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Oxygen therapy with high-flow nasal cannulas in children with acute bronchiolitis

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Abstract

Acute bronchiolitis is a common disease in children below 24 months of age. The most common aetiology of this disease is a respiratory syncytial virus infection. Since there is no effective treatment for bronchiolitis, supportive therapy alleviating symptoms and preventing respiratory failure is recommended. Oxygen therapy and appropriate nutrition during the disease are considered effective, particularly in severe cases. The choice of oxygen support is crucial. The present paper discusses oxygen therapy using high-flow nasal cannulas. Moreover, the safety of the method, its adverse side effects and practical pre-treatment guidelines are discussed.

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Key words: bronchiolitis; non-invasive respiratory support; high-flow nasal cannulas; HFNC; oxygen therapy

Bronchiolitis is an acute infection of the lower airways occurring in children below 2 years of age. It is characterised by an acute inflammatory response, oedema, necrosis of the epithelium lining the small airways, and increased mucus production [1]. The constriction of the bronchial lumen leads to air trapping and pulmonary hyperinflation along with its obstruction and atelectasis [2]. Although many viral infections can cause similar symptoms, the major pathogen in the aetiology of acute bronchiolitis is the respiratory syncytial virus (RSV), accounting for over half of all bronchiolitis cases [3]. In older children, bronchiolitis is more commonly caused by rhinoviruses. The rarer etiological factors include parainfluenza viruses, human metapneumoviruses and coronaviruses; adenoviruses, influenza viruses or *Mycoplasma pneumoniae* are sporadically involved. In 10–30% of infants, several etiological factors coexist [2].

DIAGNOSIS

The diagnosis of bronchiolitis is based on patient history and characteristic clinical symptoms, such as dyspnoea and expiratory groaning, increased work of breathing, tachypnoea, wheezing, dry rales and fine rales [4, 5]. The above symptoms are usually preceded by watery nasal discharge, coryza and fever. Severe bronchiolitis with episodes of hypoxaemia and apnoea may occur in children below 2–3 months of age and those whose physical examination revealed dehydration, tachycardia and dyspnoea [2, 6, 7]. Moreover, the risk factors of the severe course include prematurity, immune deficits or congenital heart defects. Virusological tests and chest radiography are not routinely recommended [7].

EPIDEMIOLOGY

Ninety percent of children develop RSV infections during the first two years of life; 1/3 of patients have clinical symptoms of bronchiolitis. About 3% of children require hospitalisation; 2–25% of them need to be treated in intensive care units [2]. The disease is the most common cause of hospitalisations in children during the first year of life [7–9]. Acute viral bronchiolitis cases are characterised by marked seasonality. In Poland, the peak infection season is between December and March. The RSV infection does not confer complete immunity and reinfections occur in the next infection season in almost half of children [10].

PREVENTION

The prevention of bronchiolitis involves passive immunotherapy of RSV infections in the risk groups (7). It is recommended to administer at least three out of a maximum of five doses of palivizumab at monthly intervals during the peak infection season (in Poland between October and April). The National Health Fund refunding programme includes prevention of RSV infections in children born before 29 weeks of gestation and in all children with a diagnosis of bronchopulmonary dysplasia in the first year of life, as well as in children born before 33 weeks of gestation, aged ≤ 6 months at the beginning of the infection season. Other preventive measures include: frequent hand washing, also after taking o gloves; disinfection of hands after contact with infected children; history-taking; exclusive breastfeeding during the first six months of life, education about bronchiolitis and provision of information to parents about the dangers associated with the exposure of children to cigarette smoke [7].

TREATMENT

Causal treatment of bronchiolitis is lacking, with the guidelines concerning symptomatic treatment depending on the child`s condition. During bronchiolitis, no form of respiratory physiotherapy is recommended [7]. The Cochrane analysis, including 12 randomised controlled studies, has demonstrated no physiotherapy-related benefits during this period [11]. Routine antibiotic therapy is not recommended in children with bronchiolitis, unless a concomitant bacterial infection is strongly suspected as severe bacterial infections accompanying bronchiolitis are extremely rare [7, 12]. Moreover, bronchodilators (salbutamol or albuterol) should not be routinely administered; while they only slightly improve clinical symptoms, they do not affect the respiratory function, time of symptom subsidence or necessity and length of hospitalisations [12]. Adrenaline should not be used for nebulisation in children with bronchiolitis as it has no effect on the duration of hospitalisation and incidence of complications [13]. For this reason, inhalation glucocorticosteroids are not recommended, even though they have been found effective in other respiratory diseases. Although studies focusing on the short-term use of inhalation glucocorticosteroids in combined treatment are currently being conducted, their efficacy in bronchiolitis has not been confirmed with evidence [7, 14].

The recommendations regarding treatment include only the improvement of nasal patency and suitable hydration; in hospitalised children inhalations of hypertonic solution of 0.9% NaCl are considered. In cases of difficulties in feeding, the use of a gastric tube or parenteral nutrition and oxygen therapy are taken into account. In one randomised study, the effects of parenteral nutrition, breastfeeding or feeding with formula through the gastric tube on the course of disease were compared. None of the above methods has been found to be superior [15].

OXYGEN THERAPY

If arterial oxygen saturation is higher than 90%, there is no need to use oxygen therapy [7]. In children with lower levels of saturation, oxygen has to be administered. The most common methods of oxygen therapy in children are nasal catheters, oxygen tents or high-flow nasal cannulas (HFNCs). Moreover, in children with respiratory failure, continuous positive airway pressure (CPAP) is sometimes required; mechanical ventilation has to be used in extreme cases. Recently, special attention has been paid to the mode of oxygen delivery. Sung *et al.* [16] attempted to estimate the oxygen concentration in the respiratory mixture (the fraction of inspired oxygen (FiO_2)) used in children with bronchiolitis through nasal catheters. They have demonstrated that FiO_2 cannot be assessed based on the defined gas flow during traditional low-flow oxygen delivery [16]. McKiernan *et al.* [17] analysed retrospectively the course of bronchiolitis in children when high-flow nasal cannulas were applied and in children hospitalised in the same centre prior to the introduction of HFNCs. Thanks to HFNCs, the respiratory effort and respiration rate were reduced, thus intubation was less frequently required [17]. The use of HFNCs in children hospitalised in intensive care units is equally effective in the treatment of bronchiolitis as CPAP [18]. Furthermore, the routine use of HFNCs has significantly reduced the total number of intubations in children < 24 months of life [19].

HFNC therapy was initially introduced as an alternative for continuous positive airway pressure in premature neonates. The method has proved to be equally effective, simple to use, and according to parents and medical personnel, was better tolerated by patients [20]. On the basis of a literature review carried out by Mikalsen *et al.* [21], oxygen therapy with HFNCs is a relatively safe, well-tolerated and easy-to-use method of treatment. Studies regarding children after the neonatal period have demonstrated that the use of HFNCs can limit the need for CPAP or invasive ventilation.

Oxygen therapy with HFNCs is defined as the administration of warmed and humidified mixture of oxygen and air thorough nasal cannulas (for safety reasons, their cross-section cannot exceed 50% of the nostrils) with the flow higher than the inspiratory flow of patients. Strict determination of the flow values exceeding the inspiratory flow is difficult to specify. It is assumed that in infants this flow should be > 2 L min^{-1}.

MECHANISM OF HFNC ACTION

The use of this non-invasive method of breathing support improves oxygenation and reduces the respiratory effort, which is associated with decreased energy expenditure, higher feeding tolerance and greater comfort of patients.

1. Compared with low-flow nasal cannulas or face masks, the high flow of oxygen/air mixture improves oxygenation, which is explained by washing out carbon dioxide from the nasopharyngeal dead space and a higher concentration of oxygen reaching the pulmonary alveoli. As the extrathoracic dead space in small children is proportionally two-three times higher, as compared with adults, the effects of high-flow oxygen therapy are more pronounced in younger children [22, 23].
2. The use of a humidified and warmed mixture of gases protects against airway mucosa dryness and damage; moreover, it improves mucociliary transport, which facilitates the elimination of accumulated secretions and reduces respiratory resistance [23].
3. Although an HFNC generates positive end-expiratory pressure, its value is changeable and depends on the size of flow, this does not occur in a directly proportional way. Unlike CPAP, HFNC does not allow one to set the desirable end-expiratory pressure. Its value is also affected by some other factors, e.g. mouth opening. The available study findings have demonstrated that at a flow of 2 L kg^{-1} min^{-1}, the average upper airway pressure is about 4 cm H_2O. At flows above 7 L min^{-1}, airway pressure maintains its positive value both during inspiration and expiration. The positive pressure at the onset of inspiration helps to reduce the inspiratory effort while the positive pressure during expiration prevents the collapse of fine airways and prolongs the expiration time. The above mechanism prevents atelectasis and decreases the respiration rate and inspiratory effort [23]. In HFNCs, "the safety valve" protecting against an excessive increase in airway pressure is the leak between the appropriately narrow cannulas and the lumen of nares (the recommended diameters should not exceed 50% of the nostril size) [23].
4. A decrease in respiratory effort and the use of a warmed and humidified mixture of gases reduces energy expenditure and limits tachypnoea-related water loss.

The use of HFNCs is indicated in cases of hypoxaemic respiratory failure. The method is applied to treat the respiratory failure in preterm babies, after extubation in bronchiolitis, pneumonia and dyspnoea due to heart failure, after cardiac surgical procedures, as well as in oncologic patients.

Contraindications include obstructed or deformed nares, nose bleeding, upper airway occlusion, loss of consciousness, basilar skull fracture, and multiple organ failure. Relative contraindications include uncontrolled pneumothorax, severe hemodynamic instability, symptoms of tiredness, recurrent apnoea, and nasopharyngeal procedures or injuries.

TECHNICAL PARAMETERS OF HFNC

The parameters that should be set before the onset of therapy include temperature, gas flow in litres per minute and oxygen concentration in the respiratory mixture. The recommended temperature for children ranges from 34 to 37°C. In order to obtain the optimal gas humidity, the values near 37°C are more beneficial; in cooler rooms, it may be required to set lower temperatures due to excessive liquefaction of water inside the system of tubes [23]. Many authors recommend a flow of 2 L kg^{-1} min^{-1} [21, 23, 24]. The above concerns children weighing < 10–12 kg. In older children, a flow of > 6 L min^{-1}, max. 20–30 L min^{-1}, is recommended (1 L kg^{-1} min^{-1} should not be exceeded). The Australian guidelines advise the initial concentration of oxygen in the respiratory mixture (FiO_2) to be 0.4 and to adjust it to the value of blood oxygen saturation, aiming at achieving the saturation within the range of 92–97% [23].

If maintaining blood oxygen saturation > 92% at FiO_2 0.6 is not possible, more advanced methods of breathing support should be implemented. In cases in which the respiratory effort is observed to be increasing, the gas flow should be increased (max. to 2 L kg^{-1} min^{-1}) while in cases of desaturation, FiO_2 has to be increased [2].

Early identification of patients for whom HFNCs may be insufficient is essential. The risk groups include children with tachypnoea > 90 percentile for their age, patients with symptoms of tiredness, and children with respiratory acidosis (pH < 7.3) detected in additional examinations with accumulation of carbon dioxide above 50 mm Hg. In the above groups of patients, failed HFNC therapy is associated with the necessity to start additional respiratory support [23].

The assessment of patients after the first hour of therapy is essential for prognosis and allows for distinguishing patients requiring more advanced methods of breathing support. The positive response to treatment is expressed in a reduced respiration rate and respiratory effort, decreased heart action and improved blood oxygenation, increased pH, decreased pCO_2 and increased O_2/FiO_2 > 20% of the baseline demonstrated in additional examinations [2, 23].

SAFETY AND ADVERSE SIDE EFFECTS

In the majority of reports, no significant adverse side effects of HFNC have been demonstrated. The use of HFNC therapy has been found to be safe in paediatric departments and intensive care units [21, 23, 25]. The percentage of complications after HFNC has been reported to be low, including pneumothorax and nose bleed (1% of patients each) [26]. In about 10% of patients administered HFNC therapy during

viral infections, escalation to CPAP or mechanical ventilation was required [27]. According to another study, none of the children required some other form of respiratory support; HFNC therapy was well tolerated and sedation was not needed in any of the cases described [28].

In Poland, three devices enabling the use of high-flow nasal cannulas are available: AIRVO 2TM, MR 850 TM (Fisher & Paykel Healthcare) and Precision FlowTM (Vapotherm). AIRVO 2TM allows to provide the mixture of gases of 31–37°C, the flow of 2-60 l min^{-1} (the paediatric mode — 2–25 L min^{-1} with an incremental change of flow by 1 L min^{-1}; the adult mode — 10–60 L min^{-1} — above 25 L min^{-1}, an incremental change of flow by 5 L min^{-1}) and oxygen concentration in the respiratory mixture ranging from 21 to 100 by the OptiflowTM nasal cannulas of different sizes: for full-term neonates, infants (using Wigglepads), children (S,M,L), teenagers, adults and an interface for tracheostomy. The device has a built-in generator of airflow and requires only the source of oxygen and electricity. The humidifier MR859TM is mainly applied in premature newborns and enables the use of the two smallest nasal cannulas OptifloeTM for pre-term babies and neonates (using Wigglepads) with the flow of 0.5–8 L min^{-1} and FiO2 21–100%. It has to be charged with compressed air, oxygen and electricity. The Precision flowTM is also equipped with various sizes of neonatal-paediatric and adults cannulas, including the two smallest Solo-type ones with a single cannula (for one nostril) fixed at the back of the head. The flow of 1–40 L min^{-1} can be provided (1–8 L min^{-1} — an incremental change by 0.5 L min^{-1} and 5–40 L min^{-1} — an incremental change — by 1 L min^{-1}); the oxygen concentration 21–100% can be used. The device required oxygen, condensed air.

SUMMARY

Bronchiolitis is a common disease of early childhood. Since there is no effective treatment, supportive therapy is recommended to alleviate the symptoms and to prevent respiratory failure. Oxygen therapy and proper feeding are considered effective, especially in severe cases. The choice of a suitable method of oxygen administration is vital. Based on available literature data, high-flow nasal cannulas are safe and effective. According to some authors, HFNC therapy is recommended in children when low-flow oxygen therapy has failed and has not improved the patients` condition. HFNCs can be used in neonatal and paediatric departments, especially those located far from large institutions with intensive care units. Analysis of the studies available has proved that the method is relatively safe, well tolerated and easy to apply in infants and children in paediatric departments for the treatment of bronchiolitis.

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