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Opinion

Translation and application of guidelines into clinical practice: A colour-coded difficult airway trolley

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A B S T R A C T

An unanticipated difficult airway needs immediate and well-coordinated management to maintain oxygenation and avoid a poor patient outcome. In addition to medical knowledge, technical skills, competencies and performance, human factors contribute substantially to success during unanticipated difficult airway management. Human factors can be influenced by cognitive aids like algorithms. These algorithms can be further enhanced by using a strong visual stimulus like colour coding to provide easy and fast orientation. Colour coding as cognitive aid is recommended in some difficult airway guidelines but the translation into clinical practice is underreported. This article describes the application of colour coding for cognitive aids to facilitate the management of an unanticipated difficult airway and its further local implementation in the form of a colour-coded difficult airway trolley.
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1. Background

Although anaesthesia has become increasingly safer in the last 25 years [1], the 4th United Kingdom National Audit (NAP4) [2], published in 2011, demonstrated that 10% of all airway-related anaesthetic problems led subsequently to death and disability. The NAP4 contained detailed information about and analysis of the failures of airway management and the factors contributing to poor patient outcomes, and helped shape difficult airway guidelines thereafter.

Guidelines provide a practical, evidence-based framework for decision-making and a structured approach to potentially life-threatening airway management problems. The core of any airway management guideline is usually a single-page visualization of the airway management algorithm. This “single-page algorithm” is used as a cognitive aid, and often simplifies the processes and procedures for the airway management provider by breaking down the scientific evidence into a brief, simple-to-follow recommendation of the steps to take. These algorithms need to be locally adapted, implemented, taught and trained as often as possible. Guideline visualizations in the form of such cognitive aids need to include human factors that might affect clinical performance while an unanticipated difficult airway is secured.

One way to influence and emphasise these human factors, especially for recognition of different steps, is colour coding. For example, syringes containing different drugs are labelled with stickers of different colours in addition to the drug's name and the correct dosage, to make it easier to distinguish between different categories of drugs in syringes of the same size and shape. Internationally, it is recommended to associate one colour with a specific item or medication group (e.g., syringes containing opioids usually have a blue label) [3,4]. A 2019 review article [5] reported that three out of 14 analysed society-produced difficult airway guidelines used a colour coding system [6–8], starting with green and progressing stepwise to yellow and ending in red. The aim of this article is to show how a current stepwise difficult airway

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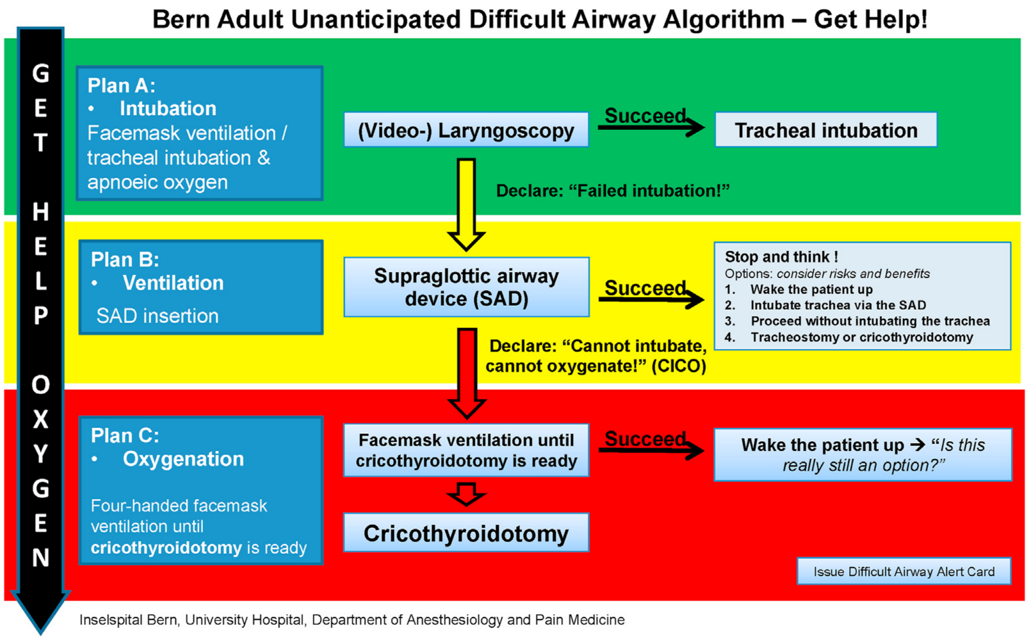

Fig. 1. Local colour-coded Adult Unanticipated Difficult Airway Algorithm.

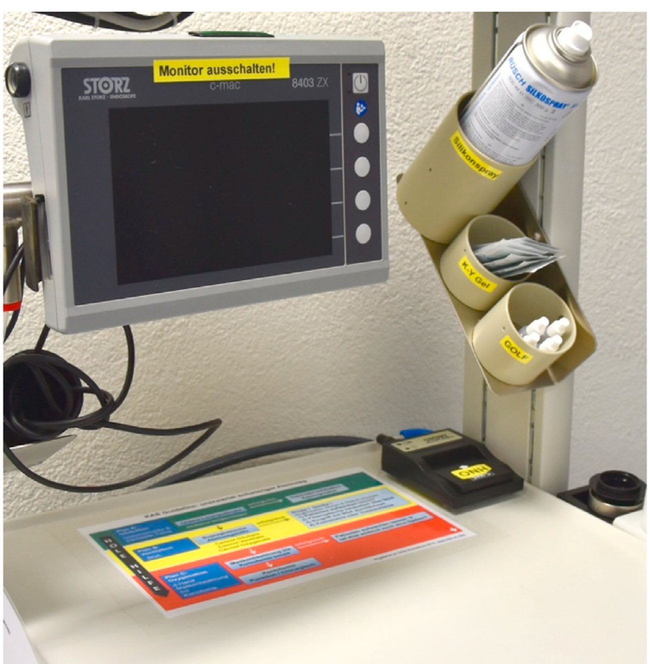

Fig. 2. Local Unanticipated Difficult Airway Algorithm attached on the working surface of the difficult airway trolley for adults.

guideline can be improved by colour coding, and ultimately implemented with the use of a colour-coded difficult airway trolley.

2. Human factors

In clinical medicine, human factors are a major cause of errors and poor patient outcome during hospitalisations [9]. Communication, leadership, teamwork, and interpersonal factors have a significant effect on clinical performance during airway emergencies [2,10–13]. Therefore, the integration of human factors into difficult airway guidelines highlights their importance – not only for clinicians, but also for teaching and training of airway management [8,14]. Unfortunately, simply adapting and publishing guidelines is not enough to improve the handling of airway management-related complications during anaesthesia. The complexity of airway management is difficult to capture in a single algorithm, and even highly skilled teams have been found to underperform when operating in a suboptimal environment [15].

During a life-threatening airway management crisis, the clinician managing the airway could potentially be overwhelmed by the available clinical information [16]. Cognitive overload can impede decision-making and lead to errors, such as focusing on the performance of particular tasks like intubation, all the while losing track of the patient's oxygenation. A well-known example of such a fixation error is the tragic case of Elaine Bromiley [17]. Cognitive aids aim to minimise cognitive overload, improving non-technical skills during airway management [18] and significantly decreasing equipment preparation errors in connection with emergency intubations [19].

Human factors in anaesthesia are often referred to as Anaesthetists' Non-Technical Skills (ANTS), and include situational awareness, teamwork, decision-making and task management [20]. They are part of a broader concept of principles related to the engineering and design of products and systems that interact with humans, with the ultimate goal being to reduce human error and enhance patient safety [21]. Of paramount importance, particularly in the case of an "unanticipated difficult airway", is how airway management equipment is stored and organised for easy access.

Traditionally, difficult airway trolleys are simple storage carts containing airway management equipment preferred by local clinicians. Often this equipment is stored in a disorganized or illogical fashion [22]. Recently, several recommendations [22–24] have warned against the approach to overstock with various different airway management equipment and its potential negative impact in stressful unanticipated "cannot intubate, cannot oxygenate" (CICO) situations.

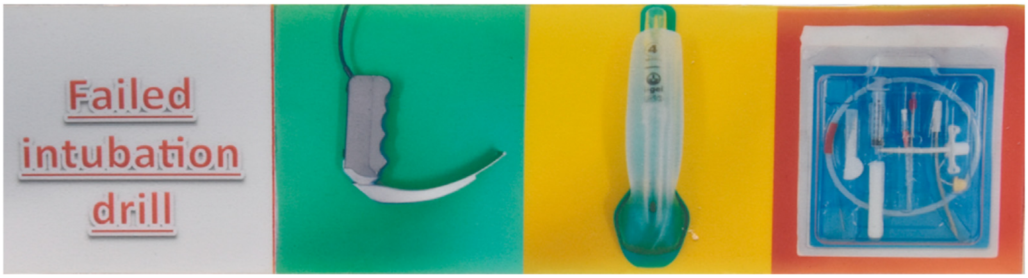

Fig. 3. Local Unanticipated Difficult Airway Algorithm as a pictogram attached on the difficult airway trolley for adults.

Fig. 4. Local Difficult Airway Trolley for adult patients.

3. Colour coding

Healthcare delivery can be improved through the targeted use of quality management principles and human factors engineering methods. One such method is colour coding, referring to the use of chromaticity to differentiate between items in a certain display. This ensures “detectability, discriminability, compatibility, meaningfulness, and standardization” [25] as well as a systematic classification of certain items, and prevents errors, therefore enhancing patient safety [26]. Colour coding has been found to be particularly effective for tasks that involve searching [27]. Colour coding is also good for “identification” tasks, but not as good as letters and numerals. Colour is seen in human factors engineering as a very useful coding dimension, as long as the general population's expectations regarding the use of colour are not violated. These population stereotypes include:

- Green: indicates “go ahead”, “system operating within tolerance”
- Yellow: indicates “caution”

Table 1
Contents of the Bern Difficult Airway Trolleys for adults and children.

	Bern Difficult Airway Trolley	
	Adult	Paediatric
Green drawer	C-MAC pocket monitor C-MAC Blades: - Macintosh size 2-4 - Miller - dBlade (paediatric & adult)	Guedel Airway (size 00–6), Laryngoscope handle (paediatric & adult) and blades: - Macintosh size 1-4 - Miller size 0-3 Single-use carbon dioxide detectors
Yellow drawer	LMA Fastrach size 3-5 LMA Fastrach TTs ID 6-8 Microlaryngeal tube ID 4.0	Ambu Aura Gain size 1-4 i-gel size 4-6
Red drawer	Universal cricothyroidotomy set (needle & surgical) Laryngectomy Tube 7.0 Dilator 16,0 French 20 cm	Cannula cricothyroidotomy set ("Melker") Frova Intubation Guide Surgical tracheostomy set
Grey Drawer		Uncuffed, micro-cuffed and cuffed TTs in sizes 2.5–8.0
Adjuncts attached on the top or side of the difficult airway trolley	Monitor C-MAC monitor C-MAC flexible intubation scopes Silicon spray Lubricant gel Anti-fog liquid	C-MAC monitor C-MAC flexible intubation scopes C-MAC blades: - Macintosh size 2-4 - Miller size 0-1 - dBlade (paediatric & adult) Frova Intubation Guide

TT, tracheal tube; ID, internal diameter.

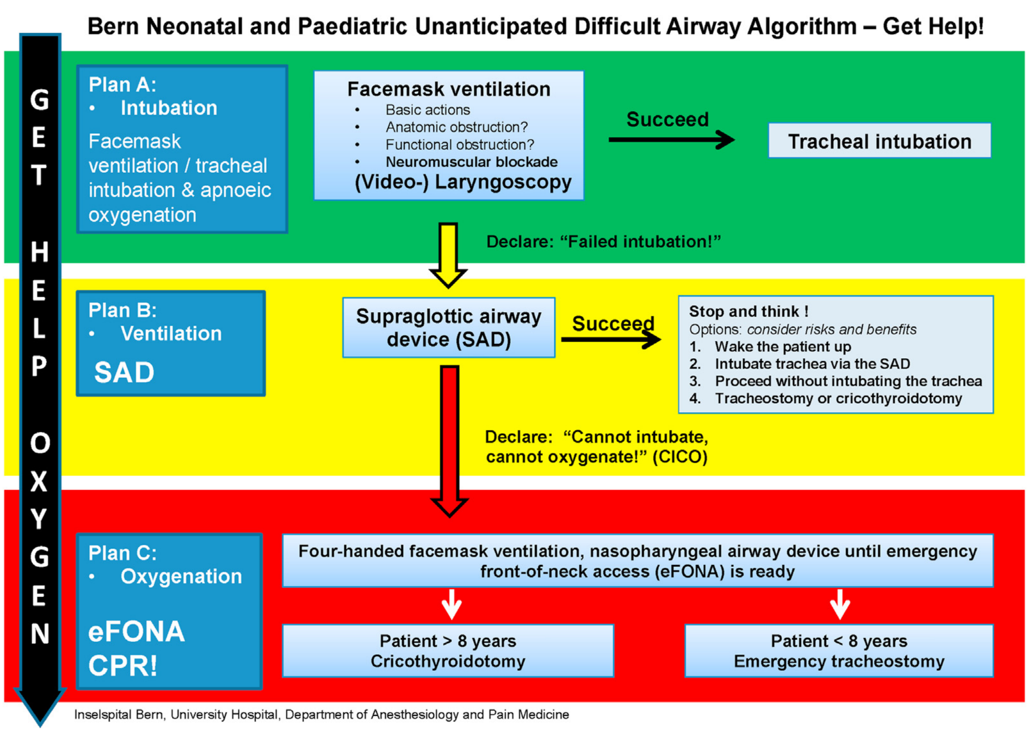

Fig. 5. Local colour-coded Neonatal and Paediatric Unanticipated Difficult Airway Algorithm.

- Red: indicates "stop", "warning", "system operating out of tolerance"

In healthcare, colour coding is used widely [28,29]:

- Drug labelling
- Gas tank and connector labelling (e.g., oxygen, nitrogen, volatiles)
- Size of airway tools (e.g., oropharyngeal tube or supraglottic airway device)
- Size of intravenous cannulas or needles
- Triage in mass casualty situations

It is also found in difficult airway guidelines [5]. Due to its economic advantage, colour coding is also an option to enhance quality of health care in low-resource settings [30]. Some organisations emphasise a structured use of the colour coding [3,4].

Fig. 6. Local difficult airway trolley for neonatal and paediatric patients.

Fig. 7. Attachment and organization of flexible intubation scopes and different videolaryngoscope blades on the paediatric difficult airway trolley.

4. Difficult airway guidelines

An unanticipated difficult airway requires an immediate, well-coordinated approach to management of oxygenation in order to avoid a poor patient outcome [2,6,8,14,31,32]. To help the provider overcome cognitive overload, equipment for each step of the algorithm needs to be carefully selected, and organised in a functionally designed “difficult airway trolley” [22,24]. Despite the need to teach the use of various devices for airway management in a teaching hospital, focusing on one device in practice (e.g., one videolaryngoscope) is advisable. This device should ideally have evidence of successful use in training and clinical practice, as this reduces the burden on the organization about teaching and training but also on the individual airway management provider in a critical situation. Limiting the items and tools available on the difficult airway trolley reduces clutter and ensures easier access. Additionally, if the difficult airway trolley is organised following the stepwise guidelines, this may simplify and guide decision-making and reduce cognitive load, particularly in stressful CICO situations. Limiting the number of available devices also enhances an institutional airway management teaching and learning strategy, ensuring that all local clinicians are proficient with the same

Fig. 8a. Red drawer of the paediatric difficult airway trolley, including the surgical tracheostomy set for children under 8 years contained in the metallic box (red star).

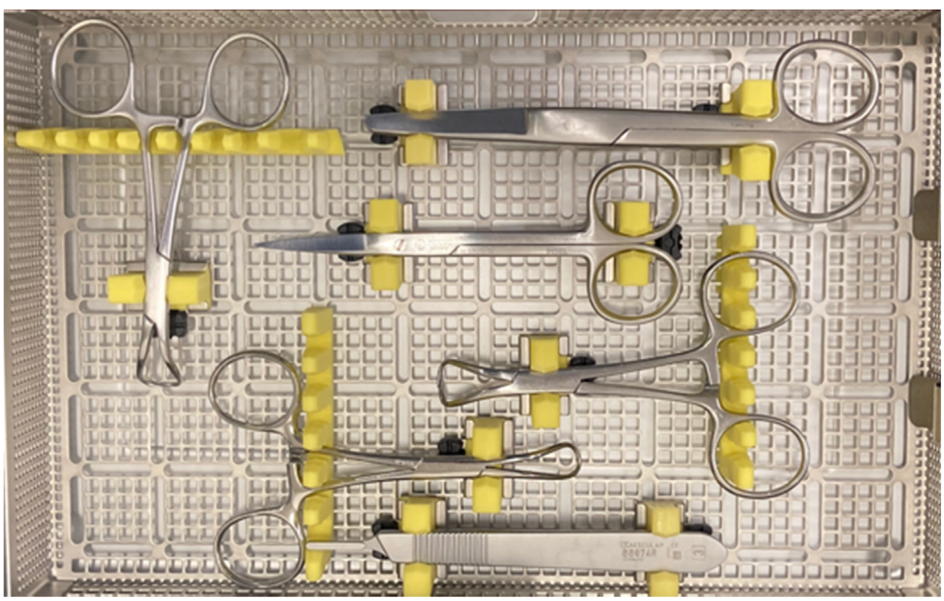

Fig. 8b. Opened surgical tracheostomy set for children under 8 years in the metallic box of the red drawer at the Bern University Hospital.

equipment.

With the introduction of mandatory capnography [33], video-laryngoscopy and second-generation supraglottic airway devices (SADs), the technical opportunities for airway management have improved substantially. In addition, human factors are increasingly recognized as a crucial factor in effective airway management. Simulation is an important way to train both the difficult airway technical skills and the human factors, such as teamwork and leadership, which seem to be crucial for further improvement of patient safety and ultimately patient outcome [10].

5. Structured layout and integration of cognitive aids

Proper and easily accessible storage of difficult airway management equipment has been recognized as a pivotal factor for successful airway management [34], particularly in critical situations. The local difficult airway trolley should always be located at the same place and needs to be organised in a way that aligns with the needs of clinicians and institutional airway management policies. Local implementation and unification of such a policy could be supported with recommendations from international and national airway management societies. The concept of "clinical integration" [22] suggests that guideline recommendations should be adapted for local clinical practice, for example that the difficult airway trolley "becomes an extension of the relevant cognitive aid" [24]. By aligning the difficult airway trolley with airway management guidelines and clinical practice, airway management teams are prompted to address airway management problems using the same strategic approach recommended by the guidelines. This is achieved by presenting the material according to the "stepwise approach" of the standard airway management algorithm (face-mask ventilation → supraglottic airway device → tracheal intubation), which stimulates the swift progression between these devices [22].

Difficult airway trolleys that support this approach might use colour-coded drawers dedicated to the different upper airway devices, as well as cricothyroidotomy sets. Colour coding and labelling facilitate the link of the difficult airway trolley to the guidelines and may result in faster equipment identification, particularly in stressful situations [22]. Connecting equipment layout and storage display in the difficult airway trolley with the process of airway management aims to facilitate decision-making. This integrated and aligned approach prompts the correct next step, and might reduce the time to reversal of hypoxaemia by aiming for adequate oxygenation. However, studies are necessary to confirm whether this integrative alignment effectively leads to safer and faster difficult airway management.

6. Implementation at the Bern University Hospital

Our hospital's local difficult airway management guidelines are based on the guidelines for management of unanticipated difficult intubation in adults, published by the Difficult Airway Society (DAS) in 2015 [14]. In a first analysis, the main steps of the DAS guidelines were identified. The original Plan B and Plan C were condensed into one step to fit into locally accepted and already existing procedures. This modified approach underlines the importance of preparing early for emergency front-of-neck access (eFONA), avoiding any delays in the introduction of this life-saving procedure. While preparing for eFONA, rescue oxygenation is attempted by two people using a four-handed facemask ventilation technique [32,35]. Our local guidelines consist therefore of three steps. The first step, similar to the “safe zone” of the “vortex approach” [11,36], corresponding to “Plan A” is colour coded green. The second step “Plan B″ is yellow (“cautious zone”), and the third step “Plan C″ is red (“danger zone”). The colour-coded algorithm we use in Bern is displayed in Fig. 1.

At the bottom of the green and yellow field, we display the airway event that triggers the next step. In the briefing before induction, the airway management team defines the person who triggers these changes and the next needed action. If intubation fails, move from green to yellow; if oxygenation fails, move from yellow to red. The colour-coded difficult airway algorithm also appears on the departmental computer-based anaesthesia record system after completion of the mandatory checklist, to be performed before the induction of every general anaesthesia. The full colour-coded algorithm is additionally attached to the working surface of the difficult airway trolley (Fig. 2); a pictogram of the algorithm is also placed above the monitor of the videolaryngoscope and flexible intubation scope (C-MAC, Karl Storz, Tuttlingen, Germany) (Fig. 3). To emphasise its importance, the colour coding was also used for each of the drawers of the difficult airway trolley. Every drawer (green, yellow and red) contains the corresponding essential equipment for each step of the local difficult airway algorithm.

The commercially available difficult airway trolley (“classic cart” and “pro cart”, IDT GmbH, Johanniskirchen, Germany) (Fig. 4) is placed centrally in the operating area. It is not only meant for unanticipated difficult airways, but can also be used for planned awake intubations with a flexible or rigid intubation scope, as well as for regular video-guided intubations and teaching purposes. The trolley is very easy to move around on the attached wheels, weighs only about 35 kg, and needs to be kept plugged in when not in use to recharge the batteries. All other materials and medications necessary for airway management are found in the anaesthesia cart dedicated to each operating room and/or induction room. The airway management teams are regularly trained and familiar with both the difficult airway trolley and the anaesthesia cart.

7. Green drawer - intubation

Plan A - Green colour. After proper preoxygenation of the patient to an end-tidal oxygen ratio of 0.85, and facemask ventilation or apnoeic oxygenation until neuromuscular blockade is confirmed, tracheal intubation is attempted primarily with a videolaryngoscope whenever the equipment is available. This is the standard procedure in the Department of Anaesthesiology and Pain Medicine at the University Hospital in Bern. Successful tracheal intubation is confirmed with the detection of end-tidal carbon dioxide. The contents of all drawers are summarised in Table 1. If intubation fails, we move to the yellow drawer.

8. Yellow drawer - supraglottic airway device

Plan B - Yellow colour. The aim is to ventilate and oxygenate the patient. Therefore, the use of a second-generation SAD is recommended. The single-use i-gel (Intersurgical Ltd, Wokingham, U.K.) in sizes 3, 4, and 5 is routinely available as a second-generation SAD [37] in all anaesthesia carts, therefore the alternative in the difficult airway trolley is the single-use LMA Fastrach (LMA North America Inc., San Diego, California, USA), a first-generation SAD. Both available SADs have the advantage of providing the possibility of guided tracheal intubation using a flexible intubation scope [38]. If ventilation with a SAD is successful, the airway management team is free to plan the next steps in treatment of the patient. Options to consider are:

1. Wake the patient up
2. Intubate the trachea via the SAD
3. Proceed without intubating the trachea
4. Perform a tracheostomy or a cricothyroidotomy

9. Red drawer − airway rescue or emergency front-of-neck access

Plan C - Red colour: The aim is to oxygenate the patient. If not done earlier, an immediate call for expert help is now indicated. An immediate emergency front-of-neck access (eFONA) or cricothyroidotomy needs to be established to avoid hypoxaemia and its further fatal consequences. Until the material for this procedure is prepared and a person properly trained in the procedure is available, the airway team must focus on oxygenation by applying face mask ventilation using a four-handed technique. If facemask ventilation is successful, a good option is then to let the patient recover to spontaneous ventilation and if possible, to let him wake up. If four-handed facemask ventilation is unsuccessful, the airway team needs to proceed immediately with eFONA, which can be achieved by the cannula-over-needle or the surgical technique [39,40]. To account for airway management provider preference and training, the difficult airway trolley is equipped with a cricothyroidotomy set which allows the provider to choose between both techniques. In CICO situations, eFONA has to be established somehow; however, the scientific debate over the best technique to achieve eFONA is still ongoing [41]. Several guidelines [6,14] and recommendations [42] favour the surgical approach, which we teach in our department and strongly recommend in a CICO situation.

10. Neonatal and paediatric airways

Children are a unique subgroup of patients because of the differences in both anatomy and physiology of the airways of children and adults. Most airway problems in children can be identified in advance [43]. Unanticipated difficulties can arise, however, and may result in serious complications. Lack of training, just like lack of experience with these sporadic and rare events, can complicate this situation significantly. Various difficult-airway algorithms can be found in the current literature, but they have limited applicability in children [44]. Analogous to the adult algorithm, we also use a colour-coded system for the unanticipated difficult airway algorithm in children (Fig. 5).

The contents of the neonatal and paediatric difficult airway trolley (Fig. 6) differ slightly from the adult difficult airway trolley (Table 1). The different videolaryngoscopy blades are attached to the working surface of the neonatal and paediatric difficult airway trolley and the flexible intubation scopes are placed on the back (Fig. 7).

Cannot-intubate cannot-oxygenate situations in healthy children are strongly associated with poor outcome [45]. Unlike adults, healthy children frequently experience functional or anatomical airway obstruction and are prone to rapid onset of oxygen desaturation, which can quickly lead to hypoxaemia, disability and death [46]. Due to poor survival in neonatal and paediatric patients we should try to avoid the need for cricothyroidotomy. To achieve that, it is imperative to (1) recognise and treat functional and anatomical airway obstructions, (2) limit the number of laryngoscopies, and finally (3) move on to advanced intubation techniques without wasting time on unnecessary tasks. Apnoeic oxygenation techniques buy additional time during paediatric airway management [47,48]. However, there may be situations in which unplanned eFONA access is necessary. In this case the person managing the airway must have the necessary know-how and training. We recently published an easy approach to paediatric eFONA with a corresponding educational approach to learning and perfecting this life-saving scalpel technique for children under the age of 8 years [49,50]. The necessary tracheostomy set is currently not commercially available but can easily be put together using everyday surgical equipment (Fig. 8a and Fig. 8b).

11. Conclusions

The use of colour coding as a cognitive aid supporting a difficult airway algorithm can easily and powerfully enhance the management of an unanticipated difficult airway. The use of the same colour coding for the drawers of the difficult airway trolley allows the anaesthesia team to quickly identify the correct and necessary equipment. Frequent training and simulation with the material and equipment in the difficult airway trolley remains crucial. Colour coding also makes it easy to obtain help from other operating room personnel who are not regularly involved in airway management, as the anaesthesia team can simply ask them to open the drawer with the respective colour to provide necessary equipment. This allows the anaesthesia team to focus on the oxygenation of the patient and delegate the task of obtaining equipment to less experienced staff.

Authors' contributions

AF wrote the outline and was the main contributor to the manuscript. MH contributed to the writing process. SN and TR critically reviewed several versions of the manuscript. RG initiated and supervised the outline and the writing process, JBE contributed to the outline and the writing process. All of the authors have read and approved the final version of the manuscript.

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Author statement

All authors have read and approved the final version of this manuscript.

Declaration of competing interest

RG is the Treasurer of the European Airway Management Society (EAMS). SN is a committee member of TEAMS (trainees of EAMS). All other authors declare no conflicts of interest.

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