

# Paediatric intensive care is feasible in a neonatal department

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## ABSTRACT

**INTRODUCTION:** Intensive care of infants below one year of age has been centralised in a paediatric intensive care unit (PICU) related to the neonatal intensive care unit (NICU) at Rigshospitalet, the University Hospital in Copenhagen in eastern Denmark (approximately 2.5 million inhabitants) since 2002. The aim of this paper was to evaluate the experiences from the PICU.

**MATERIAL AND METHODS:** A descriptive study including data from the 01.01.2002-31.12.2010-period from all the admissions to the PICU for infants below one year of age fulfilling one of two criteria: 1) born preterm and admitted to the department after 40 weeks of gestational age or 2) born at term and admitted to the department at an age older than 28 days. Data were registered prospectively including information on primary diagnoses at admission, the need for mechanical ventilation and the duration of mechanical ventilation. Mortality was evaluated in the three year-period 2008-2010 by use of the Paediatric Index of Mortality 2 score (PIM2 score).

**RESULTS:** The nine-year period saw 927 admissions to the PICU and 355 infants received mechanical ventilation (median three days). The PIM2 score was 6.7% and the mortality was 6.7% in the period during which PIM2 score was registered. The incidence of mechanical ventilation due to respiratory failure was 0.74/1,000 infants born in the region.

**CONCLUSION:** The experience from the NICU seems to compensate for a low volume of infants in the PICU. The incidence of mechanically ventilated infants due to respiratory disease in eastern Denmark is relatively low.

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The prevalence of infants and children who need intensive care such as mechanical ventilation, invasive haemodynamic monitoring or vasoactive drugs is low [1]. It may therefore be difficult to obtain and maintain sufficient skills for treatment and care of these patients. Evidence suggests that centralization is beneficial as it concentrates skills at few centres [2-4]. This strategy, on the other hand, increases the need for transport of critically ill patients. However, it seems that specialist retrieval teams can compensate for the risk associated with transport [5] and consequently paediatric intensive

care is centralized at paediatric intensive care units (PICUs) in many regions in the developed world.

In 2000, it was decided to centralize paediatric intensive care in the eastern part of Denmark at Rigshospitalet. Infants and children were previously cared for in the adult intensive care units, often at local or district hospitals [6]. In eastern Denmark, there are only approximately 2.5 million inhabitants, and it has been shown that the number of children and infants in need of mechanical ventilation in Denmark is relatively low [1, 6]. Because of the expected low number of patients, it was decided to solve PICU tasks at other intensive care units. As part of this compromise, intensive care for all infants below one year of age was referred to the neonatal intensive care unit (NICU) at Rigshospitalet with the exception of infants in need of cardio thoracic surgery. The NICU was chosen because of its existing experience in neonatal intensive care and mechanical ventilation. When this decision was made, 248 neonates were mechanically ventilated for an average annual 1,425 days [7]. Furthermore, the Department had a specialist retrieval team for neonates that, in cooperation with paediatric anaesthetists, would be sufficiently skilled to transport critically ill infants up to one year of age.

The aim of this paper was to evaluate data from the PICU related to the NICU at Rigshospitalet during the nine-year-period 2002-2010.

## MATERIAL AND METHODS

Since 2002, the PICU at the Neonatal Department at Rigshospitalet has served as regional referral unit for the eastern part of Denmark for patients below one year of age in need of intensive care (population of approximately 2.5 million, area of 9,831 square kilometres). It is a multidisciplinary unit providing both medical and sur-

## ORIGINAL ARTICLE

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## ABBREVIATIONS

CPAP = continuous positive airway pressure  
ECMO = extracorporeal membrane oxygenation  
MPT = moderately preterm (gestational age  $\geq$  32 weeks and below 37 weeks)  
NICU = neonatal intensive care unit  
PICU = intensive care unit  
PIM2 score = Paediatric Intensive Mortality 2 Score  
VPT = very preterm (gestational age below 32 weeks)

TABLE 1

Admissions to the paediatric intensive care unit in the 01.01.2002-31.12.2010 period. The values are n (%).

	Year of admission									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
Admissions	77	79	93	93	117	127	106	110	127	927
Admissions from other hospitals	24 (31)	28 (35)	33 (35)	35 (38)	45 (38)	43 (34)	31 (29)	42 (38)	42 (33)	323 (35)
Admission from same hospital or home	53 (69)	51 (65)	60 (65)	57 (61)	48 (41)	80 (63)	67 (63)	65 (59)	83 (65)	564 (61) <sup>a</sup>
Missing data as to from where the children were admitted	0	0	0	1	24	4	8	3	2	40 (4)
Transferred by the retrieval team, Rigshospitalet	16	24	21	26	39	32	32	31	21	242 <sup>b</sup>

a) A total of 52 (9%) were admitted from home; b) About 75% of the children admitted from other hospitals than Rigshospitalet were transferred by the retrieval team

TABLE 2

Cause of admission, mechanical ventilation, duration of admission and mortality.

	Admission from other hospitals (N = 323)			Admission from same hospital or home (N = 564 <sup>a</sup> )			Total (N = 887)		
	n (%)	median (min.-max.)	mean	n (%)	median (min.-max.)	mean	n (%)	median (min.-max.)	mean
Admitted due to respiratory disease	200 (62)			133 (24)			333 <sup>b</sup> (38)		
Admitted due to a surgical disease or post-operative observation	40 (12)			343 (61)			383 (43)		
Admitted due to other diseases	80 (25)			79 (14%)			159 (18)		
Extracorporeal membrane oxygenation	3 (1)			9 (2)			12 (1)		
<i>Mechanical ventilation</i>	139 (43)			216 (38)			355 (40)		
Duration, days		4.0 (1-86)			3.0 (1-63)			3.0 (1-86)	
Age at admission, days		123 (29-921) <sup>c</sup>			88 (29-778) <sup>d</sup>			100 (29-921) <sup>e</sup>	
Duration of admission, days		2 (1-88)	4.32		1 (1-65)	3.98		2 (1-88)	4.11
Mortality <sup>f</sup>	24 (7.4)			35 (6.2)			59 (6.7)		

a) A total of 52 (9%) admitted from home; b) A total of 14 of the children admitted due to respiratory disease missed data on route of admission; c) Only data on 271 children;

d) Only data on 471 children; e) Only data on 742 children; f) The mortality in all of the 40 children for whom data were missing concerning route of admission was 2.5% (n = 1).

gical paediatric intensive care to a wide range of tertiary specialty services with the exclusion of tertiary level cardio thoracic surgery which is centralised at another unit at Rigshospitalet. In addition to mechanical ventilation, the PICU thus monitors and treats circulatory problems, monitors intracranial pressure, performs renal dialysis and treats patients below the age of two years with extracorporeal membrane oxygenation (ECMO). It is recommended that infants below one year of age in need of mechanical ventilation or at risk of severe respiratory failure from the region be transferred to the PICU at Rigshospitalet, if possible by the specialist retrieval team. If an infant does not need mechanical ventilation, it is normally admitted to the paediatric semi-intensive care unit at Rigshospitalet where nasal continuous positive airway pressure (CPAP) and any necessary monitoring can be provided. Data from all admissions to the PICU are registered prospectively as a part of the daily routine and stored in the department's local database. Infants below one year of age were admitted to the PICU if they fulfilled one of the following two criteria: 1) born preterm and admitted to the department after

40 weeks of gestational age or 2) born at term and admitted to the department at an age older than 28 days. These criteria are arbitrarily used to coordinate to which department infants should be admitted when hospitalized at Rigshospitalet.

The present study includes data from all consecutive admissions and transports by the specialist retrieval team in the nine-year period from 01.01.2002 to 31.12.2010. The following data were available in our local database for all nine years: age at admission, gestational age at birth, admission source (transfer by retrieval team or by local team from another hospital or admission from another department within Rigshospitalet), primary diagnosis at admission, need for mechanical ventilation, duration of mechanical ventilation, need for nasal CPAP, duration of nasal CPAP and length of stay at the PICU. The Paediatric Index of Mortality 2 score (PIM2 score) [8] was used to evaluate the mortality rate in the PICU and was available for the three-year period 01.01.2008-31.12.2010.

The patients were divided into three groups based on the primary diagnosis at hospitalization at Rigshospi-



TABLE 3

	Very preterm <sup>a</sup> (N = 51)	Moderately preterm <sup>b</sup> (N = 69)	All preterm (N = 120)	Term (N = 204)	All (N = 324)
Age at admission, median, days <sup>c</sup>	147	116	131	126	129
Mechanical ventilation, n (%)	23	27	50 (42)	136	186 (57)
Nasal continuous positive airway pressure, n (%) <sup>d</sup>	20	29	49 (41)	48	97 (30)
<i>Duration of mechanical ventilation, days</i>					
Median (min.-max.)	5 (1-47)	5 (1-63)	5 (1-63)	4 (1-86)	4 (1-86)
Mean	7.8	10.0	9.9 (11.5)	6.3	7.1 (10.3)
Mechanical ventilation > 7 days, n	7	12	19	30	45
Mortality, n (%)	7 (13.7)	1 (1.4)	8 (6.7)	16 (7.8)	24 (7.4)

a) Gestational age < 32 week; b) 32 weeks ≤ gestational age < 37 weeks; c) Age not corrected for the preterm birth; d) Children not treated with mechanical ventilation; missing data on nasal continuous positive airway pressure: very preterm: n = 5, moderately preterm: n = 4, term: n = 3.

All children admitted due to respiratory disease: mechanical ventilation and nasal continuous positive airway pressure in relation to gestational age. Data missing on gestational age on 23 children admitted due to respiratory disease.

talet: 1) children with respiratory disease or failure, 2) children admitted with a surgical diagnosis or for post-surgical monitoring, and 3) children with a range of other diagnoses not listed above including infants admitted for ECMO. The group of children with a primary respiratory disease or failure was subsequently divided into three groups based on gestational age: children born very preterm (gestational age below 32 weeks (VPT)), children born moderately preterm (gestational age ≥ 32 weeks and below 37 weeks (MPT)) and children born at term.

We expected that all the infants with a primary respiratory disease in need of mechanical ventilation in the region were treated in our department. To calculate the incidence of mechanical ventilation in the region due to primary respiratory disease and the association between gestational age and mechanical ventilation in the first years of life, the following epidemiological data were retrieved from the statistics available from the Danish National Birth Register: there were approximately 250,000 new-born infants in eastern Denmark in the period from 01.01.2002-31.12.2010; approximately 28,000 per year. VPT constituted 1.0-1.2% and MPT 5.0-5.8% of all the new-borns in the period.

### Statistics

We used the epidemiological data from the Danish National Birth Register along with the data from our local database to calculate the regional incidence of mechanical ventilation for children admitted to the PICU due to primary respiratory disease in the region. Furthermore, we calculated the odds ratios for mechanical ventilation due to primary respiratory disease by these data for VPT and MPT children compared with children born at term.

Descriptive statistics were calculated using the statistical package SPSS 18.

*Trial registration:* not relevant.

### RESULTS

During the nine-year period, there were a total of 927 admissions to the PICU. Of these, 323 admissions were from other hospitals and approximately 75% of these infants were transferred by the specialist retrieval team (Table 1).

Table 2 shows the primary causes for referral to the PICU. These were respiratory failure in approximately 38% of the patients, surgical diagnoses or post-surgical observation in approximately 43%, and in 19% there were a wide range of other primary causes of which meningitis, sepsis, seizures and cardiac diseases were the most frequent. Approximately 1% of the infants were admitted for ECMO. In the nine-year period, a total of 355 infants were mechanically ventilated (approximately 40 infants per year) for a median period of three days (range 1-88 days).

The overall mortality for the nine-year period was 6.5% (n = 60). The PIM2 obtained from the three-year period (01.01.2008-31.12.2010) was 6.7, and the observed mortality in this period was 6.7%.

Data on infants admitted with respiratory failure as the primary diagnosis are shown in Table 3. Of the 347 infants admitted with respiratory failure as the primary diagnosis, data on gestational age were missing for 23 children. Of the remaining 324 infants with data on gestational age, 186 children (57%) were treated with mechanical ventilation and 97 (30%) with nasal CPAP only. Of the infants treated with mechanical ventilation, 23 were born VPT, 27 MPT and 136 at term. By using the data from the Danish National Birth Register, we calculated the incidence of mechanical ventilation due to a primary respiratory disease to 0.74 per 1,000 infants per year in the period. Based on the data provided by the Danish National Birth Register where VPT constituted 1.0-1.2% and MPT constituted 5.0-5.8% of all the new-borns in the period, we estimated the odds ratios for mechanical ventilation due to primary respiratory dis-

Five-month old boy treated with tube-continuous positive airway pressure gradually reducing respiratory support.



ease for all the preterm infants born in eastern Denmark to 14.4 (95% confidence interval (CI): 9.2-22.4) for VPT and 3.4 (95% CI: 2.3-5.2) for MPT infants compared with the infants born at term.

## DISCUSSION

The aim of our study was to evaluate the data from the PICU related to our NICU. The nine-year period saw a total of 927 admissions to the PICU: 65% from Rigshospitalet and 35% from other hospitals in the region. We did not have the exact number of infants since some infants were admitted more than once to the unit. The majority of the infants from other hospitals were admitted due to respiratory disease. When the PICU was established, the intention was that the critically ill infants from other hospitals should be transferred to the PICU by the retrieval team and this actually occurred in 75% of these admissions. The median duration of the admissions in the group of infants from other hospitals was only two days and this short period of time in the PICU is likely explained by the close collaboration with the paediatric semi-intensive care unit at Rigshospitalet where nasal CPAP and any necessary monitoring can be provided. In the group of infants admitted from other departments within Rigshospitalet, the majority were admitted due to a surgical disease or need for post-operative monitoring and treatment. The median duration of admission of only one day in these infants also suggests that the majority of the infants could quickly be transferred to the paediatric surgical department. Overall, the short duration of admission in the PICU also indicates that the majority of the infants did not suffer from multiorgan failure.

In the nine-year period, 40% of the 927 infants admitted to our PICU were mechanically ventilated, which is approximately 40 infants each year. We are aware that the patients requiring cardio-thoracic surgery were not admitted to our department and even though we cannot exclude that a few children may have been mechanically ventilated for a very short period of time at local intensive care units, we believe that the centralization of the treatment has been successful. Overall, the mortality in our cohort was 6.5%. In the period where the PIM2 score was registered, the mortality was 6.7% and this was not different from the calculated risk. We did not have other data than mortality to illuminate the quality of the intensive care in our PICU. The PIM2 score is a validated tool used to estimate the severity of illness in critically ill children [9], and we consider it the most relevant measure to evaluate the mortality, even if data for PIM2 score were collected only in the last three years of the study period. We acknowledge that our number of admissions to the PICU is low compared with recommendations [4, 10] and even though it would have been advantageous to have a higher volume of patients, we conclude that the experiences from neonatal intensive care seem to compensate for the low number of children. The department is thus familiar with mechanical ventilation in neonates, but the establishment of the PICU has also been followed by new initiatives shown to improve treatment and care [11]. There are on-going training programmes based on simulation for both nurses and doctors, and regular education programs have been established for the nurses who care for the PICU children. The establishment of the PICU has also promoted a closer collaboration with paediatric anaesthetists. Special invasive procedures such as central venous access and intubation are often handled by the anaesthetists who are also able to participate in the majority of the transports of infants from other hospitals conducted by our retrieval team.

We estimated the incidence of infants below one year of age needing mechanical ventilation due to respiratory disease to be 0.74/1,000 infants per year in the region and like in other studies [12], a significantly higher risk for infants born preterm with an estimated OR = 3.4 (95% CI: 2.3-5.2) and 14.4 (95% CI: 9.2-22.4) for MPT and VPT infants, respectively. Very few studies provide epidemiological data on the incidence of mechanically ventilated infants due to respiratory disease or failure below one year of age. However, compared to data from the United Kingdom (UK), our calculated incidence is low. Thus, in 2004-2007 the PICU admission rate in the UK due to acute respiratory failure was 1.80/1,000 infants with 74% of these being mechanically ventilated [12]. There may be many reasons for this difference. The classification of the aetiology for mechanical ventilation

upon admission, differences in socioeconomic living conditions, and the organization of the healthcare system may be important factors impeding international comparison of such epidemiological data. Another factor could be the Danish tradition for use of nasal CPAP. Accordingly, even among the infants admitted to the PICU with respiratory failure, 30% were treated with nasal CPAP and then transferred within a few days to the paediatric department also at Rigshospitalet for continued treatment with nasal CPAP. To our knowledge, the use of nasal CPAP beyond the neonatal period has not been extensively studied, nor has it been generally adapted into clinical care. However, studies from other countries do support this strategy [13-15]. Mechanical ventilation can be prevented with nasal CPAP in preterm infants [16] and this may thus also be possible in infants beyond the neonatal period.

## CONCLUSION

Our study suggests that the experience from the neonatal intensive care compensates for a low volume of infants in PICU which makes it possible to provide a quality of care comparable to international standards with regard to mortality. We found a relatively low incidence of mechanical ventilation in infants with respiratory disease below one year of age in eastern Denmark. We speculate that the use of nasal CPAP may be one explanation for this low number.

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