth century with the introduction of anesthesia (Humphry Davy 1830, Horace Wells 1844, Friedrich Trendelenburg with tracheal intubation 1881) and antisepsis (Holmes 1855, Semmelweis 1847, Lister 1865). These two practices led to an exponential increase in the kinds of operations that could be carried out. Other innovations followed, such as the introduction of surgical instruments to perform specific functions (Kocher, Pean) as well as the first use of surgical gloves (Halstead 1890). At the same time, there was a great change in the way patients were cared for, with women playing an increasingly important role. This culminated with the Crimean War and the nursing revolution led by Florence Nightingale. The technological innovation began with the introduction of anesthesia, the first electrocautery device, respirators and X-rays. At the beginning of the twenty-first century innovation in surgery was accelerated thanks to hemorrhagic management by mono and bipolar electrosurgery, lasers, radiofrequency or surgical innovations as ablation, laparoscopy, robotics, or innovative clinical management as preclinical assessment or ERAS. All of this has helped dispel the myth that surgery depends solely on the ability of the surgeon.

Just like medicine, as twentieth century surgery evolved, it came to encompass various specializations (from general surgery to specialist surgery) as well as the use of increasingly sophisticated, precise instruments and the presence of experts such as surgeons, anesthesiologists, surgical technologists, nurses, and other operating room technicians. What’s more, the duties of each professional must be coordinated. In that regard, even the way a surgical team is coordinated has evolved, as the more complex surgery has become, the more a positive outcome has come to depend on the ability to work together and in harmony with the other professionals involved (the concept of teamwork).

Moreover, the complexity of surgery increases even further when one considers the hospitals and facilities in which it takes place. Indeed, the effectiveness of
surgical procedures does not only depend on the knowledge, abilities, and actions of the individual team members or on the technology at their disposal, but also on how well the hospital is organized. This includes factors such as how the patient is prepared for surgery, or whether the hospital has an area for postoperative care or enough beds to accommodate the patient. There is more and more talk today about the importance of surgical blocks and patient logistics, as well as of the instruments and materials required for surgery. There is also another factor that has emerged, especially in the early twenty-first century: namely, the difference between “that which scientific knowledge and technology makes possible in theory” and “that which can realistically be done.” On the one hand, this difference is attributable to the varying degrees of organizational efficiency or inefficiency of a given hospital; on the other hand, it depends on cost control and restrictions on financial resources.

Thus, it can be said that the surgeon–patient relationship has evolved. As long as the instruments were simple and rudimentary in nature, a successful surgical procedure mostly depended on the surgeon’s skill. Later on, the surgeon’s—and indeed the entire surgical team’s—ability to use technology came to influence the effectiveness of surgery. The increasingly rapid evolution of technology has introduced new dynamics to the practice of surgery, as well as the need for every single surgical team to dialogue with other teams in order to share technology and keep pace with innovation. And the complex nature of new technology means that the concept of “team” must now include “teamwork,” meaning a group of professionals with individual skills who work together to ensure success in surgery. In other words, while a team is a group of experts who each have specific duties, teamwork is a group of people who, despite having specific duties, learn to work as an interdependent unit driven by a common goal: to resolve the patient’s problem in the best way possible. In team-working non-technical skills (organization, leadership, etc.) are as important as technical ones (surgical, anesthesiological, etc.).

In addition to these technological factors, another element has subsequently come to influence the impact of a surgeon’s (and surgical team’s) skill on patient outcomes: hospital efficiency. Indeed, several organizational factors contribute to the creation of favorable conditions for a surgical team to meet patients’ needs appropriately and effectively, including: good scheduling, satisfactory patient logistics and materials management, suitable rooms, systems capable of supplying the best materials in a timely fashion, and the availability of information.

Finally, the last link in the chain is the quality of policies, such as healthcare funding levels, hospital reimbursement criteria for services rendered, and the prioritization of different groups of patients. Surgery today takes place within a “long chain” that requires interdisciplinary knowledge. With changes in technology, organizational models, and healthcare settings (for example, intensive care units, sub-intensive care, etc.), as well as changes in funding methods and in the rules set forth in health policies, available healthcare processes have become more complex. For this reason, recovery outcomes have now come to be influenced by the sequence outlined below:
The increased complexity described in the flowchart above helps explain the reason behind publishing this book. Indeed, this publication represents the convergence of two fields of knowledge, skills and experiences, namely that of abdominal wall surgeons and that of experts in economics, management, economic evaluations, and health policy. There are a number of reasons why such a convergence is so necessary and useful. First of all, there is a need to establish a “virtuous alliance” in order to better deal with the restrictions that arise when healthcare demands and the opportunities provided by scientific progress come up against limited resources. After all, while knowledge is evolving at an exponential rate, economic growth rates have been limited when compared to the past. Just look at China and the emerging nations, which record an annual gross domestic product growth rate of 6–7%, while the USA and Europe—even after the recovery period following the recession of 2007–2008—record a 2–3% annual growth rate.

Secondly, an alliance between the two cultures will foster synergy and thus prevent vicious circles from arising when the two worlds are not able to dialogue with each other. If abdominal surgeons, like all other healthcare professionals, continue to support the principle of “providing everybody with the best”—which is understandable from a theoretical point of view—while managers and experts in economic evaluations focus their attention on restrictions and on the “impossibility of providing everybody with the best,” then it is a waste of time and energy that would be better spent on the patient. However, if the two sides can understand each other and work together, it will be possible to find solutions that “provide more (quantity and quality to meet healthcare needs) with less (resources).” Such an alliance will lead to a better understanding of why health clinics and hospitals conduct themselves the way they do, as well as the reasoning behind health policy (on a regional and national level, and in terms of public finance). Indeed, all of these factors influence the healthcare context in a way that cannot be ignored.

Thirdly, it must be emphasized that the possibility of achieving more with less depends on the efforts of the two protagonists involved. The surgeon (and the healthcare professional in general) is focused on doing right by the individual—an approach that is best expressed as the “pursuit of the optimal solution for each
patient.” The expert in economic evaluations, the business manager, the health policy-maker, is focused on doing right by the population, or at least guaranteeing equity among social groups or groups of patients that have different healthcare needs. The surgeon/doctor/healthcare professional is in direct contact with the patient: when their approach prevails, they come up with optimal solutions for each phase of the patient’s care, but only for those patients who have access to such services. Meanwhile, those who have no such access due to long waiting lists or lack of funding do not receive effective care. If the economic evaluations expert/business manager/health policy-maker’s approach prevails, then that leads to solutions which on a theoretical level might indeed aim to guarantee a general level of equity, but in practice often turn into restrictions and inflexible rules that prevent patients from receiving appropriate, effective care. The two sides must be able to dialogue and establish a common ground for discussion: only then will it be possible to achieve better optimal solutions for individual patients and general equity (or at least, less inequality) for the population.

Fourthly, a lack of mutual understanding drives a wedge between “wanting to” and actually “being able to,” because while scientific knowledge and available technology might make a certain solution theoretically possible, too often it cannot be done due to an inability to overcome the restrictions that stand in the way. To bridge this gap between “wanting to” and “being able to,” both sides need to further develop their “knowledge” (i.e., the surgeon must better understand issues concerning economic evaluation and healthcare organization, management, and policy, while experts in these fields must better understand the issues facing those who have daily contact with patients) and their “know-how” (i.e., both sides need to work together to find realistic, concrete, applicable solutions).
Part I

Abdominal Wall
Anatomy of the Abdominal Wall

Cesare Stabilini and Ezio Gianetta

2.1 General Appearance

2.1.1 Superficial Layers

The superficial layers of the anterolateral abdominal wall include the skin, the subcutaneous tissue divided by Camper’s and Scarpa’s fascia. It contains lymphatic vessels and arteriovenous structures.

2.1.2 Myoaponeurotic Structures

The muscular components of the abdomen are represented by the two rectal muscles in central positions and a layer of three large lateral muscles namely external oblique, internal oblique, and transversus abdominis. This muscular complex is contained in a system of interconnected dense connective fibers which create the aponeurotical layers of the abdominal wall.

The rectus abdominis muscle (RA) has a proximal insertion in the V–VI–VII costal cartilage and xiphoid process, distally the muscle reaches the pubic crest. The RA has three transversal tendinous inscriptions which adhere firmly to the anterior rectus sheath as a result of the embryonal development. Anteriorly and caudally to the rectus muscle, inside of its sheath, the pyramidalis muscle exerts a tensive effect on the RA with its insertions on the pubic crest and linea alba.

The external oblique (EO) muscle takes its origin from the last eight ribs intermingling with latissimus dorsi and serratus anterior. The muscle has both a muscular and an aponeurotic part, the transition line is vertical downward medially to the emiclavare line, and below the anterosuperior iliac spine (ASIS) the muscle is
totally aponeurotic. The direction of the fibers is oblique downward and internally, the distal part of the muscle is interlaced with fibers coming from the counterlateral internal oblique (IO) muscle and transversus abdominis (TA). Inferiorly, it contributes to the inguinal and lacunar ligaments and the pillars of the external oblique orifice (Colles ligament).

The internal oblique takes its origin from the thoracolumbar fascia, from the iliac crest and ASIS. The fibers are muscular in their origin and become tendinous creating a large aponeurotical structure which participates to the constitution of the aponeurosis of rectus abdominis muscle and linea alba. The more distal fibers of IO and TA merge to create the conjoined tendon, an inconstant structure of the inguinal canal.

The transversus abdominis muscle is fleshy in its middle part and tendinous at extremities, and its fibers depart from the inner surface of the last six ribs, thoracolumbar fascia, iliac crest, and from psoas fascia. From this region, the fibers run medially becoming aponeurotic along the semilunar line of Spigel. They run from the IX rib to the pubic tubercle, describing an arch with its convex part toward the midline. The Spigel fascia is the aponeurotical part between the semilunar line and the lateral aspect of the rectus muscle. The TA aponeurosis contributes to the constitution of the rectus abdominis aponeurosis, linea alba, and the transverse arch (conjoined area) of the inguinal region.

The three large muscles and their aponeuroses are separated by loose connective fibers, the outermost being called Gallaudet fascia which contributes to the external inguinal orifice, the innermost being the transversalis fascia originating from the endopelvic fascia.

Traditionally, the aponeuroses of each of the three lateral muscles are described as single laminar structures contributing on each side to the creation of anterior and posterior rectus sheaths. In reality, below the umbilicus halfway from the pubis, the deep aponeurotic layer is lacking, all the aponeuroses pass in front of the RA, and the posterior sheath of the muscle is represented only by the transversalis fascia with contribution from some fibers from the TA. The line of interruption has the shape of an arch and is called Arcuate Line of Douglas. The origin of this interruption could be caused by the presence of the urinary bladder in the retrorectus position at the embryonal stage, thus probably preventing development of the posterior sheath at this level.

Currently, this description is outdated, in particular after the studies of Askar and Rizk who modified the traditional theories on the rectus sheath and linea alba formation. They showed the two laminar components of each aponeurosis coming from the lateral muscles and their decussation at the midline. As a result, the RA is encased in a robust connective structure formed by the bilaminar aponeuroses of the three large muscles. These pass three anteriorly and three posteriorly, respectively, above the line of Douglas. Below this line, the anterior rectus sheath is formed by all six layers.

Thanks to this structure, the lateral muscle and RA abdominis are synergically connected and can exert their complementary function. An interruption of the tendinous midline center (such as after a laparotomy) carries as a consequence the functional loss of the RA.
2.1.3 Vascular Supply

The anterolateral abdominal wall is vascularized by two different systems, a deep and a superficial ones, connected by several perforator branches. The deep system is maintained mainly by the epigastric vessels: the deep superior epigastric artery (DSEA) originating from the internal thoracic artery as a terminal branch and the deep inferior epigastric artery (DIEA) coming from the external iliac vessels. These vessels create an anastomotic network connected to intercostal, subcostal, and lumbar arteries and to the ascending branch of the deep circumflex iliac artery. The main anastomotic connection between the DSEA and DIEA is at the level of the umbilical line, where the vessels bifurcate and trifurcate to join each other and give rise to inconstant umbilical branches.

The superficial system is similar and spreads longitudinally with a network created by superficial inferior and superior epigastric vessels, the type of interconnections being slightly different from that of the deep system. The superficial inferior epigastric artery, originating from the common femoral artery, vascularizes the anterolateral abdominal wall and joins the superior superficial epigastric artery in the subcutaneous tissue while communicating with the deep system via branches from its inferior surface and laterally with intercostal vessels and superficial circumflex iliac artery.

A particular attention is necessary on the subject of perforators. These vessels, originating from the anterior branches of the DSEA and DIEA, pierce the myoaponeurotic layers and reach the subcutaneous tissue. There is, according to several studies, clearly a significant periumbilical distribution of perforators, highlighting that the periumbilical skin has an effective circulation. All periumbilical and infraumbilical perforators are derived solely from the DIEA thus explaining the reliability of myoaponeurotic flaps derived from the infraumbilical region.

Tips The knowledge of this vascular supply is two-fold paramount in abdominal wall surgery. The first reason is related to the approach to complex defects and wide subcutaneous dissections typical of anterior component separations, where the interruption of perforating vessels is responsible for high rates of surgical site infections. The introduction of endoscopic approaches and open perforator sparing technique has reduced related morbidity. The second reason is explained by the increasing use of the abdominal wall in reconstructive surgery in which the areas with best vascularization (angiosomes) and the appropriate technique of harvesting must be owned by the operating surgeon for successful results.

2.1.4 Innervation

The major nervous structures of the abdominal wall are located in a neurovascular plane traditionally known as the Transversus Abdominis Plane. The intercostal, subcostal, and lumbar nerves run along with their vascular counterpart in the space...
between the internal oblique and transversus abdominis covered by a thin fascial layer. The segmental nerves of T6 to T12 enter the abdomen starting from the costal margin and then at increasingly lateral sites on the mid axillary line. They have extensive communication and interexchange of nervous fibers. This type of nervous architecture develops in a true plexus at level of the ascending branch of the deep circumflex iliac artery on each side. Muscular afferents arise from this structure directly providing innervation to the overlying oblique muscles and lateral aspect of rectus muscles. Nerves reappear after the plexus and encroach upon the rectus sheath from its lateral aspect, and they pierce the lateral margin of the linea semilunaris and enter the rectus sheath. The resulting truncal nerves are variable in number and, because of the communications noted previously, corresponded to multiple segmental origins.

**Tips** The knowledge of the innervation of the anterior abdominal wall has become increasingly important with the development of new surgical and anesthesiologic techniques which rely on the precise location of these structures to avoid direct irreversible damage or induce transient analgesic and relaxing effects.

Typical sequela of nerve section during lumbotomy for kidney surgery is atrophy of the lateral muscles due to denervation. Usually, practitioners misinterpret this condition with the presence of an incisional hernia, and the attempted repair of the affection is characterized by bad functional results. Similarly, denervation should be also taken in consideration whenever associated to a true incisional hernia since the bulging of the atrophied muscle could mimic an early recurrence.

The TAP block technique is an emerging and promising technique for the analgesia and anesthesia of the abdominal wall musculature. It is based on local anesthetic injection, under the US guidance, in the plane between transversus abdominis and oblique muscles paralyzing the aforementioned nervous structures.

### 2.2 Weak Areas of the Anterior and Posterior Abdominal Wall

While an incisional hernia can arise on the site of a previous surgical incision which can be placed everywhere in the abdominal surface, primary abdominal wall hernias take their origin in definite anatomical areas which, for several, reasons have reduced resistance to intra-abdominal pressure.

These so-called weakness areas are located mainly in anterolateral wall and less represented in the posterior part, that are:

- Linea alba
- Umbilical area
- Inguinofemoral region (or Fruchaud area or myopectineal orifice)
- Semilunar line of Spigel
Posteriorly, we can define a lumbar region, limited cranially by the 12th rib, caudally by the iliac crest, and its lateral margin is an imaginary vertical line from the extremity of the 12th rib to the iliac crest, medially by the latissimus dorsi. It is constituted by two weak areas:

- Triangle of Petit
- Triangle of Grynfeltt

### 2.2.1 Linea Alba

The linea alba is the central tendon of the anterior abdominal wall, it spans from the xiphoid process and reaches the pubic tubercle where it becomes wider including the pyramidal muscle.

Recent studies with electron microscopy examination of the linea alba contradict the description of the linea alba as a line of decussation of fibers (six aponeurotic layers, all oblique and crossing the midline). Instead, three layers have been identified:

1. The lamina fibrae obliquae consisting of intermingling oblique fibers (*on average, four to six layers of fibers*).
2. The lamina fibrae transversae containing mainly transverse fibril bundles (*on average, four to six layers of fibers*).
3. An inconstant, small lamina fibrae irregularium composed of one to two layers of oblique fibers.

**Tips** The traditional use of median laparotomy and incision of the linea alba affects the integrity and stability of the entire abdominal wall. The use of off-midline laparotomy to gain access to the peritoneal cavity is encouraged after the observation that it generates less incisional hernias and is endorsed by the current guidelines.

### 2.2.2 Umbilical Region

The umbilical region is a natural door to the abdominal cavity, surgeons use it as an entry point for laparoscopic port placement and more recently for single site surgery, it is a well-known weak point of the linea alba where hernias can be found at advanced age, in around 90% of patients.

Traditionally, the umbilical region is an anatomical structure of the linea alba surrounded by fibrous tissue belonging to rectus muscles aponeurosis and attached to the umbilical cord, created after the final rotation and internalization of the mid-gut into the abdominal cavity.

The distal two thirds of the ring are occupied by a bulk of fibrous tissue originated by fusion of urachus, umbilical artery, and skin after birth, and the superior third of the umbilicus is the true weak area reinforced by a fibrous lamina called fascia umbilicalis of Richet.
In more recent studies, it has been shown that different postnatal modifications in the development of the abdominal wall and liver can determine up to five different types of umbilical ring: in the most frequent of them (60% of cases), the urachus crosses the ring and protects from the development of an umbilical defect.

2.2.3 Inguinofemoral Region

2.2.3.1 General Description
Fruchaud’s myopectineal orifice (MPO) is one of the anatomical regions with the highest number of eponyms used to describe each single structure of which it is composed. This observation reflects the overwhelming number of authors who tried to understand the anatomo-clinical correlations between the osteomuscular structures of this region and their role in the genesis of groin hernia. Most of the knowledge of this anatomical area comes from extensive studies performed by surgeons over the past 200 years describing their personal techniques of hernia repair.

The myopectineal orifice has a rhomboid appearance, the limits of this structure are:

1. Medial: rectus muscle and its insertion tendon, the condensed part of its anterior sheath, the pubic tubercle, and lacunar ligament
2. Lateral: iliopsoas muscle covered by fascia iliaca, the adjoining pelvic brim (part of iliac bone), genitofemoral nerve, and lateral cutaneous nerve of thigh
3. Superior: the arch formed by transversus abdominis muscle, internal oblique muscle, and fascia transversalis
4. Inferior: superior ramus of pubis with its pectineal ridge, Cooper’s ligament, and pectineus muscle

The inguinal ligament divides this area in two compartments where we can identify an upper inguinal region and a lower femoral and muscular region. The knowledge of the MPO is crucial since various types of hernia arise in this region and the covering of the whole MPO with prosthetic material represents the real cure for these defects.

2.2.3.2 The Anterior View
During the embryonal development of the abdominal wall, which takes place between the 6th and 7th week of gestation, the testicle descent outside the abdominal wall in the scrotum creates the inguinal canal. In the early phase, the parietal peritoneum precedes the testicle creating a diverticular extrusion called the peritoneo-vaginal duct. This conduct obliterates after the testicle reaches its natural location; the failure of this process is the prerequisite for congenital inguinal hernias. In the female patient, the same duct is called Nuck’s canal and it allows passage to the round ligament of the uterus.