

Unanticipated difficult airway management in children — the consensus statement of the Paediatric Anaesthesiology and Intensive Care Section and the Airway Management Section of the Polish Society of Anaesthesiology and Intensive Therapy and the Polish Society of Neonatology

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Abstract

Tracheal intubation may be defined as an artificial airway established in order to provide mechanical ventilation of the lungs during surgical procedures under general anaesthesia, treatment in an intensive care unit, as well as in emergency situations. Difficulties encountered during intubation may cause hypoxia, hypoxic brain injury and, in extreme situations, may result in the patient's death. There may be unanticipated and anticipated difficult airway. Children form a specific group of patients as there are significant differences in both anatomy and physiology. There are some limitations in equipment used for the airway management in children. There are only few paediatric difficult airway guidelines available, some of which have significant limitations. The presented algorithm was created by a group of specialists who represent the Polish Society of Anaesthesiology and Intensive Therapy, as well as the Polish Neonatology Society. This algorithm is intended for the unanticipated difficult airway in children and can be used in all age groups. It covers both elective intubation, as well as rescue techniques. A guide forms an integral part of the algorithm. It describes in detail all stages of the algorithm considering some modifications in a specific age group, e.g. neonates. The main aim of Stage I is to optimise conditions for face mask ventilation, laryngoscopy and intubation. Stage IIA focuses on maximising the chances of successful intubation when face mask ventilation is possible. Stage IIB outlines actions aimed at improving face mask ventilation. Stage IIIA describes the use of a SAD (Supraglottic Airway Device) during effective face mask ventilation or in a CICV (Cannot Intubate, Cannot Ventilate) situation. Stage IIIB outlines intubation through a SAD. Stage IV describes rescue techniques and outlines possible options of either proceeding with surgery or postponing it, depending on clinical situation.

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Intubation of the trachea remains one of the most frequently performed procedures performed in anaesthesiology and intensive care. The purpose of intubation is to create an open passage through the upper airway to provide mechanical ventilation of the lungs of anaesthetized patients or those treated in intensive care and during an emergency. The frequency of intubations diminishes as non-invasive methods of ventilation are introduced into clinical practice. This trend is present in anaesthesia where laryngeal masks are used more frequently, and in intensive care, where non-invasive ventilation methods are being widely adopted [1–4]. The reduction of intubation frequency is also seen among neonatal patients, where many forms of non-invasive respiratory support have become a standard [5, 6]. As a result, physicians' experience in performing intubation may be reduced, especially among those working outside operating theatres. Despite progress in non-invasive methods, tracheal intubation remains a method of choice in respiratory therapy of a large group of anesthetized patients, or those requiring intensive care, and is life-saving in many emergency situations. Properly performed intubation is a prerequisite for invasive mechanical ventilation and protects one against pulmonary aspiration. Difficulties encountered during the intubation procedure may cause hypoxia, central nervous system damage and, in extreme situations, loss of life. The problems arising from difficult airways may be anticipated upon or may be unexpected. In only some situations intubation can be postponed, while in other cases this is not feasible. When general anaesthesia with intubation is planned, a careful history should be taken and a thorough examination performed with special emphasis on anticipated risks and difficulties connected with the intubation attempt. Such assessment can predict problems associated with difficult airways and plan intubation with increased risk beforehand. If after all precautions, intubation fails, surgery can often be postponed and the patient awakened. In emergency situations (life-threatening trauma, severe respiratory failure, urgent, life-saving operations), it is usually not possible to assess the risk of difficult airway beforehand. In such situations, immediate establishment of a patent artificial airway is a priority.

The importance of problems associated with difficult intubation was recognized by establishing a Difficult Airway Society (DAS) in Great Britain and Northern Ireland, a Task Force on Management of the Difficult Airways of the American Society of Anesthesiologists (ASA), and Section of Instrumental Airway Management (SPUDO) of the Polish Society of Anaesthesiology and Intensive Therapy. The algorithms and protocols for such situations have been developed, some of them being recommended by scientific societies [7–12].

The differences in paediatric population in relation to difficult intubation are due to the specificity of this group

of patients with natural anatomical conditions, congenital abnormalities (e.g., Pierre Robin sequence), other pathologies (e.g., mucopolysaccharidosis) and a limited availability of airway devices resulting from the small size of paediatric patients. These should be taken into account when preparing for intubation. Among children, newborns and infants are a group of patients at risk of difficult airway problems. Natural anatomical differences in these age groups, which may result in difficult airways, are primarily a large head with protruding occiput, a short and slender neck, small mouth, a broad and short tongue, the larynx being more superior, a sharp angle between the base of the tongue and glottis, a long and narrow epiglottis and physiological narrowing below the vocal cords. Although problems with intubation in children are not frequent, they are a significant problem due to the potential risks. Children, when compared to adults, are characterised by higher oxygen consumption and less oxygen reserve. This results in a worse tolerance of respiratory interruptions and leads to faster desaturation and subsequent bradycardia [13, 14]. The problem of difficult airways in children is more frequent in emergency setting and intensive care units than in the operating theatre. Ventilation problems account for the majority of childhood anaesthesia, while 80% of them involve children with low risk (ASA I and II) and children under one year of age. These problems are the second leading cause of cardiac arrest during the perioperative period in children [17, 18]. Children are a heterogeneous group, both in terms of the incidence of difficult intubation, as well as the resulting risks. Difficult face mask ventilation is very rare in children when performed by an experienced physician, while intubation is a more frequent problem [19, 20]. Difficult laryngoscopy is more common in children than in adults. It is also more common during the first year of life. The risk factors of difficult laryngoscopy in children include: ASA III and IV physical status, Mallampati III and IV, low BMI, children intubated for cardiac surgery and maxillofacial surgery. In children undergoing cardiac surgery, difficult laryngoscopy is twice as frequent as when compared to the average for all children [21, 22]. The incidence of major intra-operative hypoxaemic events is inversely proportional to the age of the child and is reported in about 25% of newborns, 10–15% of children under the age of 5 years and about 5% of older children [23]. Of note is fact that the actual occurrence of problems arising from difficult airways may be greater than it is reported in the official reports [24]. The risks related to difficult airways may be minimised by the use of the appropriate equipment and training that includes simulation techniques [25–27].

There are only few paediatric difficult airway algorithms available in the literature [28–30]. According to a survey conducted for the purpose of this study among doctors

in Poland, internal protocols for difficult intubation are used in five (33%) out of fifteen departments of paediatric anaesthesiology and intensive care surveyed, and three (9%) of the 33 surveyed neonatal departments (2nd and 3rd reference level). Physicians of all paediatric anaesthesiology and intensive care departments and 31 (94%) of the neonatal departments taking part in the survey considered the creation of a single protocol for difficult intubation both important and necessary.

The presented algorithm is a result of the work of a group of specialists whose activities were endorsed by the Section of Anaesthesiology and Paediatric Intensive Care and the Section of Difficult Airways of the Polish Society of Anaesthesiology and Intensive Therapy and the Polish Society of Neonatology.

ABBREVIATIONS

DA — difficult airway — a situation when experienced doctor encounters difficulties in face mask ventilation, intubation or both.

DMV — difficult mask ventilation — there is no effective facial mask ventilation due to an ineffective seal around the face mask and/or difficulty in air insufflation.

DL — difficult laryngoscopy — it is impossible to visualise any parts of the vocal cords with a conventional laryngoscope.

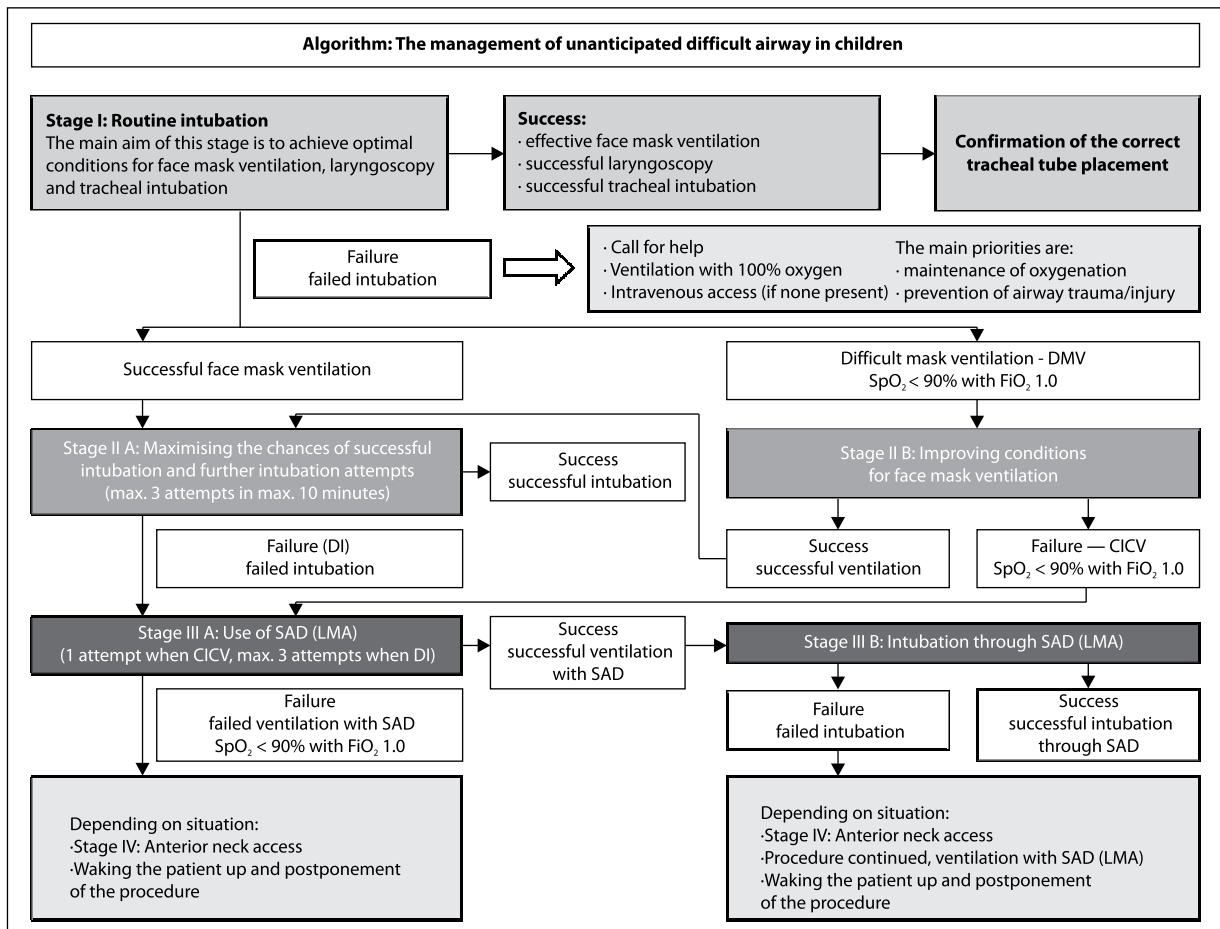
DI — difficult intubation — a situation where an experienced doctor needs at least three attempts to intubate the trachea with a conventional laryngoscope or when intubation lasts more than 10 minutes.

CICV — cannot intubate and cannot ventilate — a situation in which the patient cannot be intubated and effective facial ventilation cannot be performed.

CICO — cannot intubate and cannot oxygenate — a situation in which the patient cannot be intubated and efficient oxygenation cannot be achieved.

A GUIDE TO THE ALGORITHM

This algorithm describes the management of unanticipated difficult airway in children. It can be used in both routine induction of anaesthetic for elective cases, as well as in emergency situations such as acute respiratory failure. The below-presented algorithm can be used in all age groups. All major differences in the management in a specific age group were also described. These modifications were introduced as there are significant



changes in both the anatomy, as well as the physiology of the respiratory system. This is particularly true in neonates and infants. This algorithm may be modified in different clinical situations. These modifications may include a rapid move towards Stage IV (by-passing other stages) or waking the patient up, if clinical situation allows one to do so.

STAGE I: STANDARD INTUBATION

The main aim of this stage is to achieve optimal conditions for face mask ventilation, laryngoscopy and tracheal intubation. They are:

- 1) appropriate head and neck position
- 2) choice of an appropriate size and shape of a face mask
- 3) choice of both an appropriate laryngoscopy technique and size and shape of the laryngoscope blade
- 4) choice of an appropriate tracheal tube
- 5) effective pre-oxygenation
- 6) removal of upper airway secretions
- 7) effective anaesthetic and paralysis
- 8) use of external manoeuvres facilitating intubation e.g. BURP
- 9) use of standard malleable airway stylet

Re: 1. Neutral position is recommended in neonates, infant and children up to 2 years of age. Such an approach may require the use of a shoulder roll and avoids excessive head extension. The sniffing position is recommended in the remaining age group i.e. > 2 years old. Both the chin lift, as well as jaw thrust manoeuvres were found to be helpful/useful [28, 31, 32].

Re: 2. The choice of appropriate size and shape of a face mask is related to an individual patient's characteristics and should be made on a patient-to-patient basis. Fitting the mask to the patient's face before induction is a recognised practice.

Re: 3. The choice of the laryngoscopy technique should be individual and rely on personal preference. The two most common options exist include the use of a straight blade and lifting the epiglottis in order to obtain the laryngeal inlet view. This technique is often used in neonates and infants. In older children, a curved blade is frequently used and placed in the vallecula in order to indirectly lift the epiglottis [32, 33].

Re: 4. Uncuffed tracheal tubes are used in neonates and infants. In the remaining age groups, cuffed tubes may be used and a low-pressure cuff is recommended [34, 35]. Table 1 shows recommended sizes of tracheal tubes for neonates and depth of their insertion [36]. Size 4–4.5 tracheal tube (TT) is usually used in infants and children up to 2 years of age [37] while the appropriate size of the TT in older children can be calculated with one of the following formulae:

- for uncuffed tubes (modified Cole's rule): tube size = age (years) / 4 + 4 [38],
- for cuffed tubes (Khine's rule): tube size = age (years) / 4 + 3.0 or (Deakers' rule): tube size = age (years) / 4 + 3.5 [39, 40].

The use of a neck ultrasound has been recently introduced for appropriate tracheal tube sizing although this technique is not routinely used [41].

Re: 5. Effective pre-oxygenation lasting 3–5 minutes extends the safe apnoea time (i.e. SpO₂ drop below 90%) to approximately 1.5 minutes in neonates and infants, 2 minutes in children aged 2–5 years, 3 minutes in children aged 5–7 years and 5 minutes in older children and adults [42]. Pre-oxygenation lasting 60 seconds through a face mask with an oxygen flow of 6 L min⁻¹ is recommended in children aged 5 years and above [33, 43]. Optimal oxygenation with a tight-fitting face mask may be difficult in younger children due to anxiety and a lack of collaboration. This problem may be overcome with oxygen being delivered via nasal cannulae. Neonates require special attention, and premature babies in particular, as they are sensitive to excessive oxygen therapy/delivery while, on the other hand, being prone to hypoxia related to hypoventilation [13, 44]. Cautious pre-oxygenation is recommended in this group of patients, although there are no clear guidelines regarding either the technique or its length [33, 36].

Re: 6. Routine suction of secretions from the upper airways is not recommended although it should be performed when there are symptoms suggestive of secretion accumulation. Intravenous administration of an anticholinergic agent (atropine) decreases mucous secretion in the airways and attenuates vagal reflexes. However, the benefits of such practices in children are vague. Secretions from the upper airways should be removed under direct vision (laryngoscopy).

Re: 7. Both induction of the anaesthetic, as well as the use of neuromuscular blocking agents (NMBAs) should follow the latest anaesthetic guidelines [36, 45]. Adequate anaesthesia is an important element of successful and atraumatic intubation. Opioid administration enables one to provide effective analgesia for the pain associated with laryngoscopy. Most of authors have noted the benefits of paralysis in children as it improves the conditions for intubations [46, 47]. However, a neuromuscular blockade may be dangerous when face mask ventilation is ineffective [36, 48], although some authors have challenged this approach. The authors of these guidelines recommend the administration of NMBAs once the difficulties with face mask ventilation have been excluded. The use

of NMBA is not usually required in neonates, and in preterm babies in particular, providing that there is adequate anaesthesia [33, 36].

- Re: 8. External manoeuvres facilitating intubation are performed by a trained assistant. The BURP (Backward, Upward, Rightward Pressure) manoeuvre improves the laryngoscopic view by application of external pressure on the thyroid cartilage backwards, upwards and rightwards [49, 50]. In neonates and infants the BURP may be performed by the intubator with the fifth finger of the hand holding the laryngoscope [32].
- Re: 9. Intubation with a malleable airway stylet is routinely used in RSI (Rapid Sequence Induction) e.g. in patients with a full stomach. This technique is also used for intubation with a reinforced tracheal tube or whenever there are difficulties in insertion of the TT into the trachea. The TT should be shaped/formed around/over the airway stylet while the distal end of the stylet should not extend beyond the distal tip of the TT (risk of airway injury).

At this stage there may be two outcomes:

- 1) Success — effective/successful face mask ventilation, laryngoscopy and tracheal tube insertion.

The correct placement of the TT (a), as well as the depth of insertion (b), should be confirmed.

- Re: (a). As there is no one single best method of confirmation the tracheal tube placement, the routine approach should initially begin with a direct vision affirmation during laryngoscopy and intubation. Then ventilation should commence and adequate oxygenation should be confirmed. Other methods include the following: symmetrical chest movements during ventilation; symmetrical breath sounds; condensation of water vapour on the internal wall of the tube during expiration; a lack of auscultation sounds that are typical for oesophageal intubation; and a lack of abdominal distention suggestive of air accumulation in the stomach [31]. Low pressure/volume should be used for first breaths as such an approach prevents one from suffering excessive insufflation of the stomach when there is an unrecognised oesophageal intubation. Palpation of the suprasternal notch with simultaneous gentle movements of the tracheal tube may also be used for confirmation of the correct TT place-

ment. In the operating theatre, $E_T\text{CO}_2$ (capnography) is used while a CO_2 detector device may be used as an alternative in out-of-theatre settings [50–52]. The correct placement of the TT may be confirmed with ultrasound and a fibre-optic scope [53–56].

- Re: (b). Some tracheal tubes have a marker that should reach the level of the vocal cords in order to confirm the right depth of TT insertion.

In children aged 1 year and above, the correct depth of TT insertion may be calculated using one of the following formulae:

- based on the child's age:
 - the distance between the distal end of the TT and the gum (alveolar) ridge for oral intubation = $\text{age (years)} / 2 + 13 \text{ cm}$
 - the distance from the nares (for nasal intubation) = $\text{age (years)} / 2 + 15 \text{ cm}$ [57]
- based on the tube size:
 - the distance between the distal end of the TT and the gum (alveolar) ridge for oral intubation = $3 \times \text{ID (Internal Diameter)} \text{ cm}$
 - the distance from the nares (for nasal intubation) = $3 \times \text{ID} + 2 \text{ cm}$ [58].

Recommended depth of tracheal tube insertion (oral intubation) in neonates is presented in Table 2. Symmetrical chest movements and symmetrical breath sounds suggest that the tracheal tube is not placed too deep. The correct depth of TT insertion may sometimes require radiological confirmation (CXR) [31]. The tracheal tube placement can also be confirmed with an ultrasound [53–56, 59]. A fibre-optic scope may be used for TT placement confirmation in some clinical situations.

- 2) Failure — may result from a difficult laryngoscopy i.e. poor glottic visualisation or (rarely) from difficulty in insertion of the TT into the trachea despite a good laryngoscopic view.

A second experienced (consultant) anaesthetist should be called when a failed intubation is declared. Ventilation should be continued with 100% oxygen (FiO_2 1.0). It is of the greatest importance to gain intravenous (IV) access, if this has not been done earlier [28–30, 47]. The main priorities for further stages of this algorithm are maintenance of oxygenation and prevention of airway trauma. The ability to ventilate through the face mask will determine further action.

Table 1. Recommended tracheal tube size and depth of tracheal tube insertion for oral and nasal intubation in relation to the body weight of a neonate and an infant

Body weight (g)	Internal diameter (mm)	Depth of tracheal tube insertion (oral intubation) (cm)	Depth of tracheal tube insertion (nasal intubation) (cm)
< 750	2.5	5.5–6	6.5–7
750–1,000	3	6–7	7–8
1,001–2,000	3	7–8	9
2,001–3,000	3.5	8–9	10
3,000–3,500	3.5	9–10	11
> 3,500	4.0	b.w. (kg) + 6	b.w. (kg) + 7

Table 2. Recommended depth of tracheal tube insertion (oral intubation) in relation to the postmenstrual age

Postmenstrual age (weeks)	Depth (cm)
23–24	5.5
25–26	6.0
27–29	6.5
30–32	7.0
33–34	7.5
35–37	8.0
38–40	8.5
41–43	9.0

STAGE II A: MAXIMISING THE CHANCES OF SUCCESSFUL INTUBATION AND FURTHER INTUBATION ATTEMPTS (MAX. 3 ATTEMPTS IN MAX. 10 MINUTES)

Successful face mask ventilation results in satisfactory chest movements and good oxygenation of the patient ($\text{SpO}_2 > 90\%$). Difficult intubation may not be an immediate life-threatening situation, providing that there is effective face mask ventilation. However, as there is always a possibility of difficult mask ventilation, the patient should be ventilated with 100% oxygen [28–30, 47]. The main aim of this stage is to implement all actions that would maximise the chances of successful intubation (a maximum of 3 oral intubation attempts allowed). The risk of desaturation may be minimized by insufflation of 100% oxygen during the laryngoscopy [60, 61]. Some laryngoscopes are equipped with a dedicated channel through which oxygen can be delivered. Alternatively, a thin drain may be attached to the laryngoscope blade. All 3 intubation attempts must not last longer than 10 minutes. Oral intubation is recommended at this and the following stages of the algorithm. The causes of failure fall into two main groups: difficult laryngoscopy i.e. visualisation of the laryngeal inlet, or difficulty in tracheal tube insertion into the trachea despite a good laryngoscopic view.

— Difficult laryngoscopy

The main aim is to improve the laryngeal inlet view. The relevant actions include:

- 1) improved head and neck position
- 2) removal of any secretions from the upper airways
- 3) effective anaesthesia and paralysis (may be deepened, if required)
- 4) optimal use of external manoeuvres facilitating intubation e.g. BURP
- 5) different intubation technique, different size and type of laryngoscope blade
- 6) use of a different laryngoscope facilitating glottic visualisation e.g. video laryngoscope
- 7) use of stylets and introducers
- 8) use of a fibre-optic scope (if readily available)
- 9) use of ultrasound

Re: 1. Both excessive extension, as well as flexion of the head may be one of the causes of a poor laryngoscopic view [32, 62].

Re: 2. Removing/suction of the secretions from the pharynx and oral cavity (laryngoscopy).

Re: 3. Adequate muscle paralysis facilitates laryngoscopy while NMBA administration is considered safe and beneficial whenever face mask ventilation is effective [30, 46, 47]. Given the potential risk associated with face mask ventilation, an optimal NMBA would be rocuronium or vecuronium as both of these drugs have a specific reversal agent i.e. sugammadex (off-label use in children under the age of 2 years) [63]. It is possible to use suxamethonium after contraindications have been excluded. Suxamethonium should be administered with atropine (if it has not been given previously).

Re: 4. The glottic visualisation may be improved by external manoeuvres on the larynx e.g. BURP [49, 50].

Re: 5. A change of the laryngoscope blade, as well as intubation technique, may be useful in neonates and infants. Another option may be the insertion of the laryngoscope blade lateral to the tongue.

Re: 6. There are various laryngoscopes available which use facilitates visualisation of the laryngeal inlet. The cho-

ice depends on the size of the patient, equipment used in the particular centre and the personal preference of the anaesthetist. Although laryngoscopes with curved blades or with a movable tip and various optical laryngoscopes may also be used in the paediatric population (this includes neonates), the data on their use and clinical usefulness are equivocal [19, 37, 64–67]. Video laryngoscopes are becoming more popular and are also recommended in the youngest patients [68–72].

Re: 7. Although the use of standard/classic introducers and stylets does not improve laryngoscopic view *per se*, both of these adjuncts may be useful during tracheal tube insertion into the trachea when the laryngeal inlet is only partially visible. Of note is the fact that in such situations there is a risk of airway (laryngeal) injury. That is why such an intubation should be performed by an experienced anaesthetist. Both optical stylets and lightwands may be used for paediatric intubation although their usefulness has not been thoroughly assessed [73–76].

Re: 8. The use of fibre-optic scope is recommended in anticipated difficult airway. They may be used in emergency situations only when readily available and when there is an experienced operator [30, 77–79].

Re: 9. In the current literature there are studies evaluating ultrasound-guided intubation. Such an approach may be considered during difficult intubation when the ultrasound machine/imaging is immediately available and there is a trained operator. Currently, there is a lack of high quality evidence to routinely recommend this method [80].

— Difficult insertion of the tracheal tube despite a good laryngoscopic view

This may arise from the tip of the tracheal tube getting stuck in the anterior commissure of the vocal cords. A 90° anticlockwise rotation may solve the problem [62]. Insufficient opening of the laryngeal inlet may also cause problems. It is often due to inadequate anaesthesia and/or paralysis, laryngospasm or anatomical anomalies (both congenital and acquired, such as tumours). At this stage, airway assessment with an ultrasound may be useful when the machine and experienced operator are immediately available.

The following actions may facilitate tracheal tube insertion:

- 1) deepening anaesthesia, effective paralysis
- 2) use of smaller tracheal tubes
- 3) use of introducers and stylets

Re: 1. Deepening anaesthesia and effective paralysis facilitate intubation when there is insufficient glottic opening or there is laryngospasm [30, 45, 47]. Given

the potential risk associated with face mask ventilation, an optimal NMBA would be rocuronium or vecuronium as both of these drugs have a specific reversal agent i.e. sugammadex (off-label use in children under the age of 2 years) [63]. It is possible to use suxamethonium after contra-indications have been excluded. Suxamethonium should be administered with atropine (if it has not been given previously).

Re: 2. The use of smaller size (ID) tracheal tubes may be of benefit when there are anatomical obstacles [28].

Re: 3. An introducer or airway stylet may be useful when there is difficulty with tracheal tube insertion below the level of the vocal cords. The prevention of laryngeal/airway injury is of utmost importance. Intubation with a standard malleable airway stylet is useful when reinforced tubes are used as the TT may be formed around the stylet. A gum-elastic bougie (straight or curved) is useful when there is difficult intubation despite a good laryngoscopic view. Initially, the introducer (bougie) is inserted into the trachea and then the tracheal tube is railroaded over it. This often requires some help from a trained assistant. Other airway adjuncts may also be useful e.g. optical stylets or lightwand which are available in sizes for older children [19, 73, 74]. At this stage there may be two outcomes:

- 1) Success — successful tracheal intubation. Correct tracheal tube placement should be confirmed.
- 2) Failure — inability to intubate the patient despite taking all actions/measures aimed at maximising the chances of successful intubation.

Inability to intubate the patient in 3 consecutive attempts, despite all actions taken to maximise the chances of successful intubation, constitutes a difficult intubation (DI). DI is an indication to move to Stage III.

STAGE II B: IMPROVING CONDITIONS FOR FACE MASK VENTILATION

Difficult Mask Ventilation (DMV) indicates unsatisfactory chest movements and inability to oxygenate the patient — $SpO_2 < 90\%$ with $FiO_2 = 1.0$. In contrary to adults, it is rather rare in children [19, 81]. This is a genuine emergency and a life-threatening situation and further action should be initiated promptly. Face mask ventilation attempts should be continued with 100% oxygen even if there is initial DMV. Oxygen delivery/insufflation during laryngoscopy is recommended. Difficult mask ventilation may occur after induction but before intubation attempts. A rapid attempt to intubate the patient should be made only if the patient is well-oxygenated (effective pre-oxygenation, $SpO_2 > 90\%$). The other causes of DMV include technical problems (gas/

air leak around the face mask) and increased upper or lower (rarely) airway resistance due to functional or anatomical changes. The functional/reversible causes of DMV are: laryngospasm, chest stiffness associated with opioid administration, excessive gastric insufflation with air and bronchospasm [28, 30, 82–84].

The following actions should be taken in order to facilitate face mask ventilation:

- 1) solving of all equipment problems (air/gas leak)
- 2) removal of secretions from the upper airways
- 3) improved head and neck position, application of chin lift and jaw thrust
- 4) improved seal around the face mask
- 5) drainage of/emptying the stomach (removal of excessive air/gas)
- 6) effective anaesthesia and paralysis (may be deepened, if required)
- 7) use of oropharyngeal airway (OPA) or nasopharyngeal airway (NPA)
- 8) cautious increase of pressure/volume of inspired air/gas during face mask ventilation
- 9) administration of a bronchodilator in bronchospasm

Re: 1. All causes of air leak around the face mask and in the ventilator tubing should be eliminated. Checking the equipment before the start of anaesthesia is an important element of anaesthetic practice [85].

Re: 2. Secretions in the nostrils, oral cavity and pharynx make face mask ventilation difficult and should be ideally removed under direct vision (laryngoscopy).

Re: 3. Both excessive extension, as well as flexion of the head, may be one of the causes of difficult mask ventilation. Other causes include: insufficient chin lift and insufficient jaw thrust [28, 31, 32, 62, 86].

Re: 4. Changing the shape or size of the face mask may solve the problem. Gaining experience and adequate training is of utmost importance in order to maintain skills [87]. There may be situations in which two hands will be required to achieve an adequate seal around the face mask. In such situations, the two-person technique is recommended, one person holding the face mask and the other ventilating the patient [28, 30, 32, 86, 88].

Re: 5. Difficult mask ventilation is often associated with excessive gastric insufflation which in turn may further compromise ventilation. A nasogastric (NG) tube may be used to empty the stomach and drain the accumulated air/gas [28, 86].

Re: 6. Deepening anaesthesia is often beneficial as it improves ventilation especially when laryngospasm is present [28, 30]. The use of NMBAs is controversial. On one hand, it improves conditions for intubation and facilitates ventilation while, on the other hand, it may be dangerous in a situation when fitting face

mask is difficult [36, 48]. Some authors conclude that the benefits of adequate paralysis outweigh the potential risks [30, 45, 86]. Given the potential risk associated with face mask ventilation, an optimal NMBA would be rocuronium or vecuronium as both of these drugs have a specific reversal agent i.e. sugammadex (off-label use in children under the age of 2 years) [63]. It is possible to use suxamethonium after contra-indications have been excluded. Suxamethonium should be administered with atropine (if it has not been given previously).

Re: 7. Oropharyngeal airway facilitates face mask ventilation only when it is correctly inserted and when the right size of the OPA is used. There are various sizes available for children with the body weight of 1 kg and above. In neonates, infants and small children the OPA is inserted with the concavity facing the floor of the mouth. The correct size can be selected by measuring the distance between the child's earlobe and the corner of the mouth [32]. Although the nasopharyngeal airway is used less frequently, it is effective in difficult face mask ventilation [89-91]. NPA is available in different sizes for neonates, infants and older children. The diameter of the NPA should be the same or somewhat larger than the corresponding tracheal tube. Its length should equal the distance between the tip of the nose and the tragus [37].

Re: 8. One of the causes of difficult face mask ventilation is low inspiratory pressure or low pressure settings of the 'resuscitator' (in neonates). Cautious increase of inspiratory pressures/volumes with simultaneous changes in the head and neck positions may improve face mask ventilation.

Re: 9. The use of adrenaline/epinephrine is justified when bronchospasm is the cause of difficult mask ventilation [86].

At this stage there may be two outcomes:

- 1) Success — successful face mask ventilation is achieved (symmetrical chest movements, $SpO_2 > 90\%$)

When the above is achieved there is no immediate threat to life. This warrants the move to Stage IIA: Further intubation attempts are allowed once all actions/measures aimed at maximising the chances of successful intubation have been taken

- 2) Failure — is considered to be no improvement in face mask ventilation (no chest movements, $SpO_2 < 90\%$ with $FiO_2 1.0$) despite taking all actions/measures aimed at maximising the chances of successful face mask ventilation.

In this case, the inability to intubate and ventilate the patient should be declared (CICV, cannot intubate and cannot ventilate). It is a life-threatening situation and warrants a prompt move to Stage III A. Attempts to ventilate the patient with 100% oxygen should continue.

Table 3. Recommended laryngeal mask airway (LMA) sizing

Patient size	LMA size
Neonate, infant < 5 kg	1
Infant 5–10 kg	1.5
Infant, child 10–20 kg	2
Child 20–30 kg	2.5
Child 30–50 kg	3
Child/Adult 50–70 kg	4.0
Child/Adult 70–100 kg	5

STAGE III A: USE OF A SAD (LMA) — A MAXIMUM OF 3 ATTEMPTS ALLOWED

Failure to intubate when face mask ventilation is possible does not constitute a life-threatening situation. In contrary to this, failure to intubate and the inability to ventilate the patient through a face mask is an immediate threat to life (CICV). In this case, prompt actions should be initiated and attempts to ventilate the patient with 100% oxygen should be continued. A SAD (supraglottic airway device) is a device designed to facilitate the upper airway management and is blindly inserted into the supraglottic area. The most popular SADs are the laryngeal mask airways (LMA) and its various modifications, e.g. ILMA — Intubating Laryngeal Mask Airway. The most useful SADs are those which can be used not only for ventilation, but also for intubation when routine intubation is difficult. Although most SADs have an inflatable cuff, some designs incorporate a gel-like cuff instead. There are also double-lumen SADs, e.g. LMA Supreme and LMA ProSeal which have a special channel used for NG tube insertion. Other special designs include the iLTS-D (intubating laryngeal tube suction-disposable) and the Cobra PLA (peri-laryngeal airway). In the neonatal group, SADs are recommended in patients with a corrected gestational age of 34 weeks and above and with body weight over 2000g [32, 92–94]. While Table 3 shows the recommended sizes of LMAs for children, the recommended sizing varies among different devices [95]. The choice of a specific SAD depends on the equipment used in the particular centre and the personal preference and experience of the anaesthetist. Laryngeal tubes are currently available in sizes for use in both infants and older children. The Combitube device may be used in children that are taller than 120 cm i.e. school-aged children. These devices enable mechanical ventilation while some of them, e.g. the iLTS-D are designed to facilitate fibre-optic-assisted tracheal intubation. They are rather used in emergency medicine and rarely used for the ventilation of patients requiring general anaesthesia in theatres.

There may be two outcomes at this stage:

- 1) Success — successful ventilation with a SAD.

When the above is achieved, there is no immediate threat to life. Furthermore, successful ventilation when a SAD

is used enables/allows tracheal intubation through it. This warrants the move to Stage III B.

- 2) Failure — inability to ventilate through a SAD

Inability to ventilate through a SAD (no chest movements, inability to maintain adequate oxygenation — $SpO_2 < 90\%$ with $FiO_2 = 1.0$) together with inability to intubate and ventilate the patient (CICV) indicates a life-threatening situation and warrants a prompt move to Stage IV. Attempts to ventilate the patient with 100% oxygen should continue.

The inability to ventilate through a SAD is not an immediate threat to life when face mask ventilation is possible. In this situation, face mask ventilation should be continued while further actions depend on the clinical circumstances:

- A prompt move to Stage IV in all situations requiring artificial airway for the patient's management, e.g. severe respiratory failure.
- There are two options available when there is a failed intubation during a standard/routine induction:
 - Move to Stage IV — front of neck access when there is an emergency surgery/procedure required,
 - Waking the patient up and postponement of the surgical procedure (only when those which are elective).

STAGE III B: INTUBATION THROUGH A SAD (LMA)

When it is possible to ventilate the patient through a SAD, an attempt should be made to intubate the patient through it. The classic LMA is mainly used for mechanical ventilation although it is possible to intubate the patient through it. The ILMA is especially designed to facilitate intubation. This device, however, it only available for older children due to its limited size range [96–98]. The tracheal tube is inserted into the trachea through the lumen of the intubating SAD. The use of a fibre-optic scope is recommended for both intubation through the SAD, as well as the tracheal tube placement confirmation [96–102]. Blind intubation through intubating a supraglottic airway device with a gum-elastic bougie may only be justified when a fibre-optic scope is not readily/immediately available [103]. Intubating a SAD also enables blind tracheal intubation without a gum-elastic bougie providing that the TT is of an adequate length [104]. The choice of a specific intubating SAD depends on the equipment used in the particular centre and the personal preference and experience of the anaesthetist.

There may be two outcomes at this stage:

- 1) Success — successful intubation through a SAD.

The correct placement of the tracheal tube should be confirmed.

2) Failure — failed intubation through a SAD.

In this situation ventilation through a SAD should be continued while further actions depend on the clinical circumstances:

- A prompt move to Stage IV in all situations requiring artificial airway for the patient's
- management e.g. severe respiratory failure.
- There are three options available (depending on the assessment of risks versus benefits)
- when there is a failed intubation during standard/routine induction:
 - Move to Stage IV for all urgent/emergency procedures that cannot be done under general anaesthesia with ventilation through a SAD.
 - Surgery continued under general anaesthesia with ventilation through a SAD — for shorter procedures and with the patient in the supine position.
 - Waking the patient up and postponement of the surgical procedure — for all elective procedures that cannot be done under general anaesthesia with ventilation through a SAD.

STAGE IV: FRONT-OF-NECK ACCESS

The front-of-neck approach comprises the following methods:

- 1) needle cricothyroidotomy
- 2) surgical cricothyroidotomy
- 3) retrograde intubation
- 4) tracheotomy

The front-of-neck access is rarely used in children; the knowledge about its use is based on few reports only. In older children dedicated sets are used, while in an emergency substitute instruments, such as intravenous cannulae, may be utilized [105–107]. In life-threatening situations when bag-mask ventilation and ventilation through Laryngeal Mask Airway (LMA) is not possible, the option to achieve the quickest possible oxygenation of the patient should be chosen, according to the available equipment and the physician's experience. It has to be taken into account, however, that cricoid puncture and cricothyroidotomy is associated with high risk in children – the smaller the patient, the higher the risk [28, 108–110]. Although a tracheotomy is relatively safe when performed by an experienced surgeon (general or ENT surgeon), it is more time consuming [28, 30].

Re 1. Needle cricothyroidotomy is the fastest anterior neck access. It is performed by means of puncturing of cricothyroid membrane and inserting a cannula below the glottis. Although it enables the insufflation of oxygen, because of the thin cannula diameter, ventilation is very limited. This procedure is associated with high complication rates in children. If this method

of ventilation is chosen, high respiratory resistance should be anticipated, especially during expiration, which should be given enough time [28, 111–113]. "Jet ventilation" (high pressure, low volume) by means of the Manujet III device has been proposed [28, 114]. Its use is possible when at least minimal leak upwards from cannula insertion is present. Otherwise it is endangered with barotrauma. There are special sets for cricothyroidotomy (e.g. MiniTrach, QuickTrach), available in sizes for children older than 2 years, although its possible to perform this procedure by means of relatively large bore intravenous cannula [106, 107].

Re 2. Surgical cricothyroidotomy is a procedure that consists of a horizontal cut of the cricothyroid membrane with a scalpel and insertion of a tracheal or tracheostomy tube through the created opening. Although it requires more time to perform than a needle cricothyroidotomy, it enables efficient ventilation of the patient [106].

Re 3. Retrograde intubation is rarely performed and requires piercing the cricothyroid membrane (or cricotracheal, or between the tracheal cartilages) cephalad with a needle and threading a guidewire upwards toward patient's mouth and railroading the endotracheal tube over the guidewire into the trachea. The retrograde intubation sets are available in different sizes (e.g. Cook® Retrograde Intubation Set). Similar equipment can be created by means of Tuohy epidural needle and a guidewire from a central venous cannulation set, using a the Seldinger technique. Retrograde intubation can be combined with fiberoscopy, and with ventilation through an LMA to avoid pauses in the patient's ventilation [115–119].

Re 4. Tracheotomy consists of making an incision on the anterior aspect of the neck, visualizing the tracheal wall and putting a tracheostomy tube inside the trachea through a created opening — usually at the level between the third and fourth tracheal cartilage. While it can be performed at any age, there are very limited indications for it in neonates [28, 30]. It is an effective way of leading to proper ventilation of a patient and, in experienced hands, is a safest approach through the anterior neck [28, 30]. Although this procedure is recommended as elective, it is too time consuming for emergency situations. It can be performed either as a surgical or percutaneous technique.

- Surgical tracheotomy should be performed by an experienced surgeon (preferably an ENT or general surgeon)
 - ideally in an operating theatre. The tracheostomy tube can be with or without a cuff [28, 30, 120].
- A percutaneous tracheotomy is usually performed by experienced anaesthetists. This technique consists of

puncturing the anterior tracheal wall with a needle, introducing a guidewire to its lumen and railroading the tube over the guidewire after widening the opening in the trachea with forceps or special dilator — according to the chosen technique and set. Most techniques require a fibre-optic control to confirm the proper position of the tracheostomy tube. Special percutaneous tracheotomy sets are available in sizes for adults; therefore this method has a limited application in children [106].

In an immediately life-threatening situation with CICV/ /CICO and a lack of appropriate equipment, it is advisable to pierce the cricothyroid ligament or cricotracheal ligament or between tracheal cartilages) with any available type of cannula. Once this is performed, oxygen should be immediately administered through it.

DIFFICULT AIRWAY KIT

Table 4 contains the proposed difficult airway kit. It corresponds to all the stages of the algorithm.

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Table 4. Difficult airway kit

Stage II A: Maximising the chances of successful intubation	
Stage II B: Improving conditions for face mask ventilation	
1	Specialist/alternative laryngoscopes e.g. McCoy, Bullard, optical laryngoscope, video laryngoscope and/or optical stylet
2	Full set of malleable airway stylets and introducers e.g. gum elastic bougie
3	Full set of oropharyngeal airways (in various sizes), additionally recommended full set of nasopharyngeal airways (in various sizes)
4	Tables containing recommended sizes of tracheal tubes and recommended depth of their insertion (age-related)
5	Drugs: rocuronium, suxamethonium, atropine, sugammadex
Stage III A: Use of SAD (LMA)	
Stage III B: Intubation through SAD (LMA)	
6	Full set of laryngeal mask airway (LMA, ILMA) in various sizes, additionally recommended full set of laryngeal tubes and/or oesophageal tracheal airways (Combitube) in various sizes
7	Table containing recommended sizes of LMA
Stage IV: Front-of-neck access	
8	Original cricothyroidotomy kit e.g. Quicktrach, Mini-Trach in various sizes, additionally 16G intravenous cannula for alternative needle cricothyroidotomy
9	Original retrograde intubation set e.g. Cook® Retrograde Intubation Set in various sizes or Tuohy needle and cannulation set (Selinger technique) for alternative retrograde intubation
10	Full set of tracheostomy tubes in various sizes
11	Additional equipment: scalpel, sterile gauze/swab, skin disinfectant, sterile gloves in various sizes
Additionally recommended	
12	Manujet III device
13	Fibre-optic scope with complete kit of different sizes (essential for the management of anticipated difficult airway)

SAD — supraglottic airway device; LMA — laryngeal mask airway; ILMA — intubating LMA

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