

CPAP, Yes! But How?

Continuous positive airway pressure (CPAP), in a variety of forms (eg, positive end-expiratory pressure, noninvasive ventilation, bi-level positive airway pressure), is an indispensable tool in the treatment of respiratory disease in patients of all ages, but particularly in the newborn. It is unusual for an infant with any level of respiratory distress beyond the need for a little O₂ not to have at least some treatment with a variant of CPAP. It was commonly used on newborns, beginning in the 1970s, well before its use on children and adults became established.

The earliest application of CPAP was via bubble CPAP, described by Gregory et al in the early 1970s.¹ Initially, application of CPAP was either through an endotracheal tube or via face mask. However, the use of nasal prongs was first described in 1973,² and although other interfaces have been developed over the years, nasal prongs remain the most commonly used interface. Thus in the neonatal intensive care unit CPAP has become nasal CPAP.

In the intervening years since the 1970s a substantial number of studies have established the clinical benefits of nasal CPAP in the newborn.³ However, there is remarkably little agreement on many aspects of how it should be applied, including indications for its use and the best system to be used. De Paoli et al published an article entitled "Nasal CPAP for Neonates: What Do We Know in 2003?"⁴ As it turned out, not nearly as much as we should. Today, 7 years later, many of the questions asked by De Paoli et al remain unanswered, including: Which device should be used? Continuous or variable flow? Which interface should be used? What pressures are appropriate (single or bi-level)? When should it be applied? Should surfactant be given to infants receiving only CPAP? What are optimal flow patterns? How do various devices affect the work of breathing? Should it be used for resuscitation in the delivery room? The authors of 5 different Cochrane Collaboration systematic reviews of various aspects of CPAP in the newborn found insufficient evidence to make any substantive conclusions regarding these and other questions.⁵⁻⁹ The follow-up review by Courtney and Barrington in 2007 posed far more questions than it answered.³

One of the most vexing problems in comparing various nasal CPAP systems in the clinical environment is variations in the gestational age, condition, and size of subjects. Thus, bench studies, in which variables such as resistance, compliance, tidal volume, and respiratory rate can be tightly controlled, seemingly would allow a precise description of

the mechanics of different systems and would suggest refinements that could make results from clinical studies more definitive.

SEE THE ORIGINAL STUDY ON PAGE 544

In this issue of *RESPIRATORY CARE*, Cook et al¹⁰ address one of the questions posed by De Paoli et al, in a systematic bench comparison of 5 nasal CPAP systems representing the 4 types of nasal CPAP devices. Cook et al tested the hypothesis that different nasal CPAP systems have different load characteristics that affect V_T at constant effort. They used an electronic lung simulator to model typical lung compliance, resistance, and respiratory rate of an infant with respiratory distress syndrome, at 4 tidal volumes (3, 6, 9, and 12 mL) at a CPAP of 5 cm H₂O. Airway pressure changes throughout the entire breath were examined, and the simulated muscle pressures required to generate each tidal volume throughout the breath were determined. The levels of simulated muscle pressures required for each tidal volume provide at least an index of the work of breathing that may be required with each of the 5 nasal CPAP devices. In general, the measurements were very precise, and the experimental system showed an extremely small amount of internal variation.

The measurements not only showed changes in simulated muscle pressure throughout each breath, but also changes in inspiratory pressure drop and actual tidal volumes achieved. The achieved tidal volumes differed significantly from the reference tidal volumes for the various devices, although the differences were probably not large enough to be clinically important. The most striking differences among the various devices were in mean inspiratory pressure drop (ie, the maximum pressure drop after the start of the inspiratory effort during the breath). This is representative of the maximum resistive work load during inspiration. The highest values were for the bubble CPAP system at lower tidal volumes, and the AirLife nasal CPAP system for the higher tidal volumes, whereas the lowest values were observed in the flow-opposition fluidic (Coandă effect) device. At least one other study has shown that both resistive work of breathing and respiratory rate are higher with bubble CPAP than with a flow-opposition fluidic system.¹¹ Finally, the study showed that although the ventilator was set on CPAP, it actually supplied a small

but significant amount of pressure assist during inspiration, thereby decreasing the work of breathing. Despite the differences found in this study, however, Cook et al conclude that for infants < 1,000 g there are no clinically meaningful differences among the tested nasal CPAP systems, whereas for those > 1,000 g the ventilator-derived system may offer an advantage.

Both the design and the measurement precision in the Cook et al study suggest that it represents a highly reliable picture of the mechanical differences among the 4 types of nasal CPAP systems but represent real clinical differences. Because of a lack of glaring differences among the systems, the results would seem to send investigators back to the clinical environment, but now with the knowledge that differences observed are probably not due to mechanical differences among the systems. The difficulties in addressing clinical studies remain, however.

Two recently published studies present 2 different approaches that may help with these challenges, however. Gupta et al addressed 2 critical nasal CPAP outcomes (rate of successful extubation and duration of CPAP support) in a randomized controlled comparison of bubble CPAP versus flow-opposition fluidic CPAP.¹² Without directly addressing fundamental physiologic questions such as work of breathing, resistive work load, or lung mechanics, they found that bubble CPAP was associated with a significantly higher rate of successful extubation and a significantly shorter duration of CPAP, compared to infants treated with flow-opposition fluidic CPAP.

The second study¹³ took a different tack, looking at the level of electrical diaphragmatic activity associated with bubble CPAP versus high-flow nasal cannula (8 L/min). The study was a case report on a 26-week gestational age infant. Diaphragmatic activity and observed respiratory distress were higher with bubble CPAP than with high-flow nasal cannula. This type of data certainly represents the possibility of drawing conclusions regarding the physiologic processes occurring during nasal CPAP therapy.

The combination of these 2 approaches (one focusing on meaningful clinical outcomes and the other on physiologic processes occurring as a result of the therapy) applied simultaneously in a randomized clinical trial of sufficient

statistical power may finally provide the long-sought path to answering key fundamental questions about nasal CPAP.

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