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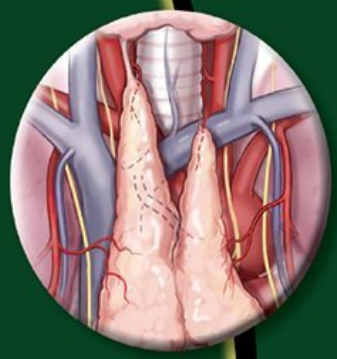

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Mc Graw Hill Education

New York Chicago San Francisco Athens London Madrid Mexico City
Milan New Delhi Singapore Sydney Toronto

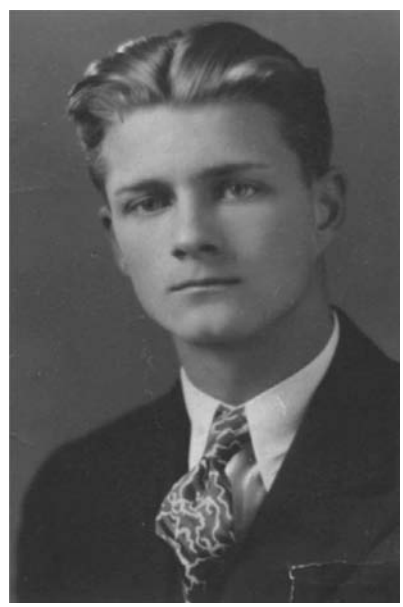
ISBN: 978-0-07-178190-9

MHID: 0-07-178190-0

The material in this eBook also appears in the print version of this title: ISBN: 978-0-07-178189-3,
MHID: 0-07-178189-7.

eBook conversion by codeMantra
Version 1.0

DEDICATION



Everett D. Sugarbaker, MD

— 1910 to 2001 —

"Wherever you are, it is 90% you and 10% institution."

Cornell University Medical College, MD, 1935
Memorial Hospital, New York, 1937
Chief of Surgery, National Cancer Institute, Bethesda, Maryland, 1940
Chief of Surgery/Chief of Staff, Ellis Fischel Hospital, Columbia, Missouri, 1942
Sugarbaker Tumor Clinic, Jefferson City, Missouri, 1948 to 1983

To my father, Everett D. Sugarbaker: inventor, author, researcher, mentor, and master surgeon.

IN MEMORIAM

Harold C. Urschel, Jr., MD

1930 to 2013

Professor of Surgery,
Department of Cardiothoracic Surgery,
Baylor University Medical Center, Dallas, Texas

Our colleague, Harold (Hal) C. Urschel, has passed since the first edition of this book was published. He will be greatly missed. Hal was not only a master surgeon, author, and mentor, but also our true friend.

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Foreword

Adult Chest Surgery is the culmination of a team effort. It would be unfair to single out any surgeon in particular, yet every team needs a vision, a driving force, an individual who is able to articulate that vision, recognize talent, acquire resources, seize opportunity, delegate responsibility, and lead. That is the hidden message of this book. Every surgeon who contributed to this volume is a leader in his or her own right. More than just a compilation of technical procedures, every author is trying to tell you something important, something they learned from the school of hard knocks, something that can make the difference between a successful and unsuccessful operation, and something that may impact your career in thoracic surgery. This impressive list of contributing authors also emphasizes the number of national and international surgeons who have dedicated their careers to the pursuit of general thoracic surgery. These individuals are the product of a focused and dedicated approach to general thoracic surgical training as practiced at multiple institutions worldwide.

As I look back upon my own experience, the unique events leading to the establishment of a separate division and training program for general thoracic surgery at Toronto General Hospital had far-reaching implications, the details of which I will relate herein.

Happenstance and good fortune placed me in the general surgery training program at Toronto General Hospital in the early 1950s when the seeds of our profession were sown. This was the same hospital where my predecessors, Dr. Norman Shenstone and Dr. Robert Janes, pioneered the Shenstone/Janes lung tourniquet in 1932. The purpose of the tourniquet was to control intraoperative hemorrhage, decrease mortality, and reduce the incidence of postoperative fistulae, and thereby ensure the safety of pneumonectomy and lobectomy for the treatment of suppurative lung diseases like tuberculosis. Previous to this, surgeons used to hold their breath during the difficult dissection of the hilum. As a result of this innovation, Toronto quickly became a leading center for general thoracic surgery in North America.

When my surgical career began, four surgeons (still operating within the division of general surgery) were responsible for the care of thoracic patients at Toronto General Hospital, including my mentor, Dr. Fredrick Kergin, as well as Drs. Norman Shenstone, Robert Janes, and Norman Delarue. Dr. Kergin played a key role in my development as well as in the evolution of general thoracic surgery. He was one of three general surgeons practicing thoracic surgery at the time and had an international reputation for his contributions to that specialty. Among his many contributions, he was largely responsible for the creation of a separate division of general thoracic surgery at Toronto General Hospital and for his foresight in bringing endoscopy (esophagoscopy and bronchoscopy) into the practice of general thoracic surgery. Previously, endoscopy had been the exclusive domain of otolaryngologists and ENT surgeons. This was the case not only in Canada but also throughout North America and most of the world.

Dr. Wilfred G. Bigelow, a young general surgeon with training in vascular disease, also played an important role. He introduced me to the more practical aspects of scientific research through a one-year fellowship in his physiology laboratory in 1951 to 1952. In 1953, Dr. Bigelow was named head of one of three hospital divisions of general surgery. Recognizing the need to develop specialized training for cardiac surgeons, he used his persuasion as surgeon-in-chief to create a dedicated division and training program for cardiovascular surgery. This decision influenced later events at Toronto General Hospital, and, eventually, across North America.

In 1958, just preceding a staff appointment to Toronto General Hospital, I benefited from a one-year traveling fellowship to Great Britain and Scandinavia. The McLaughlin Fellowship, as it was called, had been established to give young surgeons exposure to the international community prior to assuming a staff appointment. I spent six months as a senior house officer with the renowned esophageal surgeon, Ronald Belsey, in Bristol, England, and seven months in Sweden and Denmark, where I gained valuable exposure to mediastinoscopy. I was especially fortunate, after a chance meeting in the surgeons lounge while visiting the Karolinska Institute in Stockholm, Sweden, to be invited by Dr. Carlens to assist him in the operating room where I observed mediastinoscopy first hand.

In 1960, after returning to Canada, I joined the surgical staff of the Toronto General Hospital and we began to train a new generation of general thoracic surgeons. In 1966, with Dr. Kergin's blessing, Norman Delarue and I proposed that Toronto General Hospital establish the University's first dedicated thoracic surgical service. By 1968, the Royal College of Physicians and Surgeons of Canada had recognized general thoracic surgery as a distinct subspecialty, and I became chief of the first Division of Thoracic Surgery at Toronto General Hospital. Benefiting from my fellowship in Scandinavia and Great Britain, our division contributed to the development of mediastinoscopy, techniques of modern tracheal surgery, and the treatment of esophageal reflux disease through the introduction of the Collis-Belsey procedure. Subsequently, the "Toronto Program" became known internationally for its pioneering work in lung transplantation, minimally invasive procedures, and basic and clinical research. The training program in general thoracic surgery we had instituted at Toronto General Hospital became a model for training programs worldwide. The rest, as they say, is history.

Eventually, the notion of having independent, dedicated training programs in cardiac and general thoracic surgery expanded into the United States, with the creation of the first division of thoracic surgery at Brigham and Women's Hospital in 1988. Many academic centers followed suit. Indeed, today, the majority of academic thoracic surgery is performed by dedicated thoracic surgeons working in separate divisions or sections. This is a stark change from earlier days when cardiothoracic surgeons did it all.

This brings me full circle to the present. It is worth noting that although I have stressed the importance and value of dedicated thoracic training, thoracic surgeons are not the only

professional groups qualified to perform these procedures. As a result of differences in postgraduate programs or constraints sometimes imposed by the custom of practice where care is delivered, thoracic cases may be handled by a cardiothoracic surgeon with training in both cardiac and thoracic procedures or even a general surgeon who is comfortable operating in the chest. This book is intended for all three professional groups. In my opinion, the authors and editors of *Adult Chest Surgery* have prepared a masterful presentation of the thoracic discipline that is well worth your time and attention.

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Preface

Adult Chest Surgery is your guide to the future of thoracic surgery. Now in its second edition, this internationally recognized, authoritative resource builds on the reputation of the first edition, which garnered numerous awards and laudatory reviews for art, production, and science.[1-3] Intended for residents preparing for a case, surgeons seeking management tips, and surgeon specialists preparing for board recertification, the second edition remains steadfast in its mission to provide a comprehensive yet practical guide to the modern practice of general thoracic surgery. Broad in scope and straightforward in style and presentation, the volume is an excellent reference for anyone desiring a comprehensive description of the clinical nature of general thoracic surgery.

By updating the second edition in record time for a volume of this length and complexity, the editors of the second edition have assured that the information is current and applicable to present day practice. The concise description of current techniques and surgical principles for the most common thoracic surgical problems encountered in the clinic and the operating room are the thrust of this text. It expands generously on the content of the first edition with 40 new chapters devoted to a range of topics including new endoscopic techniques for antireflux surgery; percutaneous thoracic tumor ablation; peroral esophageal myotomy; robotic techniques for lobectomy, esophagectomy, and thymectomy; and other new minimally invasive approaches to standard thoracic resections.

More than 250 detailed illustrations of procedures have been added to the text, bringing the total to 850. The volume continues to represent several generations of internationally recognized surgical innovators conversant in a range of innovative techniques and technologies, as well as leading medical experts in thoracic oncology and pulmonary disease. These thought leaders have trained in centers of surgical excellence that have contributed to the discipline of general thoracic surgery. We are indebted to these individuals and especially their mentors, who sustained and nurtured general thoracic surgical education and training from the infancy of the discipline.

The editors wish to acknowledge the continued support of Ann Adams and Marcia Williams, who have brought continuity to the second edition through their excellent and precise editorial and artistic contributions.

We also acknowledge our spouses Linda Sugarbaker, Kate Poverman, Gray Lorig, Bridget Jaklitsch, Diane Krasna, and Barbara Smith for putting up with our hectic schedules; our parents Geneva V. and Everett D. Sugarbaker, Rachel and David Bueno, Thomas and Shirley Colson, Frederick and Evelyn Jaklitsch, Anne and Irwin Krasna, and Loy and James Mentzer, who inspired and supported us in our educational pursuits; our partners, trainees, and colleagues, who carry the field forward; and our patients, who put their trust and hope in our hands.

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1. Prose Awards American Association of Publishers, 2009
2. Association of Medical Illustrators, 2009
3. British Medical Association, Medical Book Awards, 2010

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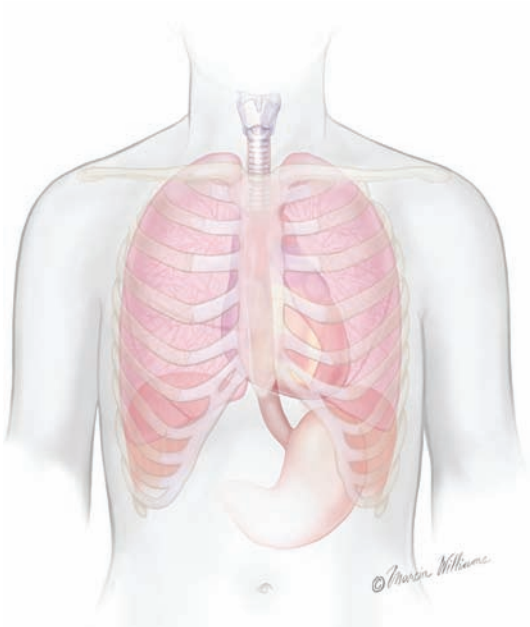

1 Introduction

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The emergence of general thoracic surgery in North America as a surgical subspecialty distinct from general surgery, congenital heart surgery, and adult cardiac surgery occurred through dramatic and tumultuous changes that once threatened but ultimately strengthened the integrity of the discipline. The discipline evolved from general surgery in the early 1900s in response to chest morbidities prevalent at that time, primarily tuberculosis and World War I-related trauma. Hence, the systems established to guide thoracic surgery were shaped by general surgeons. War continued to play a role in shaping surgery. In the 1940s, surgeons caring for soldiers in World War II struggled to manage the life-threatening chest injuries caused by modern weaponry. This spurred technological innovation during and after the war. By the 1950s, new knowledge and technology began to lift the physical and psychological barriers to surgery within the chest, including the heart. The technical achievement of extracorporeal circulation by John Gibbon, first used in humans successfully in 1953, allowed the extension of cardiac and congenital heart surgery into more complex problems, leading to new fields of specialization in myocardial revascularization, valve surgery, and heart transplantation in the late 1960s. These changes occurred as antibiotic use reduced the incidence of tuberculosis and the need for pulmonary surgery. Soon, combined cardiothoracic surgery programs began to form at leading academic centers.

The union between thoracic and cardiac surgery, however, was not altogether ideal, and thoracic training often played second fiddle to cardiac training. In 1981, Dr. Donald Paulson, President of the American Association for Thoracic Surgery, focused on the inadequacy of training in general thoracic surgery. In his presidential address, he stated: "Failure to correct the imbalance in training of thoracic surgery has resulted in a vacuum, which could lead to disintegration of the specialty."[1] By the 1990s, the realm of general thoracic surgery was so eclipsed by the dramatic developments in cardiovascular disease that funding in combined cardiothoracic programs began to be diverted in favor of cardiac training.

This pattern was played out largely in the United States, United Kingdom, and Europe, and threatened the ability of such programs to attract top-notch general thoracic surgeons. In an editorial published in 1991 in the *Annals of Thoracic Surgery*, the President of the American Association for Thoracic Surgery, Dr. John Waldhausen, addressed the broad concern that American thoracic surgery programs were failing to attract the "brightest candidates." Later that year an educational workshop was convened in Snow Bird, Utah, to define the deficiencies in American thoracic surgery.

Meanwhile, although similarly influenced by the pace of development in cardiac and congenital heart surgery, events transpired somewhat differently in Canada, where dedicated resources were committed to a separate general thoracic service and training program. Dr. F. Griffith Pearson, the first Chief of the first Division of General Thoracic Surgery at Toronto General Hospital, is widely known for his role in establishing thoracic surgery as a bona fide surgical subspecialty in North America. You can read his personal account of the Toronto experience in the Foreword to this book.

Dr. Pearson had tremendous impact in the field of general thoracic surgery[2] and is widely regarded as the father of thoracic surgery in North America. Throughout his tenure as Chief of the thoracic division at Toronto General Hospital (1967–1984) and subsequently as a staff surgeon until he retired in 1999, he oversaw important developments in lung transplantation, thoracic oncology, and clinical and basic research, mentoring many surgical leaders around the globe. American surgeons with an interest in general thoracic surgery were attracted to the Canadian programs. After training, the many successful graduates of these programs brought their experiences and commitment back to the United States, where lack of specific funding for thoracic surgery training had led to a shortage of qualified surgeons as described above.

The inevitable consequence of this pent-up demand fueled the trend of establishing separate programs in cardiac and general thoracic surgery in the United States. Dedicated thoracic surgery programs were better able to compete for funding, and training programs improved. These university centers flourished over the next several decades and have trained countless general thoracic surgeons and have promoted a multitude of group practices in general thoracic surgery.

In the first half of the 20th century, pulmonary tuberculosis was the primary focus for thoracic surgeons. After an effective chemotherapy was developed, thoracoplasty faded away in favor of drug therapy and resection only when necessary. In the second half of the century lung cancer replaced tuberculosis as the primary focus of thoracic surgery. Lung cancer became the leading cause of cancer death worldwide, and this in turn, spurred new knowledge and technological developments in general thoracic surgery.

The role of the general thoracic surgeon is diverse. Practitioners are sometimes diagnosticians, sometimes surgeons, and sometimes scientists. Today, surgical extirpation of lung and other pulmonary cancers dominates general thoracic practice, and surgical complete macroscopic resection remains the foundation of therapy in solid tumors. Over time, thoracic surgeons have made steady progress in the technical conduct of surgery, thereby reducing the morbidity and mortality of surgical resection. The primary challenge that remains for many malignancies is the propensity of these cancers to exhibit locoregional and systemic recurrence. Surgical participation in new strategies to effectively control micrometastatic disease will be required for significant progress to be made. The answers to these conundrums lie, presumably, at the molecular level. The

relevance of the thoracic surgeon in this scenario continues to grow as surgeons play an increasing role in the development of translational research strategies. In this regard, the emergence of tissue banks, organized and administered by thoracic surgeons, has promoted progress in collaboration with translational and basic science.

The education and training of general thoracic surgeons has seen much progress. The recent emergence of specialized thoracic surgery training tracks and the reorganization of training programs that will facilitate the training of highly skilled surgeons is one example. The emergence of programs that accept medical students who have decided on a focus in cardiothoracic surgery, as well as programs selecting residents midway through their general thoracic training, is another example. All of these efforts permit greater focus on individual specialties and support the training of competent and innovative surgeons. New fellowship programs are also being developed to refine specific operative skill sets. For example, fellowships in minimally invasive surgery, thoracic oncology, and more recently, robotic surgery seek to refine unique skills in a subset of members of our surgical community.

The ongoing divergence of the two subspecialties of cardiothoracic surgery is attributable to the specialization of skills and knowledge required for the diagnosis and treatment of cardiac versus lung and chest wall disease. While it is has been demonstrated that surgeons who work hard and keep abreast of their personal continuing medical education can be competent in both cardiac and thoracic operations, it is my personal belief that to create new knowledge in either field and to train dedicated cardiac or thoracic residents, a career dedicated to one or the other discipline is prerequisite. It goes without saying, for example, that acquiring sufficient knowledge to teach residents about the multitude of new cardiac valve replacement prostheses necessarily precludes the level of knowledge required to teach residents about the appropriate chemotherapy approaches in the multidisciplinary care of thoracic oncologic processes.

If asked to offer a piece of advice I have found most valuable in my role as surgical educator and mentor, it would be the following. The success of one's career depends not only on accomplished and industrious academic pursuit, but also on the ability to identify and pursue select goals with focus and singularity of purpose. This principle is illustrated in the following parable.

A young surgeon walked up to the granite wall of human disease. The wall was so shiny and black, he could see his face reflected on the surface. Anxious to make his mark, he grabbed a pick axe lying nearby and started swinging at the wall, but the blade bounced off. He tried this repeatedly without raising a speck of dust. Further down the wall, several other young surgeons were having the same problem. Feeling frustrated and discouraged, the young man stopped to rest. Suddenly, he became aware of an old surgeon sitting on a bench nearby quietly surveying the scene. He decided to approach him for advice. The surgeon took the young man's axe, held it in his hands, and looked thoughtfully at the blade, rolling it over several times. He then studied the other young surgeons flailing at the granite wall, unable to make their marks. After what seemed like an eternity, he spoke. "I notice," he said, "that everyone here is using the broad end of the pick." He swung the axe around, pulled a grind stone out of his bag, and honed the fine end of the pick to an extremely sharp point. "Try that," he suggested when he was satisfied with his work. The young surgeon walked to the wall and swung the pick with its narrow focused point. Before too long, dust began to fly, and the young man began to make progress.

The moral of this story is clear. For a surgeon to make real progress in the treatment of human disease, a clarity of purpose and focused attention will be required or the effort will be frustrating and progress slow.

It is difficult to enumerate the challenges that lie ahead for our specialty. Many factors—technological, biological, sociological, political—have the potential to influence our future course. We have the opportunity to build upon the firm base in general thoracic training and education that was established by our mentors in the 1980s. The future of our specialty will be shaped by the quality of our education and the institutions that have been established to keep our practitioners current and informed. The pursuit of excellence in our individual practices will have an untold influence on the collective practice of our specialty. Although this book is a reflection of individuals who have focused their careers in thoracic surgery, it is equally intended for general thoracic surgeons, cardiothoracic surgeons, and general surgeons who operate in the chest. Indeed, the only prerequisite for benefiting from this book is that one practice some form of general thoracic surgery. The pioneers of our profession participated in an exciting, almost unparalleled era in the history of medicine, but the story is not over. I have no doubt that the readers of this book will continue to witness and contribute to major advances in our field across the spectrum of evolving surgical therapies. Above all, this text seeks to promote and support the attainment of individual excellence in the practice of thoracic surgery so that we can continue to provide our patients with the highest quality of surgical care.

References

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2. Pearson FG. Adventures in surgery. *J Thorac Cardiovasc Surg*. 1990;100: 639–651.

2 Thoracic Incisions

Michael T. Jaklitsch

Keywords: Thoracic incisions, posterolateral thoracotomy, anterolateral thoracotomy, axillary thoracotomy, bilateral thoracosternotomy (clamshell), median sternotomy, partial sternotomy, anterior mediastinoscopy (parasternal Chamberlain), open thoracostomy, Eloesser flap, Clagett window

A surgical incision opens an aperture into the thorax to permit the work of the planned operation to proceed. If placed correctly, the operation proceeds with unimpeded visualization of the important anatomy. If placed incorrectly, it can lead to frustrating delays and difficulty in the operation. Dr. Robert E. Gross' admonition, "If an operation is difficult, you are not doing it properly," applies directly to the incision used.* This chapter is designed for both the novice and those who have already gained some experience with thoracic incisions. The artwork is designed to explain important relationships for the inexperienced. We also have provided subtle pearls that will rekindle an appreciation of different incisions for the more experienced. More important, we have tried to explain the logic behind the incisions.

Each incision is described in terms of its current general use, technical details, advantages, and disadvantages. We also provide details of chest wall anatomy, with particular attention to structures that can be injured while developing the incision. Finally, we provide surface anatomy landmarks that can be used to place the incision properly.

As the thoracic surgeon gains experience, these incisions frequently will be modified to accommodate the primary surgical objective of a given operation. Furthermore, as technology progresses, these standard incisions may begin to change. For instance, in the modern era of video-assisted techniques, even classic open incisions are decreasing in length as surgeons become more comfortable with the concept of centering the incision on the anatomy that is critical for the operation to progress. In this regard, these standardized incisions can be thought of as building blocks, similar to the notes of a musical chord. It is our belief that the more the surgeon understands the strengths, weaknesses, and possibilities of each incision, the quicker he or she will learn to use the full variety of possible incisions tailored to the individual patient.

*Personal communication with W. Hardy Hendren on the origin of Dr. Gross' sign, September 20, 2007: "The sign was made by Dr. Robert E. Gross. He was the William E. Ladd Professor and surgeon-in-chief of Children's Hospital in Boston from 1947 to 1967, when he was succeeded by Dr. Judah Folkman. Dr. Gross was then appointed cardiovascular surgeon-in-chief until he retired in 1972. The sign hung in OR 3, which, sadly, became an anesthesia workroom when the OR suite was enlarged. Dr. Folkman saved the sign, which was an important relic of the past. In 1982, Dr. Folkman elected to spend full time in his burgeoning laboratory. He was succeeded by W. Hardy Hendren, who had been for 22 years head of pediatric surgery at the Massachusetts General Hospital. When Dr. Hendren was appointed chief of surgery at Children's Hospital in 1982, Dr. Folkman presented the sign to him. It hung in OR 7 until the operating suite was once again enlarged, and the room was changed into a nursing administrative office. Alas, planners have no appreciation of historical places. Only the original Ida Smith ward, where the surgical neonates were housed back to the Ladd era, has thus far escaped the wrecker's ball. When Bob Shamberger became chief of surgery, I passed on to him 'The Sign.' It is now in his office. Perhaps it will find its way back to the OR. I hope the above will correct the record on the famous sign. Best regards, Hardy."

POSTEROLATERAL THORACOTOMY

General Use

Posterolateral thoracotomy is the standard workhorse for most thoracic surgeons. It offers excellent direct visualization of the entire thoracic cavity, including the posterior diaphragmatic sulcus and apex of the hemithorax. The incision generally is centered over the fifth intercostal space, which corresponds to the greater fissure of the lung. This provides an unobstructed view of the base of the fissure, the pulmonary artery, and the hilum. The incision generally is used for anatomic lung resections, including pneumonectomy and lobectomy. It offers the easiest access for radical lymphadenectomy. An extended posterolateral thoracotomy is used for Pancoast resection, extrapleural pneumonectomy, and aortic transection.

Technique

The patient is placed in a standard lateral decubitus position, with the ipsilateral arm extended forward. The inferior tip of the scapula is palpated and generally marked. The incision begins approximately 3 cm posterior to the scapula tip and approximately halfway between the scapula and the spinous process. The incision curves around the tip to lie along the top margin of the sixth rib (fifth intercostal space). In general, it extends to the anterior axillary line (Fig. 2-1). The soft tissue and Scarpa's fascia are divided. The latissimus dorsi muscle is divided. The auscultatory triangle, the space bounded by the lower border of the trapezius, the serratus anterior, and the medial margin of the scapula can be identified at this time. The serratus anterior muscle can be spared by freeing it from the soft tissue of the auscultatory triangle and the muscle rotated forward. Preservation of the serratus anterior muscle helps to preserve the motion of the shoulder girdle and quickens recovery time. An intact serratus anterior muscle can limit the spread of the fifth and sixth ribs. This can be overcome by detaching the lower slips of attachment of the muscle from the eighth, seventh, and sixth ribs (Fig. 2-2).

If the ribs are to be preserved, the attachment of the intercostal muscles is divided from the top of the sixth rib. It is important to stay on the top surface of the lower rib to avoid injury to the neurovascular bundle of the upper rib. This is best done by proceeding from posterior to anterior along the line of

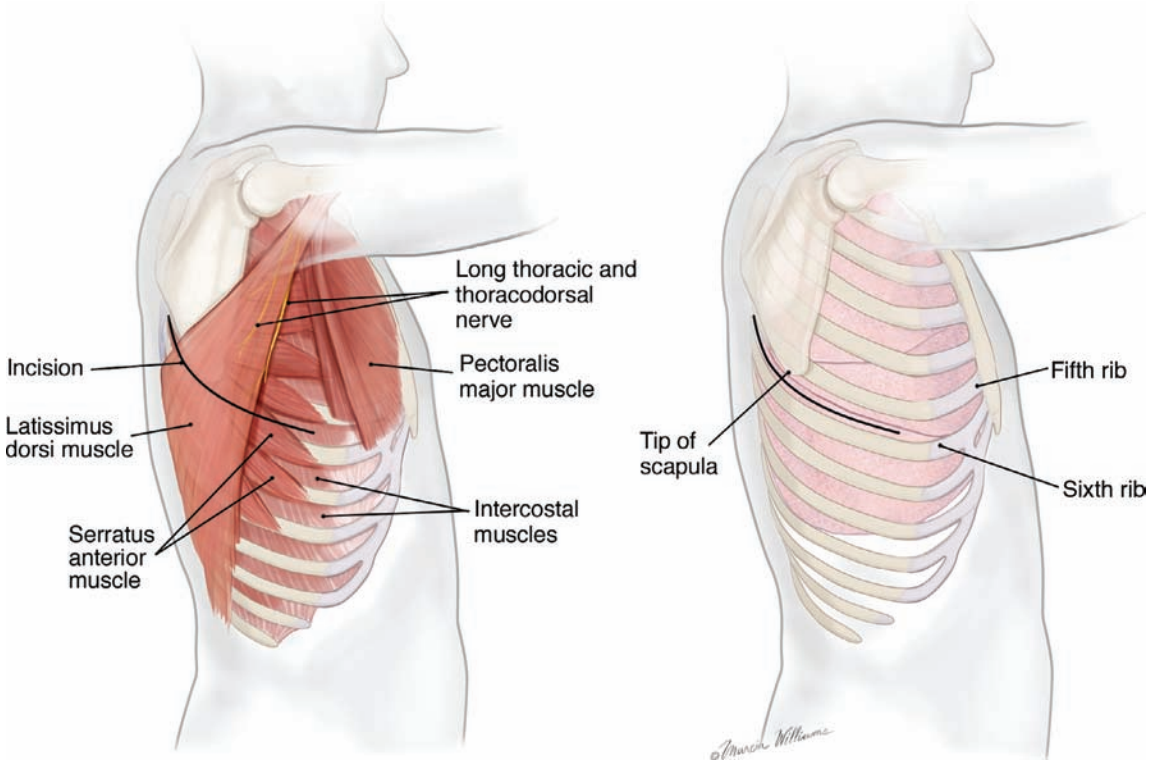

Figure 2-1. Standard posterolateral thoracotomy incision, with extrathoracic musculature and surface landmarks. The incision wraps around the tip of the scapula and parallels the course of the sixth rib.

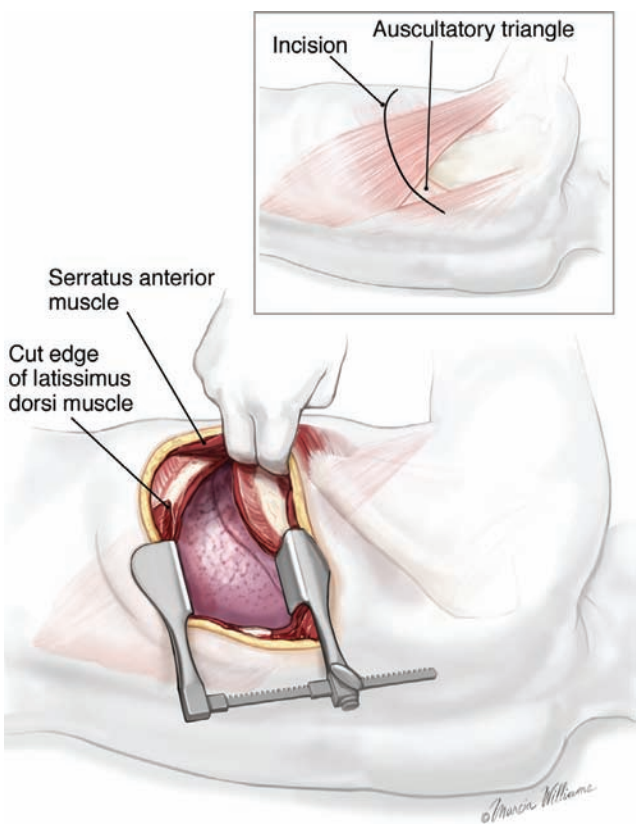

Figure 2-2. Posterolateral thoracotomy divides the latissimus dorsi muscle and rotates the serratus anterior muscle forward. The incision appears centered on the greater fissure of the lung, providing access to the pulmonary artery at the base of the fissure.

the external intercostal fibers. For maximal spread of the ribs, it is important to take down these attachments as far forward as the costochondral junction and as far posterior as the transverse processes of the vertebral body. Both these landmarks can be palpated by a finger passed just superficial to the intercostal muscle layer. In general, there is no need to disrupt the erector spinae ligament, which passes perpendicular to the posterior rib behind the posterior axillary line.

Either removing the rib or "shingling" the posterior rib can achieve additional spread of the ribcage. To remove the rib, the periosteum is raised initially by cautery, and then the plane between the cortical bone and the periosteum is dissected with a periosteal elevator. The neurovascular bundle is pushed out of the inferior groove of the rib with the elevator. The elevator is passed from posterior to anterior above the rib and from anterior to posterior below the rib to take advantage of the angle of the superficial intercostal muscle fibers as they insert into the bone. The direction of these fibers can be remembered simply by thinking of the angle of your arm when you place your hand in your pocket. After the periosteum is raised, the rib is cut, usually with a guillotine rib cutter. This device cuts the bone to one side and thus needs to be turned to remove the entire stripped portion of bone.

"Shingling" a rib involves removal of approximately a centimeter length of rib just anterior to the erector spinae ligament to allow further distraction of the fifth and sixth ribs without a subsequent midshaft fracture of the rib (Fig. 2-3). These small bony defects are much less painful than midshaft fractures. It is important to free the intercostal neurovascular bundle from beneath the inferior groove of the posterior segment of the remaining rib to prevent neuropraxia of the nerve. Increasing the distraction of the ribs can stretch the nerve if it remains fixed to the undersurface of the posterior fragment. Freeing this

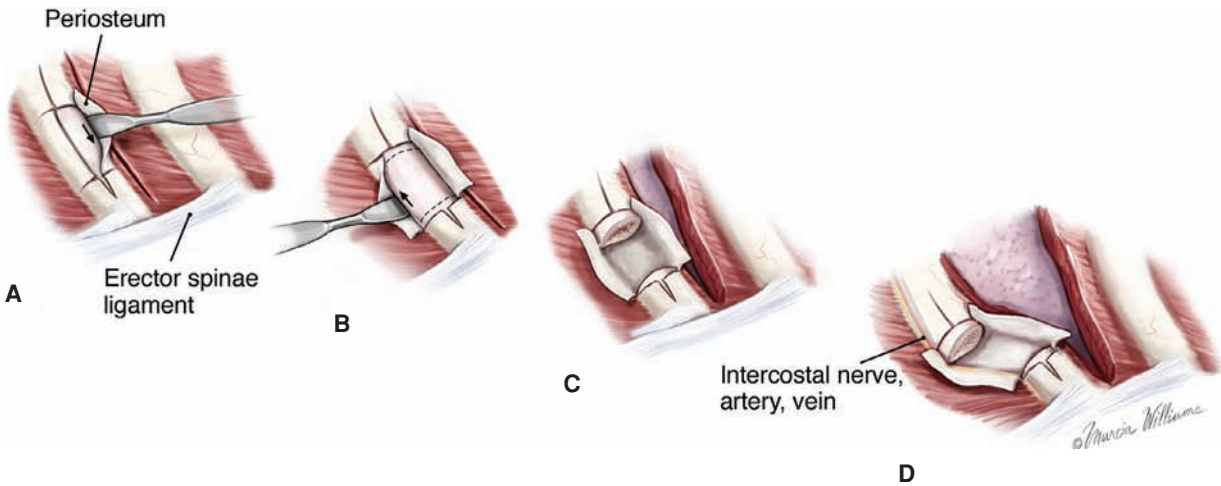

Figure 2-3. Technique to "shingle" the rib to increase exposure of a posterolateral thoracotomy. (*A*) The initial periosteal cut is made with a bovie and elevated. (*B*) Subperiosteal dissection protects the neurovascular bundle. (*C*) The osseous rib fragment is removed. (*D*) The nerve is susceptible to stretch injury unless freed from the undersurface of the rib.

nerve provides additional visualization of the thorax without nerve injury. Closure begins with placement and securing of chest tubes. Paracostal sutures then reapproximate the spread ribs. If no rib has been taken, generally four sutures suffice. If a rib has been removed, six to eight sutures are commonly required to prevent a chest wall hernia. If a midshaft rib fracture has occurred, the paracostal sutures should be placed to prevent movement of the fracture. Fracture ends sometimes are best treated by removing the jagged portion of the rib with a rib cutter, with the end result similar to a "shingle." The ribs should be approximated but not brought tightly in apposition to each other because this frequently causes the bones to fuse subsequently, which can limit surgical choices for redo thoracotomies. The serratus anterior muscle is reapproximated to the soft tissue overlying the auscultatory triangle, and then the latissimus dorsi muscle is sewn back together. Approximation of the latissimus dorsi fascia with minimal bulky muscle will minimize pain and provide a superior cosmetic result. Two additional layers of closure reapproximate Scarpa's fascia and the skin.

Advantage

The posterolateral thoracotomy incision provides the best unobstructed view of the entire hemithorax (Fig. 2-4).

Disadvantages

A generally long incision, the posterolateral thoracotomy is associated with more tissue injury to the extrathoracic musculature and soft tissue. It is also associated with a longer recovery time than almost any other incision (with the exception of the clamshell incision, which is generally slightly more morbid). It takes more time to open and close this incision compared with minimally invasive incisions. Epidural catheters have improved acute postoperative pain control and are especially helpful in the face of impaired lung function.

Chest Wall Anatomy

Key bony landmarks (Fig. 2-1) include the tip of the scapula,[1] the sixth rib (identified as the first rib contributing to the costal margin), the fifth rib (identified as the last rib inserting directly on the sternum), the erector spinae ligament, the costochondral junction, and the transverse process of the sixth vertebral body. Soft tissue landmarks include the latissimus dorsi muscle (innervated by the thoracodorsal nerve) and the serratus anterior muscle originating from the eighth to second ribs and innervated by the long thoracic nerve. A small vascular perforator enters each of the slips of the serratus anterior muscle where they insert on the rib. Both the thoracodorsal nerve and the long thoracic nerve can be injured. Ribs can be fractured if the distraction exceeds the ability of the rib to displace owing to muscle attachments.

Surface Landmarks

Tip of the scapula, the xiphoid tip, the costal margin, the sixth rib insertion onto costal margin, the fifth rib insertion into the sternum, the anterior border of the latissimus dorsi muscle, and the posterior border of the pectoralis major muscle.

ANTEROLATERAL THORACOTOMY

General Use

Although a popular incision in the 1950s for upper lobectomy, the anterolateral thoracotomy was supplanted subsequently by better visualization afforded by posterolateral thoracotomy. Video-assisted techniques have spawned a rekindled interest in this incision. It provides excellent visualization for middle lobectomies and work within the anterior chest. It is smaller and better tolerated than a full posterolateral thoracotomy. Furthermore, small utility incisions used for video-assisted thoracic surgery (VATS) lobectomy can be converted easily to a more conventional anterolateral thoracotomy for quick improvements in visualization without resorting to a posterolateral thoracotomy.

Technique

These incisions generally are placed in the fourth or fifth intercostal space (Fig. 2-5). The fourth interspace (over the top of the fifth rib) provides excellent visualization of the anterior mediastinum and hilum at the level of the superior pulmonary vein. The fifth intercostal space (over the top of the sixth rib) provides

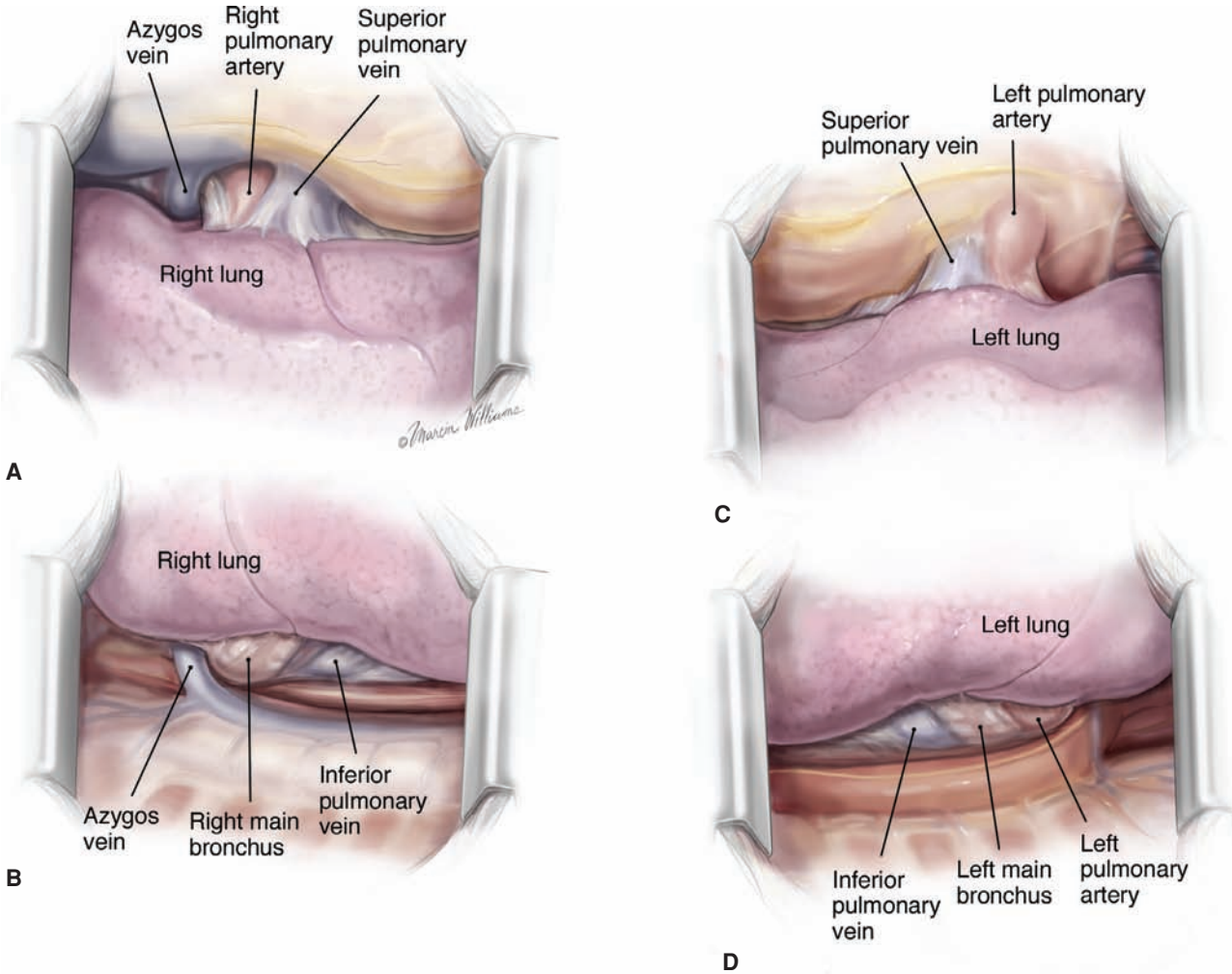

Figure 2-4. Anterior and posterior views of the hilum of the lung from a standard posterolateral thoracotomy. *A.* Anterior view of right lung. *B.* Posterior view of right lung. *C.* Anterior view of left lung. *D.* Posterior view of left lung.

better visualization for a middle lobectomy because it provides visualization of both the lower portion of the superior pulmonary vein and the top portion of the inferior pulmonary vein (Fig. 2-6).

The patient is placed in the same lateral decubitus position as for a posterolateral thoracotomy. The arm is placed in a more classic "swimmer" position with 90-degree abduction of the upper arm to allow easier access to the fourth intercostal space.

The incision starts approximately 1 cm posterior to the pectoralis major muscle and runs along the top of the rib for approximately 10 to 15 cm. The skin and Scarpa's fascia are divided. The posterior border of the pectoralis major muscle is frequently seen but not divided. The latissimus dorsi muscle is not seen. The serratus anterior muscle is divided along the course of its fibers and not rotated. The intercostal muscle is lifted from the top of the inferior rib. The intercostal muscle can be further undercut beneath the more superficial soft tissues by bluntly developing a plane just superficial to the intercostal muscle and then dividing it while not dividing the more superficial soft tissues. It is important to remove the intercostal muscle from the top portion of the lower rib to avoid injury to the neurovascular bundle of the upper rib. Although ribs can be removed or "shingled," this is rarely needed because the intercostal space gets larger as the ribs pass anteriorly. Thus there is a greater natural distraction of ribs at the anterior axillary line compared with the posterior axillary line.

Advantages

The anterolateral incision is smaller and associated with a quicker recovery compared with the posterolateral incision. The latissimus dorsi muscle is not divided, leaving better shoulder function postoperatively and preserving future use of a latissimus dorsi flap if the patient is at risk of developing a bronchopleural fistula.

Disadvantages

Although the incision provides good visualization of the anterior hemithorax, visualization of the posterior hemithorax and inferior portions of the chest are impaired. These disadvantages can be offset by the use of thoracoscopy, hence the frequent use of this incision in VATS procedures. Quick extension of the incision is hampered by the potential of injury to the long thoracic nerve posteriorly and the bulk of the pectoralis major muscle anteriorly.

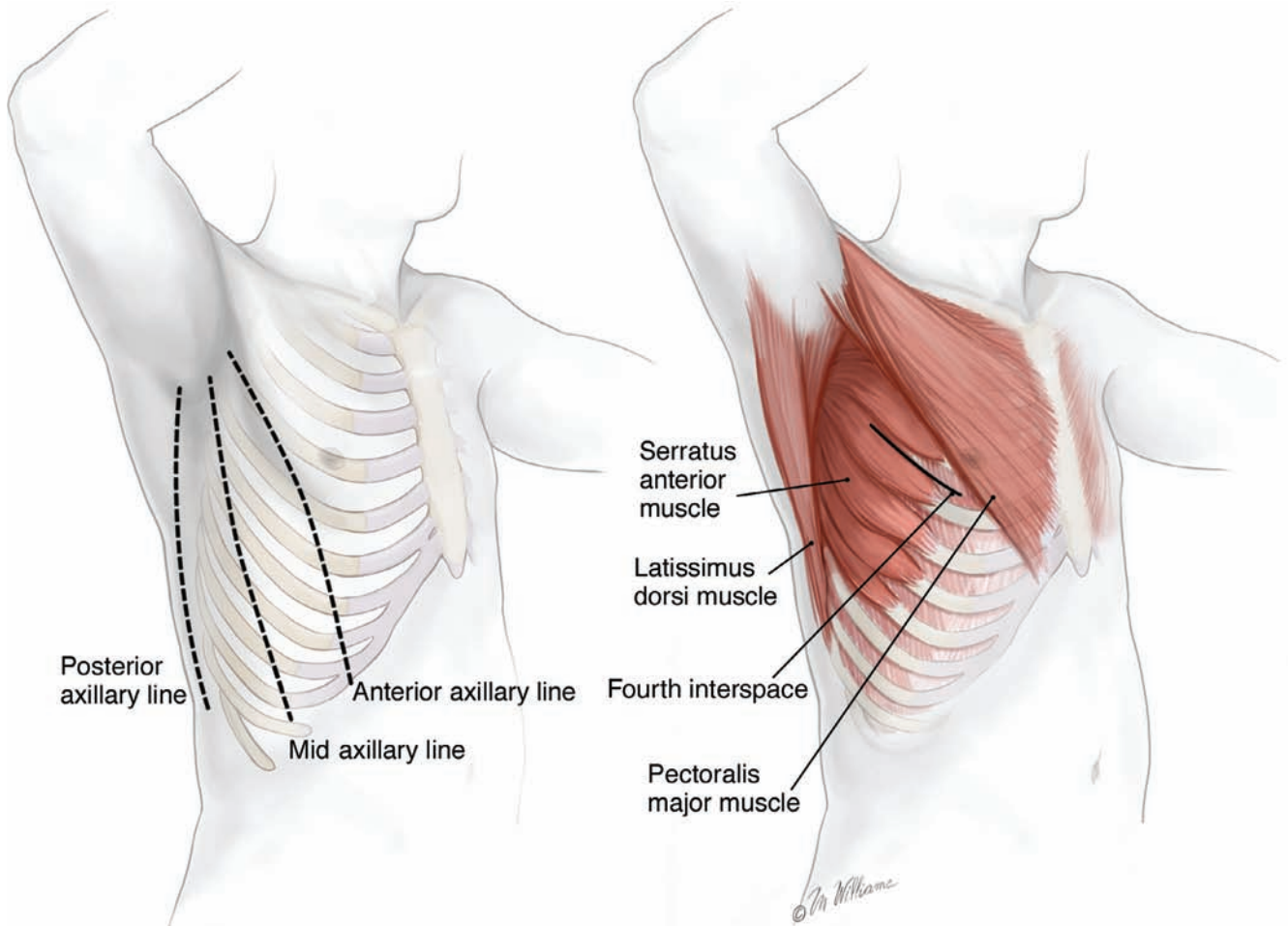

Figure 2-5. Anterior, middle, and posterior axillary lines related to the extrathoracic muscles. Anterolateral thoracotomy incision runs beneath the pectoralis major and latissimus dorsi muscles.

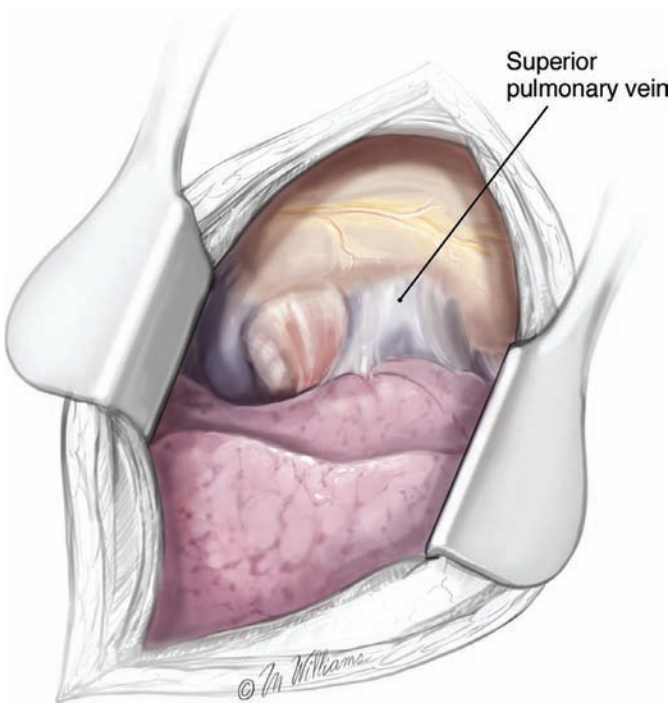

Figure 2-6. View of the right hilum from an anterolateral thoracotomy.

Chest Wall Anatomy

Key bony landmarks include the sixth rib (identified as the first rib contributing to the costal margin), the fifth rib (identified as the last rib inserting directly on the sternum), and the costochondral junction. The most important soft tissue landmark is the long thoracic nerve that innervates the serratus anterior muscle and runs just beneath the anterior border of the latissimus dorsi muscle. Since the serratus anterior muscle is divided along its fibers and not rotated, this nerve can be injured by posterior extension or misplacement of the incision.

Surface Landmarks

Posterior border of the pectoralis major, the sixth rib insertion onto the costal margin, the fifth rib insertion into the sternum, and the anterior border of the latissimus dorsi muscle.

AXILLARY THORACOTOMY

General Use

An axillary thoracotomy can be thought of as an anterolateral thoracotomy incision in the first, second, or third interspace (Fig. 2-7). It provides access to the apex of the hemithorax and is

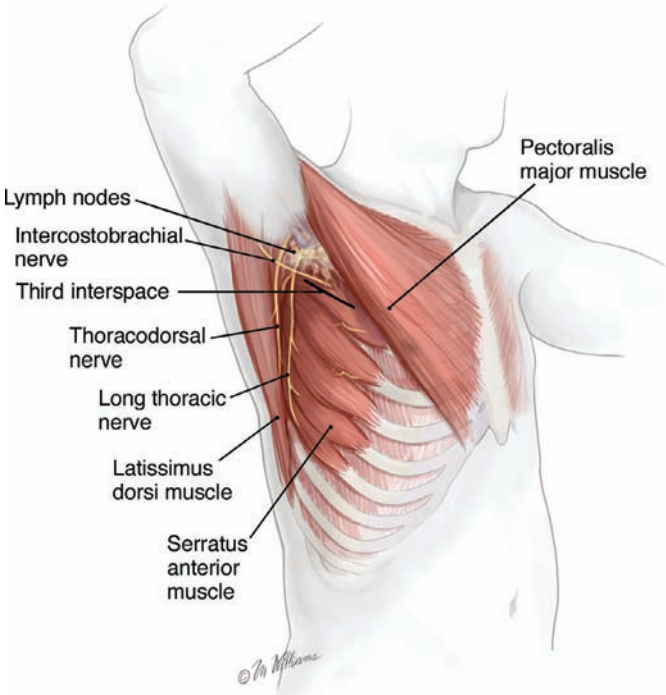

Figure 2-7. Extrathoracic structures at risk for injury with an axillary thoracotomy and proper placement of the incision.

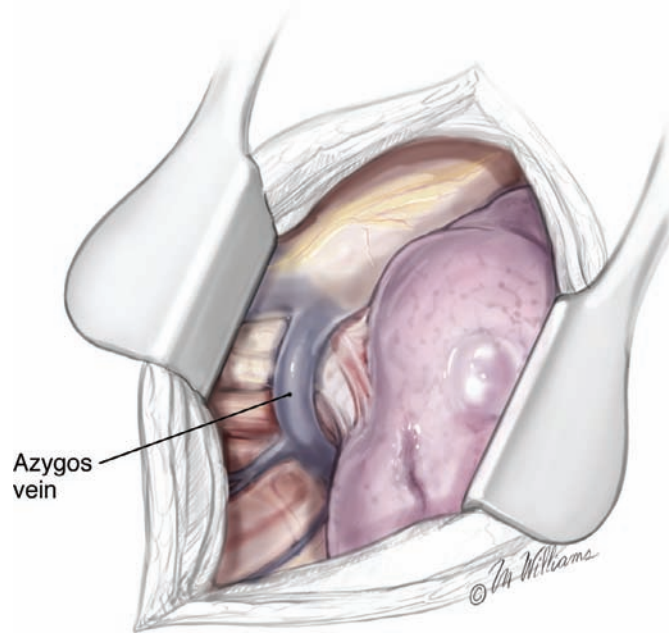

Figure 2-8. View of the right hilum from an axillary thoracotomy.

particularly useful for mobilizing a scarred apical segment from the parietal pleura during thoracoscopic procedures,[2] visualization of the posterior portion of the apex of the lung during bullectomy, and mobilization of the thymus when using a thoracoscopic approach. Because the apex of the lung lacks the bulk of the lower portion, it is easily displaced, and the anterior, middle, and posterior upper mediastinum can be visualized easily. This same incision is used for first rib resection via an axillary approach.

Technique

The ipsilateral arm needs to be put into true swimmer's position, with a 90- to 120-degree angle between the thorax and the humerus. Deep palpation of the axilla should identify the second and third intercostal space and even the first intercostal space in very thin patients. In general, the third intercostal space between the third and fourth ribs is the easiest position for this incision in males and the second intercostal space in females. The incision extends across the base of the axilla, between the anterior border of the latissimus dorsi muscle and the posterior extent of the pectoralis major muscle. This is the auscultatory triangle. It has no underlying muscles. It contains clavipectoral fascia and underlying lymphatics and lymph nodes. It is important to ligate or cauterize these lymphatics to avoid postoperative lymphoceles. Once one enters the thorax, the incision lies to the anterior side of the hilum at the level of the azygos–caval junction (Fig. 2-8). This is one rib interspace above the superior pulmonary vein.

Advantages

This approach provides adequate visualization of the upper mediastinum and posterior portion of the apex of the lung. Recovery time is very quick, and pain is modest. In general, the higher the interspace, the lower is the pain, most likely because there is less excursion of the ribs during respiration. Maximum excursion of the ribcage during forced respiration is at the level of the seventh and eighth ribs.

Disadvantages

The correct interspace for the incision needs to be considered carefully based on the goal of the operation. A second interspace incision will not allow proper visualization of the superior pulmonary vein. Incisions in the upper interspaces also do not allow much extension of the incision, if desired. Thoracoscopy can be used to place the incision, guided by direct inspection of the surface lung landmarks correlated with soundings at the skin level. This thoracoscopic port then can be used for chest tube placement at the conclusion of the procedure.

Chest Wall Anatomy

The major structures in danger of injury are the long thoracic nerve to the serratus anterior muscle, the thoracodorsal nerve to the latissimus dorsi muscle, and the intercostobrachial nerve (Fig. 2-7). The long thoracic nerve can be identified as it passes under the axillary vein at the level of the second rib. It travels inferiorly along the serratus anterior muscle parallel with the lateral thoracic artery. The thoracodorsal nerve can be identified posterior to the long thoracic nerve, just anterior to the border of the latissimus dorsi muscle. The higher the interspace chosen, the shorter is the length of the bordering ribs, and the higher is the probability of injury to these nerves, especially if the incision is extended posteriorly. If the incision is placed in the first intercostal space, the intercostobrachial nerve also can be injured, resulting in numbness to the medial side of the arm.

Surface Landmarks

Surface landmarks include the anterior axillary fold, which is the posterior border of the pectoralis major muscle, and the