Chapter 2
Origins of the Critically Ill: The Impetus for Critical Care Medicine

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Abstract The history of the organization of critical care medicine mirrors the evolution of modern medicine as it has evolved into the management of acute illness. This acute, highly specialized care is provided by anesthesiologists, surgeons, and internists, and its origins can be found within these specialties. Critical care medicine is often associated with complex life-saving treatments, and thus we can track the origins of critical care medicine to the treatment of respiratory failure with mechanical ventilation, severe infections to antiseptic treatments and antibiotics, and cardiovascular insufficiency to hemodynamic monitoring and pharmacologic support. But critical care medicine embodies more than a collection of treatments. It is a health care delivery process demanding specially skilled health care providers (physicians, nurses, respiratory therapists, pharmacists, and physical therapists) within an organizational framework that titrates often conflicting treatments, minimizes potential treatment errors, and promotes the safe and efficient application of appropriate and timely care.

Keywords Critical care medicine • Intensive care unit • Mechanical ventilation • Antisepsis • Hemodynamic monitoring • Cecil Drinker • Joseph Lister • H.J.C. Swan • William Ganz

Critical care medicine is the management of the unstable patient who needs titration of care, often life-saving, on a moment-to-moment basis. That such care is similar

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to that provided by anesthesiologists in the operating room in high-risk surgeries, surgeons in the Emergency Department treating trauma victims and internists for those with primary circulatory shock or respiratory failure defines its origins within these specialties. Furthermore, specialized expertise with life-saving treatment often requiring complex mechanical artificial life-support systems characterizes treatments. Indeed, critical care medicine is often associated with the complex life-saving treatments given as much as the close labor-intensive monitoring and management it demands. Thus, we can track the origins of critical care medicine to the treatment of respiratory failure with mechanical ventilation, severe infections to antiseptic treatments and antibiotics, and cardiovascular insufficiency to hemodynamic monitoring and pharmacologic support. But critical care medicine is more than a collection of treatments; it is a health care delivery process demanding specially skilled health care providers (physicians, nurses, respiratory therapists, pharmacist, and physical therapists) within an organizational framework that titrates often conflicting treatments, minimizes potential treatment errors, and promotes the safe and efficient application of appropriate and timely care. The history of the evolution of critical care medicine into what it is today is also the history of modern medicine as it has evolved in the management of acute illness (Fig. 2.1).

Mechanical Ventilation

The ability to artificially support failing ventilation with mechanical positive-pressure ventilation provided an initial and pivotal impetus to the development of the ICU and critical care medicine. Recording on the use of mouth-to-mouth resuscitation can be traced back to the Old Testament, in which it is described that the Prophet Elisha successfully resuscitated a dead child. In the sixteenth century, the Swiss alchemist and physician Paracelsus first provided artificial ventilation to both animals and dead humans using fireplace bellows [1, 2]. In 1543 Vesalius explored this concept and published his classical work “De Humani Corporis Fabrica,” [1–3] in which he described the ability to keep animals alive by rhythmic insufflation of air into the trachea. These are the first known applications of intermittent positive-pressure ventilation (IPPV) under controlled conditions.

Subsequent advancements in positive-pressure ventilation would await means of secure tracheal cannulation through which ventilation could be reliably delivered. Matas in 1902 first described an automatic respiratory apparatus, which employed a metal laryngeal cannula, guided by extrinsic palpation into the trachea [4–7]. In the beginning he used a double pump giving intermittent positive–negative pressure ventilation (IPNPV). Continued efforts to develop the techniques of laryngoscopy and endotracheal intubation were uniformly discouraging, and emphasis shifted to the use of subatmospheric (i.e., negative pressure) devices to create the driving pressure necessary for tidal breathing.

In 1904 Sauerbruch introduced his low-pressure chamber for use in thoracic surgery, which provided continuous positive airway pressure (CPAP) ventilation

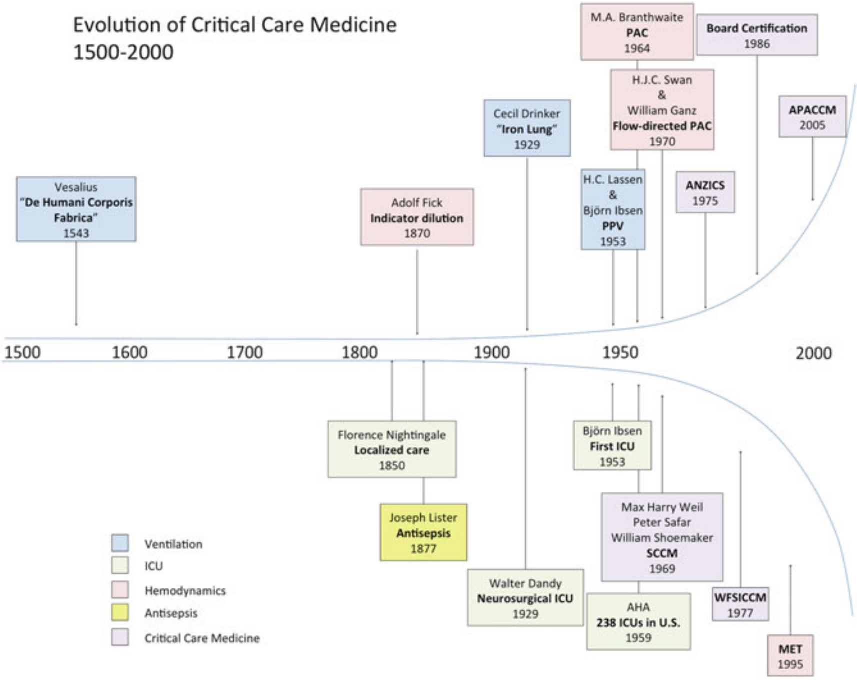

Fig. 2.1 Evolution of critical care medicine 1500–2000

[1, 8, 9]. In this initial prototype both surgeon and patient were enclosed with only the patient's head emerging through an airtight neck collar. It was soon realized that CPAP yielded ineffective ventilation, and oxygen had to be administered to prevent cyanosis [2]. Volhard [10] claimed that it was this oxygen supply, rather than the differential pressure method, that was responsible for the success of Sauerbruch's method. Thus, CPAP was correctly identified as a form of apneic diffusion oxygenation, a term introduced by Holmdahl [11].

With the emergence of the great polio epidemic, efforts to support failing ventilation were further strengthened. In 1918 Dr. Steuart constructed an airtight wooden box, which sealed the patient at the shoulders and waist and powered gas exchange by motor-driven bellows [9]. In 1929 Dr. Cecil Drinker, a Harvard University Professor of Physiology, combined efforts with his brother Philip and developed the negative-pressure tank ventilator, which subsequently became known as the "iron lung" [12, 13]. This monumental discovery was a serendipitous idea generated while observing a colleague quantify the respirations of an anesthetized cat enclosed in a metal box sealed at the neck. Recreating the experimental model, Drinker, by pumping air in and out of the box was able to sustain the paralyzed cat for hours [13]. It would be during the late 1940s, as polio ravaged both Europe and North America, that the Drinker tank ventilator would be first used to provide ventilatory support to a polio stricken child at Boston City Hospital.

The tanks became widely accepted and employed as a life-saving measure. Though numerous improvements upon the design of delivering intermittent negative-pressure ventilation (INPV) would subsequently follow, the system was not efficient in totally paralyzed patients.

The Danish anesthesiologist Ibsen [14] therefore suggested that tracheostomy and manual bag ventilation with IPPV of the patient replace the cuirass and body respirator. During the poliomyelitis epidemic in Denmark, patients were brought to the University Hospital in Copenhagen. The medical school was closed and the medical students were called upon to manually ventilate the patients in shifts. Lassen and Ibsen emphasized basic principles of airway management: protection, humidification, avoidance of elevated oxygen tension, and meticulous physiotherapy [14, 15]. This approach resulted in a drop in mortality from 80 to 25 %. The respiratory ICU was born.

The introduction of the Salk and Sabin vaccines brought eradication of polio; however, controlled airway management and positive-pressure mechanical ventilation had become established standards of practice. Giertz in 1916 [16] clearly demonstrated that artificial ventilation by rhythmic insufflation was superior to the differential pressure method of Sauerbruch. He collaborated with an otolaryngologist who had developed a series of endotracheal and endobronchial tubes and conceived the idea for an air-driven ventilator. His successor, Crafoord, a renowned cardiothoracic surgeon in Sweden, ended the dominance of Sauerbruch's method by introducing "the Spiropulsator" in thoracic surgery [1, 17]. Mörch presented his piston ventilator in 1947 primarily for use in the operating room during thoracic surgery, but it was Björk and Engström who in 1955 introduced the use of prolonged mechanical ventilation by a machine in the postoperative period after lung surgery [18, 19]. At that time, Engström had already demonstrated the advantage of his ventilator in the treatment of totally paralyzed polio victims during the Copenhagen epidemic [20]. From this time onward, mechanical positive-pressure ventilation of patients with endotracheal intubation became not only common place but also the center piece of ventilatory support in critical care medicine.

Antisepsis

Since the birth of recorded civilization, death from infection has been the most common cause, regardless of the initial problem. Women died in childbirth from either hemorrhage or sepsis. Pneumonia was aptly referred to as the "old man's friend." Surgery too was limited in its success primarily by pain, bleeding, and ultimately, infection. However, by the mid-nineteenth century, surgery had traversed the theoretical and had become a reality. The discovery of anesthetics (chloroform, nitrous oxide) eliminated the trepidation of pain, and the incidence of surgery was accelerating at an exponential pace. Now death consequent to wound sepsis remained the primary fear, and its incidence paralleled that of surgery itself.

In 1861 a new surgical facility was constructed at Glasgow with the purpose of reducing the incidence of operative sepsis and its high associated mortality. Its first director was Professor Joseph Lister [21, 22]. His initial efforts proved to be in vain, as approximately 50 % of his amputation cases died of sepsis. During this period, Louis Pasteur was demonstrating that fermentation resulted from small microbes, rather than gases of air. This information was relayed to Lister, who reasoned that fermentation mirrored the processes of wound suppuration and speculated that these same microbes were the etiology of wound sepsis. Concomitantly, an engineer named Crooks had eliminated the malodor of sewage in Glasgow by adding carbolic acid. Uniting these concepts, Lister began applying carbolic acid dressings and thereby reduced the incidence of wound sepsis. In 1877, as Chair of Clinical Surgery at King's College, Lister introduced antisepsis to surgery and simultaneously eliminated both the smell of wound sepsis and those who denounced his theories. That same year, under aseptic technique, Lister performed an open patella repair, an intervention that previously had often resulted in death. News of the operation was widely publicized, and its success was instrumental in forcing surgical opinion throughout the world to accept that his methods greatly added to the safety of operative surgery [21, 22]. A new population was thus developed that required ICU care: the postoperative patient.

Hemodynamic Monitoring

> It is astonishing that no one has arrived at the following obvious method by which the amount of blood ejected by a ventricle of the heart with each systole may be determined directly. . .

In 1870, with this introduction, Fick [23] described how to compute an animal's cardiac output (CO) from arterial and venous blood oxygen measurements.

$$\mathrm{CO} = \mathrm{VO_2}/(C_\mathrm{a} - C_\mathrm{v})$$

Fick's original principle was later adopted in the development of Stewarts's indicator-dilution method in 1897 [24]. Stewart injected a bolus of a sodium chloride solution into the central venous circulation of anesthetized dogs and rabbits, and then collected blood samples containing diluted sodium chloride from a femoral artery catheter. An electric transducer on the contralateral femoral artery sensed the arrival of diluted injectate. Fegler [25] first described the use of thermodilution for measuring cardiac output.

The clinic use of these techniques would not arrive until 1968. Though it is to Swan and Ganz that we attribute the pulmonary artery catheter (PAC) and the birth of clinical hemodynamic monitoring, it is in fact R.D. Bradley who first described the use of a miniature flow-directed PAC and its use in critically ill patients [26, 27]. In collaboration with M.A. Branthwaite, he described the assessment of cardiac output by thermal dilution using a thermistor mounted on the tip of the catheter [28]. However, it was adapting a balloon to the tip, as first demonstrated by M. Lategola, that enabled the development of the *flow-directed* PAC to measure pulmonary artery occlusion pressure, as we understand it today [29].

In 1951 Dr. Swan immigrated to America to work at the Mayo Clinic under the tutelage of Dr. Earl Wood, playing an integral role in the development of indicator dilution techniques, using indocyanine green [30, 31]. Dissatisfied with life in a communist system, Dr. Ganz emigrated to America in 1966, joining Dr. Swan in the Department of Cardiology of the Cedars of Lebanon Hospital [30, 31]. In 1968 they began to work together on the development of a flow-directed catheter [31]. Dr. Swan's conception of the flow-directed PAC occurred in a brief moment of enlightenment during an outing with his children in Santa Monica [31]. In the days preceding this event, he had used, to little success, a Bradley thermodilution catheter in managing an elderly patient. Dr. Swan noted that among the sedentary sailboats in the harbor, a large spinnaker was moving through the water at a reasonable speed. He contemplated that a sail or parachute anchored to the end of a highly flexible catheter might facilitate the safe passage of the device into the pulmonary artery. This original proposal triggered the concept to attach an inflatable balloon to the tip of a highly flexible catheter. Through the support of Edwards Laboratory, the company that had developed the Starr–Edwards heart valve and the Fogarty embolectomy catheter, he manufactured the first flow-directed PAC [30–32]. Dr. Ganz piloted their invention in an anesthetized dog. Upon balloon inflation, the catheter floated through the right heart into the pulmonary artery, "wedging" itself into a small arterial branch. The transduced waveform represented the pressure in the distal pulmonary artery. In the decades that ensued the catheter gained universal acceptance and widespread use in the management of all critically ill patients.

The introduction of the PAC in 1970 and its subsequent use in performing thermodilution CO measurements in humans translated the ability to measure CO from the experimental physiology laboratory to multiple clinical settings. Following the introduction of the PAC into clinical practice, the single-bolus thermodilution measurement of CO has been widely accepted as the "clinical standard" for advanced hemodynamic monitoring. The ability to monitor CO is a cornerstone of hemodynamic assessment for managing critically ill patients.

Intensive Care as an Organizational Rather Than Technologic Invention

The Unit

Nightingale [33] is considered to be the first to have utilized an intensive care unit (ICU). Serving on the British side in the Crimean War (1850–1854), she collected the worst injured and most infirmed soldiers in an area close to her nursing station, where she could maintain a constant eye on their condition and provide expeditious care when needed. However, it was the establishment in 1929 by Dr. Walter Dandy of the Johns Hopkins Hospital of a three-bed unit for postoperative neurosurgical patients that heralded the development of geographic centralization of critically ill patients, the ICU, in the USA [34].

No similar efforts involving intensive care were reported until the worldwide epidemic of poliomyelitis in the early 1950s. Many acknowledge that the world's first ICU, as defined as "a ward where physicians and nurses observe and treat 'desperately ill' patients 24 hours a day," was developed during this period by Dr. Björn Ibsen in Copenhagen [35]. The first patient admitted to that unit at 6 p.m. on December 21st, 1953 was a 43-year old man who had unsuccessfully attempted to hang himself.

Success of these new techniques in mechanical ventilation spread quickly and respiratory ICUs were established in many university medical centers especially in Europe and North America. The Danish anesthesiologists Bendixen and Pontoppidan, who had both participated in manual ventilation of polio victims in Copenhagen, immigrated to Boston and established the respiratory ICU at Massachusetts General Hospital [36]. By the late 1950s, ICUs had been established in a quarter of large community hospitals, and by the late 1960s, this proportion had expanded to a majority. Peter Safar, the Austrian anesthesiologist, who with Elam introduced mouth-to-mouth ventilation replacing outdated and inefficient traditional techniques used in emergencies, such as drowning victims with apnea, started the first round-the-clock physician covered ICU at Baltimore City Hospital [37, 38]. He later established the first fellowship training program in Critical Care Medicine at Presbyterian University Hospital in Pittsburgh after moving to this city from Baltimore in 1961. Safar is best known as "The Father of Cardiopulmonary Cerebral Resuscitation" having introduced and outlined the relevant steps of CPCR, all of special importance in CCM [39].

Parallel with the development of respiratory ICU services, advanced postoperative care centers also evolved into ICUs. This was initially the case for postoperative open-heart surgery patients where the combined issues of hemodynamic instability, volume shifts, and arrhythmias made recovery safer in a highly monitored environment.

The Nurse

The first ICU was introduced by a nurse, and critical care nurses remain one of the most important personnel categories in ICUs today. Although for decades constrained to acting only under direct physician order, it was soon realized that critically ill patients required nurses with special skills and knowledge to take action, often independent of direct physician supervision. Initially prevented from performing any medical intervention without a direct order from a physician, treatment protocols were developed and agreed upon by physicians and nurses that not only permitted, but actually required, ICU nurses to intervene in various acute situations, such as cardiac arrest. Soon, nurses developed their own insights and procedures. In the USA, in the late 1960s, groups of ICU and coronary care nurses were meeting to exchange experiences, and in 1969, the American Association of Cardiovascular Nurses (AACN) was created [40]. However in 1971, the name was changed to the American Association of Critical Care Nurses changing the acronym to ACCN. This association began holding annual meetings and the membership has grown enormously in recent years. The AACN also provides for specialty certification upon examination of qualifying nurses, who then become critical care registered nurses (CCRN).

The Respiratory Therapist

Since ventilatory support is central to the care of the critically ill, another important ICU personnel is the respiratory therapist [41]. They supervise and manage the function of mechanical ventilators and monitor the patient's respiratory function during mechanical ventilation and weaning from these devices, as well as, the spontaneously breathing patients until they can be discharged from the ICU. In Europe and in most other countries outside North America, these duties are provided by critical care nurses in addition to all other aspects of patient care in the ICU. It is unclear if the presence of registered respiratory therapists (RRTs) in North America has resulted in better respiratory care than in the rest of the world, since mortality rates for acute respiratory failure are similar across the developed world. However, the development of a strong respiratory therapy arm in critical care medicine in North America has certainly helped advance artificial ventilation development worldwide. In addition to the above categories of caregivers to the critically ill and injured patients, social workers, nutritionists, clinical pharmacologists, clergy, and others have become important for the complex management of ICU patients.

Transition from Perioperative Care to Other Diseases

Initially most ICUs were either medical (MICU), focusing upon the treatment of acute respiratory failure, sepsis or cardiovascular collapse, or surgical (SICU), primarily treating postoperative surgical patients. Nonetheless, they tended to favor certain types of patients based on the nature of the hospital patient mix and the bias of the ICU medical teams. In addition, cardiologists introduced separate coronary care units (CCU). Notably absent from this initial progress was the presence of pediatric ICUs. Pediatric intensive care became relevant in pediatric departments and major hospitals for sick children, and then separately for neonatal support. In the 1950s, newborn babies weighing less than four pounds were put in incubators and merely observed. Gradually, the knowledge and technology were developed for intubation and mechanical ventilation of smaller newborns, who were frequently premature, and the neonatal ICU was established.

In the USA, medical ICUs split off as separate units in large, particularly tertiary care hospitals and became the domain of pulmonary specialists with increasing emphasis on broader medical aspects of care of critically ill patients. However, this is not typical for the rest of the world outside North America. Because of the greater need for intensive care of surgical patients, especially postoperatively after increasingly complex procedures, large hospital facilities established separate ICUs for general surgery, cardiothoracic surgery, trauma, neurosurgery, burns, and transplantation [42]. Initially, these units were frequently directed by anesthesiologists, but increasingly, surgical specialists and internists became involved in the management of these patients. Today many ICUs in smaller centers are combined medical-surgical ICUs; this separation of care by patient diagnosis persists today. From a purely functional perspective there is very little difference between the treatments given to classic MICU and SICU patients outside those directly related to routine postoperative care.

In 1959, the American Hospital Association (AHA) began to collect statistical information on ICUs. At that time there were 238 ICUs in short-term acute care hospitals. However within 6 years, over 90 % of large American hospitals with more than 500 beds had ICUs. Today practically all acute care hospitals, not only in the USA but also throughout the world, have at least one ICU. Furthermore, with the change in health care economics, patients are being discharged sooner, increasing the average disease severity of the remaining inpatients. Furthermore, since maximal throughput of care usually requires some short-term stays in ICUs, the proportion of hospital beds being allotted to ICUs has continued to increase worldwide.

Hospital-Wide Medical Emergency Response Teams (MET)

Today the acute care center is the hospital, and the ICU only one part of this dynamic diagnosis/treatment complex. However, not all critical illness occurs within an ICU. In fact, recent studies highlight that up to 17 % of hospital inpatients suffer serious adverse events [43]. A significant proportion of these events is unexpected, being unrelated to the admission diagnosis or underlying medical condition. As such, these events commonly occur in environments ill prepared to properly address acute medical issues. Traditionally the responsibility of the medical unit or cardiac arrest team, these serious events are typically managed in a delayed fashion by personnel not specifically or sufficiently trained in acute resuscitation [44]. Of great concern is that they may result in excessive attributable morbidity and mortality [44–47].

The benefits of an expeditious and organized response and treatment team are well established in trauma and cardiology, and now the management of severe sepsis and septic shock [48–50]. A logical extension would be to apply these concepts of critical illness to the general inpatient population. The field of critical care medicine has made considerable progress in improving the outcomes of critically ill patients. Given that most acute illness develops through stages of deterioration, the logical step surely would be to bring intensive care equipment and expertise to any acutely ill patient, irrespective of location within the hospital, in what has been described as creating a "critical care system without walls." Critical care physicians and critical care nurses can theoretically deliver such expertise anywhere in the hospital within minutes.

The medical emergency team (MET) brings this expertise to the patient in a timely manner and supplies the "efferent arm" of this process of identification of at-risk patients and rapid delivery of appropriate care designated recently as the rapid response system (RRS).

RRSs have been introduced into hospitals to identify and treat at-risk ward patients in an attempt to reduce unplanned ICU admissions and cardiac arrests. The most common form of RRS is the ICU-based MET first described by Lee and colleagues in 1995 [51]. The MET differs from RRTs in that the team leader is a physician, typically with intensive care expertise. The principle of the MET is to "take critical care expertise to the patient before, rather than after, multiple organ failure or cardiac arrest occurs" [52]. Because the care of critically ill patients is their core specialty competency, intensive care doctors and nurses are ideally placed to provide immediate care to patients who are critically ill [44, 53].

The first evidence of a dose–response effect of the MET was demonstrated by DeVita. Introduction of objective MET calling criteria resulted in a significant increase in MET call rates [54, 55]. This was associated with a 17 % reduction in cardiac arrest rates [55]. Subsequently, it was demonstrated that increasing MET at a teaching hospital in Melbourne was associated with a progressive and dose-related reduction in the incidence of cardiac arrest in ward patients [56]. This study suggested that for every additional 17 MET calls, one cardiac arrest might be prevented. Other studies have come to similar conclusions [57].

Birth of the Field of Critical Care Medicine

CCM Societies and Congresses

Much of the success of critical care medicine as a recognized field integral to medicine can be attributed to the development of societies and congresses. As part of the process of maturing as a discipline, specialists from diverse origins with common interests in critical care medicine came together to form societies with the goal of defining core competencies for ICU physicians, providing relevant training and creating advocacy groups to promote the specialty. Their efforts over the years have resulted in many major milestones in the advancement of critical care medicine as a medical specialty associated with a list of core competencies and expected roles in the acute care setting.

At the 1968 FASEB Congress in Atlantic City, Drs. Max Harry Weil, Peter Safar, and William Shoemaker met and discussed the need and suitability for the creation of a society for those interested in intensive care [58]. Max Harry Weil, MD, PhD, an internist and cardiologist directing a shock research unit in Los Angeles, CA; Peter Safar, MD, the founding chairman of the Department of Anesthesiology at the University of Pittsburgh and initial director of the ICU at Presbyterian University Hospital; and William Shoemaker, MD, a trauma surgeon and director of Traumatology and Intensive Care at Cook County Hospital in Chicago, though representing three distinct medical specialties, possessed the same common interest in intensive care of the critically ill and injured patients. The following year, Dr. Weil in connection with his annual Shock Symposium arranged a meeting of selected physicians ($n = 28$) with documented interest in intensive care. And so was born the Society of Critical Care Medicine (SCCM), which was incorporated in 1971. That same year the Society published its first issue of the journal "Critical Care Medicine."

Over the past 40 years, the membership of SCCM has expanded from the initial 28 to a current membership of 15,000, representing 80 different countries and many disciplines: nursing, respiratory therapy, basic and clinic research science, technology, veterinarians, industry, social work, pharmacy that collectively now define intensive care. In 2001 the decision was made to create a separate pediatric critical care medicine journal, and Patrick Kochanek, professor of CCM and Pediatrics and director of the Safar Center for Resuscitation Research at the University of Pittsburgh, was elected founding editor of this new journal.

Over the next 10 years, almost every developed nation created its own national intensive care medicine society. The World Federation of Societies of Intensive and Critical Care Medicine (WFSICCM) was established in 1977 and from the onset involved national and regional societies as its members. In Europe and the north, intensive care was subsumed into the primary specialty of anesthesiology. Thus, in Scandinavia there is a regional Society for Anesthesiology and Intensive Care Medicine. Australia and New Zealand formed their own Australia–New Zealand Intensive Care Society (ANZICS) in 1975 [59]. The western hemisphere is represented by the Pan American Federation of Societies of Intensive Care Medicine. Similarly, the western pacific region created the Western Pacific Association of Critical Care Medicine (WPACCM), which later became the Asia Pacific Association of Critical Care Medicine (APACCM), when India joined in 2005.

The advantage of forming regional societies of like-minded intensivists with strong foci on patient advocacy, continuing medical education, ICU and practice standards, and training/certification spread. Eight European countries formed the European Society for Intensive Care Medicine (ESICM), which now boasts a membership exceeding 5,000. They have approached intensive care medicine education and credentialing head on, and their annual meeting is the third largest critical care medicine program in the world behind the International Symposium of Intensive Care and Emergency Medicine (ISICEM) and the SCCM annual meeting.

Later still, the American Thoracic Society (ATS), under pressure from its regular members, established a Critical Care Assembly in the late 1980s. The Critical Care

Assembly grew to become the second largest primary assembly in the ATS behind Structure and Function. Later, in recognition of the major role that critical care medicine was playing in its society and that a majority of the physicians certified in critical care medicine also have subspecialty boards in respiratory diseases, the ATS changed the name of its flagship journal from the *American Review of Respiratory Disease* to the *American Journal of Respiratory and Critical Care Medicine*. About the same time, the ESICM and the ATS created joint conferences to develop consensus on critical care issues. Perhaps the most successful were the three part series entitled the ATS-ESICM Consensus conferences on Acute Respiratory Distress Syndrome. The SCCM and ESICM have continued these consensus conferences in a more formal way up until the present.

Education and Board Certification

In the USA, the need for separate and advanced training in CCM became evident early. Peter Safar in Pittsburgh was the first to introduce a fellowship training program in CCM for anesthesiologists. In 1968, Dr. Ake Grenvik, a certified general and cardiac surgeon, joined Safar to support the inclusion of other specialists. Through SCCM, a recommendation was made in the late 1970s to the American Board of Medical Specialties to establish a board certification process in CCM [28]. A national committee was formed with the initial intention to have one common certification examination of qualifying physicians [60]. However, representatives of the American Boards of Anesthesiology, Internal Medicine, Pediatrics and Surgery did not agree. Therefore, each of these four specialty boards applied for separate certification examinations, starting in 1986. Within Internal Medicine the decision was made to require 2 years of training in CCM unless the individual already held certification in another subspecialty, commonly pulmonary medicine, in which case 1 year of CCM training would suffice. The common denominator was for all physicians seeking certification examination in CCM to have a minimum of 5 years of postgraduate training. With anesthesiology having a 4-year residency and general surgery 5 years, these two specialties required only 1 year of CCM fellowship. However, the American Board of Pediatrics, with 3 years of residency for ABP certification, decided not only to require 2 years of CCM fellowship, but also an additional year of research in Pediatric CCM-related topics.

Spain and most Latin American countries pursued a different tact and declared intensive care medicine a separate primary specialty, requiring 5 years of training. ESICM arranged a certification approach similar to, but different from the USA and Canada. The ESICM requirements are primary specialty certification with 2 years of training in ICM followed by first a written and then an oral exam for certification. This process is extended to anesthesiology, internal medicine, pediatrics, and surgery. Therefore, physicians with different primary specialty backgrounds in the USA may apply for and take the ESICM diploma exam.

To address the need to standardization across countries, the ESICM developed a Core Competency program for intensive care medicine called CoBaTrICE that emphasizes a define set of core skills and medical competencies: (1) the establishment of a European Forum for national Intensive Care Medicine training organizations that functions as an expert group and acquires ownership over future developments through the Division of Professional Development to the European Board of Intensive Care Medicine; (2) nationally survey current education and training provisions and needs so as to identify current challenges for trainers and trainees and develop a database for benchmarking and accreditation; (3) develop minimum training program standards for quality assurance and harmonize minimum accreditation standards across the European Union; (4) review workplace-based methods of assessment of individual competence, including case-based discussion, simulation techniques, multi-source feedback, link assessment methods to competencies and identify quality indicators within these measures; and finally (5) create a web-based tools for evaluation and testing support and life-long learning for trainers and trainee. To aid in the process of education, the ESICM created its own Patient-Centered Advance Care Training (PACT) program. PACT is a modular multidisciplinary distance-learning program, aimed at improving and harmonizing the quality of acute care medicine. The Program contains 44 modules covering the complete ICU curriculum. Although some of these objectives are uniquely European, most could be directly applied in North America as well.

Research

A fundamental aspect of the maturation of a new specialty is its development of a durable knowledge base and the growth of a robust and well-funded research arm to advance its field. In the early days of CCM, there were no comprehensive textbooks to which trainees and practitioners could refer. With its rapid growth, CCM identified an acute need for this resource. To address this issue Drs. William Shoemaker (surgery), Ake Grenvik (anesthesiology), Peter Holbrock (pediatrics), and Steven Ayers (internal medicine) edited the first *Textbook of Critical Care* in 1984, and continued to edit this textbook through subsequent editions in 1989, 1995, and 2000. Today the student of critical care medicine has an impressive array of superb comprehensive textbooks specializing in specific facets of the field of specialty, including pulmonary, nephrology, surgery, trauma, anesthesiology, and emergency medicine. Nonetheless, the *Textbook of Critical Care*, now in its sixth edition, continues to be the reference standard.

Originally, CCM evolved from a descriptive discipline that tended to categorize symptoms and disease states, describing hemodynamic and metabolic patterns linked closely to the use of the PAC, artificial ventilation, and cardiopulmonary resuscitation. The initial source of the data and evidence for practice and dissemination came from the medical field at large. From these humble roots, however, CCM has advanced into a field focused upon mechanism-based disease and therapeutics, and now generates much of the evidence that supports current practice. These scientific, outcomes, and processes of care data are yielded by CCM physician-scientists, whose publications routinely appear in major medical journals like *JAMA*, the *New England Journal of Medicine*, and *Lancet*. Furthermore, CCM basic science research often appears in *Journal of Clinical Investigation*, *Nature Medicine*, *Biochem Biophys Res Acta*, *Journal of Immunology*, *American Journal of Physiology*, *Journal of Applied Physiology*, and *Circulation*, which highlights the rigorous quality that the foundations of critical care medicine enjoy.

As managed care and cost containments force the less sick to be discharged much earlier and optimizing throughput of care becomes an economic survival practice for hospitals, CCM has become the epicenter of acute care medicine. Accordingly, process of care research, patient safety, ethics of life support, and health care economics have evolved into major areas of expertise and research for critical care physicians. In fact, CCM research interests and productivity compare as equals to any other specialty, an impressive statement considering that its first ICU was only built in 1963.

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