Fourth Edition

Pediatric Critical Care

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Preface

On publishing this Fourth Edition of *Pediatric Critical Care,* we are struck by how much the milieu of pediatric critical care medicine and the content of this textbook have changed over the last 2 decades. The first edition of *Pediatric Critical Care* appeared in 1992, only 5 years after the first Pediatric Critical Care Medicine certification examination. In fact, the first table of contents for *Pediatric Critical Care* was constructed to encompass the American Board of Pediatrics' original content specifications for pediatric critical care medicine. Since then, most of the authors and editors of *Pediatric Critical Care* have survived recertification and are now actively engaged in "Maintenance of Certification." However, the value of a comprehensive textbook such as *Pediatric Critical Care* remains constant; it continues to provide a comprehensive overview of pediatric critical care medicine for those working in the field.

That noted, the content of *Pediatric Critical Care* has certainly evolved through these four editions. Cardiopulmonary physiology still represents comfort food for most intensivists. Those concepts remain as fundamental as ever. However, the virtual explosion of molecular biology has fueled the expectation of personalized medicine. When the first edition of *Pediatric Critical Care* appeared, the Human Genome Project was just getting underway. Today, whole genome mapping is common in research, and, in the near future, it will probably become an element of the medical record.

Reanimation was once a comic book fantasy. Today, extracorporeal life support has become an integral component of cardiopulmonary resuscitation in many hospitals. Since the first systemic pulmonary shunt was performed in 1943, the advances in pediatric cardiac surgery and postoperative care have been nothing less than spectacular, including the growth of pediatric cardiac intensive care as a new focused subspecialty. A parallel pattern of subspecialization seems to be appearing in pediatric neurocritical care. Similarly, pediatric critical care medicine has clearly played a role in improved survival of hematology/oncology and hematopoietic progenitor cell transplantation patients.

At the time of the first edition of *Pediatric Critical Care,* family-centered care was merely an interesting and controversial concept. Now parents routinely contribute information during rounds to help inform the daily care plan. Pulmonary artery catheters were once in common use, often placed by cut-down vascular access. Today, a pediatric critical care medicine fellow is more likely to encounter a pulmonary artery catheter in a simulation laboratory, yet is skilled in vascular ultrasonography and echocardiography, techniques that facilitate placement of vascular catheters on the first pass and provide three-dimensional visualization of complex cardiac anatomy. Before the new millennium, pediatric and adult patients with hypoxemic respiratory failure were commonly supported by using tidal volumes of 10 to 15 mL/kg. Chest tube insertion equipment and draining systems were typically ordered to the bedside on initiation of mechanical ventilation because pneumothorax was an anticipated and frequent complication. Similarly, catheter-associated bloodstream infections were a troublesome and not unexpected complication of central venous catheterization. Meanwhile, over the past 20 years, there has been a remarkable decline in deaths from sudden infant death syndrome, and infants of ever-greater prematurity have survived.

Two publications, "To Err is Human: Building a Safer System" and "Crossing the Quality Chasm" would not appear until the twenty-first century and have ushered in a new hospital paradigm of continuous quality improvement.

Although there have been huge advances in knowledge of the molecular pathophysiology of sepsis since the first edition of *Pediatric Critical Care,* basic critical care principles remain paramount: early detection; early, vigorous hemodynamic resuscitation; and early antibiotics—simple concepts that clearly save lives. Success in the field of pediatric critical care medicine has allowed a change in outcome focus of interventional clinical trials from death to long-term morbidity. Particularly over the last decade, pediatric critical care medicine has seen the emergence of clinical research networks that will continue to foster translation of important basic research into practice.

With the publication of the Fourth Edition of *Pediatric Critical Care,* the editors note that new challenges continue to emerge for practitioners, particularly in a field that is now overtly international in scope. Worldwide, roughly 25 children still die of sepsis every minute. Obesity now complicates the neurogenic-inflammatory-endocrine stress response to critical illness. A growing population of children with acquired immunodeficiency increasingly find their way into the pediatric intensive care unit, as do an increasing number of children with chronic complex conditions.

As in the past, although in debt to many, we remain particularity grateful to our families, friends, and colleagues who have been patiently supportive through three revisions of this textbook. We thank our new section editors as well as the hundreds of authors who have contributed to the success of this and former editions of the textbook. Lastly, we thank the members of the multidisciplinary teams who make pediatric critical care medicine work and the patients and families who allow us into their lives at a time when they are most vulnerable. Being a pediatric intensivist remains an amazing, challenging, rewarding, humbling, and privileged occupation.

We hope this Fourth Edition of *Pediatric Critical Care* will help nurture our evolving specialty.

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Chapter 1

History of Pediatric Critical Care

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"In critical care, it strikes one that the issues are three: realism, dignity, and love."

Jacob Javits, 1986 (United States Senator)

PEARLS

- There are many heroes in medicine and in pediatric critical care medicine, but most of the courage awards go to our patients and their parents.
- The evolution of pediatric critical care medicine has been a long process of progress in ventilation and resuscitation, physiology and anatomy, anesthesia, anesthesiology, neonatology, pediatric general and cardiac surgery, and pediatric cardiology.
- The role of nursing is absolutely central to the evolution of critical care units.
- Pediatric critical care physicians have made remarkable achievements in the understanding and treatment of critically ill children.
- Until the 1950s and 1960s, intensive care units were organized by grouping patients with similar diseases. In the 1960s, neonatal intensive care units began to group children according to age and severity of illness, and pediatric intensive care units followed this example.
- The development of sophisticated interhospital transfer services was significant in reducing mortality and morbidity of critically ill children, and "retrieval medicine" holds great promise for future improvements in care.
- We have seen great progress in the national and international organization of pediatric critical care medicine as well as in education and research in the field.
- Better and increased use of technology has advanced the care of critically ill children but has also created an environment with increasing errors, complications, and sequelae and a greater need for humane, caring environments for the patients and their families.

In his book *Retrospectroscope: Insights into Medical Discovery,*[1] Dr. Julius H. Comroe Jr, wrote about the courage to fail. He concluded there is no single definition of courage but that it comes in different sizes, each with its own definition. There are four sizes.

Courage, Size 1: "This, the largest size…..The person voluntarily involves himself in an action (or sometimes inaction) that places *himself* in grave peril such as loss of life, liberty, or pursuit of happiness. Courage, Size 1…also bars as a motive any possible gain, material or otherwise, to the individual should he fail or succeed, and postulates that if he succeeds, he wants the gain to be for someone else."

Examples of Courage, Size 1 awards go to James Carroll, William Dean, and Jesse Lazear (a former house officer of W. Osler),[2] who all volunteered to be bitten by yellow fever-infected mosquitoes to prove the mosquitoes were the human-to-human vector of the disease. They proved it and Lazear died. Also Werner Forssmann, who in 1929 introduced a catheter into his own right atrium in order to improve diagnosis for treatment of certain disorders, not knowing whether the tip would cause ventricular fibrillation.[2,3] He received little acclaim for this breakthrough until 1956, when he won the Nobel Prize.

Courage, Size 2: "Size 2…… differs from Size 1 in that the investigator… is not the one who takes the risk, in initial experiments the subject is usually a close member of his family, even one of his children…An example is Lady Montague who having survived an attack of smallpox in the early 1700s, long before Jenner (cowpox) had her children inoculated with pus from patients suffering from virulent smallpox. Another is Edward Jenner who vaccinated his first son Edward with cowpox and then injected him with pus from smallpox patients on five or six occasions to prove he was immune. He then vaccinated his second son Robert.

Courage, Size 3: "This is similar to size 1, in that the individual puts his own life at risk instead of that of another…, the risk is a grim one, and considerable benefits to mankind would surely accrue if his mission should be successful. It ranks below Sizes 1 and 2 because his act is motivated by assured fame and fortune if he succeeds. There are no examples of this in medicine, but Charles Lindbergh's 1927 transatlantic flight is an example in aviation.

Courage, Size 4: "Size 4 medals go to patients who, informed by specialists they have advanced disease and statistically have only weeks, months, or years to live, elect to undergo a previously untested operation or other form of therapy…It might benefit them or lead to earlier death." Examples are the first man (1925) to have bilateral sympathectomy for very high arterial blood pressure; Dr. James Gilmore (1933), the first patient to have one whole lung removed surgically at a single operation; the family of the first patient to receive insulin; the first patient to receive penicillin; and the family of the first "blue baby" operated on by Blalock.

†Deceased.

Some physicians may get Courage, Size 4 awards when they face intense professional criticism and loss of professional esteem for their efforts, such as Dr. Ludwig Rehn, a German surgeon, who in 1896 repaired a 1.5 cm stab wound of the right ventricle of a young man, saving his life. He did this despite a pronouncement in 1883 by the dean of European surgery, Billroth, who warned others not to try. Some patients (or parents) get Courage, Size 4, awards for the willingness to try a procedure or treatment despite knowing this has met with repeated failure. For example, in 1948 Claire Ward, a 24-year-old woman, was the fifth patient to be operated on by Dr. Charles Bailey in Philadelphia for mitral stenosis. This operation had previously been reviewed and proclaimed unsuccessful, and, when Bailey revived it, his first four patients died. Mrs. Ward traveled to Chicago by train 10 days after the operation, went on to live for 23 more years, and gave birth to two children.

Some physicians may have nothing to lose but may get a Perseverance, Size 1 award for continued effort. For example, there are Zoll's attempts at converting ventricular fibrillation by the closed-chest technique; the first three patients died before his first success. Others include Smythe and Bull, who pioneered neonatal ventilation (see below).

Although we in pediatric critical care have plenty of physician "heroes" we admire and appreciate, none get Courage Size 1, 2, or 3 awards. Rarely, we encounter those worthy of Size 4 awards for having risked their professional standing. By far and away, more of our Courage, Size 4 awards go to patients and parents who have had the courage to fail when presented with bleak prognoses and offered only untested or previously unsuccessful procedures or therapies.

Definitions

An important early principle of pediatric critical care medicine (PCCM) is centralization of resources and expertise. Currently, we have highly trained individuals and sophisticated technology in specialized physical spaces. In the future, we may see these highly trained individuals extending their services into additional sites to address the problems of sick children earlier in their illness.

Definition of a Pediatric Intensive Care Unit

In the 1983, Guidelines for Pediatric Intensive Care Units (PICUs)[4] (updated 1993[5] and 2004[6]) the committee defined a PICU as "…a hospital unit which provides treatment to children with a wide variety of illnesses of life-threatening nature including children with highly unstable conditions and those requiring sophisticated medical and surgical treatment." Randolph et al.[7] have expanded this definition, stating, "A PICU is a separate physical facility or unit specifically designated for the treatment of pediatric patients who, because of shock, trauma, or other life-threatening conditions, require intensive, comprehensive observations and care."

Definition of Pediatric Intensivist

Randolph et al.[7] define a pediatric intensivist (in the United States) as "…any one of the following: (a) a pediatrician with subspecialty training in PCCM and subspecialty certification from the American Board of Pediatrics (ABP); (b) a pediatric anesthesiologist with special competency in critical care with subspecialty certification from the American Board of Anesthesiology; (c) a pediatric surgeon with special competency in critical care with subspecialty certification from the American Board of Surgery; or (d) a physician (as above) eligible for subspecialty certification by their respective board." Similar requirements for training exist or are in development elsewhere in the world.

History of Critical Care

Resuscitation and Ventilation

The key to understanding the present practice of intensive care for children lies in knowing the history of scientific study of cardiorespiratory anatomy and physiology and of the discovery of techniques to support ill patients. Although one could think our current practice suddenly emerged with the late twentieth-century technical discoveries, Downes and Todres have skillfully reminded us[3,8] that accomplishments in the development of resuscitation and ventilation that we take for granted today date back to the Bible, and numerous events and contributions led to our current practice. In a biblical story,[9] Elisha resurrected a young boy who was dead when, " …he climbed onto the bed and stretched himself on top of the child, putting his mouth to his mouth, his eyes to his eyes, and his hands to his hands, and as he lowered himself onto him the child's flesh grew warm….Then the child sneezed and opened his eyes." In 117 CE, Antyllus performed tracheotomies for patients with upper airway obstruction.[10] Paracelsus, a sixteenth-century Swiss alchemist and physician, first provided artificial ventilation to both animals and dead humans using a bellows,[10] and Andreas Vesalius, a Flemish professor of anatomy, in *De Humani Corporis Fabrica* reported ventilating open-chest dogs and pigs using a fireplace bellows in 1543.[11-13]

The French obstetrician Desault, in 1801, described how to successfully resuscitate apneic or limp newborns by digital orotracheal intubation with a lacquered fabric tube and then blowing into the tube.[3] In 1832, Dr. John Dalziel in Scotland developed a bellows-operated intermittent negative-pressure device to assist ventilation,[14] In 1864, Alfred F. Jones, of Lexington, Kentucky, built a body-enclosing tank ventilator, and in the 1880s, Alexander Graham Bell developed a "vacuum jacket" driven by hand-operated bellows.[14] In 1876, Woillez, in Paris, built what was probably the first workable iron lung, which was strikingly similar to the respirator introduced by Emerson in 1931.[14] Braun developed an infant resuscitator, as described by Doe in 1889, which was used successfully in 50 consecutive patients. A respirator developed by Steuart in Cape Town, South Africa, in 1918 apparently successfully treated a series of polio patients, but he did not report it.[14]

In 1888, Joseph O'Dwyer, a physician working at the New York Foundling Hospital who was concerned about the severe death rate in croup and laryngeal diphtheria, instituted the manual method of blind laryngeal intubation. *Despite severe criticism from associates and the other practitioners, he persisted in the use of this technique.* He assembled a series of sized tubes for the palliation of adult and pediatric laryngeal stenosis and, with George Fell, devised a method of ventilation with a foot-operated bellows connected by rubber tubing to the endotracheal tube (Figure 1-1).[12] O'Dwyer may deserve a Courage, Size 4 award for his work.

In 1898, Rudolph Matas of New Orleans adapted the Fell-O'Dwyer technique to perform chest wall surgery and, in the early 1900s, George Morris Dorrance of Philadelphia used the technique to perform resuscitations.[12] In 1910, at the Trendelenburg Clinic in Leipzig, two thoracic surgeons, A. Lawen and R. Sievers, developed a preset, electrically powered piston-cylinder ventilator with a draw-over humidifier. It was used with a tracheotomy tube during and after surgery and for a variety of diseases.[3] Over a long career, Chevalier Jackson (1858-1955), a surgeon at Temple University in Philadelphia, developed the techniques for laryngoscopy, bronchoscopy, and tracheotomy.[3]

In 1958, Peter Safar published work in which he showed the longstanding resuscitation technique of chest-pressure arm-lift was virtually worthless and, in effect, went back to Elisha and proved jaw thrust and mouth-to-mouth resuscitation superior.[15] Soon after, W.B. Kouwenhoven and James Jude at Johns Hopkins published work on the effectiveness of closed-chest cardiac massage.[16] Beck and his team, in 1946, had demonstrated open-chest electrical defibrillation, and, in 1952, Zoll and his team proved the efficacy of external defibrillation and, in 1956, the effectiveness of external cardiac pacing.[17]

Anesthesia

The evolution of PCCM is tightly linked with the demand for postoperative care for infants and children with conditions needing complex surgery. The evolution of anesthesia allowed surgeons to develop the techniques to address the problems of these patients.

In 1842, Crawford W. Long, a University of Pennsylvania Medical School graduate practicing medicine in rural Georgia, observed that bruises encountered by participants during "ether frolics" caused no pain when they occurred during the "exhilatory" effects induced by inhalation of vapor. This also occurred when nitrous oxide was inhaled. Both of these agents, at the time, were inhaled for their hallucinatory effects in the United States. Long utilized this serendipitous observation to provide ether to James Venable and incise a cyst from his neck, without pain. This was 4 years before Morton's demonstration of the use of ether at Massachusetts General Hospital in 1846. In 1849, Long reported his experience with his third patient, an 8-year-old boy who had a diseased toe, which was amputated without pain in 1842.[18]

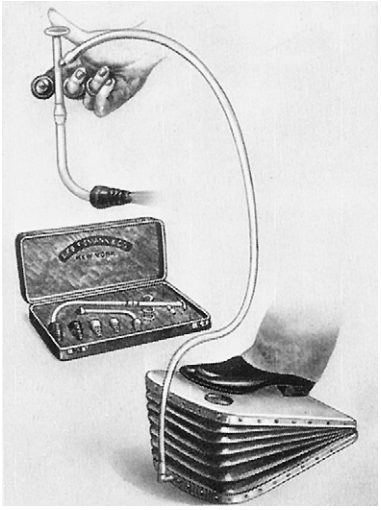

Figure 1–1. The Fell-O'Dwyer Respiratory Apparatus. *(Reproduced with permission, Blackwell Scientific Publications, Oxford.)*

The widely publicized public demonstration of the use of ether by the dentist William T.G. Morton took place at the Massachusetts General Hospital on October 16, 1846. Dr. John Collins Warren removed a mandibular tumor, without the patient experiencing pain. This great success was quickly picked up and used by John Snow in London and later by Friedrich Trendelenburg in Leipzig, who first used anesthesia via an endotracheal tube in 1869.[19]

Anatomy and Physiology

What seems simple and obvious today took a great deal of time, effort, and insight to understand. Downes[3] has provided a thorough review of this topic, and we briefly note here some of the contributions that advanced medicine and enabled the development of cardiorespiratory support and, eventually, intensive care. Andreas Vesalius (1514-1564), the Flemish anatomist, corrected many previous mistakes in anatomy and provided positive-pressure ventilation via a tracheotomy tube to asphyxiated fetal lambs. Michael Servetus of Spain (1511-1553) correctly described the pumping action of the heart's ventricles and the circulation of the blood from the right heart through the lungs to the left heart. *He was burned at the stake for his views* and thus deserves a Courage, Size 1 award. Matteo Realdo Columbo (1515?-1559) described the pulmonary circulation and the concept that the lungs added a *spirituous* element to the blood by the admixture of air. William Harvey (1578-1657), with his genius and *perseverance,* published *De Motu Cordis* (On the Motion of the Heart)[20] in 1678. Since he did not yet have the microscope available, he could not see the capillaries and thus could not include the mechanism for transfer of blood from the arterial to the venous system of the pulmonary circulation. Capillaries were described by Marcello Malpighi (1628-1694, Italian) in *De Pulmonibus* (On the Lungs) in 1661. Thomas Willis (1611-1675) and, eventually, William Cullan (1710-1790) led the way to understanding the role of the nervous system as the site for consciousness and the regulation of vital phenomena. Richard Cower (1631-1641) proved it was the passage of blood through the lungs, ventilation of the lungs, and gas exchange with blood that vivified the blood and turned it red. Stephen Hales (1677-1761) measured blood pressure with a brass tube connected to a 9-foot glass tube in a horse. Joseph Black (1728-1799) identified carbon dioxide as a gas expired from human lungs. Karl Wilhelm Scheele (1742-1785) isolated oxygen, as did Joseph Priestley (1733-1804), who named it *dephlogisticated air* and determined its vital role in supporting combustion. Antoine Laurent Lavoisier (1743-1794) identified oxygen as the vital element taken up by the lungs that maintains life and gave it its name, but its essential role in physiology and biochemistry was clarified much later. Joseph Lister (1817-1916), one of the founders of modern histology, reasoned that bacteria were the source of pus in rotten organic material and used carbolic acid in surgical fields to eliminate bacteria. This technique improved patient outcomes for wounds and after surgery. Along with the discovery of antibiotics, antiseptic technique was an important step in patient care. Nonetheless, imperfect antiseptic technique, sepsis, inflammation, and the consequences of multiorgan failure are still a major portion of what pediatric intensivists deal with today. Felix Hoppe-Seyler (1825-1895) described the transportation of oxygen in blood by hemoglobin. Robert

Koch (1843-1910) developed his postulates in 1882. William Konrad von Röntgen (1845-1923) discovered x-rays. Scipione Riva-Rocci (1863-1937), in 1846, measured blood pressure using the sphygmomanometer, and Nikolai Korotkoff, in 1905, introduced his auscultation method.[3] In the present day, cardiac catheterization, echocardiography, computerized tomography, and magnetic resonance imaging have enabled clinicians to delve into anatomy and physiology in the living patient with relative ease.

History of Pediatric Critical Care

Pediatric Anesthesiology

The development of PCCM rests on the efforts of pediatric anesthesiologists, as well as pediatric general and cardiac surgeons, and neonatologists. In fact, most of the original PICUs were founded by pediatric anesthesiologists (Table 1-1).[3,8,21-28] Much depends on the definition of a PICU, very much a moving target in the early days, with units eventually evolving from separate areas within recovery rooms and adult units to separate freestanding PICUs. In addition to those noted in Table 1-1, there were probably others which are not as well documented.

Pediatric General and Cardiac Surgery

The pioneering efforts of Dr. William E. Ladd (1880-1967) at Boston Children's Hospital (BCH) in developing many of the techniques to operate on noncardiac congenital malformations and Dr. Robert Gross, also at BCH, to operate on congenital cardiac lesions (7-year-old Lorraine, coarctation of the aorta, August 23, 1938) were instrumental in developing their surgical fields and demonstrating the need for good postoperative care. Dr. C. Everett Koop trained there for 6 months and then returned to Children's Hospital of Philadelphia (CHOP) where he, with the help of nursing staff, developed the first neonatal surgical intensive care unit in 1956. This was staffed by Dr. Leonard Bachman (anesthesiology) and his colleagues. Dr. Bachman's young associate, John J. Downes, subsequently set up the PICU in the hospital in 1967. Dr. C. Crawfoord in Sweden repaired a coarctation of the aorta in 1945, and Drs. Alfred Blalock (surgeon) and Helen Taussig (cardiologist) with Mr. Vivien Thomas (laboratory assistant) at Johns Hopkins created the subclavian-to-pulmonary artery shunt for tetralogy of Fallot, also in 1945. Dr. John Gibbon at Jefferson Medical College Hospital in Philadelphia performed the first successful open-heart surgery (for atrial septal defect) using cardiopulmonary bypass in 1953.[3] As the surgical procedures became more invasive, the need for improved postoperative support of all organ systems advanced rapidly. Although some surgeons believed the success or failure of treatment was solely determined in the operating room, others credited improved survival to better postoperative care.

Neonatology

Pediatric critical care owes a great debt to fellow neonatal pediatricians.[3,8,29] In the 1880s and 1890s special care nurseries were developed in Paris, and in 1914, the first premature infant center in the United States was opened at Michael Reese Hospital in Chicago by Dr. Julius Hess (1876-1955). In Canada, Dr. Alfred Hart performed exchange transfusions in 1928, and in 1932, Drs. Louis Diamond, Kenneth Blackfan, and James Batey at BCH described the pathophysiology of hemolytic anemia and jaundice of erythroblastosis fetalis; in 1948, the same team performed exchange transfusions using a feeding tube inserted in the umbilical vein. In the 1950s and 1960s, Dr. Geoffrey Dawes at the Nuffield Institute for Medical Research at Oxford University began work, using fetal and newborn lambs, to describe the circulation of mammalian neonates. This work was continued, and the fetal transitional circulation further elucidated, by Dr. Abraham Rudolph and colleagues at the Cardiovascular Research Institute (CVRI) of the University of California, San Francisco (UCSF).

Dr. Clement Smith at Boston Lying-In Hospital published his textbook of neonatal physiology in 1945, and in 1959, a research fellow at Harvard, Dr. Mary Ellen Avery (with mentor Dr. Jere Mead) discovered the deficiency of alveolar surfactant in lungs of newborns dying from respiratory distress syndrome (RDS). Dr. L. Stanley James from New Zealand was recruited to Columbia in New York by Dr. Virginia Apgar (anesthesiology) in the 1960s and helped confirm the work of Dr. Dawes. In the 1960s, neonatologists altered the practice used in adult ICUs of cohorting patients with similar diseases by establishing units with infants with a variety of life-threatening conditions and shifted from supportive care to more invasive measures to treat organ failure.

In 1959, Drs. Peter Smythe (pediatrician) and Arthur Bull (anesthesiologist) had the first real success in long-term mechanical ventilation of neonates, treating infants with neonatal tetanus for 4 to 14 days using tracheotomy and a modified Radcliff adult ventilator.[30] Up until that time, infants were not given ventilatory support for more than a few hours using manual ventilation. There were no pediatric ventilators, humidifiers, or blood gas analysis. Dr. Smythe had to overcome these obstacles by innovation. On July 13, 1957, he began intermittent positive-pressure ventilation on a baby with neonatal tetanus at Groote Schuur Hospital, with the assistance of anesthesiologist Bull. This was truly a landmark event in the evolution of PCCM. There are three interesting points to be made about their work. First, although considered a success story in that it was the first time infants survived long-term positive-pressure mechanical ventilation, the first 7 of 9 patients died. Eventually their survival rate reached 80% to 90%. Surely Smythe and Bull deserve Perseverance, Size 1 awards. Second, they commented that, "No praise can be too high for the nursing staff, who were all student nurses and without any special training." And third, Dr. David Todres, a medical student at the time, administered intramuscular curare to these patients. Dr. Smythe moved to Red Cross Children's Hospital when it opened in 1958, and established a 6-bed neonatal tetanus unit.

In 1963–1964 in Toronto, Drs. Paul Swyer, Maria Delivoria-Papadopoulos and Henry Levison were the first to successfully treat premature infants with RDS with positive-pressure mechanical ventilation and supportive care.[31] They emphasized the importance of a full-time team, *including dedicated nurses and therapists* as well as physicians. In 1968, Dr. George Gregory and colleagues demonstrated greatly improved survival with the addition of continuous positive airway pressure (CPAP) and positive end-expiratory pressure (PEEP) to the mechanical ventilation regimen.[32] However, as always, progress in treating a disorder leads to unforeseen complications and new disorders, and successful treatment of RDS led to

Table 1–1 Early Pediatric Intensive Care Units and Programs

Year	Institution/Location	Medical Director(s)	Director(s) Specialty
1955	Children's Hospital, Goteborg, Sweden	G. Haglund	Pediatric Anesthesiology
1961	St. Goran's Children's Hospital, Stockholm, Sweden	H. Feychting	Pediatric Anesthesiology
1963	Hospital St. Vincent de Paul, Paris, France	J.B. Joly G. Huault	Neonatology Neonatology
1963	Royal Children's Hospital, Melbourne, Australia	I.H. McDonald J. Stocks	Pediatric Anesthesiology Pediatric Anesthesiology
1964	Alden Hey Children's Hospital, Liverpool, England	G.J. Rees	Pediatric Anesthesiology
1965	Children's Hospital District of Columbia, Washington, DC	C. Berlin	Pediatrics
1967	Children's Hospital of Philadelphia, Philadelphia, Pennsylvania	J.J. Downes	Pediatric Anesthesiology
1968	Children's Hospital Calvo Mackenna, Santiago de Chile	E. Bancalari	Pediatrics
1969	Children's Hospital of Pittsburgh, Pittsburgh, Pennsylvania	S. Kampschulte	Pediatric Anesthesiology
1969	Yale-New Haven Medical Center, New Haven, Conn.	J. Gilman N. Talner	Pediatric Anesthesiology Pediatric Cardiology
1971	Massachusetts General Hospital, Boston, Mass.	D. Shannon I.D. Todres	Pediatric Pulmonology Pediatric Anesthesiology
1971	Hospital for Sick Children, Toronto, Canada	A. Conn	Pediatric Anesthesiology
1971	Long Island Jewish Hospital, New York	B. Holtzman	Pediatric Pulmonology
1971	Montefiore Hospital, New York	R. Kravath	Pediatric Pulmonology
1972	Sainte Justine Hospital, Montreal, Canada	M. Weber A. Lamarre	Pediatrics Pediatric Pulmonology
1972	Children's Hospital "Dr. R. Gutierrez," Buenos Aires, Argentina	J. Sasbon	Pediatrics
1972	Children's Hospital "Pedro Elizade," Buenos Aires, Argentina	C. Bonno	Pediatrics
1972	Sick Kids, Edinburgh, Scotland	H. Simpson	Neonatology
1974	Red Cross Children's War Memorial Hospital, Cape Town, South Africa	M. Klein	Pediatric Pulmonology
1974	Great Ormond Street Children's Hospital, London, England	D. Matthews	Pediatrics
1975	Private Hospital, Uruguay	M. Gajer	Pediatrics
1975	National Children's Hospital Medical Center, Washington, DC	P.R. Holbrook A. Fields	Pediatrics Pediatrics
1975	Children's Medical Center, Dallas, Texas	D. Levin F. Morriss	Pediatrics Pediatrics/Pediatric Anesthesiology
1976	Hospital Infantil La Paz, Madrid, Spain	F. Ruza	Pediatrics
1977	Johns Hopkins Medical Center, Baltimore, Maryland	M.C. Rogers	Pediatrics/Pediatric Anesthesiology
1977	Sheba Medical Center, Israel	F. Barzilay	Pediatrics
1977	Children's Hospital of San Diego, San Diego, California	B. Peterson	Pediatrics/Pediatric Anesthesiology
1977	Hospital das Clinicas, Sao Paulo, Brazil	A. Wong	Pediatrics
1978	Sophia's Children's Hospital, Rotterdam, The Netherlands	E. van der Voort H. van Vught	Pediatrics Pediatrics
1978	Children's Hospital of Los Angeles, Los Angeles, California	E. Arcinue	Pediatrics
1979	University of Minnesota Hospital, Minneapolis, Minn.	B. Fuhrman	Pediatrics
1980	Moffett Hospital, San Francisco, California	G. Gregory	Pediatric Anesthesiology
1980	Children's Hospital Boston, Boston, Mass.	R. Crone	Pediatrics/Pediatric Anesthesiology

Adapted from references 3, 8, and 21 through 28.

survivors with chronic lung disease, retinopathy of prematurity, and hypoxic brain injury. When Morriss and Levin were first working in Dallas they complained that the beds were taken up by chronic patients. One of the pediatricians commented, "Before you started doing this, we didn't have chronic patients." This was an early observation still relevant today: Pediatric intensive care allows successful treatment of disorders previously considered hopeless, but may also result in a population of children with long-term problems that also require study and clinical attention.

Pediatric Cardiology

As previously indicated, the vision of Dr. Taussig in devising a method to treat "blue babies," in cooperation with pediatric cardiac surgeons, led to infants and children who survived surgery and then needed postoperative care. This sequence has been well documented by Dr. Jacqueline Noonan.[33] She notes that, "Much success of the surgery can be attributed to a group of pediatric intensivists, pediatric intensive care units, improved ventilatory support, and trained respiratory therapists." Advances in technology, especially for imaging, have allowed clinicians to "see" into living patients with astounding accuracy. Increased understanding of anatomy and physiology has led to improved surgical care for children with very complex problems. Perhaps ironically, some recent developments in cardiac catheterization and interventional radiology have enabled clinicians to treat many lesions without surgery, improving outcomes without the need for open-heart surgery and potentially difficult postoperative intensive care. The burgeoning growth of techniques, both interventional and surgical, has resulted in many centers creating specific cardiac intensive care units often run by pediatric cardiac intensivists, although not without some controversy in the world of PCCM.

Poliomyelitis

The interwoven history of resuscitation and ventilation, anesthesia, anatomy and physiology, pediatric anesthesiology, pediatric general and cardiac surgery, neonatology, and pediatric cardiology all come together in an astounding story of the treatment of paralytic polio and respiratory failure ("bulbar polio"). The confluence of great scientific and clinical minds and the organizational efforts of physicians, nurses, and technicians addressing the needs of polio patients rapidly led to the creation of PICUs. In 1929, Philip Drinker, an engineer, Dr. Louis Shaw, and Dr. Charles F. McKhann published their experience with a mechanical ventilator which was an electrically powered negative-pressure body tank, eventually termed the "iron lung" by a now unknown journalist (Figure 1-2).[34] On October 12, 1928, an 8-year-old girl with polio and difficulty breathing was admitted to BCH. On October 13, her respiration was failing and she was placed in the respirator at low pressure. She improved and was taken off the device, but on October 14, she was comatose and cyanotic and was placed back in the respirator at high pressures. She regained consciousness and a little later asked for ice cream. "Most of the people who witnessed the scene were in tears."[14] Even though this patient died on October 19, with necropsy findings of poliomyelitis and bronchopneumonia, the device subsequently saved the lives of a student nurse at Bellevue Hospital in New York and a Harvard College student at Peter Bent Brigham Hospital.

As dramatic as this was, it seems to be overshadowed by the remarkable polio epidemics in Los Angeles in the early 1950s and in Copenhagen in 1952.[14] Writing in 1953,[35] H.C.A. Lassen, Chief Epidemiologist of the Department of Communicable Disease, Blegdam Hospital, Copenhagen, describes treating 2772 patients for polio between July 24 and December 3, 1952. Of these, 866 patients had paralysis and 316 of these were in respiratory failure. Of the 316, 250 eventually underwent tracheotomy. Previously, starting in 1948, such patients underwent tracheotomy and suctioning for secretions without ventilatory support, but all died. Of the 15 patients treated with a mechanical respirator without tracheostomy, five patients, one adult and four children, survived. During the first month of the 1952 epidemic, of the 31 patients with respiratory paralysis, 27 died, for a mortality rate of 85% to 90%. Thereafter they consulted Dr. Bjorn Ibsen, an anesthesiologist, who suggested tracheotomy, rubber-cuff tubes, and manual positive-pressure ventilation ("iron lungs" were not commonly available in Europe at the time) using a rubber bag. From August 28 to September 3, 1958, they were admitting 50 patients a day, 12 of whom had respiratory failure and were admitted *to a special unit for respiratory care.* In this unit they had as many as 70 cases at once in respiratory failure. There were 200 patients admitted to the unit who underwent tracheotomy, manual positive-pressure ventilation with 50% oxygen, and suctioning. They employed 200 extra nursing

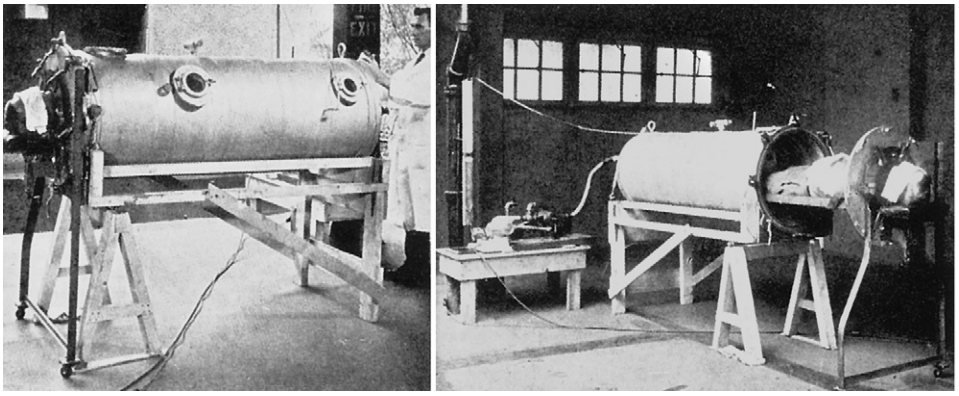

Figure 1–2. The Drinker negative-pressure mechanical ventilator. *(Reproduced with permission, Blackwell Scientific Publications, Oxford.)*

auxiliaries (students and aides), 200 medical students at a time each working 8-hour shifts to provide manual ventilation (1000 in all), and 27 technicians per day to care for the patients.[35-37] The mortality decreased from 90% to 40%. Ibsen adds that the first patient was a 12-year-old girl with paralysis of all four extremities and atelectasis of the left lung, who was gasping for air and drowning in her own secretions. She had a temperature of 40.7° C and was cyanotic and sweating. The tracheotomy was done under local anesthetic and a cuffed endotracheal tube was inserted. During the procedure she became unconscious. They connected her to the ventilator but could not ventilate her. He then gave 100 mg of pentothal IV and she collapsed, her own respirations stopped, and he could then provide manual ventilation. She then developed signs of carbon dioxide retention even with full oxygenation (rise in blood pressure, skin clammy, and sweating), and she again started her own respirations with gagging and bucking. Secretions began to pour out of her mouth and nose. This was relieved in a few moments with increased ventilation but then her blood pressure dropped and she appeared to be in shock. He gave a blood transfusion and her condition improved, with her skin becoming warm, dry, and pink, "Which always makes an anesthesiologist happy." A chest radiograph showed atelectasis of the left lung and she was placed on a mechanical positive-pressure ventilator, after which all the signs of underventilation recurred, along with cyanosis. She was given supplemental oxygen and her color improved, but she still showed signs of carbon dioxide retention. Manual ventilation was started and she improved.[36]

He concluded that tracheotomy with local anesthetic without an endotracheal tube in place was too difficult. The patients were anxious, vomited, aspirated, and had airway spasms. Few survived, so they started doing the tracheotomies earlier with endotracheal intubation and anesthesia and had great success.[36,37] Another change in strategy was that patients from outlying areas were being sent in ambulances without sufficient attendants and airway care and arrived moribund. They started to send teams in ambulances out to the pick up the patients in the countryside, with marked improvement ("retrieval teams"). This was the beginning of an important aspect of PCCM that many believe still has great potential for improving care in the future and which remains far from fully implemented. They also started passing stomach tubes for nutrition and the rubber-cuffed tubes were replaced with a silver cannula. Even with all the improvements he concludes, "Naturally we ran into a lot of complications."[37]

They also received help from other bright people who were focusing their efforts on treating polio. The clinical biochemist Poul Astrup developed a method to measure carbon dioxide, and C.G. Engstrom constructed a volume-preset positive-pressure mechanical ventilator. This spectacular and thrilling story resulted in a cohort of patients in respiratory failure in a single geographical area being cared for by full-time physicians, nurses, and technicians.

Although these units tended to disband after the summer-fall polio season, they led to the creation of full-time units, the first of which was described by Dr. Goran Haglund in 1955, at the Children's Hospital of Goteberg, Sweden.[23] He called the unit a Pediatric Emergency Ward. The patient who inspired Dr. Haglund to organize the unit was a 4-year-old boy who was operated on in 1951 for a ruptured appendix. Postoperatively, he lapsed into a coma and the surgeon declared they had done all they could and he would die of "bacteriotoxic coma." The anesthesiologist offered to help and the boy was intubated, given manual positive-pressure respiration with generous oxygen, tracheostomized, and given a large blood transfusion. After about 8 hours, the bowels started to move, and 4 hours later he was out of coma. After 20 hours, he had spontaneous respiration and had been successfully treated for respiratory insufficiency and shock. The unit had 7 acute care beds, 6 full-time nurses and 15 nursing assistants, with 24-hour coverage. In the first 5 years, the team treated 1183 infants and children, with a mortality rate of 13.6%. Haglund goes on to state, "But what we did was something else. It was the application of the basic physiology to clinical practice. Our main purpose was not to heal any disease, it was to forestall the death of the patient. The idea was—and is—to gain time, time so that the special medical and/or surgical therapy can have desired effects."[23] (Morriss and Levin[38] took this approach in organizing the first edition of their textbook in 1979.) He was also careful to point out that, "There are few jobs more exacting, demanding, and taxing than emergency nursing. Our nurses and nurse assistants are tremendous. They must be!"[23]

Nursing

As has been shown, the dissemination of the knowledge and skills that the anesthesiologists had developed in the operating room to postoperative recovery rooms, surgical and medical wards, and eventually to geographically defined units, permitted improved treatment of patients with a variety of disorders, only some of which required surgical intervention. Among the diseases treated were polio in the 1920s to 1950s, tetanus in the 1950s and 1960s, and Reye syndrome in the 1970s and 1980s.[3] These epidemics, along with developments in neonatology, pediatric general and cardiac surgery, and pediatric cardiology created a demand for greater services for more unstable patients. The events paralleled those in the world of adult critical care, with early intensive care units opened in 1923 at Johns Hopkins in Baltimore, a three-bed unit for postoperative neurosurgical patients directed by Dr. W.D. Dandy,[10,39,40] in 1953 at North Carolina Memorial Hospital in Chapel Hill, North Carolina, in 1954 at Chestnut Hill Hospital, Philadelphia, in 1955 at the Hospital of the University of Pennsylvania in Philadelphia,[41] and 1958 at Baltimore City Hospital (Dr. Peter Safar) and Toronto General Hospital (Dr. Barrie Fairley).[3]

Although many sources emphasize the role of advanced technology in the creation of adult, neonatal, and pediatric ICUs,[3,24] it is interesting to consider the important role of nursing in this evolving process. Porter,[42] as well as others, reminds us of the vital role of nursing in triage and organization of care for patients by degree of illness. Long before the organizational efforts just described, Florence Nightingale (1820-1920) organized the military hospital at Scutari in 1854, during the Crimean War, to provide more care to the most severely injured soldiers by grouping them together. Although the care consisted mostly of better hygiene and nutrition, the mortality rate dropped from 40% to 2%.[43] These efforts were continued in the United States by Dorothea Dix (1802-1887) and Clara Barton (1821-1912), the "Angel of the Battlefield," during the American Civil War, and when Barton brought the Red Cross to America in 1882. It was Nightingale who provided the definition of nursing as "helping the patient to live."[42,43] Fairman and Kagan[41] conducted an interesting study looking

at the creation and evolution of an adult intensive care unit by researching the historical records and interviewing the people involved at the Hospital of the University of Pennsylvania from 1950 to 1965. They emphasize that there really was no new equipment, only the migration of existing equipment from the operating room to the wards. In fact, some nurses remembered that they did not really have much in the way of equipment at all, even monitors. Certain social factors and the need for nurses were much more influential in forming geographically defined units away from the operating room or recovery room. Most patients at that time were operated on for gallbladder disease, appendectomies, and tonsillectomies. Poor patients were admitted to the ward postoperatively and wealthier patients were admitted to private or semi-private rooms and hired, at their own expense, private-duty nurses to care for them. This resulted in a two-tier system, with poorer patients having little postoperative care. Then a shortage of private-duty nurses occurred; many private-duty nurses refused to work nights, weekends, and holidays, and nurses with less training worked "off-shifts." Surgeons and families complained they could not get care, and of course the poorer patients did not receive adequate care at all. The hospital, to save money, (the average cost per patient per day for recovery room care in 1960, at Baltimore City Hospital, was $50 to $80)[44] demanded more from existing hospital nurses, tried to hire more private-duty nurses at family expense, and failing that, shifted some semiprivate patients to the ward. This resulted in complaints of noise (from patients) on the ward and understaffing to the point of safety concerns. One of the patients became disconnected from a ventilator and died unnoticed.

There was a move by nurses for better training, improved safety, and better staffing, as well as for more specialized rooms to organize the care of the sickest surgical and medical patients in architecturally distinct areas at no extra cost to the patients. This resulted in the creation of the Fifth Special Unit, closure of obsolete wards, and a more egalitarian admission policy to the special unit. There developed a shared sense of adventure between nurses and physicians in the ICUs, which seemed like experimental laboratories. Similar development was mirrored in PICUs, and the camaraderie and spirit were evident. The ICU nurse in adult, neonatal, and pediatric units rose to the top of the ladder in the hospital hierarchy. As one graduating Dartmouth Medical School student said in his class address, "When I started on clinical rotations I needed to learn how to function in the hospital. In order to do this I needed to understand the hierarchy in the institution. It quickly became apparent to me that the ICU nurse was at the very top of the pecking order."[45]

Several other references to the central importance of nursing in creating and enabling intensive care to develop have been cited.[3,8,23,30,31,42] As Fairman and Kagan[41] conclude, "…powerful social contextual forces, such as workforce and economics, architectural changes, and an increasingly complex hospital population—rather than new technology—supported the development of critical care."

Pediatric Critical Care

Getting Started

As we have seen, geographically defined PICUs, directed by specific medical and nursing personnel, emerged in the 1950s and 1960s and gathered momentum in the 1970s. These early units were heavily influenced by pediatric anesthesiologists (Table 1-1). But even in the 1970s, the future of these units and the role of pediatricians in them were far from certain.

We all owe a great deal to the efforts and leadership of Drs. Downes, Todres, Shannon, and Conn. The first physician-directed multidisciplinary PICU in North America was established at Children's Hospital of Philadelphia (CHOP) in January, 1967, as an outgrowth of a hospital-wide respiratory intensive care service.[3] The unit consisted of an open ward of six beds equipped with bedside electronic monitoring (electrocardiography, impedance pneumographic respiratory rate, and two direct blood pressure channels) and respiratory support capabilities. An adjacent procedure room could serve as an isolated seventh bed. An intensive care chemistry laboratory, manned 24 hours per day by a technician, was located next to the unit with a pass-through window for handing blood samples and receiving written reports. The nurses were assigned full-time to the unit, and most had previously served in the recovery room or the infant ICU for patients on the cardiac surgery or respiratory intensive care services. Dr. Downes was the medical director and worked closely with two other anesthesiologists, Dr. Leonard Bachman, Chief of Anesthesiology, and Dr. Charles Richards, an allergist/pulmonologist, Dr. David Wood also shared duties and call. One of four pediatric anesthesiology/critical care fellows was in or immediately available to the PICU on a 24-hour basis. Rounds with the nurses, fellows, and anesthesiology staff physician on service were conducted each morning and late afternoon. They were most fortunate to have close relationships with Dr. C. Everett Koop (Chief of Surgery and strong supporter of critical care), Dr. William Rashkind (the father of interventional pediatric cardiology), Dr. John Waldhausen (one of the nation's few full-time pediatric cardiac surgeons and a creative thinker), and Dr. Sylvan Stool (a pioneer in pediatric otolaryngology), as well as the support of numerous pediatric and surgical consulting staff and house officers. In 1971, at the Hospital for Sick Children in Toronto, Dr. Alan Conn resigned as director of the department of anesthesiology to become director of a new multidisciplinary 20-bed PICU, by far the largest and most sophisticated unit in North America. The establishment of this unit and a critical care service culminated a decade of efforts by Dr. Conn and his associates. They were able to cohort critically ill older infants and children in one geographic area that was not a postanesthesia recovery area. This advanced complex was the forerunner of units developed in major pediatric centers throughout North America over the following decade.[3] Also in 1971, Dr. David Todres, an anesthesiologist, and Dr. Daniel Shannon, a pediatric pulmonologist, founded a 16-bed multidisciplinary unit for pediatric patients of all ages at the Massachusetts General Hospital.[3,8] Each of these units also established vibrant training programs in critical care medicine and conducted clinical research. Among their numerous accomplishments, Dr. Conn became a noted authority on the management of near-drowning victims, and Dr. Todres pioneered long-term mechanical ventilation for children at home with chronic respiratory failure. These early PICUs and their training programs had a favorable impact on mortality and morbidity rates—particularly those associated with acute respiratory failure—and led to the development of similar units and programs in most major pediatric centers in North America and Western Europe during the 1970s and early 1980s.

In 1966, after internship, Dr. Max Klein joined Drs. H. de V. Heese and Vincent Harrison in a two-bed neonatal research unit at the Groote Shuur Hospital in Cape Town. Over the course of the next 2 years and more, their research resulted in many significant papers, not the least of which was "The Significance of Grunting in Hyaline Membrane Disease,"[46] demonstrating that oxygen tensions fell when infants were not allowed to grunt. This provided the rationale for the application of CPAP, an artificial grunt, to these patients. By 1969, pediatric patients at Red Cross War Memorial Children's Hospital with respiratory failure (e.g., Guillain-Barré) were ventilated on the wards and deaths were common. There was no centralized facility for older children. He encouraged Dr. Malcolm Bowie (consultant) to start a six-bed ICU, or "high-care ward," originally in collaboration with the anesthesiology staff. In 1971, Dr. Klein did a year of adult pulmonary fellowship with Professor M.A. de Kock at the University of Stellenbosch and then 2 years at the CVRI, UCSF. When he returned to Cape Town in 1974, he combined the neonatal tetanus ward of Dr. Smythe and the six-bed ICU of Dr. Bowie into the first full-time PICU in South Africa. An important aspect of the effort was that, at the time, the hospital was racially segregated. It took Dr. Klein *25 years of persistent effort* to create a nonsegregated PICU. He is truly deserving of a Perseverance, Size 1 award.[47]

The path to providing care for the sickest patients on a full-time basis remained unclear for an extended period. Subsequent early leaders in the field each carved out his own path. Dr. Daniel Levin completed pediatric cardiology and neonatology fellowships to learn how to take care of sick children, but found few chairmen interested in hiring an "intensivist." Dr. Nicholas Nelson, Chairman of Pediatrics at Penn State University Medical School in Hershey, would permit him to work at developing a PICU on the side, but he did not think it would work. A few years later he hand wrote a letter to Levin, actually apologizing and indicating that he now believed that in the near future, children's hospitals would be nothing but ICUs and most other patients would be cared for as outpatients. In 1974, Dr. Abraham Rudolph, one of Dr. Levin's mentors, inscribed his new book, *Congenital Diseases of the Heart,* "Wishing you the best in your chosen career as an 'intensivist" (quotes his). A career as a pediatric intensivist was far from a sure thing. In 1975, Drs. Levin and Frances Morriss (pediatrics and pediatric anesthesia) were recruited to Dallas by Dr. Theodore Votteler, Chief of Surgery and a former trainee of Dr. Koop, and by Heinz Eichenwald, Chairman of Pediatrics, to start a PICU at Children's Medical Center of Dallas.

In 1970, when Dr. Peter Holbrook finished medical school, he had been exposed as a student to the work of Dr. John Downes at CHOP. He also knew he wanted to work full-time taking care of the sickest children, but during his residency at Johns Hopkins he was discouraged by prominent pediatricians and told by some of the earliest leaders in the field that he needed to become an anesthesiologist. Dr. Peter Safar at Pittsburgh, however, welcomed him as a fellow in critical medicine in a personalized program to prepare him for PCCM. Dr. Safar told him, "We've been waiting for you."[27] In 1975, Dr. Holbrook and pediatrician Dr. Alan Fields, who also trained in Pittsburgh, went to Children's Hospital National Medical Center, as pediatricians in the Department of Anesthesia, to run their PICU.

Dr. Bradley Fuhrman finished his residency in 1973 and did both pediatric cardiology and neonatology fellowships to master both cardiovascular and pulmonary life support. In his words, "it seemed like the best route at the time."[48] After finishing the fellowships, he started the first PICU at the University of Minnesota Hospital in 1979.

Dr. Mark Rogers recognized the lack of senior supervision of interns during his pediatric residency in Harvard-affiliated hospitals. Like many of the early intensivists he was discouraged that junior people were left in charge of the sickest children. He subsequently studied pediatric cardiology and then chose to complete an anesthesiology residency. He was appointed director of Pediatric Intensive Care at Johns Hopkins after his residency. There were so few of this new breed of "intensivist" that many became directors right after completion of residency or fellowship. At the beginning, no one wanted to be responsible for pediatric intensive care.[28]

Dr. Bradley Peterson[49] went into the military service after his pediatric and neonatology training and then took an anesthesiology residency at Stanford. Upon completion of the latter, he opened the PICU at Children's Hospital of San Diego in 1977. Dr. George Lister[50] had many of the same experiences and thoughts as a resident at Yale. He found sicker older children scattered around the hospital without an organized approach to their care. He studied cardiorespiratory physiology and improvised a training program at the CVRI to gain the background and knowledge to take care of critically ill children. Post-cardiac surgery infants were cared for in the NICU and older children in the adult ICU, at Moffett Hospital. He started his attending career there in 1977 in the combined adult-pediatric ICU and, due to the director's illness, quickly found himself as the co-director of the unit.[51]

Eventually more and more pediatricians decided to devote their careers to being members of a multidisciplinary team taking care of the sickest children in hospitals on a full-time basis. In 1975, the CHOP program started to accept PCCM trainees who were pediatricians without anesthesia residency. The field grew rapidly in the late 1970s and 1980s.

During this time period, Calvin[39] indicated there was a struggle for authority in adult units, with some clinicians trying to change the culture of intensive care from one in which each different service cared for its "part" of the patient to one in which a full-time service was consistently available, and cared for the whole patient, with the help of consulting specialties. Although this conflict was probably worse in units for adults, it was certainly a prominent issue in PICUs as well.[27]

The Present

Although the field of PCCM was undergoing a period of rapid growth, it faced several problems. These were: (1) the need for a common "home" or national structure in which to meet and communicate; (2) acceptance or validation of pediatric critical care as a subspecialty; (3) education within the field; and (4) academic credibility with meaningful research.

A small group of interested people met at the Society of Critical Care Medicine (SCCM) National Education Forum in San Francisco in 1979 to discuss structure and a home.[27,52] There were about 15 people present, and memories have faded, but Drs. Holbrook, Gregory, Downes, Raphaely, Vidayasagar, and Levin were among them. It was decided to petition the SCCM to form a section of pediatrics. The society had no

subsections, but the petition was successful, and the pediatric section was formed in 1981.[3] In 1981, Dr. James Orlowski, with the support of others, petitioned The American Academy of Pediatrics (AAP) to form a section of Pediatric Critical Care or Intensive Care Medicine within the AAP. Although there was some controversy and some within the AAP wanted the new section to be housed within in an existing section (such as Anesthesiology, Emergency Medicine, or Diseases of the Chest), the petition was successful and the section began in 1984.[52] These organizations provided structure, places to meet, and opportunities to discuss common goals and concerns. Increasing international investment in pediatric intensive care was recognized with the first World Congress of Pediatric Intensive Care in Baltimore in 1992 and foundation of the World Federation of Pediatric Intensive Critical Care Societies (WFPICCS) in Paris in 1997 by Dr. Geoffrey Barker and others, providing a global platform for the field.[28]

Acceptance and legitimization were reflected in, and enhanced by, establishment of a new sub-board of Pediatric Critical Care Medicine of the American Board of Pediatrics in 1985, and the first certifying examination occurred in 1987.[53] Certification provided clear guidelines for hospital credentialing of PCCM physicians[54] and in 1989, special requirements for training in PCCM were developed by the American College of Graduate Medical Education (ACGME) with formally accredited programs first recognized in 1990.[53] In 1983, a committee of the SCCM developed guidelines for PICUs,[4] which have been regularly updated.[5,6]

In 1979, Ross Planning Associates indentified 150 PICUs of four or more beds, and another 42 were thought to exist (total 194).[3] Only 40% had a pediatric intensivist available at all times. Forty percent had fewer than seven beds and only one half had transport systems. By 1995, there were 306 general PICUs and in 2001 there were 349. Of these, 94% had a pediatric intensivist on staff. Pediatrics ward beds decreased by 22.4% between 1980 and 1989, by 10.8% between 1990 and 1994, and by 15.7% between 1995 and 2000. During the same three time periods, PICU beds increased by 26.2%, 19.0% and 12.9%, respectively.[7] The first subboard examination in 1987 certified 182 PCCM subspecialists. By 2006, there were 1454. In 1983-1984 there were 32 PCCM training programs, and the ACGME accredited 28 of them in 1990. By 2008, there were 62 PCCM training programs.[53] The number of fellows enrolled in PCCM has increased by 40.8% since 1997 (2006 figure) and the percent of women fellows increased from 39.6% to 44.6% from 1997 to 2006, peaking at 45.4% in 2000-2001. Eighty-five percent of applicants intended to work exclusively as intensivists.[54]

Education within the field has progressed rapidly. Educational programs at the annual SCCM, AAP, Pediatric Academic Societies, and American Thoracic Society meetings have been supplemented by a unique volunteer effort, started in 1983 by Dr. Hector James, a pediatric neurosurgeon from San Diego, and continued by Dr. Peter Holbrook in 1984, called the Pediatric Critical Care Colloquium (PCCC). National and regional organizations around the world conduct many other specialty-specific meetings. There have been many textbooks in the field in many languages including texts specifically for PCC nurses (Table 1-2). Through the efforts of members of the SCCM, that society's journal, *Critical Care Medicine*, and WFPICCS, a new journal, Pediatric Critical Care Medicine, began in 2000, edited by Patrick Kochanek.[81]

Academic credibility that results from meaningful scientific research has come slowly. In the early days, intensivists were mostly consumed by clinical and administrative responsibilities, but high-quality science, addressing a broad range of problems, has gradually emerged. Huge amounts of effort and money in PCCM have gone into clinical trials in attempts to improve therapy, but have failed to deliver on some promises[24] such as liquid ventilation,[82,83] recombinant bacterial/permeability–increasing protein ($rBPI_{21}$),[84] and activated protein C.[85] This may have as much to do with the incredibly difficult task of performing large clinical trials on very sick children as the validity of the concept or experimental design.

In the early 1990s, the Pediatric Critical Care study group was formed and led by Dr. Gregory Stidham of LeBonheur Children's Hospital.[24] In 1998, Dr. Adrienne Randolph initiated a clinical trials group with early assistance from Drs. Jacques Lacroix and Douglas Willson, that was initially formed to assist each other with oversight and conductance of three multicenter trials[86-88] and which subsequently evolved into the Pediatric Acute Lung Injury and Sepsis Investigators (PALISI). By directly applying the already successful programmatic model of research developed by the Canadian Critical Care Trials Group (CCCTG),[89,90] PALISI has grown and prospered due to the cooperative volunteer spirit of the more than 70 North American member units, with[91] many publications in high-quality journals, ongoing funded clinical trials and observational studies, and active new protocol development. The Virtual PICU started in 2000, and Drs. Randall Wetzel of Children's Hospital of Los Angeles and Thomas Rice of The Children's Hospital of Wisconsin have created a massive database for research and quality control.[24] In Canada, the "Pediatric Interest Group" was created in the year 2000 within the CCCTG by Drs. Jacques Lacroix, James Hutchison, and Haresh Kirpalani, with the help of the Canadian Institutes of Health Research.[92]

In April 2004, the National Institute for Child Health and Human Development established funding (renewed in 2009) for the first network supporting pediatric critical care research, the Collaborative Pediatric Critical Care Research Network (CPCCRN), "To initiate a multicentered program designed to investigate the safety and efficacy of treatment and management strategies to care for critically ill children, as well as the pathophysiologic basis of critical illness and injury in childhood."[93] In the first 5 years, a number of landmark studies including observational studies on bereavement, opioid tolerance, and pertussis were initiated as well as several interventional trials, including a randomized controlled trial of immune prophylaxis and a study developing and testing a functional status outcomes scale. The NIH has also supported research in PCCM through the Pediatric Critical Care Scientist Development Program (PCCSDP), a K-12 program funded by the Eunice Kennedy Shriver National Institute of Child Health Development to support the development of young physician scientists in pediatric critical care. The PCCSDP entered its second project period in 2009, under the continuing direction of Dr Michael Dean at the University of Utah.[94]

The growth of education and research in PCCM has coincided with better care for children. In addition to the examples of diseases such as polio, tetanus, and Reye Syndrome that were stimuli for forming the subspecialty, examples such as the decrease in mortality from septic shock help demonstrate the improvement. During the period from 1958 to 1966, the

Table 1–2 Textbooks in Pediatric Critical Care Medicine

1st Edition	Title	Editors	Ref #
1971	*The Care of the Critically Ill Child*	R. Jones, J.B. Owen-Thomas	55
1971	*Pediatric Intensive Care: Manual*	K. Roberts, J. Edwards	56
1972	*Nelson's The Critically Ill Child: Diagnosis and Medical Management*	J. Dickerman, J. Lucey	57
1979	*A Practical Guide to Pediatric Intensive Care*	D. Levin, F. Morriss, G. Moore	38,58-60
1980	*Tratado de Cuidados Intensivos Pediatrucos* (Textbook of Pediatric Intensive Care)	F.J. Ruza	61
1984	*Nursing Care of the Critically Ill Child*	M.F. Hazinski	62
1984	*Textbook of Critical Care*	W.K. Shoemaker, W.L. Thompson, P.R. Holbrook	63
1984	*Pediatric Intensive Care*	E. Nussbaum	64
1985	*Temeas em Terapia Intensiva* (Issues in Pediatric Intensive Care)	J. Piva, P. Carvalho, P. Celiny Garcia	65,66
1985	*Critical Care Pediatrics*	S. Zimmerman, J. Gildea	67
1987	*Pediatric Intensive Care*	J.P. Morray	68
1988	*Pediatric Intensive Care*	M. Rogers	69
1992	*Pediatric Critical Care*	B.P. Fuhrman, J.J. Zimmerman	70
1993	*Textbook of Pediatric Critical Care*	P.R. Holbrook	71
1994	*Urgences & Soins Intensif Pediatriques*	J. Lacroix, M. Gauthier, F. Beaufils	72
1995	*Critical Heart Disease in Infants and Children*	D.G. Nichols, D.E. Cameron, W.J. Greeley, D.W. Lappe, R.M. Ungerleider, R.C. Wetzel	73
1996	*Critical Care of Infants and Children*	I.D. Todres, J.H. Fugate	74
1996	*Critical Care Nursing of Infants and Children*	M.A. Curley, J. Bloedel-Smith, P.A. Moloney-Harmon	75
1997	*Illustrated Textbook of Pediatric Emergency & Critical Care Procedures*	R.A. Dieckmann, D.H. Fiser S.M. Selbst	76
1997	*Paediatric Intensive Care*	N.S. Morton	77
2001	*Manual de Cuidados Intensivos Pediatricos*	J. Lopez-Herce Cid, C. Calvo Rey, M.J. Lorente Acosta, A. Baltodano Aquero	78
2005	*Cuidudo Intensivo Pediatrico y Neonatal*	J. Forero, J. Alarcon, G. Cassalett	79
2007	*Pediatric Critical Care Medicine: Basic Science and Clinical Evidence*	D.S. Wheeler, H.R. Wong, T.P. Shanley	80

mortality of gram-negative bacteremia in patients less than 16 years of age at the University of Minnesota was 60% in medical and 40% in surgical patients.[95] The mortality in septic shock was 95%. Now is it less than 10% and continues to be a major focus of clinical and research attention.

Drs. Murray Pollack and Timothy Yeh have shown us how to study severity-adjusted mortality in pediatrics and demonstrated that patients do better[96] when cared for by pediatric intensivists. Dr. Debra Fiser's group[97] has shown us there is improvement in mortality in patients with respiratory disease. Although many would attribute the improvements to technology and scientific advances, Dr. Yeh and others remind us it is possible that the presence of a full-time team and attention to a few basic principles rather than great investment in exotic high-technology solutions improves outcomes.[98] This is echoed by Dr. Frank Shann, who has two rules of PCCM: Rule 1 is "the most important thing is to get the basics exactly right all of the time"; Rule 2 is "organizational issues are crucially important.[28] Yeh as well as Ibsen[37] and Richard Orr have emphasized the important contributions of regionalization and the quality of PCCM transport teams in improving outcomes.[99,100]

The Cost of Success

Everything comes at a cost. In the field of PCCM, as in many others, advances have lead to increased cost, chronic disease, medical errors, and dehumanization of patients. The spiraling cost of medicine in general and intensive care in particular are well known and have been well presented by Dr. Downes[3] so will not be discussed further here.

As mentioned earlier, most intensivists are fully aware of and are distressed by the increased population of chronic patients who have prolonged PICU stays and frequent readmissions. Most of these patients did not exist previously; they died. Although we return many sick children to complete health, many children who would have died previously now live with chronic neurologic, respiratory, cardiac, and renal disease and residual problems from surgery, oncologic disease, and other causes.

Medical errors come in many forms. In addition to the well-publicized problems with staff fatigue, the tremendous complexity of the patients and environment makes individual errors a frequent occurrence. In addition, many systemic errors occur, not due to individual staff members' mistakes or fatigue but due to overarching issues such as equipment design and use, treatment regimens, communications, inherent problems with medications, and others. These have been well documented in neonatology by Drs. Silverman[101] and Robertson.[102-104] Well-intentioned, but in some cases not well-designed or reasoned, interventions have caused a great deal of morbidity and mortality. Many approaches that for long years were thought to be correct are now thought to be harmful, useless, or incorrect (e.g., normalizing $PaCO_2$ and PaO_2,[105] and transfusing patients from hemoglobins of <10 g/dL to >12 or 13 g/dL[87]).

In an extremely technical, frenetic environment, dehumanization of patients is always a danger. The story of intensive care for children has moved from triumph to triumph. However, in the process, the public has perceived that although medicine has succeeded on the technical level, it has lost much of its human touch, becoming more impersonal and forbidding. Some have stated that medicine has lost its way, although clinicians have started to reclaim this lost heritage of caring and compassion. This has been particularly true in end-of-life care, with the combined expertise of both intensivists and palliative care-givers. Pediatric intensivists have come to the realization that caring for critically ill children requires the simultaneous gathering of information in two areas. One is the disease itself, which includes the symptoms, signs, investigations, and clinical management. The other is the context of illness, which is the patient's and family's agenda of concerns, expectations, feelings, and thoughts that are unique to each individual and family. An intensivist acts to bring about a positive good or benefit to the patient; however, experience in the PICU has shown that conflicts arise when the presumption to save life (a good) requires interventions that may cause undue suffering. The more aggressive are the efforts to reverse illness, often the more suffering is inflicted on the patient. This leads to a situation where the physician begins to question how far to pursue these procedures. These ethical dilemmas are increasingly receiving the attention of intensivists. Ethics committees have been helpful in providing the health care team with important perspectives in approaching these difficult issues. Early on we asked, "How to do procedures," then we asked "When to do procedures," and increasingly we have asked, "Should we do procedures?"

In many units an increasingly diverse patient population has sensitized intensivists to the need to understand and respect individual cultural differences. Stereotyping a particular culture fails to respect individual differences. Increasingly, care is centered on the patient and family in recognition of the effects of personal spiritual/religious, cultural, and family values on patients' illness and recovery and in coping with the end of life. In many PICUs, chaplains are brought to the bedside and become part of the intensive care team.

The addition of child psychiatrists and social workers to the PICU consulting team has helped families and children cope with the severe and devastating effects of critical care illness. For the health care team, the long hours of stressful work and the occasional feelings of despair and frustration that all the hard work is not making a difference lead to emotional distress and a sense of loss of fulfillment in their professional lives. Understanding this problem and helping the team to realize they are making an important difference and are valued will reduce burnout and enhance staff morale. To illustrate the importance of knowing that one's effort does make a difference in people's lives, the following letter received by one of the nursing staff after a visit to the family at home stated,

"In the almost 3 weeks that we were in the pediatric ICU (PICU), we witnessed two deaths besides our son's….We know that death is part of your job and therefore must be dealt with as each sees fit….it seems funny that we'd be so happy to see people we barely know but your visit and the effort you took to come signifies a great deal. It meant that you DID care about our baby. And the solace received from your caring was—and is—immense. Special thanks for that….Please do not feel that your encouragement helped to give us false hope. Hope is what got us through those 3 weeks. Despair could wait."

One way we have attempted to support patients and families is to include families as members of the team by having them present at rounds with their child.[106] This effort allows the family, and often the patient, to hear what the team has to say and to ask questions, both of which empower the family and build trust.

Around the World

We have alluded to the many contributions of people around the world to the evolution of PCCM, both through innovative treatment of specific diseases (e.g., polio[3,14,35,36] and tetanus[30]), and in organizing and creating PICUs (see Table 1-1), and education (see Table 1-2).[107] What follows below are the varied contributions from many places, using a geographical approach.[8]

Canada

At the Hospital for Sick Children in Toronto, Dr. Alan Conn, anesthetist-in-chief, had the vision of developing an ICU utilizing his anesthesiology skills. In 1971, he took on the position of full-time director of critical care and initiated a flourishing clinical and research program. Dr. Conn was followed by Dr. Geoffrey Barker, who continued to promote the unit as one of the leading PICUs in the world. Dr. Barker's vision of the need to bring together intensive care from many parts of the world led to his directorship of the WFPICCS, which has done much to foster the development of pediatric critical care in countries around the world and to bring the skills and experience so vital in this practice to the benefit of multiple countries. In Montreal, the first patient was mechanically ventilated outside the postoperative recovery room in 1965, in what would later be named the PICU. This unit was first run by Dr. Paul Stanley, a pediatric cardiac surgeon. A medical PICU was created in 1972 by a pediatrician, Dr. Michel Weber, and pulmonologist Dr. André Lamarre. The units were merged in 1982. Drs. Marie Gauthier and Jacques Lacroix (Université de Montreal) and John Gordon (McGill University) were very active in the development and implementation in 1992 of a fellowship program in PCCM supervised by the Royal College of Physicians and Surgeons of Canada.[92]

Africa

Dr. Pat Smythe, a pediatrician working with Dr. Arthur Bull, an anesthesiologist at the Red Cross Children's War Memorial Hospital in Cape Town, South Africa, conceived a brilliant

therapeutic plan to treat infants afflicted with tetanus from infected umbilical cord stumps. This was the first successful long-term mechanical ventilation of sick infants. A dedicated group of nursing aides caring for these infants played a crucial role in their survival. Monitoring these infants depended on close observation of chest movement and visualization of cyanosis. Routine blood gas analyses had not yet entered the scene. The Severinghaus electrode (Pco_2) appeared in 1959 and the Clark electrode (Po_2) in 1961. However, using the Van Slyke method on a sample of end-tidal gas provided a measure of Pco_2. This labor-intensive method, which was performed by the pediatric resident, was applied somewhat infrequently! In combination with the efforts of Dr. Christiaan Barnard (cardiac surgery) and Dr. Jannie Louw (general surgeon) during the 1950s and 1960s, this experience led to the logical step of applying these principles of ventilator-supported care to the other critically ill infants and children, which followed later with the designation of a special unit for critically ill children in 1974 with full time intensivists. Dr. Max Klein with Drs. Louis Reynolds, Jan Vermeulen, Paul Roux, Cass Matola, and later Andrew Argent assumed this role with distinction. Dr. Klein's commitment to psychosocial issues in the care of patients was exemplary. His vision went beyond the PICU. In an excellent home-care tracheostomy program of 60 to 70 children, he, with nurse Jane Booth, were successful in ensuring the care of these children despite dreadful home conditions. In talking with him about the program, Dr. Todres recalled his enthusiasm for the need to have these children nurtured away from the hospital, and his staff provided these children with visits to the public gardens![47,108]

Asia: Japan

In the 1960s, Dr. Seizo Iwai, Chief of Anesthesia at the National Children's Hospital in Tokyo, was the first Japanese physician to introduce long-term mechanical ventilation and arterial blood gas analysis of critically ill infants, fostering a tradition of anesthesiologists taking care of every critically ill child outside of the operating room if a child should need their expertise. He was a strong force in developing a close relationship with other Asian countries and invited trainees from those countries to promote the teaching and development of pediatric critical care. His close working relationship with Drs. Conn and Barker in Toronto, Canada, paved the way for Dr. Katsuyuki Miyasaka to study in Philadelphia with Dr. Downes. Dr. Miyasaka returned to Japan in 1977 and, in October 1994, opened the first geographically distinct PICU in Japan at the National Children's Hospital and founded the Japanese Society of Pediatric Intensive Care. He continues to foster the development of a new generation of pediatric intensivists and to play a major role in facilitating this process.[109]

India

Development of neonatal and pediatric critical care in India has been described in detail before.[110] As in the developed countries, the discipline of neonatology and neonatal critical care preceded the development of the discipline of pediatric critical care in India. NICUs in India were established in 1960s, first at All India Institute, Delhi, and subsequently at teaching hospitals in major cities.

Today almost all major cities in India have NICUs providing different levels of intensive care. The well-established NICUs provide care on a par with NICUs in the Western countries. They are equipped to provide inhaled nitric oxide therapy and to manage complex cases including extremely low birth weight, surgical, and cardiac surgical cases. The outcome results are very encouraging.[111]

The first PICUs were established at major postgraduate centers (Delhi, Chennai, Chandigarh, Mumbai, and Lucknow) nearly two decades after the development of NICUs.[112] A special interest group of the Indian Academy of Pediatrics (IAP) working in PICUs was formed in 1997, and the Section of Pediatric Intensive Care was formed in the Indian Society of Critical Care Medicine (ISCCM) in 1998.[113] The Pediatric Critical Care Council (PCCC), a joint body of the Intensive Care chapter of the IAP and the Pediatric Section of the ISCCM,[114] provides the professional practice guidelines for pediatric critical care for the practitioners and the hospitals, and has initiated fellowship training programs in recognized units.[115] Today, PCCM is the fastest growing pediatric subspecialty in India. The growth of PICUs had been mainly in the private sector, although major government teaching hospitals are also improving the PICUs in their hospitals.

Prompt access to the available critical services is critical for pediatric patients. A study at a Children's Hospital in Hyderabad, Andhra Pradesh, India has shown that patients travel long distances (up to 500 km) to seek pediatric critical care, with survival inversely proportional to the distance traveled.[116] To overcome these difficulties, a bold and innovative statewide patient transport program, the Emergency Management and Research Institute (EMRI), was started in 2005 with a fleet of 70 ambulances deployed in the state of Andhra Pradesh, India.[117] The public-private collaborative organization has 2500 staff including EMTs, support staff, and associates, and a call center in the capital city of Hyderabad. A call using number 108 from any phone in the state gives access to ambulance service in the remote parts of the state. After 5 years, EMRI has a fleet of 652 ambulances and covers 23 districts and attends to over 4500 emergency calls per day. The EMRI center is linked to 331 private and public hospitals throughout the state and because of its success, the model is being adopted in other states of the country.[118]

Replicating this success elsewhere in India and the developing world will have an immense impact on resource needs. In view of the high birth rates (annual births of 25 million) and large pediatric population (35% of total or approximately 300 million) the required number of NICU and PICU beds will be enormous. It would therefore be prudent that all District hospitals (750 in the country) be upgraded to provide good level II services to meet the needs of rural communities.[119]

Although the development of PICUs is essential for overall improvement in child survival of the developing countries, the high cost of intensive care limits patients' access to PICU services. A recent study in Papua New Guinea demonstrated that the use of pulse oximetry in addition to clinical signs before initiating antibiotics, according to a World Health Organization (WHO) protocol, decreased mortality by 30%.[120] Similar low-cost innovative approaches may meet the demands of critical care in the developing world. It is therefore important to train health care personnel in early detection of infants at risk, for example, for respiratory distress, and in early initiation of treatment that would reduce the need for admissions to PICUs.

Australia and New Zealand

As in the United States and Canada, Australian PICUs started forming in the early 1960s, arising out of postoperative recovery wards with congenital heart surgery. In 1963, Drs. John Stocks and Ian McDonald in Melbourne introduced postoperative respiratory support with prolonged nasal intubation. Other units followed in Adelaide, Perth, Sydney, and Brisbane. An important contribution to the development of intensive care was the use of plastic endotracheal tubes for prolonged intubation and ventilation. Dr. Bernard Brandstater, an Australian working in Lebanon, reported prolonged intubation as an alternate to the tracheostomy at the First European Congress in Anesthesia in 1962. The first report of prolonged intubation in 50 patients was described in the *British Journal of Anesthesia* in 1965 by Drs. McDonald and Stocks.[121] Australian pediatric critical care is highly regionalized in tertiary university services supported by sophisticated retrieval services. Until 1991, all critically ill children in New Zealand received care in adult ICUs. The first PICU opened in December 1991 at the Starship Children's Hospital in Auckland.

Since 1996, all units have contributed outcome and other data to the Australian and New Zealand Pediatric Intensive Care Registry. The registry has evolved into a multicenter trials research group, affiliated with the Australian and New Zealand Intensive Care Society Clinical Trials Group. Recent evidence utilizing various scoring systems including the registry-developed PIM (Pediatric Index of Mortality) score reveal that outcomes in the region are better than predicted.[122] A formalized training scheme evolved during the 1990s and a separate College of Intensive Care Medicine will control all training in intensive care for the region from 2010 onwards.[123,124]

Europe

In Europe, pediatric intensive care followed shortly after the poliomyelitis epidemic in Denmark in 1952. Even in the early years, it was recognized that children had a higher mortality than adults in these poliomyelitis respiratory units; thus separate PICUs were developed in Uppsala and Stockholm in the 1950s. In 1955, Dr. Goran Haglund, an anesthesiologist, established the first PICU for infants and children at the Children's Hospital in Goteborg in Sweden. In 1961 Dr. Hans Feychting, a pediatric anesthesiologist, established the first PICU in Stockholm, Sweden, and became recognized as a pioneer in the development of pediatric intensive care in Europe. He introduced many of the skills that had been developed for the operating room and were later applied to pediatric intensive care.

In France, in July 1963, a newborn presented with tetanus and was admitted to l'Hôpital des Enfants Malades of Paris. Shortly afterward, Dr. Gilbert Huault opened the first multidisciplinary PICU, in Saint Vincent de Paul Hospital. This unit was the first pediatrician-directed PICU in Europe; it soon became a major influence on the development of ICUs, and in it, Drs. Francois Beaufils and Denis Devictor were to play an important role in the further development of critical care practice in pediatrics.

In Britain, in 1964, the first PICU was opened by Dr. G. Jackson Rees, an anesthesiologist, at the Alder Hey Children's Hospital in Liverpool. Other units soon followed, essentially serving as areas allowing prolonged postoperative support. Dr. Todres worked in such a unit at the Hospital for Sick Children, Great Ormond Street, London, in 1966. Although not designated "a pediatric ICU," in essence it was a unit that operated in this manner. This experience formed the foundation of intensive care practice that followed, with primary attention to conditions that led to failure of ventilation and circulation. Here Dr. David Hatch was instrumental in developing a PICU that provided outstanding clinical care and research.[125,126]

In Spain, a pediatrician, Dr. Francisco Ruza, had started working in neonatal surgical intensive care in 1969. By 1976, he opened a multidisciplinary medical-surgical PICU for older infants and children at the "Hospital Infantil La Paz" in Madrid. This center, directed by Dr. Ruza, has served as a major training center for pediatric intensivists not only from Spain but from South America as well.[127]

The first PICUs in The Netherlands were established in the late 1970s and early 1980s at the Sophia Children's Hospital in Rotterdam, the Wilhelmina Children's Hospital in Utrecht, and the Emma Children's Hospital at the Academic Medical Center in Amsterdam. In 1995, a section on Pediatric Intensive Care Medicine was founded by the Dutch Pediatric Association, which certifies the training of nearly all Dutch pediatric intensivists in fellowship programs. The PICUs are multidisciplinary, and all are part of university teaching hospitals. A nationwide transport system to connect this centralized care system of pediatric critical care was developed. Dr. Albert Bos in Amsterdam and Dr. Edwin van der Voort in Rotterdam continue to foster the highest standards of pediatric critical care. Units were opened in Germany[128] and Slovakia[129] as well as in many other places at that time.

Israel

Although located in the Middle East, Israel has traditionally been part of the European scientific organizations. The first PICU in Israel was established in 1977 by Dr. Zohar Barzilay as a five-bed facility located within the Children's Hospital at Sheba. Now, 32 years later, Israel has 12 PICUs and two cardiac PICUs. Extracorporeal membrane oxygenation services as well as cardiac transplantation are provided nationwide as part of the national health insurance program. A special chapter in Israel pediatric critical care medicine belongs to the Palestinian pediatric population. About 30% of the patients in many of the PICUs in Israel come from the Palestinian Authority. Palestinian physicians trained in PCCM in Israel established the first PICU in Gaza.[130,131]

Latin America

In Argentina, the first PICU was established in Dr. Ricardo Gutierrez Children's Hospital in Buenos Aires in 1969 as part of a general surgery ward. In 1972, Dr. Jorge Sasbon became the first staff director of the PICU. In 1972, a PICU was set up in Pedro de Elizalde Children's Hospital under the guidance of Dr. Clara Bonno, and the unit has been a pillar of the specialty in Argentina.

Critical care progressed steadily, and the first liver transplant in a pediatric patient was performed in 1987. With the introduction of international fellowships, physicians were able to travel abroad for further training in units in Toronto, Pittsburgh, Madrid, and London. The J.P. Garrahan National Pediatric Hospital was inaugurated as a tertiary center in 1987, and has developed a sophisticated PICU under the direction of Dr. Jorge Sasbon.

In Brazil in the 1970s, epidemics of polio and meningococcal disease with high mortality led to the creation of small units for the care of these patients, attended to by personnel with skills and technical resources (although they were scarce). These units were the precursors of PICUs later established at Hospital das Clínicas São Paolo by Dr. Anthony Wong (1977), at Hospital São Lucas in Porto Alegre by Dr. Pedro Celiny (1978), and in Rio de Janeiro. At the same time, neonatal intensive care was developing, and the model of the NICU was transferred to the care of critically ill children in the 1980s. In 1982, Dr. Jefferson Piva opened a 13-bed PICU at Hospital da Criança Santo Antonio in Porto Alegre.[132]

In 1984, the first Brazilian Pediatric Intensive Care Congress in São Paolo took place. These congresses continue annually. At the three major tertiary centers in São Paolo, Rio de Janeiro, and Porto Alegre, government agencies actively support research programs. Pediatric intensivists in the Brazilian Pediatric Society and the Brazilian Critical Care Society worked together to establish the subspecialty, with examination certification commencing in 1990. Brazil's intensivists also are active in cooperative efforts with other Latin American intensive care societies. One of the pioneers of development of pediatric critical care in Latin America was Dr. Mauricio Gajer, a dedicated physician from Uruguay. Dr. Gajer, with the stimulus of Professor Ramon Guerra, created the first PICU in Uruguay in 1975. He traveled to France, where he worked with Professors Huault and Beaufils. After returning to Uruguay he created the first private ICU in Uruguay. With his enthusiasm to bring all Latin American pediatricians together in the cause of critical care, he organized the first Latin American Pediatric Intensive Care Congress in Uruguay in 1993, which led to development of the Pediatric Intensive Care Society. In Colombia, Pediatric Intensive Care started in the early 1960s, with postoperative care of cardiovascular patients in the Clínica Shaio of Bogotá, with adult cardiologists in charge. In the 1970s the cardiovascular patients were taken care of by Dr. Merizalde, a pediatrician with training in pediatric cardiology. In 2007, the first pediatric critical training started in Bogotá, and 2 years later there are five programs in three cities.

In 1956, in the Luis Calvo Mackenna Children's Hospital in Santiago, Chile, a single-bed postoperative care unit was started by Drs. Helmut Jager (cardiac surgeon) and Fernando Eimbecke (cardiology). In 1968 this evolved into a five-bed PICU started by Dr. Eduardo Bancalari who was later joined by Drs. Patricio Olivo and Jaime Cordero (pediatricians). In the 1970s, Dr. Carlos Casar started a PICU at the Roberto del Rio Children's Hospital in Santiago, Chile and was later joined by Dr. Bettina von Dessauer (pediatrician).[133] There was no formal training in PCCM and these pediatricians devised individual programs to prepare themselves for taking care of sick children. Intensivists there have devoted great effort toward developing transport systems to overcome the impact of Chile's difficult geography.

In a similar fashion, the first intensive care unit in San Jose, Costa Rica was opened in 1969 as a postoperative cardiac care unit. It was initially a nine-bed unit run by anesthesiologists and surgeons. Eventually pediatricians, without special PCCM training, became involved. Dr. Aristides Baltodano was the first formally trained (Toronto) pediatrician to work in intensive care in Costa Rica, joining the staff in 1982. They now have a 22-bed multidisciplinary unit with more than 1000 admissions per year.[134]

Our Heroes

As previously noted, there are people in medicine who deserve Courage, Size 1 awards. These include, but certainly are not limited to, Dr. Jesse Lazear (yellow fever), Michael Servetes (pumping action of the heart), and a Guatemalan physician, Dr. Juan Francisco Pratesaba, who refused to stop treating wounded guerilla soldiers who presented themselves to his clinic during the civil war. He disappeared shortly thereafter, and was tortured and killed.[135] There are no Courage, Size 1 awards in PCCM. There are Courage, Size 4 awards (e.g., O'Dwyer) and probably many Perseverance, Size 1 awards (e.g., Smythe and Bull, and Klein). Certainly our most prominent awards are Courage, Size 4 to our patients and their families.

But we do have "heroes" by other measures, who have been recognized for their contributions to the field by their peers and organizations. These include the international pioneer awards of the WFPICCS (Box 1-1), the distinguished career awards of the Section on Critical Care of the AAP (Box 1-2), the chairs of the PCCM sub-board (Box 1-3), pediatric intensivist presidents of SCCM (Box 1-4), chairs of the

Box 1–1 International Pioneer Awards World Federation of Pediatric Intensive Care Societies*

Alan Conn, Canada
John Downes, United States
Hans Feychting, Stockholm, Sweden
Maurico Gajer, Uruguay
Gilbert Huault, France
Seigo Iwai, Japan
Max Klein, South Africa
John Socks, Australia

*Awarded Montreal, 2000

Box 1–2 Distinguished Career Awardees, Section on Critical Care, American Academy of Pediatrics

1995: I. David Todres, MD
1996: John Downes, MD
1997: Peter Holbrook, MD
1998: George Gregory, MD
1999: George Lister, MD
2000: Russel Raphaely, MD
2001: Murray Pollack, MD
2002: Daniel Levin, MD
2003: Ann Thompson, MD
2004: Bradley Fuhrman, MD
2005: J. Michael Dean, MD
2006: David Nichols, MD
2007: Ashok Sarnaik, MD
2008: Patrick Kochanek, MD
2009: Jerry Zimmerman, MD
2010: M. Michelle Moss, MD

Critical Care Executive Committee of the AAP (Box 1-5), chairs of the pediatric section of the SCCM (Box 1-6), and those honored by the SCCM (Box 1-7); and there are many more to come.

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Box 1–3 Chairs, Pediatric Critical Care Medicine Subboard, American Board of Pediatrics*

1985-1987	Peter Holbrook, MD
1988-1990	Bradley Fuhrman, MD
1991-1992	Thomas Green, MD
1993-1996	Ann Thompson, MD
1997-1998	Daniel Notterman, MD
1999-2001	David Nichols, MD
2002-2003	Jeffrey Rubenstein, MD
2004-2004	Alice Ackerman, MD
2005-2007	Donald Vernon, MD
2008-2009	Karen Powers, MD

*Medical Editor, 1985-2004, George Lister, MD

Box 1–4 Pediatric Intensivists, Presidents of Society of Critical Care Medicine

1982	George Gregory, MD
1984	Dharampuri Vidyasagar, MD
1988	Peter Holbrook, MD
1992	Russel Raphaely, MD
2001	Ann Thompson, MD
2004	Margaret M. Parker, MD

Box 1–5 Chairs, Executive Committee, Section on Critical Care Medicine, American Academy of Pediatrics

1984-1987	Russel Raphaely, MD
1987-1990	Fernando Stein, MD
1990-1992	J. Michael Dean, MD
1992-1996	Kristian Outwater, MD
1996-2000	Timothy Yeh, MD
2000-2004	M. Michele Moss, MD
2004-2008	Alice Ackerman, MD
2008-2010	Donald Vernon, MD

Box 1–6 Chairs, Pediatric Section, Society of Critical Care Medicine

1980-1981	Peter Holbrook, MD
1981-1983	Russel Raphaely, MD
1983-1984	Bernard Holtzman, MD
1984-1985	Bradley Furhman, MD
1985-1986	Frank Gioia, MD
1986-1987	Timothy Yeh, MD
1987-1988	Fernando Stein, MD
1988-1989	Thomas Rice, MD
1989-1991	Ann Thompson, MD
1991-1994	J. Michael Dean, MD
1994-1996	Debra Fiser, MD
1996-1998	Tom Green, MD
1998-2000	Daniel Notterman, MD
2000-2002	Richard Brilli, MD
2002-2004	M. Michele Moss, MD
2004-2006	Stephanie Storgion, MD
2006-2008	Edward Conway Jr, MD
2008-2010	Vicki Montgomery, MD

Box 1–7 Pediatric Award Recipients, Society of Critical Care Medicine

Shubin-Weil Master Clinician/Teacher: Excellence in Bedside Teaching Award

1990	John J. Downes, MD
1993	Alan I. Fields, MD

Grenvik Family Award for Ethics

1993	Robert D. Truog, MD
1999	I. David Todres, MD

Distinguished Service Award

2002	Patrick M. Kochanek, MD
2004	Ann E. Thompson, MD
2007	Margaret M. Parker, MD
2009	Richard J. Brilli, MD
2009	Alan I. Fields, MD

ACCM Distinguished Investigator Award

2002	Murray M. Pollack, MD
2007	Patrick M. Kochanek, MD

Barry A. Shapiro Memorial Award for Excellence in Critical Care Management

2010	M. Michele Moss, MD

Lifetime Achievement Award

2010	John J. Downes, MD

Devictor, Gideon Eshel, Bradley Fuhrman, George Gregory, Mary Fran Hazinski, Peter Holbrook, Max Klein, Patrick Kochanek, Jacques LaCroix, George Lister, M. Michele Moss, David Nichols, Bradley Peterson, Jefferson Piva, Arnold Platzker, Bala Ramachandran, Adrienne Randolph, Francisco Ruza, Hirokazu Sakai, David Schell, Fernando Stein, Ann Thompson, James Thomas (reviewer), Dharmapuri Vidyasagar, Gary Williams, Douglas Willson, Timothy Yeh, the AAP, and the SCCM.

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References are available online at http://www.expertconsult.com.

Chapter 2

The Intensivist in the New Hospital Environment: Patient Care and Stewardship of Hospital Resources

Margaret M. Parker

PEARLS

- Effective teamwork is essential for optimal care of the critically ill child in the setting of limited resources.
- Communication and collaboration among members of the health care team improve the quality and efficiency of patient care.
- The intensivist, as "captain of the ship," must manage the clinical care of the critically ill child and the organization of the intensive care unit to make optimal use of limited resources.

Intensive care units (ICUs) create an environment in which critically ill patients can be supported and many lives can be saved. By their very nature, ICUs are resource intensive with respect to both technology and the need for skilled health care providers. A large percentage of hospital costs are attributed to the ICU. As the cost of health care increases, the need to manage the resources of the ICU as efficiently and effectively as possible increases in importance as well.

Many studies in the literature have reported that management of the ICU and critically ill patients by intensivists increases survival rates and decreases resource utilization.[1-4] In addition to improvement in resource utilization, Gajic et al.[3] reported that the presence of a critical care specialist was associated with improved staff satisfaction, an important consideration when considering the increasing staffing limitations. Not all studies have reported a benefit in outcome, however. In sharp contrast to the many studies showing improved outcomes associated with intensivist staffing, Levy et al.[5] reported that patients managed by intensivists had a higher risk of death than did those who were not managed by them. It is not clear why this study had such disparate results from previous studies, but one likely reason is that the study design was very different from that of previous studies, as were the definitions used.[6] The systematic review by Pronovost et al.[1] defined high-intensity staffing as the ICU policy requiring that the intensivist have responsibility for care for all of the patients in the ICU (closed ICUs) or that there be a mandatory consultation by an intensivist. In the study by Levy et al.,[5] the involvement of the intensivist was elective (i.e., not decided at the unit level but by the choice of the attending physician). According to the definition by Pronovost et al.,[1] ICUs that allow the choice of whether to involve an intensivist are low-intensity staffing models. The effect of intensivists in low-intensity–staffed ICUs has not been studied adequately. Levy et al.[5] did a separate analysis of no-choice ICUs versus choice ICUs and reported that the mortality rate was higher in the no-choice ICUs, raising the question again as to whether intensivist staffing may increase mortality rates, although a mechanism by which this outcome might occur is not apparent. The preponderance of available studies continues to show a benefit of management by an intensivist.

Unlike adult critical care units, nearly all pediatric ICUs have trained pediatric intensivists who manage most (if not all) of the patients. In the United States, only about 30% of the adult ICUs are staffed by trained intensivists. Regionalization of trauma services for adults has improved outcomes of trauma patients.[7] Regionalization has been recommended as a way to improve the care of critically ill or injured adults and children, although the barriers to regionalization are far greater for adults than for children.[8,9] Regionalization effectively puts limited resources together to maximize the effectiveness and availability of these resources to a greater number of patients, although at the expense of travel for many patients and their families.

Organization and Quality Issues

During the past 2 decades, the cost of health care in the United States has increased dramatically, with hospital costs increasing more rapidly than other cost indexes. Controlling critical care medicine costs will be an important issue as health care reform is discussed. Critical care consumes an increasing proportion of hospital beds as the acuity of hospital inpatients increases. Although the cost of critical care is rising, the proportion of national health expenses used in critical care medicine has decreased over time.[10,11] Different methods for calculating critical care medicine costs create some discrepancies in the estimates of these costs, making it difficult to ensure that efforts to control costs are really effective.

The ICU provides support to a variety of services that could not be offered without ICU care, such as cardiac surgery and transplantation. Defining the ICU as the cost center gives a very different picture of the expense of ICU care than would attributing the costs of such patients to the services that use the ICU. Similarly, attributing some of the revenue that such services generate to the ICU and critical care physicians rather than solely to the surgical service per se provides a different view of the value of the ICU to the institution. Different strategies for controlling costs have potential benefit but often have unintended consequences. Shifting costs from the ICU to the supporting hospital services further complicates efforts to account for accurate ICU costs. True critical care medicine cost containment is extremely difficult, if not impossible.[12]

Today's intensivist must be knowledgeable about the economic aspects of managing the ICU and balance economic realities with the needs of the critically ill patient. Controlling costs of care without compromising the care of the patient requires a multitude of administrative and clinical skills. Close attention to both clinical details and financial considerations is necessary to meet these dual challenges. The intensivist needs to demonstrate flexibility and adaptability in order to navigate the business aspects of critical care while providing the best possible care for the patient.

Effective multidisciplinary care requires developing a teamwork model in the ICU. True teamwork recognizes the importance of the role of each member of the team and requires respect and trust for the other professions represented on the team. Effective communication between all members of the health care team and the patient/family cannot be overemphasized. A collaborative partnership with shared responsibility for maintaining communication and accountability for patient care includes the recognition that no one provider can perform all parts of patient care; the whole team is much more effective than each member of the team alone. True teamwork is a complementary relationship of interdependence.[13]

An effective team is critical to both the clinical and financial health of the ICU.[14] Good teamwork requires a number of skills. A team performance framework for the ICU requires communication, leadership, coordination, and team decision making. Effective team leadership is crucial for guiding effective team interactions and coordination. Leadership performance can be measured; the leadership performance of attending intensivists is associated with accomplishment of daily patient goals.[15] Important leadership characteristics include communication skills, conflict management, time management, acknowledging others' concerns and one's own limitations, focus on results, setting high standards, and showing appreciation for the work of the team.

Quality improvement is an important part of ICU management. The intensivist must be responsible for leading and ensuring quality improvement efforts. The Institute of Medicine's "six aims for improvement" are safety, effectiveness, equity, timeliness, patient centeredness, and efficiency.[16] These aims are certainly relevant to pediatric critical care practice and can provide a framework for improving quality in the pediatric ICU (PICU). Acuity scores have been used as tools for measuring quality in the ICU. It is important for the intensivist to understand the various available scoring systems and how they can be used to ensure appropriate use of these tools.[17]

The use of clinical pathways has been shown to improve efficiency of care and decrease resource utilization.[18] The intensivist, as leader of the team, must ensure that these guidelines are developed with input from all members of the ICU team to optimize acceptance and smooth implementation of such guidelines. Standardization of care increases the likelihood that every patient will get the appropriate treatments at the right time. A common objection to standardization is that ICU patients are too complex or too different to be able to standardize their care. However, some aspects of care should be provided to most, if not all, patients and can be overlooked easily if they are not standardized. One example is insertion of central venous catheters using full-barrier precautions to prevent line-associated bloodstream infections. Checklists are helpful to remind all members of the team to carry out the "routine" steps every time. In the case of a patient who has a contraindication to "standard" care, the contraindication should be documented. In an environment that is increasingly complex, ensuring reliability in processes of care is exceedingly difficult. Standardizing the processes means that everyone on the team knows what to expect. Empowering every member of the team to speak up if he or she observes an unsafe condition further increases the safety of the patient and the reliability of care.

A systematic review by Carmel and Rowan[19] described eight organizational categories that may contribute to patient outcome in the ICU. These factors include staffing, teamwork, patient volume and pressure of work, protocols, admission to intensive care, technology, structure, and error. Pollack and Koch[20] demonstrated that organizational factors and management characteristics can influence health outcomes in the neonatal ICU. The intensivist, as captain of the ship, is responsible for ensuring that these important organizational factors are optimized in the ICU.

Manpower Issues

By its very nature, critical care is an intense and stressful field. Optimal clinical care and management in the ICU depends first and foremost on the availability of sufficient numbers of trained critical care professionals. Shortages of all types of critical care providers are an increasing concern. The Society of Critical Care Medicine, the American College of Chest Physicians, and the American Thoracic Society performed a manpower analysis of critical care specialists in 1997 and projected an increasing shortage of intensivists during the next 2 decades.[21] These three professional societies, along with the American Association of Critical-Care Nurses, further reviewed the available literature to identify causes of the shortage of critical care professionals and possible approaches to redesigning critical care practice.[22] These groups recommended common standards across the critical care field to promote uniformity and quality, use of information technology to promote standardization and improve efficiency, government incentives to attract health care professionals to critical care, and sponsorship of research defining the optimum role for intensive care professionals in the delivery of critical care. In an interesting study that looked at intensivist/bed ratio, Dara and Afessa[23] reported that differences in intensivist/bed ratios from 1:7.5 to 1:15 were not associated with differences in mortality rates, but a ratio of 1:15 was associated with increased ICU length of stay. Shortages of intensivists, which lead to higher numbers of patients per intensivist, may further limit the availability of ICU beds by increasing the

length of stay. Although these projects and the resulting documents were primarily aimed at critical care services for adults, the need for which will unquestionably increase markedly as the population ages, there are similar and equally pressing shortages of well-trained pediatric critical care professionals.[24] The pediatric intensivist needs to be aware of the importance of the health care professional as one of the most important resources of the PICU.

A matter that is at least as concerning as the physician shortage in the ICU is the increasing shortage of critical care nurses. As the supply of nurses decreases, the nurse/patient ratio in many ICUs increases. Increasing the number of critically ill patients a nurse must care for has negative effects on both patient care and on nursing morale and job satisfaction.[25,26] Decreased morale leads to increased turnover and the loss of experienced and highly skilled nurses. This situation, in turn, places patients at increased risk.

The presence of a pharmacist on rounds in the ICU has been shown to reduce drug errors and improve patient safety. Pharmacists are another group of critical care professionals who are in increasingly short supply.[27]

With the increasing shortage of intensivists has come consideration of other ways to provide adequate numbers of practitioners to care for critically ill patients. Hospitalists provide a substantial amount of critical care in the United States. One study reported that after-hours care in the PICU by hospitalists was associated with improved survival rates and shorter length of stay compared with care by residents.[28] Numerous studies have looked at the role of nurse practitioners and physician assistants as physician extenders in the PICU.[29-31] These practitioners can effectively complement the physician staff in the ICU, especially as resident work hours decrease.

Summary

Health care costs continue to increase and will likely do so until there is meaningful health care reform in the United States. Critical care consumes a large, although not increasing, share of health care costs. With the increasing complexity of management of the critically ill patient, careful management of the very limited resources available to promote optimal outcomes is increasingly important. The pediatric intensivist must be skilled in the management not only of the critically ill child, but also in the administration of the PICU and the appropriate use of all of its resources. Effective teamwork will be the key to ensuring optimal care in the face of limited resources.

References are available online at http://www.expertconsult.com.

Chapter 3

The Nurse in Pediatric Critical Care

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PEARLS

- Nursing's unique contribution to patients within the health care environment is that nurses create safe passage for patients and families.
- Nurses coordinate the patient's and family's experiences by their continuous attention to the person who exists underneath all the advanced technology that is being employed.
- Building a humanistic environment that endorses parents as unique individuals capable of providing essential elements of care to their children lays the foundation for family-centered care.
- Caring practices are a constellation of nursing activities that are responsive to the uniqueness of the patient/family and create a compassionate and therapeutic environment with the aim of promoting comfort and preventing suffering.
- Excellence in a pediatric critical care unit is achieved through a combination of many factors and is highly dependent on a healthy work environment.
- Studies have demonstrated that a stable, established, and proficient nursing workforce improves patient outcomes.
- A successful critical care professional advancement program recognizes varying levels of staff nurse knowledge and expertise and fosters advancement through a wide range of clinical learning and professional development experiences.
- Technical training alone is insufficient in meeting patient and family needs in the critical care environment.

Pediatric critical care nursing has evolved tremendously over the years. The nurse is the singular person in the pediatric critical care unit who creates an environment in which critically unstable, highly vulnerable infants and children benefit from vigilant care and who coordinates the actions of a highly skilled team of patient-focused health care professionals. Pediatric critical care nursing practice encompasses staff nurses who provide direct patient care, nursing leaders who facilitate an environment of excellence, and professional staff development that ensures continued nursing competence and professional growth. This chapter discusses the essential components of pediatric critical care nursing practice.

Describing What Nurses Do: The Synergy Model

The synergy model describes nursing practice based on the needs and characteristics of patients and their families.[1] The fundamental premise of this model is that patient characteristics drive required nurse competencies. When patient characteristics and nurse competencies match and synergize, optimal patient outcomes result. The major components of the synergy model encompass patient characteristics of concern to nurses, nurse competencies important to the patient, and patient outcomes that result when patient characteristics and nurse competencies are in synergy.

Patient Characteristics of Concern to Nurses

Every patient and family member brings unique characteristics to the pediatric intensive care experience. These characteristics—stability, complexity, predictability, resiliency, vulnerability, participation in decision making, participation in care, and resource availability—span the continuum of health and illness. Each characteristic is operationally defined as follows.

Stability refers to the person's ability to maintain a steady state. Complexity is the intricate entanglement of two or more systems (e.g., physiologic, family, and therapeutic). Predictability is a summative patient characteristic that allows the nurse to expect a certain trajectory of illness. Resiliency is the patient's capacity to return to a restorative level of functioning using compensatory and coping mechanisms. Vulnerability refers to an individual's susceptibility to actual or potential stressors that may adversely affect outcomes. Participation in decision making and participation in care are the extents to which the patient and family engage in decision making and in aspects of care, respectively. Resource availability refers to resources that the patient/family/community bring to a care situation and include personal, psychological, social, technical, and fiscal resources.

These eight characteristics apply to patients in all health care settings. This classification allows nursing to have a common language to describe patients that is meaningful to all care areas. For example, a critically ill infant in multisystem organ failure might be described as an individual who is

unstable, highly complex, unpredictable, highly resilient, and vulnerable, whose family is able to become involved in decision making and care but has inadequate resource availability.

Each of these eight characteristics forms a continuum, and individuals fluctuate at different points along each continuum. For example, in the case of the critically ill infant in multisystem organ failure, stability can range from high to low, complexity from atypical to typical, predictability from uncertain to certain, resiliency from minimal reserves to strong reserves, vulnerability from susceptible to safe, family participation in decision making and care from no capacity to full capacity, and resource availability from minimal to extensive. Compared with existing patient classification systems, these eight dimensions better describe the needs of patients that are of concern to nurses.

Nurse Competencies Important to Patients and Families

Nursing competencies, which are derived from the needs of patients, also are described in terms of essential continua: clinical judgment, clinical inquiry, caring practices, response to diversity, advocacy/moral agency, facilitation of learning, collaboration, and systems thinking.

Clinical judgment is clinical reasoning that includes clinical decision making, critical thinking, and a global grasp of the situation coupled with nursing skills acquired through a process of integrating formal and experiential knowledge. Clinical inquiry is the ongoing process of questioning and evaluating practice, providing informed practice on the basis of available data, and innovating through research and experiential learning. The nurse engages in clinical knowledge development to promote the best patient outcomes. Caring practices are a constellation of nursing activities that are responsive to the uniqueness of the patient/family and create a compassionate and therapeutic environment with the aim of promoting comfort and preventing suffering. Caring behaviors include, but are not limited to, vigilance, engagement, and responsiveness. Response to diversity is the sensitivity to recognize, appreciate, and incorporate differences into the provision of care. Differences may include, but are not limited to, individuality, cultural practices, spiritual beliefs, gender, race, ethnicity, disability, family configuration, lifestyle, socioeconomic status, age, values, and alternative care practices involving patients/families and members of the health care team. Advocacy/moral agency is defined as working on another's behalf and representing the concerns of the patient/family/community. The nurse serves as a moral agent when assuming a leadership role in identifying and helping to resolve ethical and clinical concerns within the clinical setting. Facilitation of learning is the ability to use the process of providing care as an opportunity to enhance the patient's and family's understanding of the disease process, its treatment, and its likely impact on the child and family. Collaboration is working with others (i.e., patients, families, and health care providers) in a way that promotes and encourages each person's contributions toward achieving optimal and realistic patient goals. Collaboration involves intradisciplinary and interdisciplinary work with colleagues. Systems thinking is appreciating the care environment from a perspective that recognizes the holistic interrelationships that exist within and across health care systems.

These competencies illustrate a dynamic integration of knowledge, skills, experience, and attitudes needed to meet patients' needs and optimize patient outcomes. Nurses require competence within each domain at a level that meets the needs of their patient population. Logically, more compromised patients have more severe or complex needs; this in turn requires the nurse to possess a higher level of knowledge and skill in an associated continuum. For example, if a patient is stable but unpredictable, minimally resilient, and vulnerable, primary competencies of the nurse center on clinical judgment and caring practices (which include vigilance). If a patient is vulnerable, unable to participate in decision making and care, and has inadequate resource availability, the primary competencies of the nurse focus on advocacy/moral agency, collaboration, and systems thinking. Although all the eight competencies are essential for contemporary nursing practice, each assumes more or less importance depending on a patient's characteristics. Optimal care is most likely when there is a match between patient needs/characteristics and nurse competencies.

Clinical Judgment

Clinical judgment, that is, skilled clinical knowledge, use of discretionary judgment, and the ability to integrate complex multisystem data and understand the expected trajectory of illness and human response to critical illness defines competent nursing practice. In critical care, the novice nurse focuses on individual aspects of the patient and the environment. As expertise develops, the nurse develops a global understanding of the situation. The expert nurse anticipates the needs of patients, predicts the patient's trajectory of illness, and forecasts the patient's level of recovery. Evolving clinical expertise creates safe passage for patients. The very best nursing care often is invisible, as it should be, because untoward effects and complications are prevented. Nursing's unique contribution to patients within the health care environment, which encompasses all nursing's competencies, is that nurses create safe passage for patients and families. Safe passage may include helping the patient and family move toward a greater level of self-awareness, knowledge, or health; transition through the acute care environment or stressful events; and/or a peaceful death.

Clinical Inquiry

Clinical inquiry optimizes the delivery of evidence-based care. Studying the clinical effectiveness of care and how it affects patient outcomes provides information that helps balance cost and quality. Quality improvement methods include use of multidisciplinary teams that work together to help systems operate in a way that promotes the best interests of patient care. Collaborative practice groups working with clinical practice guidelines (CPGs) provide the opportunity to initiate evidence-based interventions.

CPGs—that is, patient-centered multidisciplinary and multidimensional plans of care—help the team provide evidence-based practice and improve the process of care delivery. CPGs ensure practitioner accountability, encourage coordinated care, decrease unnecessary variation in practice patterns, improve quality and cost-effective services, and provide a means to systematically evaluate the quality and effectiveness of practice in moving patients toward desired outcomes. Effective CPGs are driven by patient needs and help provide

evidence linking interventions to patient outcomes. CPGs help guide the appropriate use of resources, limiting interventions. Evidence-based guidelines can help to eliminate interventions that do not benefit patients but frequently are steeped in tradition and opinion.

Caring Practices

Caring practices bring clinical judgment to view. Caring practices are activities that are meaningful to the patient and family and enhance their feelings that the health care team cares about them. Families equate caring behaviors with competent behaviors. Families trust that nurses will be vigilant. Vigilance, which includes alert and constant watchfulness, attentiveness, and reassuring presence, is essential to limit the complications associated with a patient's vulnerabilities.[1]

Nurses coordinate the patient's and family's experiences by their continuous attention to the person who exists underneath all the advanced technology that is employed. This steady attention can make an important difference for patients by helping patients and their families better tolerate the experience of critical illness. This aspect of practice, our presence with patients, is unique to the profession of nursing.[1] For example, in working with patients with head injuries, caring nurses acknowledge the person by surrounding them with their possessions, such as family pictures and cards from friends, and their favorite music. Nurses talk with their unresponsive patients, orienting them and telling them what is going on, which preserves the patient's "humanness." Occasionally a patient responds as evidenced by as an increase in heart rate or blood pressure, a decrease in intracranial pressure, or the shedding of a tear. Nurses take this level of communication one step further by teaching this process to family members so they too can interact with their critically ill loved one.

Pediatric critical care nurses, more than any other intensive care unit (ICU) nursing subspecialty, have made significant progress in integrating family-centered care into the practice of critical care. Building a humanistic environment that endorses parents as unique individuals capable of providing essential elements of care to their children lays the foundation for family-centered care. Family-centered care is more than just providing parents with unlimited access to their children.[1]

Nursing research provides the foundation for this change in practice. Based on nursing research, we know that parents have the need for hope, information, and proximity; to believe that their loved one is receiving the best care possible; to be helpful; to be recognized as important; and to talk with other parents with similar issues. Pediatric critical care nurses have gone beyond the identification of family needs to illustrating interventions that patients and families find helpful.[1] We provide families with what they need to help their child. Parents believe the most important contribution pediatric critical care nurses make is to serve as the "interpreter" of their critically ill child's responses and of the pediatric ICU environment.

Response to Diversity

Response to diversity honors the differences that exist in the people we are and in the individuals we care for. At a minimum, it requires that care be delivered in a nonjudgmental, nondiscriminatory manner. Effective communication with patients and families at their level of understanding may require customizing the health care culture to meet the diverse needs and strengths of families. Skilled nurses foresee differences and beliefs within the team and negotiate consensus in the best interest of the patient and family.

Advocacy/Moral Agency

Moral agency acknowledges the particular trust inherent within nurse-patient relationships, a trust gained from nursing's long history of speaking on the patient's behalf in an effort to preserve a patient's "lifeworld" (Hooper, personal communication, 1996). The holistic view of the patient that nurses often possess is a reflection of moral awareness.

When a cure is no longer possible, nurses turn their focus to ensuring that death occurs with dignity and comfort. Nurses "orchestrate" death, supporting parents and family members through the death of their loved one. Nurses often coordinate the experience for patients and families when death is imminent. This most intimate aspect of nursing care is a profound contribution to humankind.[2]

Pediatric critical care nurses provide critical support of the practice of family presence during procedures and resuscitation. Including family members during pediatric resuscitation is not a universal practice. However, one study established that the parents who were able to be present during their child's resuscitation collectively believed that their presence provided comfort to their child and themselves.[3] Parents who were not able to stay regretted not being able to comfort their child in the final moments of his or her life. The study authors advocated that policies be developed to facilitate parental presence during resuscitation. A study of physicians ascertained that most respondents encouraged family members to be present during their child's resuscitation.[4] The majority of physicians believed that being there was helpful to parents and that physicians should be prepared for this practice. Nurses take on the essential accountability of preparing families to stay with their child.[5]

Facilitator of Learning

Nurses facilitate learning so that patients and their families become knowledgeable about the health care system and can make informed choices. Teaching is an almost continuous process that involves helping the patient and the family understand the critical care environment and therapies involved in critical care. Also essential is reinforcement of the patient's experience and how, most likely, the infant or child will cope with the ICU experience. This education provides patients with the capacity to help themselves and for parents to help their infants and children.

Collaboration

Collaboration requires commitment by the entire multidisciplinary team. A classic study done by Knaus et al.[6] found an inverse relationship between actual and predicted patient mortality and the degree of interaction and coordination of multidisciplinary intensive care teams. Hospitals with good collaboration and a lower mortality rate had a comprehensive nursing educational support program that included a clinical nurse specialist and clinical protocols that staff nurses can independently initiate. The American Association of Critical-Care Nurses Demonstration Project also documented a low mortality ratio, low complication rate, and high

patient satisfaction in a unit that had a high perceived level of nurse/physician collaboration, highly rated objective nursing performance, a positive organizational climate, and job satisfaction and morale.[7]

Systems Thinking

Nurses are constantly challenged to design, implement, and evaluate whole programs of care, manage units where programs of care are provided, and determine whether the health care system is meeting patient needs.[8] These vital components require a patient-centered culture that stresses strong leadership, coordination of activities, continuous multidisciplinary communication, open collaborative problem solving, and conflict management.[9] For many years nurses have learned to manipulate the system on behalf of their patients; however, systems thinking[10]—that is, the ability to understand and effectively manipulate the complicated relationships involved in complex problem solving—is a new but necessary skill in taking overall responsibility for the caregiving environment.

Managing complex systems is essential to creating a safe environment. Nurse-patient relationships commonly occur around transitional periods of instability brought about by the demands of the health care situation. Helping patients make transitions between elements of the health care system—for example, into and out of the community—requires systems knowledge and intradisciplinary collaboration.[11]

Optimal Patient Outcomes

According to the synergy model, optimal patient outcomes result when patient characteristics and nurse competencies synergize. The study of many patient outcome measures is appropriate, including physiologic, psychological, functional, and behavioral outcome measures, as well as symptom control, quality of life, family strain, goal attainment, utilization of services, safety, problem resolution, and patient satisfaction.[12] A "nurse-sensitive" outcome, a term first coined by Johnson and McCloskey,[13] defines a dynamic patient or family caregiver state, condition, or perception that is responsive to nursing interventions. Brooten and Naylor[14] note: "The current search for 'nurse-sensitive patient outcomes' should be tempered in the reality that nurses do not care for patients in isolation and patients do not exist in isolation." Outcomes have been described at three levels: patient, provider, and system.

Patient Level Outcomes

Major patient level outcomes of concern to pediatric critical care nurses include hemodynamic stability and the presence or absence of complications. Outcomes related to limiting iatrogenic injury and complications of therapy demonstrate the potential hazards present in illness and in the critical care environment. Patient/family satisfaction ratings are subjective measures of health and/or the quality of health services. Patient satisfaction measures involving nursing typically include technical/professional factors, trusting relationships, and education experiences.[15] Patient-perceived functional change and quality of life are multidisciplinary outcome measures. Linking patient satisfaction, functional status, and quality of life is important because the three factors often are related.

Provider Level Outcomes

Provider level outcomes include the extent to which care/treatment objectives are attained within the predicted time period. Nurses coordinate the day-to-day efforts of the entire multidisciplinary team. The nurse's role as the coordinator of numerous services is essential for optimal patient outcomes and shorter lengths of stay. As discussed, nurse–physician collaboration and positive interaction is associated with lower mortality rates, high patient satisfaction with care, and low nosocomial complications.[6,7]

System Level Outcomes

Critical care units must manage resources and maintain quality as collaboratively defined by both users and providers in the system. The goal is high-quality care at moderate cost for the greatest number of people. Important patient-system outcome data include recidivism and costs/resource utilization. Recidivism, that is, rehospitalization and readmission, is repeated work that adds to the personal and financial burden of providing care. In addition to patient and system factors, nurses can decrease the patient's length of stay through coordination of care, prevention of complications, timely discharge planning, and appropriate referral to community resources. Reducing length of stay and tracking emergency department visits and rehospitalization ensure that cost shifting is not occurring.

Nightingale Metrics

One population-specific approach to measurement of nurse-sensitive outcomes is the Nightingale Metrics.[16] This program was developed so that bedside nurses could be actively involved in identifying nurse-sensitive metrics important to their unique patient and family population. Nurses give care in an environment that supports the capacity of the patient and family to heal. Much of nursing is preventive care that often is not measured; thus care is often invisible. When measuring outcomes, it is important to measure the invisible aspects of nursing that have a tremendous impact on patients. For example, invisible are the large numbers pressure ulcers that never develop because of good nursing care. The Nightingale Metrics reflect current standards of care, are based on evidence, and are measurable (Box 3-1).

Box 3–1 Pediatric Intensive Care Unit—Nightingale Metrics

- Pain and sedation scores every 4 hours
- In patients with a central venous line, changing the dressing every 7 days
- Establishment of a nutrition plan within 24 hours of admission
- Pressure ulcer bundle: If patient is immobile, documentation of position change every 2 hours and positioning of heels off the bed; if not on bed rest, documentation of patient being out of bed or held in parent's or nurses' arms
- Ventilator-associated pneumonia bundle: Head of bed elevation at 30 to 45 degrees; documentation of oral hygiene twice in 24 hours; peptic ulcer prophylaxis (in patients not receiving tube feedings); discussion of extubation readiness test on rounds; daily holiday from sedation or chemical paralysis
- "Time to critical intervention": response to panic laboratory value, the time intervals from sending specimen to laboratory to first intervention to correct laboratory value