History of Thoracic Anesthesiology

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Key Points

- Because of the concern relating to the natural history of pneumothorax, the development of a thoracic surgery discipline comparatively was late.
- Tuberculosis was the stimulus to overcome concern and caution.
- Control of contaminating secretions was an early anesthesia objective.
- Rigid bronchoscopy, lung separation, and positive-pressure ventilation are milestones of significance.
- Modern materials have enabled considerable advances in essentially early ideas.
- The anesthesia challenge of surgery of respiratory failure is to counteract the negative effects of positive-pressure ventilation.
- Surgery for lung cancer remains the bulk of workload.

Introduction

Infantry in disciplined armies like those of the Romans were trained to inflict a penetrating stab injury to the chest wall. Early depictions capture the paradox of a small and bloodless injury inevitably being fatal: and a dignity to a transition into another world as deep to the wound the lung collapses, respiration becomes paradoxical, and carbon dioxide retention and hypoxia ease the passing. In the nineteenth century, as surgery was advancing apace because of antisepsis and anesthesiology, it was opined that the surgeon's knife would for these old reasons inevitably lead to the death of the patient: surgically attempting to incise into the thorax was something of a taboo, only to be breached by *Ferdinand Sauerbruch (1875–1951)* little more than a century ago (Fig. 1.1).

The late beginning to the thoracic surgery discipline is overlooked. The author occasionally assisted the distinguished *Phillip Ayre (1902–1979)* who had worked with a surgical collaborator of Sauerbruch. This was *Laurence O'Shaugnessy (1900–1940).* A casualty of the Second World War, he left to posterity one of the earliest surgical methods of treatment for angina and distinctive forceps that graced thoracic surgical instrument trays for 60 years and has been modified for minimal access use (Fig. 1.2).

The fatal process – wound, pleural penetration, lung collapse, respiratory, and cardiac arrest – was interrupted with construction of an operating environment that counteracted the elastic force that paralyzes respiratory function. With encasement of the surgeon and patients' torso in a negative-pressure chamber, atmospheric pressure (now positive in physiological terms) operated at the patient's exposed mouth and prevented the lung collapsing as soon as parietal pleura was breeched. Expired tidal ventilation and gas exchange can continue to counter the toxic effect, described as "pendelluft," of moving physiological dead space gas back and forth between the lungs. Accumulation of carbon dioxide in the self-ventilating patients was delayed and albeit limiting operating time was enough to open the historical account of thoracic surgery.

The Sauerbruch technique was replaced by more efficient methods to reverse intrapleural dynamics and based on supra-atmospheric pressures applied to the airway – a move recognizable in modern day practices of tracheal intubation and positive-pressure ventilation. The change is typical of an early phenomenon: the thoracic discipline attracted inspired minds, with ingenious ideas to build on templates of pioneers. Here are to be found stories of great physiologists, physicians, surgeons, and anesthesiologists without whom, for instance, the groundwork for a diversification into cardiac surgery would have been significantly delayed. Indeed in many countries, the latter services still are rooted in establishments that once were sanatoriums, serving the needs of early patients for chest surgery.

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P. Slinger (ed.), *Principles and Practice of Anesthesia for Thoracic Surgery*, https://doi.org/10.1007/978-3-030-00859-8_1

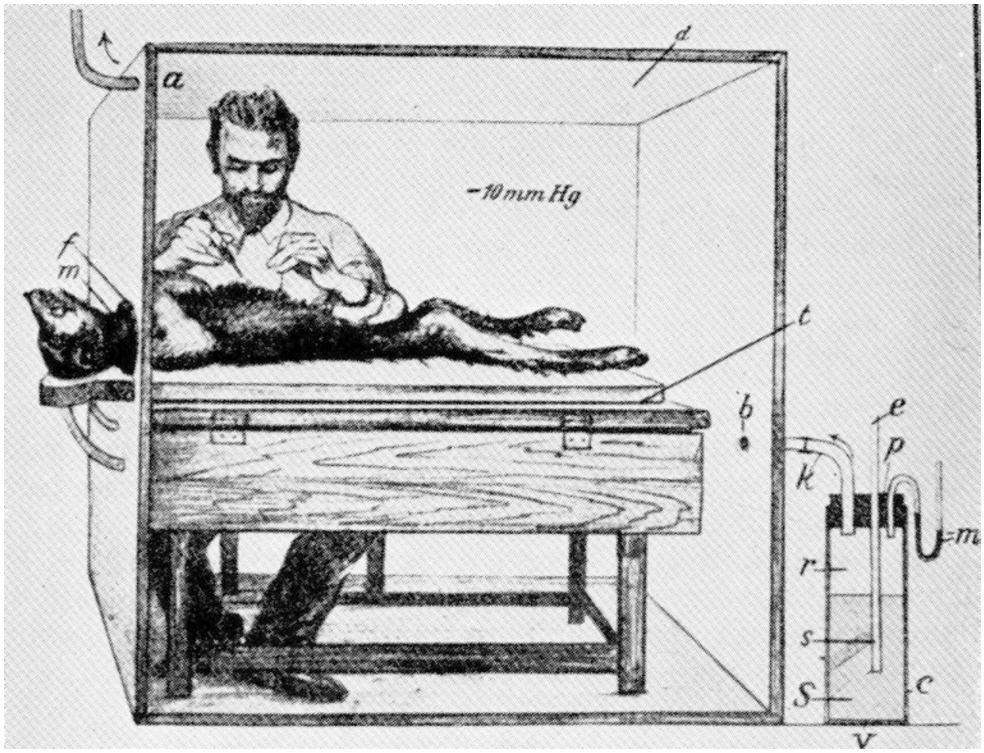


Fig. 1.1 A diagram of Sauerbruch's negative-pressure chamber for thoracic anesthesia. The animal or patient's torso and the surgeons were enclosed in an airtight chamber evacuated to −10 cm H_2O pressure. The subject was then anesthetized breathing air-ether spontaneously from a mask. When the thorax was opened, the lung did not collapse and hypoxemia was averted, although hypercarbia would gradually develop due to pendelluft. This marked the beginnings of elective thoracic anesthesia and surgery. (From Mushin W, Rendell-Baker L. The principles of thoracic anaesthesia. Oxford: Blackwell Scientific Publications; 1953.)

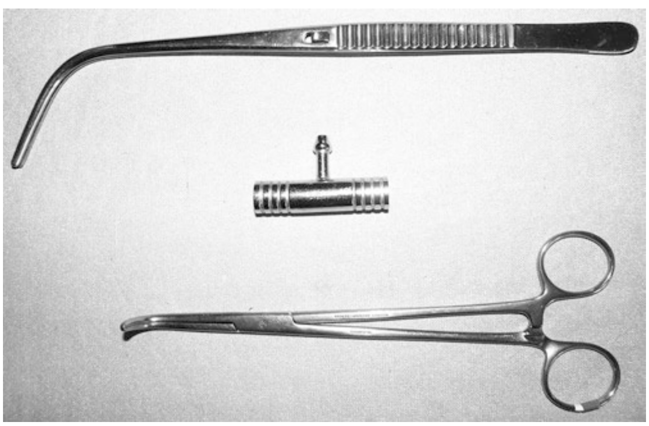


Fig. 1.2 Thoracic ephemera. From top to bottom: Krause's Forceps, Ayres "T" piece, O'Shaughnessy Forceps

In each development, an anesthesiologist of the day has had to innovate, adapt, and change with new ideas, materials, and advances being presented to him or her. A formative beginning with candle power disappeared with antimicrobial therapy but leaves a legacy of thoracoscopy, lateral thoractomy, lung separators, and pain relief techniques that are but little modified.

Paradigm shifts are usually marked by the two World Wars of the twentieth century. Though these are defining elements of any historical analysis, and certainly colored the individuals who are part of the story, developments in thoracic surgery that now govern modern practice are better seen in the light of changes in the medical challenges of disease which changed coincidentally at the same time points.

Ages of Thoracic Surgery

Surgery for Infective Lung Disease

The nineteenth century, a time of great population and societal movement particularly in and from Europe, was blighted by the "white plague" (tuberculosis), an indiscriminate killer – irrespective of class, wealth, national boundaries, and unstoppable, a foreshadowing of AIDS: a heroine in the throes of consumption, a last hemoptysis, death – stuff of opera. Into this hopelessness strides the surgeon to deal with pulmonary cavities, septic foci, decayed and destroyed lung, bleeding points, and copious, poisonous secretions that were more than capable of drowning the patient. Surgical repertoire after the Sauerbruch revelation was the artificial pneumothorax, empyema drainage, plombage (insertion of inert material into the thoracic cavity to promote lung collapse as therapy for tuberculosis), phrenic nerve crush, the thoracoplasty, and some tentative steps at resection – ordeals staged over days and weeks but with an accrual of lifesaving consequences for countless (Fig. 1.3).

With no mechanisms of control of secretions and an ever-present danger of respiratory failure, standards for anesthesiology were sedation with opiates, topical, regional, and field blockade with local anesthetics to preserve self-ventilation so that cough and the ability to clear the airway were not lost.

Operating position became important. That of Trendelenburg was most effective to ensure that secretions, blood, and lung detritus drained gravitationally and not into

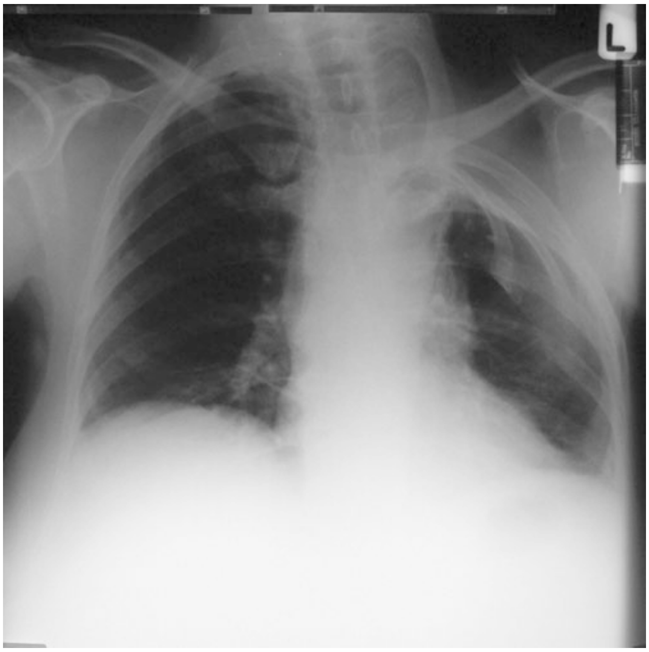


Fig. 1.3 Chest X-ray of a left-sided thoracoplasty, the ribs of the upper left hemithorax have been resected to promote left upper lobe collapse for tuberculosis therapy

the nonoperated lung. But, in the cachectic and septic sufferer of pulmonary tuberculosis or bronchiectasis, adoption of such steep head-down postures could prove fatal. The prone and semiprone positions were gentler and less compromising. Surgeons got used to operating and approaching the lung and its constituents through a posterior thoracotomy. This spawned the posterolateral thoracotomy, once tracheal intubation techniques enabled alternative, nongravitational ways of dealing with the secretion problem. The lung, esophagus, and heart became grist to the thoracic surgical mill.

As the era closed, the anesthesiologist (and the dawn of the specialist was at hand) had an experience of nitrous oxide and several volatile agents other than ether, notably chloroform and cyclopropane. Insufflation techniques, tracheal intubation, and rudimentary bronchial blocking techniques, which required a skill in rigid bronchoscopy, were tools of the expert. Several were using assisted ventilation before the advent of muscle relaxants. Prototype endobronchial tubes, bronchial blockers, and early positive-pressure ventilation techniques were in position for a new age – ushered in with curare.

There is no greater symbol of the transition than the pneumonectomy of the British King, *George VI (1895–1952).* Operated on in 1951 – for lung cancer – by a surgeon (*C. Price Thomas (1893–1973)*) who was credited with his own operation (sleeve resection) for tuberculosis, the anesthesiologist (*Dr R. Machray*) had devised his own tracheal tube (but on the occasion used a Thompson bronchus blocker) and wielded measured doses of diamorphine and pethidine, nitrous oxide, and the new agent, curare. And in the wings, spurred by intraoperative problems with ventilation, a trainee anesthesiologist (*William Pallister (1926–2008)*) was inspired to invent a new endobronchial tube specifically for the surgeon and his operation to avoid such critical incidents in the future. The surgeon later developed lung cancer for which he was operated on! The cigarette was yet to be seen as the cause and that this particular blight was largely man-made.

Surgery for Lung Cancer

Pulmonary resection for lung cancer came to dominate operating lists as the tuberculosis hazard receded to a point of rarity in developed countries with advances in public health that followed the Second World War. The favored method was general anesthesia with volatiles such as the new agent halothane, lung separation – commonly with double-lumen tubes – muscle relaxants, and, after the polio epidemics of the 1950s, positive-pressure ventilation with increasingly sophisticated ventilators. The Academic of the day, having acquired scientific tools, was beginning to recognize and investigate the subtle pathophysiological changes wrought by one-lung anesthesia.

In general, advances were defined by greater understanding of pulmonary physiology, limits and limitations of surgery particularly degree of resectability, and the fitness of patients to withstand ordeals of process, and more regard for quality of postresection existence. The crude practice of inserting a blocker through a rigid bronchoscope under topical anesthesia applied with Krause's Forceps, to test for the potential to survive a pulmonary resection, could be abandoned! Besides safeguarding the technological skills of an earlier era, the anesthesiologist needed to acquire a bedside expertise of the potential for respiratory failure to develop in a particular patient, based on simple pulmonary function tests (wet spirometry). In this era predating a foundation or philosophy for prolonged recovery with ventilator support and postoperative care resource, forecasting was on the basis that fatalities were theoretically due to carbon dioxide retention or right heart failure if excess lung was resected in reaching for a cure for a cancer: in practice sepsis and renal failure usually proved terminal.

The ending of this work pattern followed advances of plastics technology on equipment, fiber optics on diagnostics and operating instruments, and computers on monitoring and performance. Surgery was moving into an age that had a patient demand to push operability beyond limits established for cancer. This desire was to be met with larger resource for intensive levels of postoperative care.

Although advances were truly innovative, these were fraught with risk. For a perspective on this, recall that pulse oximeters were experimental not universal and end-tidal carbon dioxide measurement nonexistent: operational decisions depended on blood gas monitoring with unsophisticated and slow automated systems and the occasional use outside the laboratory of Swan-Ganz type pulmonary flotation catheters.

Surgery for Respiratory Failure

Defining elements include transplantation but also revisits to treatment of emphysema (which had with chronic bronchitis reached significant proportions in developed countries) and technological and material advances for trachea-bronchial disease which heretofore were off limits to all but a few establishments with special expertise and cardiopulmonary bypass technology.

Orthotopic lung transplantation had been attempted in extremis (1963), but success in terms of long-term viability was not to be achieved for another two decades (1986). A new immunosuppressant therapeutic era was to enable further, and this time, successful efforts. Much of the credit goes to the Toronto group, under Dr. Joel Cooper, whose selection and management templates resolved problems previously encountered by attempting to treat paraquat poisoning, routine use of corticosteroids for airway disease, tracheobronchial dehiscence, and reimplantation. Matching of lung preservation techniques to those for cardiac donors was a final step from experimental to mainstream and to the current healthy state of a thoracic organ transplant discipline.

Chronologically, not far behind, is lung volume reduction surgery, driven by many of the same innovators. Historically, this was just a revisitation of old ideas and not a monumental surgical advance; but the lessons learnt were in particular for anesthesiology. In learning to deal with emphysema lung pathophysiology, a "downside" of positive-pressure ventilation was encountered with great frequency. The prevention and treatment of dynamic hyperinflation scenarios ("breath stacking") is now, after a century, as big a challenge as that of "pendelluft" breathing was in its day.

Lung Separators

Three systems have evolved to facilitate one-lung ventilation: bronchus blocker, endobronchial tube, and double-lumen tube. The first two were of concept and had prototypes about the same time. Gale and Waters in 1931 have the credit for intubation of the contralateral bronchus prior to pneumonectomy: Crafoord and Magill as firsts for bronchial blocking. The double-lumen tube is a later development and as concept was taken from catheters, most notably the Carlens, devised for bronchospirometric research, assessment, and investigation.

Devices were manufactured out of red rubber, and over the years many adaptations were made: right- and left-sided versions, carinal hooks, right upper lobe slots, and extra-inflatable cuffs, cuffs of red rubber and of latex rubber, net-covered – to mention but a few.

The Blocker Story

It is to the particular genius of *Ivan Magill (1888–1986)* that the bronchus blocker is owed. With minor modifications it became a dominant technique for practitioners, use of which, as mentioned, had become a test for fitness for operation. Inserted through a rigid bronchoscope, the blocker could be placed accurately in the most complex of anatomical distortions wrought by tuberculosis. The state-of-the-art device was that of *Vernon Thompson (1905–1995)* (Fig. 1.4). However, endobronchial tube availability and the versatility of double-lumen tubes meant that by the latter part of the twentieth century, there were few but a dedicated band of practitioners with the skill to place and use blockers effectively and first choice status was lost. Plastics and fiber optics led to reinvention for the twenty-first century. "Univent," Arndt, and Cohen systems follow in quick succession as the concept was revitalized.

The Endobronchial Tube Story

These very obvious adaptations of tracheal tubes gave anesthesiologists a range of devices that served purpose for half a century. That of Machray was a long, single-cuffed tracheal tube and was placed in the left main bronchus under direct vision using an intubating bronchoscope as introducer

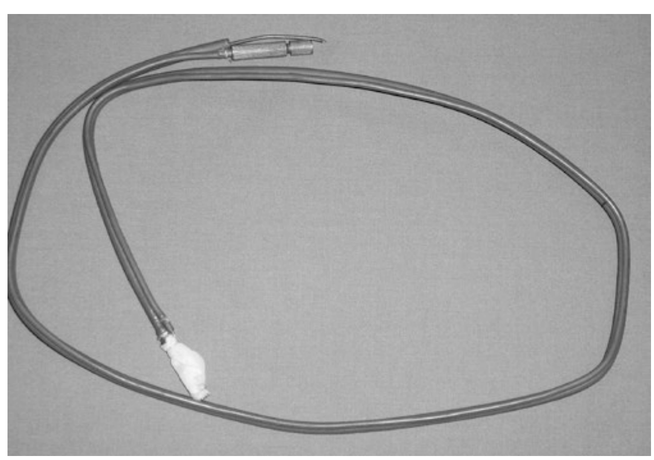


Fig. 1.4 Vernon Thompson bronchus blocker (circa 1943)

Fig. 1.5 Machray endobronchial tube and intubating bronchoscope

(Fig. 1.5). Being able to mount these devices on a rigid scope, again a Magill credited idea, defined these tubes. The characteristic facilitated placement in the most distorted of airways and allowed for ventilation through a wide-bore tube, bettered only by using a bronchus blocker outside and beside an endotracheal tube. Left-sided Macintosh-Leatherdale and Brompton-Pallister and the right-sided Gordon-Green were to prove the most enduring.

The Double-Lumen Tube Story

Unlike the other types of lung separators, the double-lumen tube was adapted and adopted rather than invented for the purpose of one-lung anesthesia and ventilation. The prototypes, notably that of *Eric Carlens (1908–1990)*, were for physiological investigation. Models with the ventilation lumens positioned coaxially and anterior-posterior were tried but that of *Frank Robertshaw (1918–1991)* with its side-by-side lumens, anatomical shape, range of size, and low resistance characteristic dominated, to be later reproduced as plastic and disposable materials (e.g., Sheridan, Broncho-Cath) that replaced the increasingly unsuitable and anachronistic red rubber. The right-sided version was actually invented from a Gordon-Green endobronchial tube, the slot of which has remained the most effective device to ventilate the right upper lobe – an efficacy dependent on properties of red rubber (Fig. 1.6).

Plastic and practice penetration by fiberoptic bronchoscopes of decreasing size and increasing sophistication and practicality led to much contemporary discussion about the "blind" placement of lung separators that replaced the tradition of rigid bronchoscopy as an aid to lung separation and bronchial cannulation. Though modern protocols are more fail-safe than reliance on clinical and observational skills, the modern didactic of medicolegality has trumped debate and stifled argument.

Origins of Thoracic Endoscopy

The ancient entertainment of sword swallowing had long demonstrated the feasibility of inserting rigid instruments into the esophagus. In 1895 a scope was first passed through a tracheotomy opening to be quickly followed by

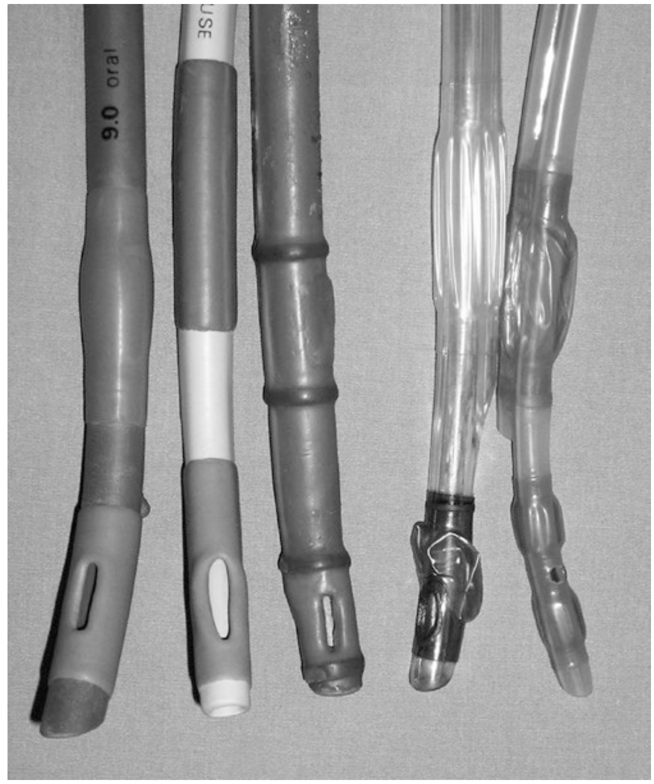
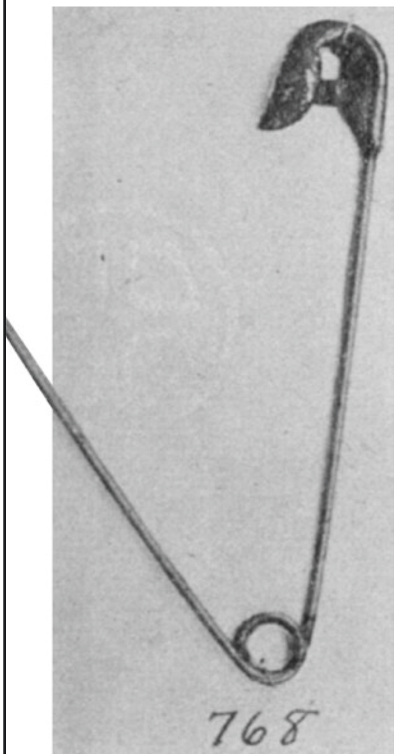


Fig. 1.6 Tubes with right upper lobe ventilation slots. From left to right: Gordon-Green endobronchial, Robertshaw double lumen, Carlens (White model) double lumen, "Broncho-Cath" double lumen, and "Portex" prototype double lumen

endoral attempts but at the limits of proximal lighting systems. *Chevalier Jackson (1865–1958)* was not the originator, but he certainly was a pioneer and the first master of distal lighting systems, with a record on removal of foreign bodies that stands unsurpassed to this day (Fig. 1.7). To him are owed the rules that made the dangerous art of sword swallowing into a scientific tool for therapy and diagnosis both in the esophagus and in the tracheobronchial tree and the subtleties of neck positioning that ensure either the esophagus or trachea is cannulated: a whole philosophy of skill that has been negated by the flexible nature of modern tools.

Now the only indications for rigid bronchoscopy are foreign body removal and occasional stent insertion, but there was a time when rigid bronchoscopy was indispensible for operative assessment, bronchography, diagnostics, insertion of lung separators, postoperative lung toilet, and treatment of bronchopleural fistula. Under careful local anesthetic application, topical, regional, and cricothyroid puncture, the technique could be conducted with such skill that no less an illustrious patient than *Geoffrey Organe (1908–1989)*, the Professor of Anaesthesia, Westminster Hospital, London, was able to declare the experience as "more pleasant than going to the dentist."

Fig. 1.7 A series of safety pins removed from the airway by rigid bronchoscopy. (From Jackson C. Foreign bodies in air and food passages. Charted experience in cases from no. 631 to no. 1155 at the Bronchoscopic Clinic; 1923)

Fbdy. 768 	15 yrs.	Safety-pin open	Right main bron-chus, 3 weeks
Fbdy. 786 	4 yrs.	Safety-pin open	Larynx, point up, 3 days
Fbdy. 794 41 	18 yrs.	Safety-pin open	Right lower lobe bronchus. Point up. 1 yr. 10 mos.

Trying to produce an artificial pneumothorax frequently failed because of adhesions. In 1913, a Swedish surgeon, Hans Christian Jacobaeus, reported on the use of a modified cystoscope to look into the chest and used a second port for instruments, such as probes and cautery, to deal with recalcitrant adhesions. It is not hard to see how this concept has evolved.

Tracheobronchial Stenosis

As technological advance is on the brink of tracheal reconstruction using biological methods, it is important not to forget that this state has been reached by a long and hard struggle to overcome the challenge for surgery and healing inherent in innately poor mammalian vascular supply of the tracheobronchial tree. The era of tracheal resection and repair was to be dominated by *Hermes Grillo (1923–2006*), the Chief of Thoracic Surgery at the Massachusetts General Hospital. There was a brief period of tracheoplasty and silicon replacements, all of which were major anesthesiological undertakings, but developments in stents, largely modeled on similar devices for esophageal stricture, had become prevalent at the end of the twentieth century. Solid-state devices of silicon were replaced by a range of self-expanding ones made of nonreactive and malleable materials such as nitinol which have resulted in less challenging anesthesia scenarios.

Esophageal Surgery

Originally, surgery on the esophagus was very much a development of chest surgery. Several medical cultures retained a linkage late into the twentieth century, but this was largely a technical connection because of commonality of anesthesiological requirements like lung isolation. Most countries have now broken the connection, and the esophagus is largely seen as outside the hegemony of thoracic practice. Cancer, achalasia, and hiatus hernia, once part of the tougher end of the surgical diet, are now treated less traumatically and invasively.

As with pulmonary resection, early developments were based on totemic patients by small teams, whose successes and tribulations sustained knowledge that relief by surgical means ultimately was going to be of benefit to many more. A single case survivor of 13 years after transpleural esophagectomy by *Franz Torek (1861–1938)* in New York in 1913 was a beacon for three decades. The anesthetist was *Carl Eggers (1879–1957)* who administered ether through a woven silk tracheal tube to a self-ventilating patient. In 1941, the world experience of the technique was 17 survivors of 58 patients.

Pain Relief

Modern analgesics can be traced to the coca leaf, opium poppy, and willow bark, but administration other than by ingestion or inhalation needed the hypodermic needle. Spinal injection (1898), intercostal nerve blockade (1906), paravertebral injection (1906), and extradural (1921) are the historical sequence for local anesthetic procedures of context.

Survivors of thoracoplasty operations tell of hearing their ribs being cracked as, in the later stages of the operation, the thoracic cage was rearranged: few attendants were prepared to risk general anesthesia. A specimen technique of Magill's for this operation, first performed in the UK by *Hugh Morriston Davies (1879–1965)* in 1912, included premedication with opiates, supraclavicular brachial plexus block, intercostal nerve block, dermal infiltration of skin incision site and towel clip points as well as subscapular infiltration and much titration of dilutions of adrenalin (epinephrine). *J Alfred Lee (1906–1989)* (author of the classic *A Synopsis of Anaesthesia*, first produced in 1947) states advantages of local as opposed to general anesthesia: reduced risk of spread of disease, better elimination of secretions as cough reflex is not abolished, quicker convalescence because patient is less upset by drugs and needs less nursing care, and abolition of explosion risk.

Paravertebral blockade, first credited to Sellheim, went on to be used for operative pain relief, postthoracotomy neuralgia, and even angina and thoracic pain of unknown etiology. Subarachnoid block enjoyed a period in thoracic surgery, but the "high" nature meant that it was a hazardous technique because of uncontrolled hypotension and suppression of respiration. Epidural anesthesia was limited by the toxicity of agents, hazard of hemodynamic collapse, the short-lived nature of single-shot procedures, and logistics and feasibility of process in the context of hospital environment. Continuous analgesia perioperatively was only realistic with small-bore tubing and got impetus from the link to improved postoperative respiratory function.

Correlation of pain relief and reversal of some of the negative effects of surgery led to recognition that pain relief objectives could be broadened from humanitarian and reactive. A new philosophy has arisen: it is a proactive one to capitalize on observations that pain relief techniques contribute to the healing process by promoting a sense of well-being, preserving gastrointestinal function, improving anastomotic blood flow, and facilitating management of comorbidity.

Conclusion

The impetus for surgical development and advance are all in context, and in none more than thoracic practice is this true: phases, even paradigm shifts, defined by disease, sociology and advances in knowledge, and therapeutics and, in the case of anesthesiology, by drugs, materials, and technology. As historical evolution, much of current practice is recognizable.

A modern age is already characterized by a circumspect use of volatile agents, but predictable forces of surgery are the demand for minimal access and the use of once-only disposable materials that have already seen the demise of much of local infrastructure to process sterile equipment and surgical hygiene. Hospital-acquired infection morbidity is a given, as are epidemics of asbestosis-related pleural-pulmonary disease as this ubiquitous "pathogen" escapes from the twentieth-century confines. A new epidemic, obesity, will gain momentum. Lung cancer treatment options show little sign of being bettered by other than surgical methods. Tuberculosis has a new drug-resistant guise. Could history repeat itself? Many countries, notably in Africa and those previously part of the USSR, have endemic populations harboring and, sadly, nurturing drug-resistant tuberculosis. Some are now contemplating revisiting and revising early surgical techniques (e.g., thoracoplasty) to add to future projects to tackle what has to be one of the most predictable and threatening of microbial conditions with a future to impact on thoracic anesthesiology and on all health-care systems.

Further Reading

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