EDITORIAL OPEN ACCESS

A historical overview of respiratory support in the newborns

Nilay HAKAN, Samet BENLI, Mustafa AYDIN

There has been a significant reduction in neonatal mortality and morbidity in recent years. Advances in obstetric care and innovations in neonatal medical and surgical care have contributed to this decline. One of the factors contributing to developments in neonatal care is the important development in respiratory support [1]. In this article, the historical evolution of respiratory support applied in the newborn period will be presented.

Respiratory failure has been considered a cause of death in newborns since ancient times. Hwang Ti, a Chinese philosopher and Emperor (2698–2599 BC) noted that respiratory failure is more common in preterm infants [2]. The Old Testament Book of Kings (4:32–35) is the first written document concerning the provision of "mouth-to-mouth ventilation/resuscitation" to a child [3]. "When the Prophet Elisha (850–800 BC) came home, he saw that the boy had died and was lying in his bed. He stood up, reached over the child and put his mouth over his mouth, his eyes over his eyes, his palms over his palms, the child's body was warm and the child opened his eyes." Although the resuscitation here has been applied on a child, it is undoubted that assistive respiratory support has also been used in neonatal resuscitation since ancient times.

Galen (129–199 AD) reported that chest expansion was observed with tracheotomy and positive pressure ventilation on dead animals [4]. In the 1000s AD, Ibn'iSina described the intubation of the trachea with gold or silver cannulas [1, 2]. Maimonides (1135–1204 AD) stated how to detect respiratory arrest in newborn babies and described a manual resuscitation method [1, 2]. Paulus Bagellardus wrote the first book on pediatric diseases in 1472 AD and redefined the mouth-to-mouth resuscitation of the newborn [1]. Paracelsus (1493–1541 AD) was the first scientist to introduce lung ventilation in humans using a "fire bellows" [5]. Andreas Vesalius [6], Belgian professor of anatomy (1514–1564 AD), performed tracheostomy, intubation, and positive pressure ventilation in a pregnant pig and wrote a work named "De Humani Corporis" on this subject. Although this work reveals the power of mechanical ventilation, it has not found a field of practice for several centuries. Later, Robert Hooke (1635–1703 MS) [7] ensured that a dog survived for more than an hour by placing a bellows in its trachea.

Benjamin Pugh first described correct endotracheal intubation with airway cannulas in neonatal ventilation in 1754 [8]. In the sixteenth and seventeenth centuries, respiratory physiology, tracheostomy, and intubation techniques were studied, and simple forms of continuous and regular ventilation were developed by 1667 [9]. There were several definitions of neonatal resuscitation in the literature during this period, but these were anecdotal. In 1780, François Chaussier developed a face mask and a ventilation balloon; translaryngeal intubation was performed in the newborn, and oxygen was used for the first time [10].

Interest in neonatal resuscitation and mechanical ventilation increased in the early 1800s. In this period, principles for mechanical ventilation of adults were determined, and rhythmic support of breathing was provided by means of tubes placed inside the trachea with mechanical devices [1]. In 1806, the French professor of obstetrics Vide Chaussier shared his work on the intubation and mouth-to-mouth breathing of asphyxiated and stillborn babies [11]. His followers developed the "aerophore pulmonaire," the first device designed for neonatal resuscitation and short-term ventilation. This device is the precursor to the balloon used today and consisted of a rubber balloon attached to a special tube [9]. Charles-Michel Billard (1800–1832) wrote the book explaining the clinical-pathological relationship of lung disease of newborns. In this work, he described the breathing difficulties experienced by newborn babies during birth [12]. The emergence of interest in neonatal care during this period led to a better understanding of the physiology of the newborn and the development of new devices to support his/her breathing. Frenchman Pierre Budin documented advances in neonatal care

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and developed follow-up programs for high-risk infants, and also known as the "father of neonatology" for his contributions [13]. In the nineteenth century, instead of applying positive pressure for ventilation, it was seen that the lung was ventilated by applying negative pressure from the outside, the first negative pressure ventilator (iron lung) was made by Alfred F. Jones in 1864, but he could not implemented it into practice. In this application, the patient was in a sitting position in a box from the neck and allowed to breathe with the help of a piston [8]. One of the most important inventions, "spirofor," which resembles the iron lung, was made by Alfred Woillez in 1876 [14]. In 1887, O'Dwyer reported the first use of positive pressure ventilation in 50 children with croup. Immediately afterwards, Egon Braun and Alexander Graham Bell independently developed devices for intermittent negative pressure/positive pressure resuscitation of the newborn [9, 15, 16].

In 1914, Von Reuss described the use of continuous airway pressure (CPAP) in neonatal resuscitation [2]. At the beginning of the twentieth century, Flagg suggested the use of an endotracheal tube with positive pressure ventilation for neonatal resuscitation [17]. The tools he described were very similar to those used today. Innovations in intermittent negative pressure and positive pressure ventilation devices during the same periods led to the development of various devices to support ventilation in infants. The first metal lung, which was widely used by Drinker and Shaw in 1929 [18], was mainly designed for use in polio.

In the 1930s and 1940s, the foundations of modern neonatology were laid with the understanding that preterm birth was the most common cause of infant mortality and that premature babies should be provided with heat control, fluid and nutrition, and protected from infection [13]. In the early 1950s, Bloxsom reported that positive airway chamber was used in the resuscitation of infants with respiratory distress in the delivery room. This device resembled an iron lung and applied intermittent positive and negative pressure [19]. However, Apgar [20] and Kreiselman showed that in non-breathing dogs, and Townsend [21] in premature infants with apnea, this device did not adequately support them. In the mid-twentieth century, many centers used balloons and face-tight masks to provide long-term respiratory support to infants.

The era of modern automatic mechanical ventilation for newborns began in 1953 by Donald and Lord [22] using a servo-controlled patient cycle ventilator. They reported that three to four babies were successfully treated with these devices. In the years following these efforts, significant improvements were achieved in mechanical ventilation. After the polio epidemic in the 1950s, experience was gained with the use of tank-type negative pressure ventilators, the success of these devices on children encouraged physicians to try it on newborns. However, intermittent positive pressure ventilation (IPPV) was unsuccessful in premature infants with respiratory distress syndrome [23]. In 1959, Avery and Mead [24] showed the deficiency of surfactant antigen (surfactant) in the lung fluids of infants who died due to hyaline membrane disease (HMH), which was groundbreaking in the treatment of these infants and led to the discovery of surfactant replacement therapy.

The premature birth of President John F. Kennedy's son in 1963 drew the world's attention to prematurity and the treatment of HMH. Kennedy's baby was born at the 34th gestational week, weighing 2100 g, and was treated with hyperbaric oxygen, the most advanced treatment of the time. However, he/she died from progressive hypoxemic respiratory failure at the age of 39 hours. In the years following this event, programs focused on the respiratory support of premature infants and treatment of HMH were initiated in many neonatal units in the United States; first, Delivoria-Papadopoulos et al. [25] from Toronto reported the successful ventilator treatment in HMH. After that, modified adult-type ventilators became available nationwide, but then a new morbidity, called bronchopulmonary dysplasia, was reported by Northway et al. [26]. There was a great improvement in 1971, Gregory et al. reported that they achieved significant improvement in ventilation and oxygenation with the use of continuous airway pressure (CPAP) in the treatment of respiratory distress syndrome (RDS) in newborns. They noticed that the main problem in RDS was collapse of the alveoli, and applied continuous positive pressure to the airway in both the inspirium and expirium with an endotracheal tube or head chamber [27]. This method was then modified by Bancalari et al. [28], and Kattwinkel et al. [29] developed nasal prongs.

In 1972, it was reported by Howie and Liggins that antenatal corticosteroid administration to pregnant women in preterm labor accelerated fetal lung maturation, thus reduced the risk of HMH and associated mortality. Until the early 1970s, the ventilators used in the neonatal intensive care unit (NICU) were a modification of adult-type ventilators and implemented IPPV by providing intermittent gas inlet. In 1971, Kirby et al. [30] developed by neonatal ventilator. Since the T-piece concept was used in this device, the ventilator provided continuous gas flow and allowed spontaneous breathing of the baby between mechanical breaths. This combination of mechanical and spontaneous breathing and continuous gas flow was called intermittent mandatory ventilation (IMV). Intermittent mandatory ventilation has become the standard method in newborns. Thus, physicians' problem of "baby struggling with ventilator" was eliminated and babies did not need to be paralyzed, and venous return was affected less than IPPV. Meanwhile, there have been advances in the medical treatment of respiratory failure caused by RDS in the newborn due to the development of surfactant replacement. In 1980, Fujiwara et al. [31] reported the beneficial effect of exogenous surfactant in the treatment of premature infants with HMH. However, controversy continues over the type and dose of surfactant preparations, as well as treatment regimens (prophylactic vs rescue).

Between 1971 and 1990, many special ventilators were produced for newborns. These included BABY bird 1, Bourns BP200, and Bourns LS 104/150 [32]. All of these ventilators were new generation neonatal ventilators that operated on the principle of IMV and capable of performing CPAP. After that, new technologies were used in second-generation ventilators, which respond faster to the intervention of the clinicians allowing the selection of more sensitive and wider ventilator parameters. During this period, high-frequency positive pressure ventilation (HFPPV) with a conventional ventilator, which was thought to cause less harm to the baby, was recommended in the treatment of RDS [33]. In the same period, extracorporeal membrane oxygenation (ECMO) and literally high frequency ventilation (HFV) were developed [34, 35]. Although these methods are primarily recommended as rescue therapy, over time HFV has become the preferred practice as the initial mode of treatment of RDS [36].

Third generation neonatal ventilators emerged in the early 1990s, and modes such as synchronized intermittent mandatory ventilation (SIMV), assist control (A/C), and pressure support ventilation (PSV) were introduced in these devices [1]. Since 2005, microprocessors with various technological features have been developed, such as patient-triggered, volume-targeted, and pressure support modes, and monitoring of respiratory functions at the bedside with ventilator graphics. The importance of controlling tidal volume led to changes in ventilation strategies when doctors became convinced that ventilator-related lung damage was secondary to volutrauma rather than barotrauma [1].

While such advances have been made in mechanical ventilators, there has been a trend toward noninvasive respiratory strategies in recent years. Nasal CPAP, synchronized intermittent positive pressure ventilation (SIPPV), and "neurally adjusted ventilatory assist" (NAVA) have become more widely used ventilator mods in premature infants with RDS to avoid trauma due to intubation and ventilator-associated lung injury. The approach to noninvasive ventilation is also supported by recent studies, emphasizing the reduction in the need for intubation in the treatment of respiratory failure with the use of this method in the early period [1]. The ultimate method for safe and effective ventilation support in neonatal respiratory failure is not yet known. It is likely that new approaches are needed to take further steps in this regard.

Keywords: History, Newborn, Respiratory support

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Samet BENLI – Acquisition of data, Analysis of data, Interpretation of data, Drafting the work, Final approval of the version to be published, Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

Mustafa AYDIN – Conception of the work, Design of the work, Revising the work critically for important intellectual content, Final approval of the version to be published, Agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved

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Authors declare no conflict of interest.

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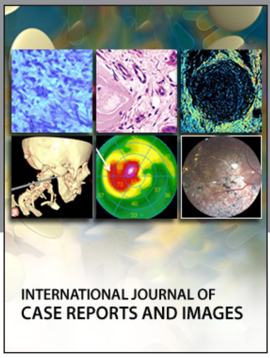
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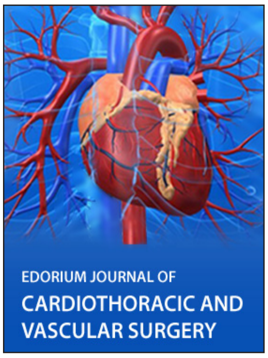
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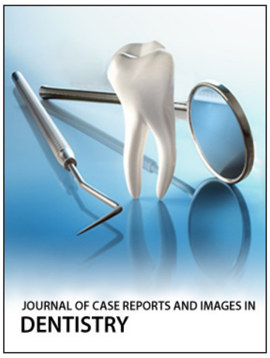
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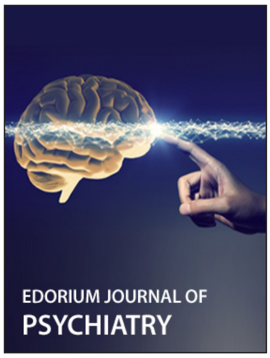
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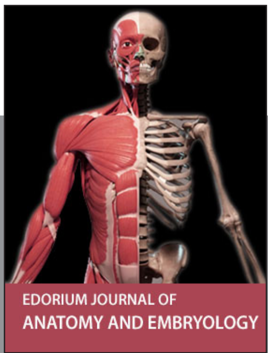
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