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Case Report

Neonatal abdominal support to address CPAP belly: Two cases report and literature review

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Abstract. Gaseous distension of the abdomen from the use of continuous positive airway pressure (CPAP) in the preterm population is of increasing concern for its unintended consequences. Methods to treat and prevent CPAP belly deserve further investigation. An intervention to provide abdominal support to address CPAP belly is presented in these case studies.

Keywords: Abdominal binder, CPAP belly, neonatal, premature

Abbreviations

CPAP	Continuous positive airway pressure
ZOA	Zone of apposition

1. Introduction

Gaseous distension of the bowel in the premature infant on continuous positive airway pressure (CPAP) was first acknowledged in the literature as a benign condition [1] and is commonly referred to as "CPAP belly". It was found to be common in infants less than 1000 grams occurring 82% of the time [1]. Though, at the time, it was not correlated with serious morbidity, namely necrotizing enterocolitis [1], discussion continues as to the potential consequences of CPAP belly.

An editorial by Dr. Kim in 2018 voiced concerns for gastrointestinal motility, spontaneous ileal perforation and potential sepsis due to effects on bowel wall integrity [2]. Priyadarshi et al added a concern for the potential need to escalate care from non-invasive to invasive ventilation due to the inhibitory effect of abdominal distension on respiration as well as exposure of an infant to x-rays and a septic workup to address an infant with significant CPAP belly [3]. CPAP belly is not always a benign experience for the infant and presents a complex challenge for neonatal intensive care providers.

CPAP is now widely used making its implementation the topic of quality improvement efforts to decrease its complications [4]. The case studies in this article will describe CPAP belly addressed with an intervention which avoids the escalation in support while resolving the infant's distension.

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2. Case report 1

An infant was born at 26 weeks with APGAR scores of 3, 3, and 4 at 1, 5 and 10 minutes respectively. The infant was delivered via Cesarian section due to maternal respiratory failure, was ventilated for transport from an outlying hospital and transitioned to CPAP on admission.

The infant had been on CPAP at 6 cm H_2O pressure and had had mild distension which increased to significant gaseous distension at 31 weeks (Fig. 1). A surgical consultation was acquired. No pathology was found per surgical team, with continuous bowel gas pattern identified on the abdominal x-ray. Medical management was escalated, including stopping feeds and a replogle tube placement for gastric decompression, however the x-ray on the following day did not improve (Fig. 2). While these measures avoided introducing more gas into the stomach, the infant needed to remove the gas already present in the bowel. Concern for NEC was ruled out in this case by x-ray and in consultation with the surgical team. The decision was made to use abdominal support. A Fabrifoam® band was applied with the goal of support for and enhanced activation of the abdominal wall musculature rather than compression of the abdomen. The band was applied circumferentially at the length of the abdominal girth, covering the abdomen from the anterior iliac crests to the xiphoid process, and secured with Velcro® strips. This was mindfully applied to act as an external transverse abdominis, optimizing the capability of the abdominal wall muscles to decrease distension while minimizing potential adverse effects of abdominal compression. In hours, the girth decreased by 1.5 cm from 33.5 to 32 cm and the belt was fit to girth again. This procedure was repeated as the girth decreased. Bowel dilation improved on the x-ray after one day of starting the intervention (Fig. 3). After two days of the intervention, the abdominal girth had reduced to 27 centimeters (Fig. 4). Figure 4 also demonstrates integrity of the abdominal wall muscles which sometimes look like a prune belly after CPAP is discontinued. The bowel gas pattern also normalized as shown in the corresponding x-ray (Fig. 5). The infant was able to wean off CPAP the following day. This non-invasive abdominal support prevented this infant from requiring escalation of support sometimes needed in these cases when gaseous distension inhibits respiration [3].

Fig. 1. Case 1. Photograph of infant's abdomen pre-support.

Fig. 2. Case 1. Abdominal x-ray pre-support.

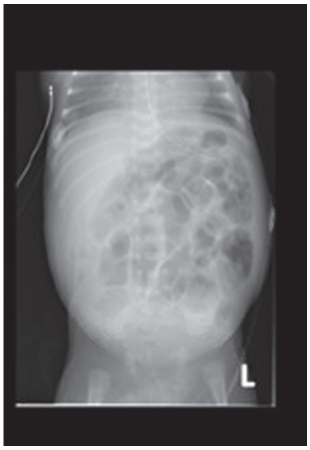

Fig. 3. Case 1. Abdominal x-ray one day after application of support.

2.1. Case report 2

This infant was born at 24 weeks 6 days gestation. The infant was delivered via Cesarean section due to vaginal bleeding and breech presentation. Resuscitation was provided with bubble CPAP of 8 cm H2O pressure in 30 percent oxygen and infant was later

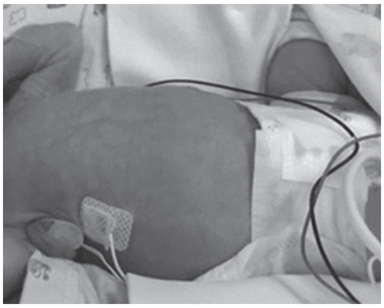

Fig. 4. Case 1. Photograph of infant's abdomen two days after application of support.

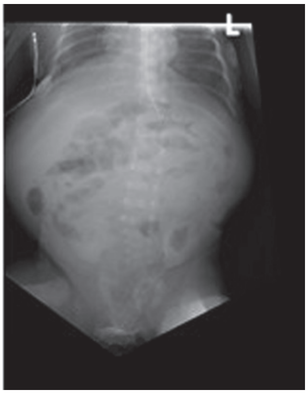

Fig. 5. Case 1. Abdominal x-ray two days after application of support.

Fig. 6. Case 2. Photograph of infant's abdomen with normal circumference during use of abdominal support.

admitted on CPAP of 7 cm H2O pressure in 21 percent oxygen. The infant was able to wean to 6 cm H2O pressure in the first day of life. Abdominal circumference in a ratio to head circumference was monitored using reference values established in Setruk 2020 [5].

Fig. 7. Case 2. Photograph of abdominal support in use.

On day of life 23, the infant was noted to have a ratio at the upper margin of normal range defined as the 75th percentile. Discussion was had with family and medical team and agreement to use an abdominal support was reached. Abdominal support was applied on day of life 25, at which time the abdominal to head circumference ratio had increased to the 94th percentile. Two days after application, the ratio had returned to the 75th percentile. A week later the abdominal circumference to head circumference ratio had reached the 50th percentile (Fig. 6) and, with use of the abdominal support (Fig. 7), it was maintained within the normal range for the remainder of the infant's course on CPAP. The level of support remained at 6 cm H2O pressure and room air during this time. CPAP was discontinued at thirty-two weeks gestational age per unit protocol and this infant remained in room air with an abdominal circumference in the normal range two weeks after CPAP had been discontinued.

3. Discussion

Due to the immaturity of the respiratory system, premature infants require many types of respiratory support. The ventilatory drive commonly requires assistance in the form of caffeine due to an immature central nervous system [6]. The airways and tissues involved in gas exchange in the premature population require support by invasive ventilation ranging from high frequency to high flow [7, 8]. The muscular pump is the third component and includes, but is not limited to, the diaphragm intercostal muscles and abdominal muscles [9]. Support for the muscular pump is not specifically used in the neonatal population.

The typical role of the abdominal wall muscles in respiration is to steady the abdominal viscera, opposing diaphragm descension and preserving diaphragm length [10]. This maintenance of length sustains the zone of apposition, or area of the rib cage internally apposed to the diaphragm. Through the length-tension relationship, the magnitude of the zone of apposition (ZOA) defines the contractility of the diaphragm[10–12]. This illustrates how the rib cage and abdominal muscles act together to optimize the mechanical advantage of the diaphragm [13].

In the newborn, and more significantly in the premature infant, this relationship is changed by ribs that are highly compliant [14] and oriented more horizontally [15] decreasing the zone of apposition [16]. When the ZOA nears zero, as when the lungs are nearing total lung capacity, the diaphragm no longer moves down to exert pressure in the abdomen, instead it pulls in on the ribs creating an expiratory rather than inspiratory effect [10, 12]. This is a known phenomenon in the neonate which is worsened when the muscles of respiration, including the abdominal wall muscles are less active, a situation which occurs both in supine position and during REM sleep [17–19].

Thus, in the premature infant, the decreased mechanical advantage of the diaphragm is exacerbated by a compliant abdomen. Abdominal viscera are no longer held steady to oppose the diaphragm, abdominal pressure fails to increase, and air is able to easily infiltrate the abdomen [10]. When the person is supine with the head of the bed tilted up, this effect increases [10]. Further contributing to the decreased respiratory function of the abdominal muscles is their excessive elongation during abdominal distension, decreasing their pressure-generating ability [20]. Therefore, in significant CPAP belly, the abdominal wall can no longer counter the gaseous infiltration. These conditions of abdominal compliance, continuous airway pressure decreasing the ZOA and supine head of bed up positioning often coexist in the premature infant, predisposing them to gaseous abdominal distension or CPAP belly.

As the abdominal wall is expanded, the lower rib cage and the diaphragm are disadvantaged in respiration. This often leads to an increase in the level of CPAP administered. The diaphragm is known to be at a disadvantage to fulfill its role on increasing levels of CPAP [21]. Concerns for diaphragm dysfunction in premature infants on higher levels of CPAP, defined as 7–9 cm H20 pressure, have been expressed in the literature [21]. And, in fact, levels of CPAP higher than 6 were not found to have any further effect on ventilation efficiency or respiratory muscle function [22]. Diaphragm dysfunction has been found to be associated with poor prognosis in ability to successfully wean from mechanical ventilation for the neonatal population [23]. Increasing inspiratory muscle function has been found to improve weaning [24] and this observation could be especially important for neonates weaning from respiratory support, as the activity of the diaphragm just after inspiration is responsible for the maintenance of functional residual capacity, and the prevention of collapse of the recruited alveoli through controlling expiration [25]. Therefore, CPAP belly may be of concern not just because it is inhibiting respiration during CPAP use, but also because it inhibits the musculoskeletal pump's ability to take over active respiration during weaning from respiratory support.

An external support in the form of an abdominal binder has been used to restore the role of the abdomen in effectively optimizing respiration in populations with increased abdominal wall compliance [26, 27]. An external compressive force on the abdomen will increase the inspiratory action of the diaphragm on the lower ribs while minimizing chest wall distortion while supine with a compliant abdomen [10]. Abdominal binding has been used to prevent respiratory failure in persons with prune belly syndrome from 1969 to 2020 [28, 29]. In a study with preterm infants, an elastic band used to stabilize the lower rib cage was found to improve oxygenation [30]. Another study used a blood pressure cuff to provide abdominal loading in preterm infants and found improved inspiratory coupling of the rib cage and diaphragm, as well as reduction of rib cage distortion [31]. As thoracoabdominal synchrony is a measure of the work of breathing [32], this demonstrated the ability of abdominal binding to decrease the work of breathing [33]. These examples support the theory that abdominal binding supports the respiratory pump in preterm infants.

Evidence exists that materials such as TheraTogs® and Kinesiotape® increase muscle activity on EMG [34, 35]. Due to the immaturity of preterm skin, adhesive is avoided until later gestational ages [36]. Therefore, a Fabrifoam® material which has elasticity and an inner surface of thin foam that is tacky on the skin but not adhesive, could be used to provide a boundary to abdominal compliance while facilitating abdominal muscle activation and participation in respiration.

This intervention is simple to implement and could have ramifications in neonatal medicine if further studies explore using this method to prevent CPAP belly and optimize respiration throughout CPAP use. Maintaining rib cage and abdominal wall mechanics could improve success rates during weaning of respiratory support. By preventing CPAP belly, escalation of support and intubation due to respiratory inhibition of abdominal distension could be reduced, as well as other invasive procedures to work-up concerns for pathology. The discomfort of the condition itself and pain of invasive procedures could be avoided for the neonate; reducing pain and stress which is known to be detrimental for neonatal brain development [37]. This clinician is aware of Kinesiotape® strategies [38] to rehabilitate abdominal wall weakness in older infants, however, no such use of continuous abdominal support while on CPAP is routinely utilized in neonatal intensive care to this clinician's knowledge.

To employ this method more widely, further research is warranted as valid concerns exist regarding abdominal pathology and using such a strategy safely by ensuring the absence of pre-existing pathology. Protocols which establish an infant with normal bowel gas pattern and stooling pattern could be two examples of safety criteria. New methods are being explored to rule out pathology which could minimize radiation exposure, such as point of care ultrasound [39], and ease the way to use of this intervention. Neonatal abdominal girth norms have been established and can be useful in identifying when distension increases beyond normal girth and/or if normal girth has been maintained [5, 40].

4. Conclusion

Concerns regarding the clinical significance of CPAP belly have been expressed in the literature, calling for creative solutions to address this issue which can no longer be called benign due to the invasive interventions required to redress the issue. This novel neonatal abdominal support intervention is one creative, non-invasive solution with the potential to optimize respiration through the support of the abdominal wall, subsequently minimizing gaseous distension and its inhibitory effects on respiration. This intervention warrants further research as to its safety as well as its effectiveness in optimizing respiration while minimizing adverse effects of gaseous distension from CPAP.

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