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Use of Continuous Positive Airway Pressure (CPAP) in Neonatal Units – A Survey of Current Preferences and Practice in Germany

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Abstract
There is only limited evidence regarding the equipment or the settings (pressure and flow) at which CPAP should be applied in neonatal care. Aims of this nationwide survey of German neonatal units were to investigate (1) for which clinical indications CPAP was employed, (2) which CPAP equipment was used, (3) which CPAP settings were applied.

A questionnaire on the use of CPAP was sent to all children's hospitals in Germany. Data were stratified and compared by level of medical care provided (non-academic children's hospital, academic teaching hospital and university children's hospital).

274 institutions were contacted by mailed questionnaire. The response rate was 86%, 90 non-academic children's hospitals, 119 academic teaching hospitals and 26 university children's hospitals replied. (1) There were no statistically significant difference in CPAP use between the institutions: 231 (98%) used CPAP for treating respiratory distress syndrome, 225 (96%) for treating apnoea-bradycardia-syndrome and 230 (98%) following extubation. (2) Commercial CPAP systems were employed by 71% of units, the others used a combination of different devices. Respirator generated CPAP was most commonly used. Exclusively mononasal CPAP was used by only 9%, and binasal CPAP by 55% of institutions. (3) Median CPAP was 4.5 cm H_2O (range 3-7), median maximum CPAP was 7 cm H_2O (range 4-10), with no statistically significant differences between the hospitals.
Conclusion: Between units, CPAP was given via a broad range of CPAP systems and at varying pressure settings. The reported differences reflects personal experiences and preferences, rather than sound evidence from clinical trials.

Key words: continuous positive airway pressure, equipment, nasal prongs, respiratory distress syndrome, neonate

Abbreviations:
BW = birth weight
CPAP = continuous positive airway pressure
GA = gestational age
RDS = respiratory distress syndrome
ELBW = extremely low birth weight
NICU = neonatal intensive care unit
ICU = intensive care unit
Inst. = institution

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Introduction

Continuous positive airway pressure (CPAP) as a treatment for neonatal respiratory distress syndrome has first been described by Gregory et al. in 1971 [1]. Thanks to the works by Gregory, Dunn and Wung JT et al. [1, 2, 3], CPAP has become recognized as a means to improve both pulmonary and extra pulmonary outcomes by avoiding prolonged mechanical ventilation in prematurely born infants [4]. Recent prospective and retrospective studies involving extremely low birth weight infants (ELBW) suggest that the survival rate, the need for retinopathy of prematurity (ROP) surgery and the length of hospital stay were significantly reduced in the era of routine CPAP use, compared to routine endotracheal intubation [4, 5, 6].

Today, CPAP is increasingly being used as a mode of respiratory support in neonates world wide [7]. A variety of different commercial CPAP systems and nasal prongs are available. Both mono- and binasal CPAP systems are used, and a distinction is being made between bubble CPAP, and continuous or variable flow CPAP devices [8, 9]. CPAP can also be provided via a facial mask or by a head box [10, 11].

Notwithstanding the widely accepted use of CPAP for neonates, there are no uniformly accepted guidelines on the use of CPAP in the neonatal setting. In two recent, comprehensive reviews on the current state of CPAP therapy in neonates, Polin R. A. et al and DePaoli et al. [12, 13] identified several areas as to where there remains insufficient evidence, including the optimal mode of CPAP delivery, the pressure source, the level of flow and of CPAP according to different gestational ages, etc.

Given the wide variation of CPAP equipment available today and differing local practice in neonatal units, we surveyed all German neonatal units with an aim to identify the current preferences and practice of CPAP therapy. We sought to investigate whether there were detectable variations between institutions of different levels of care regarding the indications for giv-

ing CPAP, the equipment used and the clinical settings at which CPAP was applied in neonates.

Methods

Between September 2005 and October 2006 we conducted a prospective questionnaire based survey on the use of CPAP at all German children's hospitals. The questionnaire was developed in our clinic and pretested on our senior medical staff.

Questionnaire

The questionnaire contained four sections:

- *Characterization of the institution under investigation:* We asked about the level of care provided (institution 1: non-academic children's hospital, institution 2: academic teaching hospital, institution 3: university children's hospital), the number of in house births, the number of ELBW infants (< 1500 gr.) born and cared for at the hospital, presence of and number of admissions to an in house intensive care unit (ICU), number of ventilator equipped beds and number of ventilated patients per year.
- *Indications:* The general indications for giving CPAP (RDS, apnoea, post extubation, etc.) were enquired, space was granted to add further indications.
- *CPAP equipment:* We asked about the types of CPAP system in use, specifically whether these were commercially available systems, a combination of such or self-made equipment. The makes of the CPAP generator (ventilator, flow driver or bubble CPAP system) were investigated. We enquired about the type of CPAP provided, the use of mono-nasal, binasal or mask CPAP and the type of prong used.
- *Settings:* Questions were asked regarding the general CPAP settings (pressure in cm H_2O) and corresponding flow (l/min) settings, the preferred body position and feeding modalities while on CPAP. We wanted to know whether the institution had a designated CPAP protocol or guideline for the use of CPAP in neonates.

Protocol

The questionnaire was sent by posted mail. We identified the names and addresses of all German children's hospitals through the address database of the German Society of Neonatal and Paediatric Intensive Care (GNPI), as well as through the directories supplied by Abbott® pharmaceuticals, Nestle® and Fisher & Paykel Healthcare®. A questionnaire was sent to the Head of the Paediatric Department of each children's hospital. The recall rate was monitored and the questionnaires checked for completion by our research assistant (AK). After four weeks, a reminder questionnaire was sent out the non-compliant institutions, followed by Email or telephone contact. The data were entered into the database by the study nurse (JB).

Statistical Methods

The reported characteristics were described by incidences or median and range. The differences between the institutions in the reported parameters were compared by chi-square test, the exact Fischer test or Mann-Whitney rank test, as appropriate. For statistical evaluation the software STATGRAPHICS (Vers. 3.0, Manugistics Inc., U.S.A.) was used. A level of statistical significance of $p< 0.05$ was accepted.

Results

Institutions

Of the 274 institutions contacted, 147 (54%) answered to the initial questionnaire and a total of 235 (86%) questionnaires were obtained after a reminder Email or telephone call (Fig. 1). Of these questionnaires 221 (94%) were fully completed, in 14 (6%) there was some missing data, mostly regarding the institutions details, for example the number of patients admitted to the ward per year.

The responding institutions comprised of 90 (38%) non-academic children's hospitals (Inst. 1), 119 (51%) academic teaching hospitals (Inst. 2) and 26 (11%) university children's hospitals (Inst. 3). Between the institutions there were statistically significant differences regarding the number of admissions per year, number of ventilated patients per year, and number of ELBW infants cared for per year.

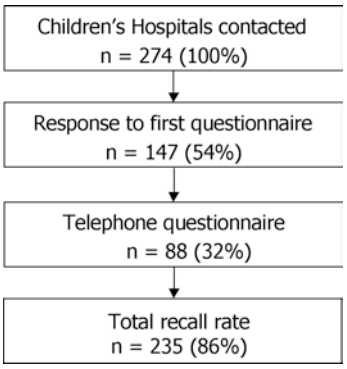

Fig. 1. Algorithm of data aquisition.

Indications for Applying CPAP

Despite the differences in the number of patients ventilated per year, there were no statistically significant differences between the institutions regarding the indications for establishing CPAP therapy. CPAP was commonly applied for conditions like respiratory distress syndrome (RDS) (98.8% Inst. 1, 97.5% Inst. 2, 100% Inst. 3) or apnoea of prematurity (93.3% Inst. 1; 96.6% Inst. 2, 100% Inst. 3). Nasal CPAP was used in 175 (75%) of all units as the primary treatment of respiratory support immediately following delivery, without statistically significant differences between institutions.

Statistically significant differences were observed regarding the degree of prematurity at which CPAP was started to prevent ventilation. In infants <28 gestational weeks CPAP was used as a primary treatment in 60% of Inst. 1, 80% of Inst. 2, and 90% of Inst. 3, the dif-

Table 1. Characteristics of participating institutions. Data presented as median (range).

	Non-academic children's hospital (n = 90)	Academic teaching hospital (n = 119)	University children's hospital (n = 26)	p Value
Admissions to ICU / year	231 (20 – 1000)	290 (50 - 1000)	300 (18 –1100)	0.02
Number of ventilated patients / year	30 (0 - 150)	50 (4 - 250)	120 (30 - 480)	< 0.0001
Admissions infants <1500gr	20 (0 – 120)	30 (1 – 110)	62 (2 - 120)	< 0.0001

ference between institutions was statistically significant (p = 0.009).

Other quoted indications for giving CPAP included: the treatment of transient tachypnea of the newborn, pneumonia, pulmonary congestion in congenital heart disease, for stabilising the airways in tracheomalcia, and respiratory support for congenital malformations, like for example Pierre-Robin syndrome.

Equipment

A wide range of different CPAP systems and CPAP generators were found to be used in Germany, without statistically significant differences between the institutions. The predominant mode of CPAP delivery was ventilator generated CPAP with the Draeger Babylog 8000® Series (35%), and the Stefanie® ventilator (10%). Exclusive CPAP generators, such as the Infant Flow Driver® were used by 32% of the institutions, bubble CPAP systems, like the Fisher & Paykel Bubble CPAP kit®, were used by 9% (Fig. 2). Exclusively commercial CPAP systems were employed by 71% of units, 20% used a combination of different commercially available devices and only 8% of institutions combined CPAP devices with self designed CPAP components.

CPAP-application

Use of facial masks for the delivery of CPAP were reported by 38% of all institutions, they were commonly used for initial respiratory support in the delivery room. Head box CPAP was not used. On the ward CPAP was commonly applied either as mono- or binasal prong CPAP. The predominant choice of mono- and binasal prongs by institution is shown in Fig. 3. There were no statistically significant differences between the institutions regarding the choice of mono- or binasal CPAP. Exclusively mononasal CPAP was used by only 9% of the institutions, binasal CPAP was used by most institutions (55%) and both mono- and binasal CPAP were used by 36% of the institutions (Fig. 3).

CPAP-settings

Table 2 shows the pressure and flow settings at which CPAP was regularly provided, there were no statistically significant differences in pressure and flow settings between the institutions. The median starting CPAP was 4.5 cm H_2O for Inst. 1 and 4.0 cm H_2O for Inst. 2 and Inst. 3, with a range from 3 to 7 cm H_2O (Table 2). The minimum reported CPAP was 1 cm H_20 and the

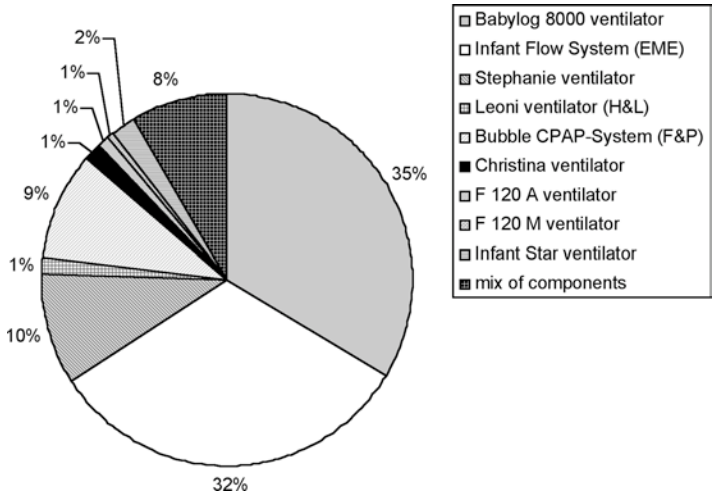

Fig. 2. Choice of CPAP system in Germany.

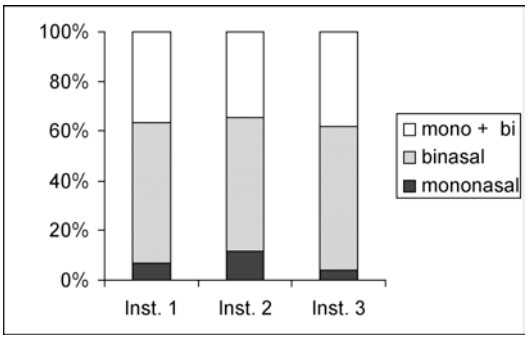

Fig. 3. Use of mono- and binasal CPAP prong by institution.

Table 2. CPAP settings by institution (median (range)).

	Non-academic children's hospital	Academic teaching hospital	University children's hospital	p Value
Starting CPAP at cm H_2O	4.5 (3 - 6)	4.0 (3.5 - 6)	4.0 (3 - 7)	0.939
Maximum CPAP installed (cm H_2O)	6.25 (4 - 10)	6.0 (4 - 10)	7.0 (5 - 10)	0.237
Minimum CPAP installed (cm H_2O)	3 (2 – 5)	3 (1 – 5)	3 (2 – 5)	0.898
Gas flow (l/min)	5 (4 - 9)	5 (4 - 10)	5 (4 - 7)	0.667

maximum reported CPAP 10 cm H_2O. High CPAP between 8 - 10 cm H_2O was rarely administered (n = 17, 7%). Most units chose a moderate flow of 5 l/min (range 4 – 10 l/min), a flow of 6 - 10 l/min, was only reported by a few units (n = 17, 7%).

CPAP Protocol or Guidelines

The majority (n = 133, 57%) of institutions conceded to having either CPAP guidelines or a designated CPAP protocol. These were compiled and maintained by a medical professional, either a doctor (n = 111; 84%) or a nurse (n = 21, 16%). There was no statistically significant difference in the use of guidelines between the institutions (p = 0.103).

Discussion

Our survey of German neonatal units established that nasal CPAP is a widely accepted mode of treatment for a number of respiratory conditions, even for the smallest of patients. Although there was good nationwide agreement between the institutions on the indications for giving CPAP therapy, we found a broad variation of how CPAP was applied. Most often, CPAP was generated by a ventilator. As the commonest form of CPAP therapy, binasal CPAP was used, but there was a wide variation in the applied settings like flow and level of CPAP. Most units used commercial CPAP systems. Despite a wide variety of commercial systems available almost every 10th unit still employed custom made CPAP equipment.

The over all response rate of the hospitals was 86% and comparable with other epidemiological studies of clinical practice in Germany [14]. There was no financial incentive for the participants to complete the questionnaire. We speculate that this high level of compliance is indicative for the general interest in the results of our survey. Still, however meticulously the participating institution or investigators (JB, AK) sought to fill in every item required, certain information, as for example the number of patients admitted to the ward per year were not always available. The drop out rate was <10%, it is therefore likely not to have an impact on the results of the study.

The majority of neonatal and ELBW infants will be treated in centres of high dependency, like university children's hospitals. These institutions answered significantly more often to giving CPAP as a first line treatment for RDS in patients with lower GA. However, despite the above differences in the number of the treated ELBW infants, no statistically significant differences were found regarding the preference or practice of CPAP therapy between the institutions.

Another area of interest was whether there were differences in the CPAP system chosen. Our prerogative was that binasal CPAP would be the primary choice at university children's hospitals, given by the higher ELBW turnover and expertise with ventilated infants those institutions. Despite this assumption, we found that although only 4% of university children's hospitals used only mononasal CPAP and more than 58% chose entirely binasal CPAP, both mono- and binasal CPAP treatment were applied throughout at around 40% of all institutions. There was also no statistically significant relationship between the level of care provided and choice of CPAP application. This is surprising, since good evidence supports the use of binasal CPAP [15, 16]. Only one study addressed the issue of effectiveness of mono- vs. binasal CPAP in children > 1250 gr [17]. These authors suggest the use of binasal CPAP for children of less than 2500 g, and mononasal CPAP for those children weighing more than 2500 gr., mainly because of the significantly reduced time on CPAP in the latter group [17]. More data is needed to answer questions like which CPAP system and which settings are most favourable at different levels of lung development and for which underlying lung pathology.

We established that mechanical ventilators were used as the predominant source of flow generators for delivering CPAP, followed by a specific CPAP Flow Driver System and then bubble CPAP. It remains to be clarified why most units still apply ventilators as CPAP generator, since Lee and colleagues have shown that bubble CPAP, compared to ventilator generated CPAP, significant improved respiratory mechanics and reduced respiratory frequency and work of breathing in neonates [18]. We speculate that financial restrictions in times of continuously limited resources and increas-

ing patient turn over may, at least in part, explain this finding. On the other hand, since especially bubble CPAP had initially started out from using self made devices (such as under water bubble CPAP through bottled sterile water), a proportion of units may hang on to their traditional equipment, with which they have gathered good experience.

When comparing the clinical settings under which CPAP is applied, it became apparent that there is a wide variation of flow and CPAP-pressure, but with no statistically significant difference between the institutions with different level of care. In general, moderate settings for both CPAP-pressure and flow were chosen, only few centres dared to surpass the mark of 7 cm H_2O as CPAP-pressure or a flow of 6 l/min. A surprisingly low CPAP of as little as 1cm H_2O was once chosen. The general CPAP setings in neonates deserve discussion. As early as 1975, Suter and colleagues defined the best positive end expiratory pressure (PEEP) as the level of PEEP resulting in the maximum oxygen delivery [19]. Despite groundbreaking work of Kirby and colleagues, who could show that even high levels of endexpiratory positive pressure improve oxygenation without compromising cardiac output or CO2 rebreathing in the adult patient [20], the ideal level of CPAP in the preterm neonate remains to be defined [21, 13]. If the CPAP is to high, over distension may occur and CO2 removal may be compromised, too low a CPAP may result in loss of FRC and lung collapse [21]. According to a Cochrane review by Davis and Henderson-Smart, a CPAP greater than 5 cm H_2O appears to be more effective than lower CPAP to prevent re-intubation following extubation of neonates [22]. In the absence of comprehensive clinical studies, neonatologists obviously follow experience and personal reason when choosing a level of CPAP for a particular baby. However small the amount of available data on the clinical use of CPAP may be, it is reassuring to see that more than half of the institutions have local protocols or guidelines for CPAP therapy, and hence try to base their treatment on published evidence.

Our study exemplifies that the majority of Germany's children's hospitals choice of treatment is in accordance with the best available evidence [15, 21, 12]. However, the wide variation of both the CPAP systems used and the clinical settings at which CPAP is applied indicates a lack of sound data and established guidelines to aide physicians when treating neonates with respiratory disorders. This results in significant differences in neonatal care between institutions, even in a comparatively small, but relatively well organized country like Germany. Nonetheless, until further studies are available, it will remain a matter of speculation whether these differences would explain some of the described differences in outcomes of preterm infants [23], and these differences require further investigation and specification.

SUMMARY

In Germany, CPAP is a well established method for different respiratory conditions in neonates. In clinical practice, it is nationwide being applied at varying pressures and flow settings. Irrespective of the growing number of available commercial CPAP systems, many units choose to combine different CPAP devices. Approximately 10% of the surveyed hospitals still apply CPAP via custom made equippment. The reported differences regarding the use of CPAP reflect on the personal experience and preferences of the individual units, rather than sound data. Despite significant advances in the field of neonatal CPAP, there is still a paucity of objective evidence regarding the optimal choice of CPAP system, devices and settings used for common neonatal indications.

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