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Paediatric airway management

Oskrba dihalne poti pri otrocih

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Abstract

Paediatric airway greatly differs from airway in an adult. There are many anatomic and physiologic differences that we must consider during any airway manipulation. Well-taken medical history and proper clinical airway assessment are very helpful in predicting the possibility of difficult mask ventilation or problems during intubation. Many factors help us predict difficult intubation but they are not always reliable. We use many different tools to manage the airway. Each tool has its advantages and disadvantages, but only endotracheal tube prevents aspiration. In case of difficult intubation, we should follow strict algorithms that help us solve the most common problems during airway management. Paediatric airway is more reactive to any manipulation, and the possibility of laryngospasm is higher. Laryngospasm is an urgent condition that must be solved immediately to prevent breathing and possible cardiac arrest.

Izvleček

Dihalna pot pri otrocih se pomembno razlikuje od dihalne poti pri odraslih. Obstajajo anatomske in fiziološke posebnosti, na katere moramo biti posebej pozorni. Na prvem mestu sta dobra anamneza in klinični pregled, s katerima lahko predvidimo možno težko predihavanje z masko ali težave pri intubiranju. Obstajajo številni dejavniki, s pomočjo katerih lahko napovemo možnost težke intubacije, žal pa niso vsi vedno zanesljivi. Za vzpostavitev dihalne poti uporabljamo različne pripomočke, med katerimi ima vsak svoje mesto, svoje pozitivne in svoje negativne lastnosti. Endotrahelni tubus pa je edini pripomoček, ki varuje pred aspiriranjem. Ob težki intubaciji so nam v pomoč algoritmi za hitro in učinkovito reševanje težav. Pri otrocih lahko zaradi večje odzivnosti zgornjih dihal pride do laringospazma, kar je urgentno stanje in lahko hitro vodi v dihalni in celo srčni zastoj.

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1 Introduction

Unlike the airways of an adult, the scaled-down nature of a child's airway presents its own issues. Given that all dimensions are smaller in a child, with more delicate tissue that is easier to damage, care must be taken with any airway intervention. The anatomical and physiological differences need to be recognized, with special attention being paid. The medical history and clinical examination of the airway are very important for an assessment of possible problems with establishing an airway and ensuring ventilation. Despite all predictive factors of a difficult intubation being present, it is not certain that in practice, the intubation will be difficult; on the other hand, intubation can be difficult in the absence of all known risk factors. There are many instruments available to help establish an airway. Each has their own advantages and disadvantages, but none, apart from the tracheal tube, protects against stomach content aspiration. In case of difficult face mask ventilation or problems with intubation, algorithms for rapid and efficient problem solving can be of help. Laryngospasm can occur more commonly in children, and requires urgency if detected: knowing its causes and treatment is crucial, as there is little time to resolve it before respiratory arrest occurs.

2 Anatomical and physiological features of the paediatric airway

2.1 Anatomical features

The most obvious difference is the head to body size ratio. The head is large and the neck is shorter, so in the supine position the neck is in flexion, causing airway obstruction. To relax the airway and make face mask ventilation easier, padding behind the child's shoulders can be of help. The child's tongue is relatively larger, the mandible is smaller, and the larynx is displaced anteriorly and highly positioned - in infants it is at the level of the cervical vertebrae C2-C3, and with growth it descends towards C4-C5. The longitudinal axis of the airway thus lies in an inferior and anterior direction. In preschool children, the palate and pharynx can be very convex and further reduce visibility (1,2). The hypopharynx is shorter and narrower and the larynx is highly positioned. The airway's narrowest point is at the level of the cricoid cartilage, which is at the level of the C4 vertebra at birth, at the level of the C5 vertebra at the age of six and at the level of the C6 vertebra in adults. The epiglottis is larger than in adults and has a U-shape, covering the entrance to the larynx at a 45° angle. To visualize the larynx, the epiglottis needs to be lifted with the laryngoscope tip – in infants, the use of the straight-bladed Miller laryngoscope is recommended. The trachea is shorter, so after intubation, respiration symmetry needs to be checked and the tracheal tube fixed in position. The tracheal rings are soft and easily compressible. In a partial airway obstruction, the negative pressure during breathing causes additional airway obstruction (3,4).

All these differences and traits contribute to the higher probability and rapid onset of airway obstruction and cause difficulties for the anaesthesiologist during face mask ventilation; they can impair visibility during direct laryngoscopy and make intubation more difficult. The differences in the airway anatomy between individual age groups of children must also be taken into account. In addition to anatomical changes, the drugs used to induce anaesthesia also cause a loss of muscle tone in the upper respiratory tract and thus contribute to airway obstruction.

2.2 Physiological features

There are numerous factors that cause the haemoglobin oxygen saturation in children to decrease faster than in adults. Oxygen consumption in children is up to two times higher at rest (6 mL/kg/min compared to 3 mL/kg/min in adults), and the functional residual capacity is lower. Carbon dioxide production is also higher (100–150 mL/kg/min compared to 60 mL/kg/min in adults). Respiratory volume in mL/kg is comparable to that of adults, so in children, the breathing rate is increased to maintain adequate levels of carbon dioxide in their blood. Airway resistance is inversely proportional to the fourth power of the airway radius. As a result, the child's respiratory effort can be greatly increased even with minor changes in the airway radius (due to secretions or mild injury of the mucous membranes, leading to oedema). Infants up to five months of age breathe through the nose, so despite the patent airway between the mouth and lungs, they may be in respiratory distress (5,6).

Table 1: Mallampati classification – we compare the tongue's size with the size of the oral cavity. Patients are classified from class I to class IV. Adapted from Mallampati, SR, 2015 (8).

Mallampati classification	
I	Soft palate, uvula, fauces, pillars visible
II	Soft palate, major part of uvula, fauces visible
III	Soft palate, base of uvula visible
IV	Only hard palate visible

Visualization of the uvula, faucial pillars, soft palate and posterior pharyngeal wall is used. The more structures are visible, the lower the Mallampati score is.

Table 2: Cormack-Lehane classification system – views obtained during laryngoscopy are classified from grade 1 to grade 4. Adapted from Cormack RS, 1984 (9).

Cormack-Lehane classification system	
1	Full view of glottis
2	Partial view of glottis or only arytenoid cartilages
3	Only epiglottis seen
4	Epiglottis not seen

The more larynx is visible, the lower the score.

3 Airway assessment

When assessing the airway, we need to assess whether intubation of the child can present difficulties. We start by taking a medical history; potential perinatal complications, previous trauma or surgery in the oropharyngeal region, symptoms such as problems with swallowing, breathing, hoarseness, snoring, stridor or sleep apnoea are all of interest. Attention is paid to any congenital or acquired conditions that change the structure or responsiveness of the airway. Down syndrome, Treacher-Collins syndrome, and Pierre-Robin syndrome are examples of the most common congenital conditions, while the most common acquired conditions include tumours, trauma, acromegaly, burns, arthritis, obesity and airway oedema. A possible upper respiratory tract infection in the previous two or three weeks is also important. An infection significantly alters the responsiveness to any airway procedures, which can lead to laryngospasm, an airway obstruction that can lead to respiratory failure or cardiac arrest.

Anatomical features and tests predicting difficult intubation in children:

- Length of upper incisors. With longer incisors, there is less room for the laryngoscope and endotracheal tube.
- Protrusion of the mandible. Ability to move the lower incisors anteriorly to the upper incisors.
- Limited ability to open the mouth (less than two widths of the child's finger) and reduced range of cervical motion.
- High arched and narrow palate.
- Thyromental distance less than three widths of the child's finger.
- Short and wide neck.
- Mallampati classification, which compares the tongue's size with the size of the oral cavity and predicts the difficulty of laryngoscopy. Patients are classified from class I to class IV. A higher score means a higher risk of difficult intubation (Table 1).
- The Cormack-Lehane scale classifies views obtained by direct laryngoscopy. A grade of 3 or more is a predictor of difficult intubation (Table 2).

Despite this large number of tests and characteristics, the measurement's reliability is low. In principle, when multiple risk factors are present, intubation is more likely to be difficult; however, intubation may not actually be difficult despite all risk factors being present. It can also be the case that the absence of risk factors cannot exclude the possibility of a difficult intubation (7-12).

Figure 1: Face masks of different sizes – larger, appropriate for adults, and smaller, appropriate for children and infants.

Figure 2: Oropharyngeal tubes, arranged by size - larger to the left and down to the smallest to the right.

Figure 3: Laryngeal masks (I-gel®) in original packaging of various sizes. Smaller sizes are suitable for younger children or even infants.

Figure 4: Endotracheal tubes with cuffs. Smaller tubes are on the left, suitable for infants or children, compared to the larger ones on the right, suitable for adults.

4 Airway management

The basic manoeuvre in airway management is correct face mask ventilation (Figure 1). As with adults, a one- or two-handed technique can be used. After induction of anaesthesia, muscle tone in the upper airway decreases and airway obstruction with soft tissues occurs. The easiest way to relax the airway is with a head tilt, chin lift and jaw thrust manoeuvres, and manual ventilation with positive pressure. The head can be tilted slightly to the side, which should contribute to better airway management, particularly in children with an enlarged adenoid (13). An oropharyngeal airway can be of help (Figure 2), which prevents the tongue from obstructing the airway. The correct size is chosen by measuring the distance between the corner of the mouth and the earlobe or between the first incisors and angle of the jaw. An oropharyngeal airway that is too short will push the tongue back and cause obstruction, while an one that is too long can cause laryngospasm. A nasopharyngeal airway can also be used to reduce the possibility of laryngospasm. Adequate sedation or anaesthesia should be maintained, as inadequate anaesthesia and thus inadequate suppression of upper airway reflexes can cause laryngospasm. The correct size of the face mask should be used; it should be large enough that the mouth remains open during ventilation, but not so large that it would cover the eyes. The soft tissues under the chin should not be pressed with our fingers, as this closes the airway by itself. Should the bag not adequately fill, the position of the mask needs to be corrected, re-check the airway manoeuvres and increase the positive ventilation pressure. Either before or after successful establishment of the airway, a naso- or orogastric tube must be inserted; despite good face mask ventilation technique, at least partial gastric inflation cannot be avoided. Gastric overinflation interferes with the functioning of the diaphragm and thus with breathing (14-16).

A laryngeal mask may also be used in airway management (Figure 3) as an alternative to endotracheal intubation. These are recommended for shorter procedures, while endotracheal intubation is recommended for longer ones (Figure 4). Choosing the correct size of the laryngeal mask is important as an incorrect size may lead to air leakage and inadequate ventilation.

Aside from an endotracheal tube, no airway management device protects against regurgitation and aspiration of gastric contents or upper respiratory tract secretions. Thus, endotracheal intubation remains the safest form of airway management.

5 Induction of anaesthesia and endotracheal intubation

As with any other technique for airway management, we need to prepare for endotracheal intubation.

Figure 5: Working Miller laryngoscope with a straight blade. Above it on the left are different sizes of straight Miller blades, and on the right, there are curved MacIntosh blades.

All medications and devices for the induction of anaesthesia should be available. These include a face mask, supply of oxygen, anaesthetic machine, working laryngoscope (the Miller laryngoscope with a straight blade or the MacIntosh laryngoscope with a curved blade) in several sizes (Figure 5), supraglottic devices and orotracheal tubes in several sizes. Additionally, a suction tube, aspirator, bougie and appropriate breathing system filters are required (Figure 6).

In children, preoxygenation is most important as they have a lower functional residual capacity and rapidly lose oxygen saturation. With preoxygenation with 100% oxygen, we aim to replace all the nitrogen in the airways with oxygen and thus gain time for intubation. Normally, a few minutes of breathing or eight deep breaths of 100% oxygen suffices. Induction of anaesthesia with inhalational or intravenous anaesthetics follows. Before the administration of an anaesthetic, we administer an analgesic, most commonly fentanyl 2-5 ug/kg or alfentanil 5-10 ug/kg. The effect of alfentanil is

Figure 6: Different sizes of filters, appropriate for an anaesthetic breathing system. For children, choosing the right filter is important due to dead space. A larger filter makes an important contribution to additional dead space during ventilation and can cause ventilation problems in the youngest children.

Table 3: Endotracheal tube with or without a cuff diameter, used in endotracheal intubation in children in different age groups until two years of age.

Age	No cuff	With cuff
Neonates < 3 kg	3.0	-
Neonate	3.5	3.0
Four months	4.0	3.5
12–16 months	4.5	4.0

only about 25% of the effect of fentanyl, and the duration of action is only 15–20 minutes compared to 45–60 minutes with fentanyl, making it particularly advantageous for shorter procedures. Sevoflurane is most commonly used as an inhalational anaesthetic. When used at a concentration of 8%, only a few breaths are enough to calm the child and slowly transition to sufficient anaesthesia, while spontaneous breathing is maintained. The concentration is subsequently reduced accordingly by maintaining a sufficiently deep, but not too deep, anaesthesia. Propofol 2–4 mg/kg or thiopental 4–5 mg/kg are most commonly used as intravenous anaesthetics. After loss of consciousness and confirmed adequate face mask ventilation, a muscle relaxant is used, most commonly rocuronium in a dose of 0.6 mg/kg or 1.2 mg/kg body weight during emergency intubation. The combination of an analgesic, sedative and muscle relaxant thus creates effective conditions for endotracheal intubation. The analgesic inhibits the sympathetic response and airway reflexes during laryngoscope manoeuvres, the sedative additionally inhibits reflexes and causes loss of consciousness, and, in the case of insufficiently paralyzed reflexes or vocal cord spasms, the muscle relaxant prevents injury by a passing endotracheal tube. The muscle relaxant takes effect after approximately two minutes; until then, adequate face mask ventilation with or without other supraglottic devices is important (15,17,18).

Due to the larger epiglottis and its position, the Miller laryngoscope with a straight blade is commonly used, with which we can directly lift the epiglottis and visualize the laryngeal opening. A bradycardic reflex can be triggered, so care must be taken. The endotracheal tube is selected according to the child's age. For children under two years of age, a tube with or without a cuff is selected, and the tube's diameter is chosen to correspond to the diameter of the distal phalanx of the child's fifth digit. See Table 3 for further assistance. For children over two years of age, use the following

formula: endotracheal tube diameter = 4 + (age/4) for tubes without a cuff or tube diameter = 3.5 + (age/4) with cuffed tubes. The advantage of cuffed endotracheal tubes is better sealing, but overinflation of the cuff should be avoided as it can damage the airways. When we visualize the vocal cords with a laryngoscope, carefully insert the endotracheal tube. Keep in mind that the narrowest part of the paediatric airway is at the level of the cricoid cartilage, so despite successfully passing the vocal cords, we may not be able to go deeper. In this case, choose a narrower endotracheal tube (19,20).

We should keep in mind that each device, extension and filter used in airway management increases dead space during ventilation. A correct choice of filter according to the child's age or body weight is important to reduce the additional dead space as much as possible. In children younger than five years, paediatric breathing circuits with smaller hoses should be used in anaesthetic machines.

6 Difficult intubation

As per the definition of the American Society of Anaesthesiologists (ASA), difficult intubation is defined as the clinical situation in which a conventionally trained anaesthesiologist experiences difficulty with face mask ventilation of the upper airway, difficulty with tracheal intubation, or both, and the resolution of which is dependent on the anaesthesiologist's experience, patient specifics, type of procedure and clinical situation (7).

Difficult intubation can be expected based on the patient's history and clinical examination. In case of expected difficult intubation, the use of indirect videolaryngoscopes, endotracheal intubation through a laryngeal mask or endotracheal intubation of a conscious patient with the help of a fibreoptic bronchoscope is recommended. However, because children can be restless, this can also be difficult. Sedation or mild anaesthesia with agents that maintain spontaneous breathing, such as ketamine, midazolam or dexmedetomidine is advised. Anaesthesia with sevoflurane or intravenous infusion of propofol with maintenance of spontaneous breathing is also possible (21-23).

A bigger problem arises when difficult intubation is not anticipated. The first problem arises with face mask ventilation. In this case, airway obstruction (supraglottic, glottic, or infraglottic) has occurred. Supraglottic obstruction is the easiest to resolve. Check whether the airway opening manoeuvres have been correctly performed, put padding under the shoulders of children under two years of age, use two persons for ventilation (one maintains a patent airway with both hands, the other squeezes the bag) or use supraglottic devices.

Glottic airway obstruction is known as laryngospasm, discussed in the next chapter. Infraglottic obstruction is probably bronchospasm. Severe bronchospasm, which prevents face mask ventilation, is best prevented by intravenous adrenaline, as inhaled bronchodilators will not work due to practically absent gas exchange in the lungs. If obstruction cannot be resolved with these rapid manoeuvres, we should urgently call for help, discontinue all medications, try with endotracheal intubation, wake the patient or, if unsuccessful, initiate the "can't intubate, can't ventilate" algorithm.

In case of unexpectedly difficult endotracheal intubation, it depends on whether face mask ventilation is successful or not. If it is successful, we can try to intubate with a laryngoscope only once more after the first failed attempt. Even in this case, it is better to choose a videolaryngoscope. In case of a second failed attempt, the patient should be adequately ventilated; after that, we can try with intubation through a laryngeal mask or with a fibreoptic bronchoscope. If, after all attempts, face mask ventilation proves unsuccessful, we attempt the aforementioned manoeuvres to improve face mask ventilation; if these are unsuccessful, we should insert the intubating laryngeal mask, wake the patient or initiate the "can't intubate, can't ventilate" algorithm in case of haemodynamic instability. If the patient is stable, we should discontinue all medications, administer medications for reversal of muscle relaxants and immediately wake them. In case of haemodynamic instability, immediate surgical assistance should be requested. If there are no available surgeons, needle cricothyroidotomy should be performed; the surgeon performs a tracheostomy (24-27).

7 Laryngospasm

Laryngospasm is an involuntary, uncontrolled and persistent spasm of internal laryngeal muscles. It is actually a protective airway reflex and manifests itself as partial or complete obstruction. It is mostly caused by inadequate anaesthesia (at induction or recovery from anaesthesia) and in response to mucosal irritation and incompletely suppressed reflexes in the upper respiratory tract. In most cases, it subsides spontaneously and ventilation improves. In the opposite case, rapid action is required as it can quickly lead to respiratory and subsequently cardiac arrest. The first measures are removing the stimulus, calling for help, establishing intravenous access, relaxing the airway and giving 100%

oxygen. Manual ventilation with positive pressure is tried without force that would only cause gastric inflation and thus further impair ventilation. In addition to all general measures, the first step is to increase the depth of sedation. This is best achieved with a bolus of propofol, which relieves laryngospasm in 75% at a dose of 0.25-0.8 mg/kg; in practice, slightly higher doses are normally used. However, if increasing the depth of sedation does not resolve laryngospasm, a muscle relaxant should be used. Succinylcholine is used primarily intravenously at a dose of 1.5 mg/kg. If intravenous access is not available, intraossal administration with the same dose or intramuscular administration at a dose of 4 mg/kg should be used, albeit with a later onset of action. Rocuronium, which has a similar onset of action as succinylcholine, can also be used intravenously at a dose of 1 mg/kg. If laryngospasm persists and several attempts end in failure, a needle cricothyroidotomy or surgical tracheostomy is required (28-30).

8 Conclusion

Despite knowing the anatomical and physiological features of a paediatric airway, a good history and clinical examination are crucial. Despite the absence of all risk factors for difficult intubation, problems can arise in airway management. Basic knowledge of airway management is a good technique with face mask ventilation, which can be upgraded with mastering the use of other devices for final or temporary airway management. The choice of correct device is just as important as its correct use, as the wrong choice or use can lead to injury of the sensitive soft tissues, or laryngospasm. When we encounter problems, we should quickly seek assistance and use established protocols, which help us to quickly and properly resolve problems during airway management.

Conflict of interest

None declared.

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