

## **Infectious diseases and the origins of pediatric critical care medicine**

**<sup>1</sup>Dr. Sarah E. Gardner Yelton, <sup>2</sup>Dr. Daniel L. Levin**

<sup>1</sup>Advocate Children's Hospital, United States, [sarah.gardneryelton@aah.org](mailto:sarah.gardneryelton@aah.org)

<sup>2</sup>Geisel School of Medicine, United States, [sarah.gardneryelton@aah.org](mailto:sarah.gardneryelton@aah.org)

### **ABSTRACT**

While several accounts of the early days of pediatric critical care medicine as a subspecialty are published, in this work we explore how early pediatric critical care units formed through the lens of poliomyelitis, tetanus, sepsis and rheumatic fever. We describe how each outbreak or illness through the 19<sup>th</sup> and 20<sup>th</sup> centuries drove innovations in airway and ventilation management in small patients, in addition to stimulating novel approaches to patient grouping, ultimately leading to the creation of the modern field of pediatric critical care medicine.

### **INTRODUCTION**

Centuries of innovation inspired by critical illness in children have culminated in the modern concept of pediatric critical care medicine (PCCM).<sup>1</sup> Infectious diseases in the 19<sup>th</sup> and 20<sup>th</sup> century played a central role in the development of the field. In the 1870s, Robert Koch made a series of discoveries linking microorganisms such as anthrax and cholera to disease processes, leading to major public health initiatives targeting hand hygiene and clean water.<sup>2</sup> Dr. Albert Blodgett recorded one of the first successes using continuous oxygen therapy in 1890 to revive a woman with pneumonia.<sup>3</sup> In 1919, Dr. Russell Haden reported the use of hyperosmolar therapy for cerebral edema associated with epidemic meningitis.<sup>4</sup> While others have published an extensive account of the many individuals involved in the inception of PCCM as a subspecialty across the world, we will describe how early pediatric intensive care units formed through the lens of infectious disease processes poliomyelitis, tetanus, sepsis and rheumatic fever in the early 20<sup>th</sup> century.<sup>5,6</sup>

### **POLIOMYELITIS**

Poliomyelitis (polio) outbreaks heavily influenced advances in the treatment of respiratory failure. In the early 1900s, polio epidemics debilitated entire populations. Building on earlier iterations of similar technology, Drinker and Shaw created the first widely used negative

pressure, body-enclosing mechanical ventilator in 1929. Later termed the *iron lung*, the system treated respiratory failure associated with weakened thoracic musculature from polio, but did nothing to resolve associated upper airway obstruction and inability to clear secretions, leaving mortality in polio patients close to 90%.<sup>7,8</sup> This cumbersome mode of ventilation precluded access to the patient, altered hemodynamics and was very difficult to titrate.<sup>9</sup> In 1952, to support the growing number of patients in respiratory failure secondary to polio, Danish anesthesiologist Dr. Bjørn Ibsen and his staff performed tracheal intubation in a series of 200 patients.

Around this time, discoveries related to respiratory support for pilots at altitude led to the first positive pressure mechanical ventilators. While not the earliest ventilators, both the “Bennett” and “Bird” intermittent positive pressure breathing devices inspired further iterations of invasive and non-invasive support.<sup>9</sup> These ventilators were not intended for long term continuous ventilation and were not widely available. Therefore, to support his patients, Dr. Ibsen and his team trained 400 nursing students, aids, and medical students to manually provide continuous positive pressure ventilation and tracheal suctioning on a 24-hour basis. The mortality in these patients decreased from 90% to 40%.<sup>10-12</sup> For efficiency of care, the team geographically cohorted these patients. In 1953, capitalizing on this concept, Ibsen converted a student nurse classroom into what many see as the first full-time intensive care unit at the Municipal Hospital in Copenhagen.<sup>13</sup>

## TETANUS

Early mechanical ventilators such as those used throughout the polio epidemics were asynchronous with patient breaths and also delivered a constant tidal volume regardless of patient size. Ventilating pediatric patients safely was therefore challenging. One of the earliest efforts at ventilating infants targeted neonates suffering from tetanus, a disease which induces muscle spasms and rigidity leading to respiratory failure. In 1957, at Groote Schuur Hospital in Cape Town, South Africa, pediatrician P.M. Smythe and anesthesiologist Arthur Bull encountered high rates of neonatal tetanus, associated with traditional umbilical cord care practices. Since there was no known treatment for tetanus, infant survival depended on adequate airway support. Drs. Smythe and Bull performed the first reported successful pediatric tracheostomies and subsequent positive pressure ventilation in a series of infants with respiratory failure from tetanus. Future leader in pediatric intensive care and medical student at the time, David Todres, administered curare to the infants to relax the tetanic

spasms and allow for ventilation. Although mortality was still high, the team was able to ventilate babies for up to 14 days via a modified adult ventilator, something that had not yet been achieved in pediatrics.<sup>14</sup>

Simultaneously, obstetricians, pediatricians, and anesthesiologists across the world noted similar difficulties in ventilating babies. They began to form “special care nurseries” to care for infants with respiratory distress syndrome (RDS). Supporting the smallest patients required new ventilation strategies, resulting in innovations in pediatric mechanical ventilation, and leading to the first child-specific intensive care units and the field of neonatology.<sup>15</sup> It was not until the mid 1960s that the first mechanical ventilator designed for children was finally implemented.<sup>16</sup>

## **SEPSIS**

It is no coincidence that most early pediatric intensive care units were run by anesthesiologists. Bacteriotoxic coma, or sepsis, was a leading cause of mortality in the early days post-surgery, and the care of many critically ill children occurred primarily in the post-anesthetic recovery room. In 1951, in Gotenborg, Sweden, anesthesiologist Dr. Goran Haglund treated a 4-year-old boy with a ruptured appendix. Following surgery, the patient remained unresponsive. Dr. Haglund intubated the patient, performed manual positive-pressure ventilation, and gave the patient a blood transfusion, successfully resuscitating the patient, who then survived to discharge from the hospital. Thirty years later, in the 1980s, Dr. Roger Bone developed definitions for the clinical “sepsis syndrome,” highlighting a central focus of critical care research that persists to this day.<sup>17</sup> Inspired by the boy’s recovery and survival, in 1955 Dr. Haglund created the first “pediatric emergency ward”.<sup>18</sup> This first pediatric intensive care unit (PICU) had seven beds with full-time nurses and nursing assistants providing 24-hour coverage.

Physicians in Copenhagen began to send specialized retrieval teams in ambulances to pick up critical patients in the countryside, markedly improving patient status on hospital arrival and jumpstarting the concept of transport medicine.<sup>10,12</sup> Although certainly advances in medical treatment, such as the introduction of antibiotics, contributed to decreases in mortality, transporting critically ill children to centers with a full-time specialized critical care team consisting of physicians, nurses, respiratory therapists and social workers has vastly improved outcomes.<sup>19-22</sup> Dr. Haglund’s pediatric emergency ward treated 1183 infants and

children in its first 5 years, with a mortality rate of just 13.6%.<sup>11</sup> Between 1958 and 1966 at the University of Minnesota, mortality from septic shock in children under the age of 16 decreased from 95% to 10% with PICU care.<sup>23</sup> Today, the mortality rate from septic shock is as low as 5%.<sup>24</sup>

## **RHEUMATIC FEVER**

There are few better examples of subspecialized multidisciplinary care and its positive effects on child health than pediatric cardiology and cardiac surgery. In the 1900s, prior to the widespread use of penicillin, children with rheumatic fever and rheumatic heart disease occupied the majority of pediatric hospital beds.<sup>25</sup> After losing two sons to rheumatic fever, a couple in Baltimore opened the Harriet Lane Home for Invalid Children in 1912. At the center that would later become Johns Hopkins, Dr. Helen Taussig's journey into pediatric cardiology began as she treated children with rheumatic fever.<sup>25</sup>

Pediatric heart surgery was in its infancy and surgeons had yet to use cardiopulmonary bypass in humans. The first successful congenital heart surgery occurred in 1938, when Dr. Gross of Boston successfully closed a patent ductus arteriosus. Targeting cyanotic heart disease, Drs Taussig and Blalock with Vivien Thomas performed the first subclavian artery to pulmonary artery anastomosis for a patient with Tetralogy of Fallot in 1944, a major achievement in pediatric cardiology.<sup>26</sup> In tandem, advances in pediatric general surgery led by C. Everett Koop in Philadelphia, allowed patients with previously fatal anomalies, such as biliary atresia, to survive.<sup>27</sup> As PICUs formed, pediatric surgical and cardiac-specific intensive care units followed suit, allowing for these new groups of complex critically ill patients with shared physiology to be cared for together.

## **EVOLUTION TO THE MODERN PICU**

Between 1967 and 1971 the earliest PICUs formed, led by Children's Hospital of Philadelphia.<sup>1,5, 28</sup> These units established vibrant training programs in PCCM and conducted clinical research. **Table 1.** Early PICUs had a favorable impact on patient outcomes, particularly those associated with acute respiratory failure, leading to the development of similar units in most major pediatric centers in North America, Western Europe, and Japan during the 1970s and early 1980s. Hospital architecture evolved to reflect this change in care. Hospital leaders built stand-alone PICUs, focusing on things like spatial configuration, efficiency, family involvement, noise and even exposure to nature.<sup>29</sup>

Growth in the field of PCCM has changed the landscape of medicine. Children with previously fatal diseases may now survive into adulthood with complex multi-system disease processes, technology dependence and chronic critical care needs. PCCM has expanded to encompass a focus on comfort, psychosocial, developmental and spiritual needs, rehabilitation, and family-centered, culturally sensitive care. Quality improvement programs, such as central-line associated infection bundles, are essential in minimizing mortality in this increasingly complicated population of children.<sup>30</sup> The decreases in mortality are not universal, and death from common childhood diseases now rare in the United States remain commonplace in resource-limited countries. Additionally, long overdue recognition of burnout associated with exposure to trauma and challenges with work-life balance experienced by those working in the PICU is now at the forefront. We owe a great deal of gratitude to those who have come before us, allowing us the privilege to care for children and the families of critically ill children in the current manner.

*In memoriam Daniel L. Levin, John Downes, I. David Todres*

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**Table 1:** Timeline from earliest units to legitimacy as a subspecialty<sup>5</sup>

1953	Bjorn Ibsen creates the first known intensive care unit, Copenhagen, Denmark
1955	Goran Haglund's pediatric emergency care ward, Gotenberg, Sweden
1967	Children's Hospital of Philadelphia forms dedicated PICU
1969	American Association of Critical Care Nurses Founded
1970	Critical Care Nurses join SCCM
1975	Guidelines for the organization of children's intensive care units created by the AAP, Disease of the Chest section
1979	Russell Raphaely chairs the first SCCM subsection on pediatrics
1983	AAP and SCCM published its first joint guidelines for pediatric intensive care units
1984	Section of Critical Care Medicine established in the AAP
1985	PCCM Subboard of AAP
1987	First certifying exam
1989	Training requirements for PCCM established by ACGME
1990	Formal accreditation of programs by ACGME
Mid-1990s	Pediatric critical care nurses establish their own society and peer-reviewed journal, advanced practice nurses and nurse practitioners specialize in pediatric critical care
2000	<i>Pediatric Critical Care Medicine</i> journal established

2004	First federally funded pediatric critical care research
2022	346 active PICUs in the United States
2024	76 accredited training programs, 624 enrolled fellows (65% F), 3689 subspecialists certified since inception of the board

**Abbreviations:** PICU (pediatric intensive care unit), SCCM (Society of Critical Care Medicine), AAP (American Academy of Pediatrics), PCCM (pediatric critical care medicine), ACGME (Accreditation Council for Graduate Medical Education)