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Title:

Implementation of NAP4 emergency airway management recommendations in a quaternary level pediatric hospital.

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Short Title:

Improving intubation safety

SUMMARY (ABSTRACT):

Background: Emergency airway management, particularly outside of the operating room, is associated with a high incidence of life-threatening adverse events.

Aim: Based on the recommendations of the 4th National Audit Project, we aimed to develop hospital-wide systems changes to improve the safety of emergency airway management.

Methods: We describe a framework for governance in the form of a hospital airway special interest group. We describe the development and implementation of the following systems changes: 1. A local intubation algorithm modified from the Difficult Airway Society's plan A-B-C-D approach, including clear pathways for airway escalation, and emphasizing the concepts of resuscitation prior to intubation, planning for failure, and avoidance of fixation error. 2. Simplified and standardized airway equipment located in identical airway carts in all critical care areas. 3. A pre-intubation checklist and equipment template to standardize preparation for airway management. 4. Availability of continuous wave-form end-tidal capnography in all critical care areas for confirmation of correct endotracheal tube placement. 5. Multi-disciplinary team training to address the technical and non-technical aspects of non-operating room intubation. In addition, we describe methodology for ongoing monitoring of performance through a quality assurance framework.

Conclusion: Changes in the process of emergency airway management at a hospital level are feasible through collaboration. Their impact on patient-based outcomes requires further study.

Keywords: Child; Emergency Service, Hospital; Intubation, Intra-tracheal; Patient Safety; Quality Assurance, Health Care

INTRODUCTION:

Non-operating room (OR) intubation is a complex, infrequently performed procedure, with a high adverse event rate (1). The physiological changes that occur with induction of anaesthesia, muscle relaxation, and the institution of positive-pressure ventilation may lead to life-threatening cardio-respiratory failure in critically unwell patients (2-4). This risk is compounded when intubation is performed by team members from different backgrounds in unfamiliar environments using unfamiliar equipment (5).

The Institute of Medicine (IOM) has focused attention on health systems contributing significantly to patient safety outcomes (6). Systems theory may be applied to emergency airway management to improve outcomes, ensure quality and safety, and reduce errors or mitigate their adverse effects (7). Tactics include: reducing complexity, optimizing information processing, using automation and constraints, and mitigating the unwanted effects of change (8). During emergency airway management, complexity may be reduced through the use of cognitive aids and standardization. Information processing may be improved through human

factors training (designated team leader, clear role allocation, leadership and followership, closed loop communication, standardized terminology), and post procedure debriefing (to identify performance gaps in individuals, teams, and systems, and to inform quality improvement interventions) (9, 10). Automation and constraints may help avoid fixation error, such as clear oxygen saturation stop-points for intubation attempts, empowering observers, and limitations on the number of attempts per provider. Mitigating the unwanted effects of change may involve using quality improvement methodology to monitor for balancing measures (11). It remains unclear, however, whether the safety of non-OR emergency airway management can be improved using these tactics (12).

In 2011 the Royal College of Anaesthetists and the Difficult Airway Society published the findings of the 4th National Audit Project (NAP4) (13). This registry of major complications of airway management in the United Kingdom is the largest repository of cases involving adverse airway-related outcomes both in OR and non-OR settings from which systems changes can be informed. The registry identified emergency department (ED) and intensive care unit (ICU) intubations as higher risk for major airway events. Additionally, airway events in these locations were more likely to lead to permanent harm or death than those occurring in the OR. The project made several systems recommendations aimed at reducing the gap between current practice and best practice, termed the “safety gap” (14). These included: the development of clear pathways for airway escalation, standardization of approach and equipment, universal use of a pre-intubation checklist, universal use of end-tidal capnography to confirm correct endotracheal tube placement, and joint training in airway technical and non-technical skills.

We implemented these changes at a hospital level and herein describe the process. **The Royal Children’s Hospital, Melbourne, Australia is a quaternary level hospital providing all subspecialty services and receiving referrals from tertiary level hospitals.**

AIRWAY SPECIAL INTEREST GROUP

In keeping with NAP4 recommendations, consultant leads from critical care specialties involved in emergency airway management developed a hospital airway special interest group. This group included representatives from the Department of Anesthesia and Pain Management, the ED, the pediatric ICU, and the neonatal ICU. The group’s primary aim was to improve the safety of hospital-wide airway management through governance, including: shared mental models, uniform equipment stocking and layout, and a focus on avoidance of human factor error (e.g. fixation). In addition, educational needs including training, accreditation, and ongoing competency; research; and ongoing review were overseen by the airway special interest group.

SYSTEMS CHANGES

1. *Airway Algorithm*

The first task of the airway special interest group was to develop and implement a local airway algorithm through collaboration and using the best available evidence. The representation of multiple craft groups during algorithm development was important in ensuring its relevance and applicability in different care settings, and in developing hospital-wide pathways for airway escalation. We dedicated a single phone number for each critical care area for local airway help, and a phone number that was held by an airway expert 24 hours per day for hospital-wide airway help.

Best available evidence was used in developing the algorithm. Review of the evidence supporting the routine use of cricoid force (pressure) to prevent passive regurgitation and aspiration during the apnoeic period in children indicated that this practice may be a harmful (15, 16). The use of cricoid force was therefore not considered a standard of care during algorithm development. Evidence for some practice points was non-existent or equivocal, leading to no specific recommendation. Literature review found no evidence for superiority of curved over straight laryngoscope blades (17, 18), for direct over indirect laryngoscopy (19), or for a needle over a scalpel-based technique for front-of-neck access (20, 21).

The local airway algorithm was modelled on the plan A-D approach advocated by the Difficulty Airway Society (DAS) (22). Like the DAS, we developed a detailed version for use as a teaching/learning tool (figure 1), and simple streamlined version for use as a cognitive aid just prior to intubation (figure 2). Emphasis was on the non-technical aspects and teamwork required to manage the emergency airway, as prior audits of local performance highlighted human factors as major contributors to adverse events (1). Plan A in the algorithm includes the initial (up to three) attempts at securing the airway. Plan B is the best attempt at securing the airway the hospital can provide at the time. Plan C emphasises maintaining oxygenation and waking the patient (with recognition that this is rarely an option in emergencies). Plan D is front of neck access. The algorithm is not prescriptive as to which specific technique or piece of equipment the airway practitioner should employ for each attempt, allowing deference to expertise in complex airway emergencies. Rather, the focus of the algorithm is on preparation; assessment of the patient, the airway, and team skills; clear communication of the airway plan between the airway team and team leader; and avoidance of fixation error. Fixation error occurs when the airway practitioner loses situational awareness; common errors and solutions are listed in Table 1 (23).

The algorithm was disseminated in multiple ways throughout the hospital. This included online exposure through a state-wide, publically available Clinical Practice Guideline (http://www.rch.org.au/clinicalguide/guideline_index/Emergency_airway_management/),

posters in all critical care areas, and as part of pre-reading for all airway courses and workshops.

The airway algorithm provided a framework for the development of all subsequent airway interventions. The algorithm was colour coded as a further cognitive to match the clinical condition of the patient. Pink for preparation / plan A (pink patient), blue for plan B (blue patient), black for plan C, and red for plan D (red patient). This colour coding was carried through to the location of airway equipment storage (e.g. the equipment necessary to conduct Plan A was in a drawer with a pink Plan A label), the design of an airway equipment template, and the design of a red plan D front of neck access equipment pack. A pre-intubation checklist referenced the algorithm with mandated verbalization of plans A-D.

Training in the application of the algorithm occurred in multi-disciplinary airway workshops and departmental simulation-based initiatives.

2. Simplified and Standardized Airway Equipment

Prior to this review, departmental airway equipment was stocked on an ad-hoc basis without standardization between departments. Through discussion and review of the literature, a list of airway equipment was created that would be universally available on airway carts located in all critical care areas (Table 2) (24). Rather than stocking extensive, diverse, and complicated airway equipment, emphasis was placed on having standard basic airway equipment available in all places where intubation may occur in the hospital. Uniformity, standardization, and redundancy allows staff to be trained in correct equipment use and application in appropriate clinical scenarios. Limiting the diversity of airway equipment also encourages competency with available equipment, and standardization between departments facilitates airway rescue by practitioners attending patients outside of their primary working location. In addition to the “universal” equipment, each department could add “site specific” airway equipment to suit individual needs, such as flexible fiber-optic intubation scopes in the OR, McCoy laryngoscope blades in the ED, and advanced tracheostomy equipment in PICU. One type of video laryngoscope, the GlideScope Cobalt system®, was chosen for hospital-wide use. This facilitated familiarity and proficiency with use across departments, as well as provided hospital-wide redundancy in the event of equipment failure. The process of simplification and standardization involved discarding much complex and unfamiliar airway equipment, such as Seldinger-based retrograde intubation kits.

Storage of universal airway equipment mirrored where equipment was likely to be used in the airway algorithm. Color coded stickers were used to label the drawers containing equipment for Plans A, B, or D.

Evidence for the safety of (Microcuff®) cuffed endotracheal tubes was sufficient for them to be stocked in all airway trolleys (25, 26). Lack of evidence for superiority of second generation supraglottic airways (SGAs) over first generation SGAs (27), and the relative expense of the former, resulted in all airway trolleys being stocked with first generation SGAs.

The airway special interest group felt that the as yet unquantified benefit of specialty second generation SGAs designed to facilitate intubation did not outweigh the potential disadvantages of staff unfamiliarity and the need for further training in their appropriate use. The first generation SGAs currently in use allow flexible fibre-optic intubation through their lumens.

3. Checklist and Equipment Template

Standardized preparation and planning for emergency intubation is emphasised in the NAP4 recommendations, and the use of a pre-intubation checklist is recommended for use in all ED intubations (13). We modified the checklist provided in the NAP4 audit to fit local processes and procedures (figure 3). The checklist retained the format suggested in NAP4, divided into preparation of team, patient, IV / drugs / monitors, and equipment. The checklist was formatted and designed in accordance with the “checklist for checklists”, submitted for commentary to projectcheck (<http://www.projectcheck.org/>), and piloted by senior medical and nursing staff prior to introduction into standard practice. The checklist is read aloud in a challenge-response format by the team leader prior to every emergency intubation.

The checklist is designed to address both technical and non-technical aspects of pre-intubation planning. Technical aspects addressed include standard equipment preparation, and standard patient monitoring (including preparation of continuous waveform end-tidal CO₂ to confirm correct endotracheal tube position). The non-technical aspects addressed include prompts for clear role allocation, development of an intubation plan (referencing the airway algorithm), adequate pre-intubation resuscitation (with a focus on avoiding hypoxia and hypotension), choice of induction agents (and forethought regarding dose), post intubation sedating agents, and assigning a leader for post-intubation debriefing.

The checklist is designed to be used in conjunction with an airway template, which standardizes the location of intubation equipment (figure 4) (28). This allows nursing and medical staff to predictably and reproducibly prepare airway equipment, and cognitively unload equipment preparation from overall airway management.

Dissemination of the intubation checklist and template involves visual display in all clinical areas where emergency intubation may occur. The template is placed on the surface of all airway trolleys, both are provided in smart-phone format, publically available and downloadable from the hospital Clinical Practice Guidelines, and are published in peer-

reviewed journals (28). Implementation during multi-disciplinary airway workshops and departmental simulation based initiatives is used to improve clinical uptake.

4. Availability of continuous waveform end-tidal capnography

The use of continuous waveform end-tidal capnography to confirm correct endotracheal tube placement is recommended by NAP4, and its non-use been associated with desaturation and death from unrecognized esophageal intubation (13). The use of continuous wave-form end tidal capnography in our hospital was considered standard practice prior to the introduction of other systems changes.

5. Multidisciplinary Training

The airway special interest group developed a half-day workshop targeting all senior critical care medical and nursing/technician staff. These workshops are offered twice per year, with an emphasis on orientation, skill exposure, and non-technical airway skills. All workshops include multi-disciplinary participants. The workshop schedule consists of pre-reading, an interactive introductory lecture, skills stations, and scenario based training. The pre-reading material includes a published local audit of intubation performance with recommendations for improvement (1), the locally developed airway algorithm, a short power-point presentation with video links to skills taught, an introduction to crisis-resource-management (CRM) document, and a participant program. Based on participant feedback, the introductory lecture is limited to a brief review of pre-reading material and a set of ground rules for the workshop. Participants are asked to sign a consent form to ensure confidentiality and a safe learning environment. Skills stations include bag-mask ventilation (1 and 2-person) and SGA insertion, standard and 2-person intubation using a bougie and external laryngeal manipulation, a video-laryngoscopy station, an intubation aides station (which includes bougies, airway exchange catheters, and stylets), and neonatal oxygenation and ventilation using a neo-puff ®. These are in keeping with NAP4 recommendations, with the exception of emergency front of neck access (FONA), which is taught separately as a 3-hour skills workshop to senior medical staff only, and accredited by the Royal Australasian College of Anaesthetists. Scenario training makes up the bulk of the workshop based on participant feedback. Participants maintain their real-life roles during scenarios (medical and nursing). The scenario is run in 3 parts, involving preparation, failed initial intubation attempts (Plan A) and successful final intubation attempt (Plan B) in a critically unwell infant. Each part is followed by a debrief, where key learning points are delivered using an advocacy-enquiry methodology. Participants rotate between participating and observing, allowing maximal participant exposure to the scenario environment. The workshop closes with participant written feedback and a faculty debrief. Suggestions from participants are instrumental in refining course content. An abridged version of the airway workshop is been offered to all

rotating junior medical staff in the ED, following the same format but less resource intensive, and run 4 times per year.

MONITORING OF PERFORMANCE

The NAP4 audit suggests regular audit of performance as a means of quality improvement (13). We have identified multiple safety gaps in our emergency intubation performance (1), and aim to close this safety gap in part through changes in the systems in which clinical staff work. This does not necessarily ensure improved patient safety, however, and ongoing audit of performance with attention to latent and overt threats is part of our initiative for reducing iatrogenic harm during non-OR intubation (14). We are studying the impact of the above interventions on patient centred outcomes through an ongoing quality improvement framework.

BARRIERS

Multiple barriers to developing, implementing, and studying the impact of the above measures were encountered. The historic jurisdiction of airway management lies in the hands of anesthesiologists, yet our institutional audit demonstrated that, outside of the OR, the risk of airway related adverse events was independent of intubator specialty. We therefore adopted a patient-centered and collaborative approach to airway management, with active involvement from all critical care specialties. Key to this process was the maintenance of relationships between airway special interest group members through face to face meetings, participation as faculty in airway training, and mutual respect. Lack of buy in with culture change was largely overcome by demonstrating safety gaps in airway management through institutional audit. The logistics of coordinating meetings and training between airway special interest group members who were all time poor was a significant obstacle. The group tried to ensure redundancy with departmental representatives, with at least two per department, appreciating that not all members could be present for all meetings and training sessions. Lack of evidence for patient centered benefit from any of the airway interventions undertaken was a significant barrier. We regarded this group of interventions as a “bundle”, with each component insufficient on its own to improve patient outcome. The largest cost barrier encountered was the time of airway special interest group members. The group was unfunded, and all interventions were paper based and inexpensive. The biggest driver that keeps the group alive is the passion and commitment of members, and the belief that the interventions undertaken will improve the safety of emergency airway management in children.

DETAILS OF AUTHORS CONTRIBUTIONS

EL wrote the initial manuscript draft, all authors revised the document and approved the final copy prior to submission. All of the authors have had significant involvement in the

development and implementation of airway initiatives. SS chairs the Airway Special Interest Group.

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DECLARATIONS OF INTERESTS

None of the authors have any declared conflicts of interest.

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TABLE 1. Fixation errors encountered during emergency airway management and their potential solutions.

Common fixation errors	Solutions
Perseverance with intubation attempts despite patient desaturation	Use of auditory cues for hypoxia (saturation monitor) Clear saturation stop point for aborting intubation attempts and beginning re-oxygenation (SpO ₂ <93%) Empowering observers (airway assistant / team leader) Prioritization of avoidance of hypoxia over intubation of the trachea
Perseverance with the same intubation technique despite lack of success of that technique	Planning for subsequent attempts prior to intubation Mandating change in position / provider / equipment / or technique between intubation attempts Team familiarity with airway algorithm (shared mental model)
Perseverance with orotracheal intubation despite multiple failed attempts	Use of alternative methods for oxygenation (supra-glottic airway) Upper limit for number of intubation attempts before calling for help (3) Clear hospital-wide pathways for airway escalation (dedicated phone for airway expert)

TABLE 2. Universal airway equipment stocked in all airway trolleys.

Top surface of trolley	Laminated Emergency Intubation Algorithm Laminated Airway Equipment Template Laminated pre-intubation checklist
Pink drawers (Plan A)	Mask ventilation equipment Masks Oro-pharyngeal airways Naso-pharyngeal airways T-piece circuit with oxygen tubing Self-inflating bags Basic intubation equipment Laryngoscope handles Blades: Mac, Miller, Renshaw, McCoy Endotracheal tubes (2.5-9.0) End tidal CO2 tubing Magill Forceps Other Suction: tubing, yankauer, Y suction Hudson Mask, Nasal Prongs Syringes (5ml) ETT securement: Tube fastener, tape Tongue depressors Lubricant Cuff Manometer
Blue drawers (Plan B)	Supra-glottic airways (1-5) GlideScope Blades ("Stats®"). Glidescope GlideRite introducer Syringes (20ml)
Red drawer (Plan D)	Laminated can't intubate can't oxygenate Algorithm Can't intubate can't oxygenate pack Cannula cricothyroidotomy instruction sheet Scalpel-bougie instruction sheet Melker Emergency Cricothyroidotomy Set Tracheostomy Equipment
Side of trolley	Bougies

	Airway Exchange Catheters
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	Frova Intubating Introducer with stiffening cannula
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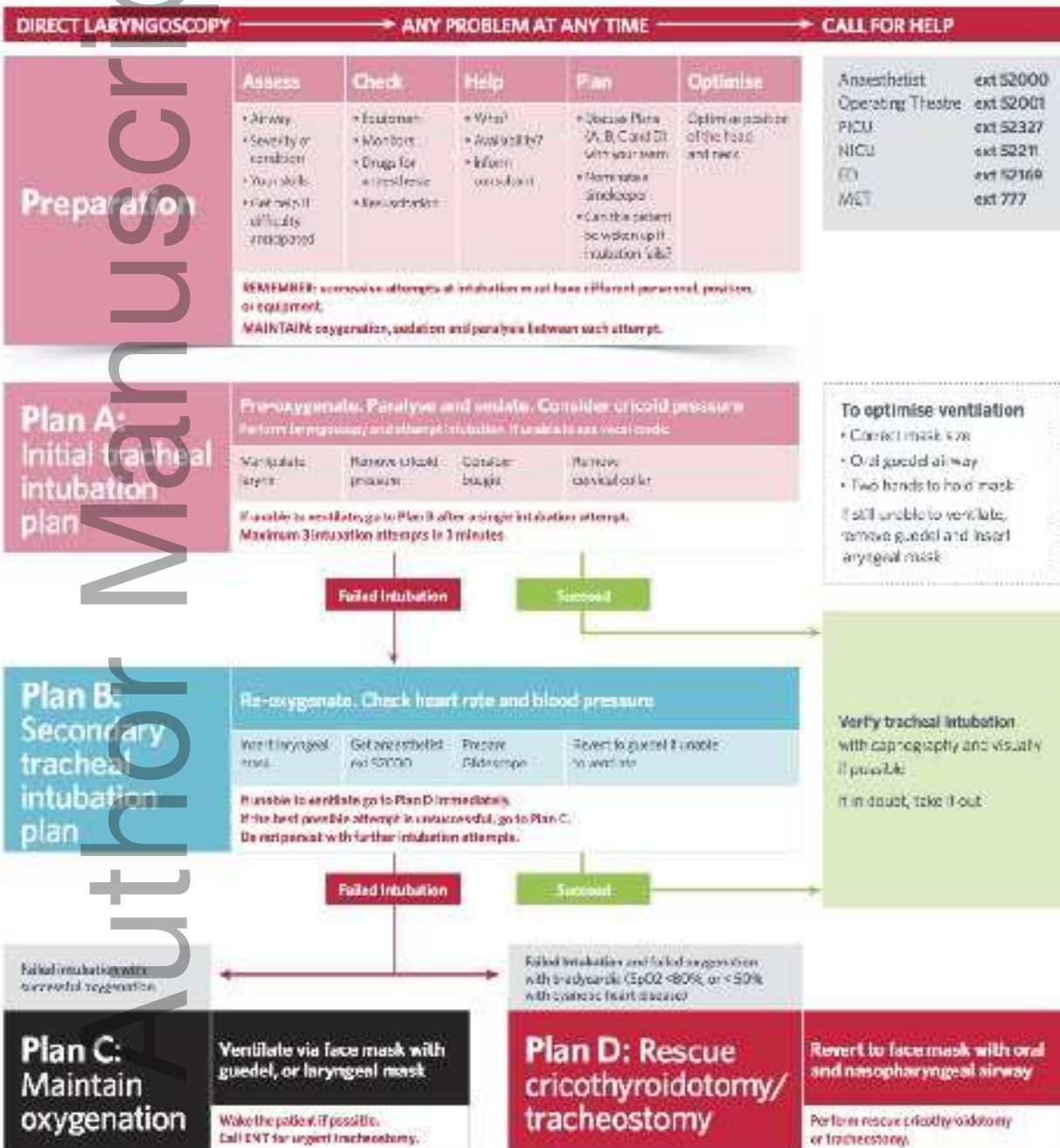
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Emergency Intubation

USE IN CONJUNCTION WITH BASIC LIFE SUPPORT GUIDELINES. SEE RCH AIRWAY MANAGEMENT CLINICAL PRACTICE GUIDELINES.



Anaesthesia, PICU, NICU, and Emergency

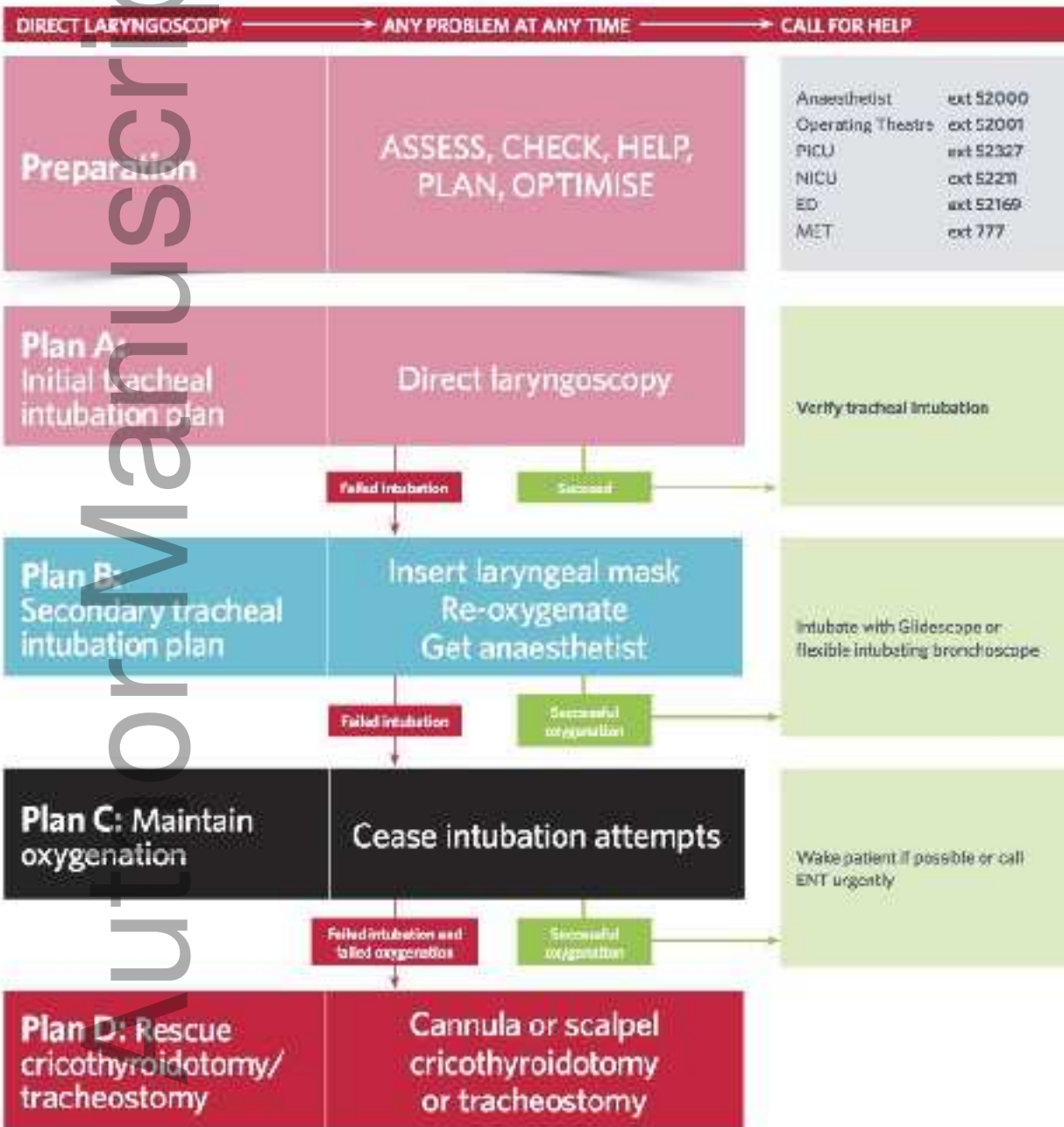


Emergency Intubation

USE IN CONJUNCTION WITH BASIC LIFE SUPPORT GUIDELINES. SEE RCH AIRWAY MANAGEMENT CLINICAL PRACTICE GUIDELINES.



Anaesthesia, PICU, NICU, and Emergency



Emergency Intubation Checklist

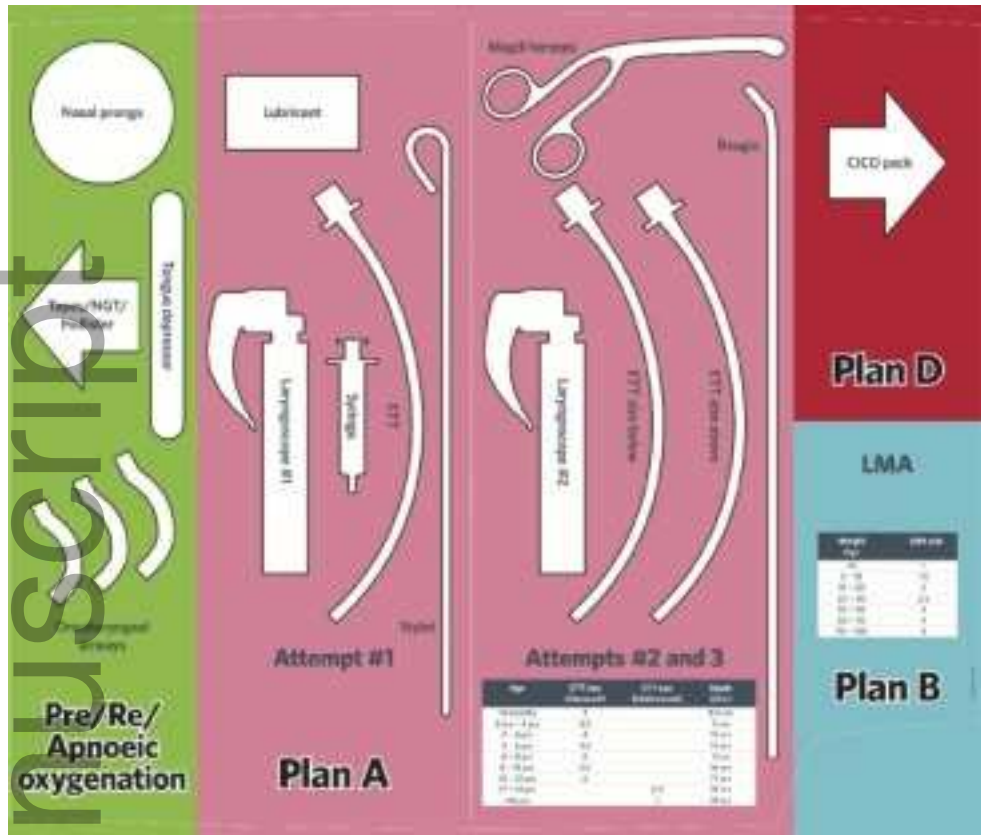
For TEAM LEADER use prior to every EMERGENCY INTUBATION



Emergency Department

TEAM	PATIENT	IV DRUGS MONITORS	EQUIPMENT
<ol style="list-style-type: none"> 1. Notify senior ED staff 2. Mutual verification of intubation 3. AFO code roles 4. Verify intubation plan* <ol style="list-style-type: none"> A. Initial tracheal intubation attempt: 1-3 B. Final tracheal intubation attempt C. Resuscitation during oxygenation D. Resuscitation for final intubation attempt 5. Assign roles for post-intubation stabilisation <p>*See Emergency Intubation Algorithm</p>	<ol style="list-style-type: none"> 1. Optimise haemodynamics, consider: <ul style="list-style-type: none"> • Fluid bolus • Inotropes/vasopressor • Bolus dose vasoactive drug if used 2. Optimise pre-oxygenation consider: <ul style="list-style-type: none"> • 100% FiO₂ • PEEP via 5-piece • Apnoeic oxygenation (NP) > 1.2 l/min (F1 / min) • Elevate head of bed 3. Optimise position, consider: <ul style="list-style-type: none"> • < 60 year: towel/trauma mat under shoulders • > 60 years: towel/roll under head <p>If any difficulties anticipated CALL FOR HELP</p>	<ol style="list-style-type: none"> 1. IV access function test 2. Intubation drug/dose drawn and drawn up 3. Capniox monitoring 4. BP (2 minute cycle) 5. SpO₂ 6. EtCO₂ 7. Post intubation sedation drawn up 	<ol style="list-style-type: none"> 1. Tapes, face mask if used in leak 2. Suction functioning (ys/tray and flat top) 3. Airway equipment: humidifier/condensate 4. Glucoscope at bedside/landed on
<p>Airway Group The Royal Children's Hospital Melbourne 246 Praeger Road Parkville Victoria 3124 Australia Email: airway@rcri.org.au www.rcri.org.au</p>			

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