Non-invasive ventilatory support of foals

Final report summary

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Abstract

Respiratory disease is an important problem to address in thoroughbred foals, and improved care is likely to optimise health outcomes. Non-invasive ventilation (NIV) provides respiratory support without the need for a breathing tube (intubation) and is now standard practice for respiratory support of preterm babies and in a variety of other hospital intensive care settings for people. This project has demonstrated that NIV improves gas exchange and decreases the work required to breathe in foals. Computer tomography was used to demonstrate improved lung aeration and increased lung volumes following NIV in foals. Respiratory support was well-tolerated by hospitalised foals with compromised breathing, and by sedated healthy foals with reversible respiratory insufficiency. Based on the findings of this study, draft recommendations have been developed to implement NIV in foals to optimise respiratory care, but there is a need to improve diagnosis and for objective monitoring of foals with respiratory insufficiency.

Objectives

The objective of this project was to develop and accurately assess strategies to improve respiratory support of newborn foals. It is hoped these strategies can be used in equine veterinary hospitals or on-farm using readily available, off-the-shelf NIV equipment, such as ventilators used for at-home management of sleep apnoea (snoring) in people. Guidelines for field and hospital implementation of respiratory support were expected as an outcome of this study. As respiratory distress, the retention of carbon dioxide (CO₂) and low tissue oxygen (O₂) concentrations are common precursors to morbidity and mortality in newborn foals, the strategies developed in this project are expected to improve foal survival rates using readily implemented approaches and mask delivery of NIV, without the need for intubation.

Background

Respiratory disease is an important cause of morbidity and death in foals presented for veterinary care. More than 13,000 foals are born each year in Australia, and about 6% of these require intensive care or resuscitation. Of foals with problems identified within 48 hours of birth, at least 25% require respiratory support. Lung function is performance-limiting, even in healthy horses. Early and appropriate respiratory support can help ensure optimal short and longer-term health outcomes. Nasal administration of oxygen is often the only available treatment strategy for respiratory support of foals. However, the administration of supplementary oxygen does not improve the removal of CO₂ or decrease the work required to breathe, and can be associated with adverse effects. Mechanical ventilation represents the next level of support, but is invasive (requires patient intubation), technically challenging, expensive and available in very few specialist equine hospitals. NIV is the preferred method of respiratory support for preterm babies and in other intensive care settings. We have previously demonstrated that an ‘off-the-shelf’ continuous positive airway pressure (CPAP) ventilator designed for at-home care of sleep apnoea (snoring) in people improves lung function in foals and calves, and have suggested this might be a cost-effective and readily available support strategy for foals. However, CPAP is consistently associated with CO₂ retention in foals. The provision of lower pressures during expiration using bi-level positive airway pressure (biPAP) devices might be expected to improve NIV for foals.

Research

This project was completed in two studies conducted in consecutive breeding seasons. In Study One (2018), the efficacy of a commercial bi-PAP device was compared with mask delivery of oxygen in a small number of foals hospitalised with respiratory insufficiency, and in healthy research foals with pharmacologically induced (reversible) respiratory insufficiency. Effects were assessed by comparing nasal airway pressures, whereas increased pressure support (the difference between inspiratory and expiratory pressures) was associated with increased breath holding. Ventilator data and graphics demonstrate the efficacy of NIV for respiratory support of foals. Beneficial effects in this study were attributed to longer expiration times than had been achieved in previous studies. Increased lung volume and improved aeration of lung fields were evident in CT images. Foals demonstrated an incremental beneficial response to increased inspiratory pressures, whereas increased pressure support (the difference between inspiratory and expiratory pressures) was associated with increased breath holding. Ventilator data and graphics correlated well with spirometry findings, and provided important information on patient response to ventilation. Although results were similar to previous findings in this species, only one of three pulse oximeters evaluated proved suitable for use in foals.

In addition, the elimination of CO₂ was assessed by volumetric capnography (Vcap), a technique that plots the CO₂ content of expired air against the expired breath volume. Three pulse oximeters were compared to monitor blood O₂ content, and venous blood gas results were compared with arterial values to assess ventilation.

Outcomes/key findings

NIV was effective in both studies. The commercial biPAP ventilator used in Study One improved oxygen extraction and mechanics of breathing in both healthy and hospitalised foals, as was observed previously during CPAP. However, higher blood CO₂ content was observed, particularly in healthy foals. Although increases were mild and hospitalised foals appeared less susceptible to CO₂ retention, two foals experienced unacceptable increases in CO₂ that were rapidly reversed when biPAP was discontinued.

In Study Two, NIV was associated with increased oxygenation, enhanced CO₂ elimination and improved breathing mechanics, without accumulation of CO₂. These were important improvements over previous results achieved using cheaper off-the-shelf CPAP and biPAP devices, demonstrating the efficacy of NIV for respiratory support of foals. Beneficial effects in this study were attributed to longer expiration times than had been achieved in previous studies. Increased lung volume and improved aeration of lung fields were evident in CT images. Foals demonstrated an incremental beneficial response to increased inspiratory pressures, whereas increased pressure support (the difference between inspiratory and expiratory pressures) was associated with increased breath holding. Ventilator data and graphics correlated well with spirometry findings, and provided important information on patient response to ventilation. Although results were similar to previous findings in this species, only one of three pulse oximeters evaluated proved suitable for use in foals.

Venous blood gas analysis and Vcap appeared promising for the assessment of ventilation, but further studies are required in foals with more severe CO₂ retention than was observed in this project.
Implications for industry

The project findings extend previous research that demonstrated that NIV is an effective method to improve lung function and respiratory support in foals. Using NIV, lung aeration is increased, with consequent beneficial effects on the efficiency of gas exchange and decreased work of breathing. In foals, ventilator settings should ensure expiratory times of up to three to four seconds, to ensure there is sufficient time for exhalation and to prevent CO$_2$ retention.

The use of off-the-shelf positive airway pressure devices (CPAP and biPAP) may have adverse effects on respiratory function due to inadequate expiratory time. However, results obtained from the use of a ventilator with improved control and monitoring features has provided insight into optimal ventilator settings. Individual responses may vary, and there is a need for reliable, non-invasive monitoring of breathing efficiency and response to NIV in foals. Based on these findings, NIV is likely to be an important addition to the clinical management of respiratory insufficiency in foals by supporting lung function and offering improved patient care.

Draft guidelines for the implementation of NIV in foals have been prepared, and should be refined based on cumulative and diverse clinical experience. The use of nasal prongs for NIV delivery should be investigated.

References


4 Hussain WA, Marks JD. Approaches to noninvasive respiratory support in preterm infants: From CPAP to NAVA. Neoreviews 2019;20:e213-e221.


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