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Rising to the occasion – Institutional standardization and organization of equipment for 'can't intubate, can't oxygenate' (CICO) crisis

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Abstract : 'Can't intubate, can't oxygenate' (CICO) scenario is a rare anesthesia crisis for which the management has been suboptimal in the past. Inadequacy and disorganization of airway equipment have been identified as one of the latent factors that contribute to the failure of CICO management. We initiated a quality improvement project to review the equipment aspect of CICO management in our department. We revised our emergency front of neck access (FONA) airway equipment based on available evidence and organized the equipment with custom-made CICO kits. The CICO kits could potentially streamline management, and institutionally standardized equipment across all critical care departments. Our approach may serve as a practical guide for implementation of standard practice for CICO management.

Key words : 'can't intubate, can't oxygenate' (CICO), front of neck access (FONA), equipment standardization, equipment organization.

"Under pressure, we don't rise to the occasion, we sink to the level of our training". This quotation which was espoused by the United States Navy Seals, describes the conundrum we face with the 'can't intubate, can't oxygenate' (CICO) situation. CICO is a rare anesthesia crisis, which was estimated to occur in 1 in 10,000 routine general anesthesias (1). A more recent multicentre study by Kheterpal *et al*. (2) revealed that the incidence of CICO is perhaps less than previously thought. Of the 492,239 anesthesia cases reviewed, only one patient required an emergent cricothyroidotomy. This rarity is a curse in disguise; while anesthesiologists are grateful it does not happen as often anymore, it has certainly limited our exposure and experience in managing such crises. Therefore, anesthesiologists, despite being highly regarded as experts in airway management, have had occasions of under-managing such events. This is evidenced by the fact that CICO accounts for over 25% of all anesthesia-related deaths (3, 4), which is unacceptably high.

It takes more than just regular training to rise to master the CICO occasion. The above staggering figures have led to the focus on root cause analysis of the issues in CICO management. Greenland et al. and a recent report from the Australian and New Zealand College of Anaesthetists (ANZCA) Airway Management Working Group have provided a comprehensive overview of factors leading to failure to manage CICO scenarios and also strategies for improving CICO management (4, 5). These include setting up a centralized database for patients with difficult airways, performing proper airway evaluations, standardizing airway equipment, having regular training and forming an interdisciplinary team to oversee airway management programs. The recent 2015 Difficult Airway Society (DAS) guidelines have placed considerable emphasis on the preparedness of the practitioner in a difficult airway situation (6). These recommendations have resonated strongly with our devotion to undertake evidence-based approaches to reduce life-threatening complications associated with difficult airway management.

Local problems and intended improvement

The Princess Alexandra Hospital in Queensland, Australia, is a tertiary teaching hospital in which anesthesia services are provided in 21 operating theatres (OT) and in remote sites such as emergency departments (ED), intensive care units (ICU), cardiac catheterisation laboratories,

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Foong.indd 103 22/11/17 16:02

endoscopy suites, day surgery units and radiology departments, which majority are on different floor levels, away from the main OT complex.

Our anesthesia department conducts regular difficult airway and CICO management education sessions for anesthesia staff with emphasis on crisis resource management, human factors, front of neck access (FONA) techniques and simulations of CICO scenarios. Studies have shown that complex procedural skills such as FONA techniques are retained for at least a year after a single high-fidelity simulation training session (7, 8). We strongly support and recognise the importance of training and simulation. However, we are also aware of our limitation to provide regular training sessions for all staff members. We looked into optimizing other latent factors that might contribute to failure in CICO management. By reviewing our airway equipment inventory, we recognized that our FONA equipment was disorganized, lacking essential items and has included items not relevant to CICO management, which all could lead to confusion during a CICO crisis.

Having identified these insufficiencies, we aimed to rectify them in stages: firstly to revise our equipment, secondly to organize them in a way that will streamline CICO crisis management, and lastly to standardize the equipment across all critical care departments.

Revising FONA airway equipment

A literature review was performed on the recommended CICO algorithms, FONA techniques and their corresponding equipment. The main recognized FONA techniques are needle cricothyroidotomy and scalpel cricothyroidotomy. Needle technique uses narrow-bore cannula followed with Seldinger conversion, or large-bore cannula (e.g. Cook Melker kit). Scalpel cricothyroidotomy could involve scalpel-bougie technique or scalpel-finger-cannula/bougie technique for difficult airway (4, 9-12). We acknowledge that the 4th National Audit Project (3) of the Royal College of Anaesthetists (NAP4) reported a low success rate for needle cricothyroidotomy and the 2015 Difficult Airway Society (DAS) recommended scalpel-bougie cricothyroidotomy as the preferred primary technique (6). However, there is no randomized controlled trial to date, to validate or compare different techniques in the actual CICO situation. It is also well recognized with other rare events such as anaphylaxis that large randomized trials would be impossible to conduct (13). Published results from simulated environment studies have been conflicting as they vary in fidelity of simulation, anatomic validity, clinical endpoint, and prior experience and training level of personnel performing cricothyroidotomies (12). The recommendations/opinions from these studies should not be generalized and imposed on the management of the mutable CICO crisis. Indoctrinating "one and only one" FONA technique does not only underestimate the complications that result from any procedure, for example bleeding with scalpel technique or barotrauma from jet ventilation in the case of needle cricothyroidotomy, but also, more disastrously, it delays changing of plan, should that technique fail. The above highlights the importance of anesthesiologists being skilled in more than one FONA technique. This is in-line with the ANZCA's position for CICO crisis management, which advocates that anesthesiologists should learn both techniques and encourages developing institution-specific education sessions that satisfy local needs, incorporating local staff, work environ-ments, non-technical skills and point-of-care equip-ment and resources (4, 14).

With no recommendation of one technique over another, we compiled our existing equipment and compartmentalized them according to the main FONA techniques: "Needle", "Scalpel" and "Melker" (Table 1). We recognize that "Melker" cricothyroidotomy is not a first-line technique for FONA. We nevertheless dedicated a compartment to "Melker", the reason being, its use does not only limit to Seldinger conversion from cannula cricothyroidotomy, but also the short curved airway catheter can be a useful adjunct to the scalpel-bougie technique should the endotracheal tube (ETT) fail to move down through the Frova bougie, as described by Parameswaran *et al.* (15) and observed in our simulation scenarios.

As part of the needle cricothyroidotomy equipment set, we explored the options for transtracheal jet ventilation for oxygen delivery. Currently, more commonly used commercial devices in Australia include Manujet III (VBM, Medizintechnik GmBH, Sula and Neckar, Germany), Ventrain (Dolphys Technologies B.V.), Enk Oxygen Flow Modulator (OFM) (Cook Inc, Bloomington, IN, USA), and Rapid O_2 (Meditech Systems Ltd, Shaftesbury, UK). Being a pressure-regulated device, Manujet owns the risks of causing potentially dangerous high airway pressure and barotrauma if not used properly. It is also bulky and does not have a vent for expiration (16, 17). Ventrain is a novel flow-regulated device with suction-generated

Foong.indd 104 22/11/17 16:02

Table 1

Inventory of CICO equipment in CICO kit

FONA Techniques	Content
Needle (cannula) cricothyroidotomy set	14G *Insyte* IV cannula 5 ml syringe (non-Luer lock) 10 ml ampoule of normal saline Enk OFM kit o Enk OFM + catheter tubing o 6.0 Fr/7.5 cm catheter needle o 5 ml syringe
Scalpel-bougie cricothyroidotomy set	Scalpel (size 10) Frova bougie Rapi-Fit Adapter (14Fr, 15 mm connector) 6.0 mm ID cuffed ETT 10 ml syringe
Melker (Seldinger) cricothyroidotomy set	In the package Two 18G introducer needle: 5 and 7 cm 5 ml syringe Guide wire Scalpel Curved dilator Curved airway catheter Trach tape

expiratory ventilation assistance, designed for ventilation through narrow-bore (e.g. transtracheal) catheters (18). Its efficacy in achieving a normal minute volume and augmentation of expiration by suction has been confirmed in a few in-vivo studies and published clinical reports (19-22). However, its ventilation efficacy in a partially obstructed airway remains controversial (23). As promising as this rather new device is, more clinical experience of its use is needed before Ventrain can be considered as part of the CICO management. Incorporating the device into CICO management training could help break the barrier of device unfamiliarity for novice users.

On the other hand, Enk OFM and Rapid-O_2 are lightweight portable devices and may be less deleterious to use as compared to Manujet in complete airway obstruction as they have a pressure and flow vent, although there is no study comparing their efficacy. One of the advantages of Rapid O_2 over Enk OFM is its cost. Rapid O_2 costs approximately ten times less than Enk OFM. In addition the large bore exhaust hole in Rapid O_2 gives immediate tactile feedback should there be blockage/kinking of the cannula (24). Enk OFM, on the other hand, has an injection port for drug administration and comes with a dedicated kink-resistant (reinforced) transtracheal catheter (25). We have used the Enk OFM based on local availability and preference. However we continuously review the options for transtracheal jet ventilation based on local experience. When replicating the kits, we advise our readers to substitute their preferred devices for any or all of the devices specifically named in this article.

Organizing EC equipment with CICO kits

Disorganization and lack of available CICO equipment have been identified as contributing factors leading to failure of CICO management (3, 4). Two audits surveying standards of airway management equipment in metropolitan hospitals in Australia and New Zealand (26, 27) have revealed that it is not unusual to find deficiencies and inconsistencies of airway equipment, which are also non-compliant with ANZCA guidelines (28). Individual anesthesia departments might have a complete inventory of CICO equipment. However, it is not ideal, if their locations are spread across the OT complex, the anesthesia storeroom or the difficult airway equipment trolleys. It is also not uncommon to see an array of airway equipment, particularly FONA equipment, in one drawer, which does not support decision making in a time-critical CICO crisis (26).

At the conclusion of our FONA equipment inventory, we envisioned a kit/container that does not only accommodate the equipment, but also serves as a cognitive aid to streamline the management

Foong.indd 105 22/11/17 16:02

of CICO crisis. An internet search and enquiries to the local hospitals revealed a number of CICO kits either in the form of non-compartmentalized grab bags or compartmentalized heat-sealed plastic kits (29). As heat-sealed plastic kits have the advantage of preventing relocation and misplacement of the equipment, we attempted to replicate them as our CICO kits. During the process we came to find that this form of CICO kit did not suit our department's need. Indeed, as anticipated, the heat-sealed plastic kits have to be replaced frequently as we regularly conduct difficult airway and CICO simulations for anesthesia and critical care staff.

Exploring other options for CICO kits, most kits were not feasible due to low durability, despite low cost. The manufacture of a custom-made kit was deemed most suitable for our needs. We drafted a design for the kit and contacted a local manufacturer for production. The soft kit is made of nylon and polyvinylchloride (PVC), which can be folded into A4 size (Figure 1A). The kit provides three main zipped compartments to accommodate the equipment for each of needle cricothyroidotomy, scalpel-bougie cricothyroidotomy and Melker set (Figure 1C). The kit also has separate clear pouches to hold the inventory card for each compartment, CICO algorithm and nursing check sheet (Figure 1B). Apart from aiming to take the stress out of organizing equipment during the paralyzing moment of CICO situation, the kit is well labeled for easy and fast identification of equipment. The kit is kept immediately available at every anesthesia location in our institution. The 2004 DAS guidelines recommended that an emergency airway cart should be located "not more than a couple of minutes" from each anesthesia site (11). This could potentially be difficult to achieve in situations where the OT complex is huge, at remote locations or during after-hours work. There is no clear recommendation on the proximity of an emergency airway cart. Theoretically it should be based on how rapidly a patient desaturates in an airway emergency. A lung model study showed hemoglobin desaturation from SaO_2 90 to 40% occurred at 33% per minute with an obstructed airway and 26% per minute with an open airway (30). Extrapolating these findings, it takes approximately two minutes for a patient to deteriorate critically in a CICO situation, which could be even more rapid in critically unwell patients or patients with altered physiology such as obese patients, parturients, and small children. Therefore the location of the CICO kit should not complicate time-critical CICO management and should be kept readily available.

Marshall *et al*. have shown that Anesthetists' Non-Technical Skills (ANTS) are improved with the use of cognitive aids, such as a CICO algorithm in CICO crisis (31). We believe that cognitive aids are not restricted to algorithms. A well-organized and well-labeled CICO kit could be used as a cognitive aid in addition to a CICO algorithm. On the inventory cards in our kits, the equipment listing is in the order of the steps performed for the FONA procedure (Table 2). This provides a guide for the proceduralist and assistant on the steps of the procedure. With the kit compartmentalized to the three main FONA techniques, it also provides a cue to the proceduralist to move on to an alternative technique should the primary technique fail.

There was a debate in the department regarding placing seals on the kits to prevent scavenging. The Australian Incident Monitoring Study (AIMS) recognized that equipment deficiencies, which were primarily due to 'failure to check', contributed to a third of the deleterious factors identified in difficult airway reports (32). A New Zealand audit revealed a 50% incidence of checklists not corresponding with contents, indicating scavenging and inadequate checking (27). In addition, they also found staff were unfamiliar with the location and contents of difficult airway containers. Interpreting these data, we deduced that the root of the problem lies in individual departmental policies and attitude towards equipment maintenance. Sealing the kits may prevent scavenging, but, on the other hand, it presents a barrier which deters staff from checking and familiarizing themselves with the equipment. We therefore did not place seals on the CICO kits.

WebAIRS data

WebAIRS is the web-based anesthesia incident reporting system created and managed by the Australian and New Zealand Tripartite Anesthesia Data Committee (33). WebAIRS has collected 4000 incident reports over the period between 15 September 2009 and 3 August 2016.

A word search was performed in the narrative section of the database to identify WebAIRS reports where a cricothyroidotomy kit was used or was considered. The search term 'cricothyr' was used to identify any reports containing a word starting with this sequence of characters such as "cricothyroidotomy". A search was also performed for "crycothyr" to identify reports with a common misspelling of cricothyroidotomy. Other search terms included "trachy", "surgical airway" and "front of neck access".

Foong.indd 106 22/11/17 16:02

Table 2

The equipment listing on the inventory card is in the order of the steps performed for the FONA procedure.

Steps in performing scalpel-bougie FONA[9]	**Equipment needed to perform scalpel-bougie FONA**
1. Identify cricothyroid membrane (CTM)	
2. Make horizontal stab incision through CTM with scalpel	➔ Scalpel size 10
3. Rotate blade 90° and pull scalpel towards operator maintaining perpendicularity to produce a triangular hole	
4. Insert bougie	➔ Bougie
5. Attach Rapi-Fit Adapter to bougie and reoxygenate via bougie	➔ Rapi-Fit Adapter (14Fr 15 mm connector)
6. Railroad endotracheal tube (ETT)	➔ 6.0 mm cuffed ETT
7. Remove bougie	
8. Inflate cuff and ventilate	➔ 10 ml syringe

Figure 1. — CICO kit. (A) CICO kit folded into A4 size. (B) The kit has separate clear pouches to hold the inventory card for each compartment, CICO algorithm and nursing check sheet. (C) Three zipped compartments to accommodate the equipment for needle, scalpel-bougie and Melker FONA.

The search returned three reports that specifically mentioned a cricothyroidotomy kit. In one of these reports it stated that the cricothyroidotomy kit was not available, as it had not been replaced. In the second report the anesthesiologist checked that the kit was available before commencing anesthesia for a patient with a potentially difficult airway. In the third report a cricothyroidotomy kit was used in a case where there was a grade IV Cormack-Lehane view on direct laryngoscopy, and it was not possible to adequately ventilate with either a face mask or a size 4 laryngeal mask airway. One of the attending anesthesiologists performed a cricothyroid puncture and inserted a 16 needle and cannula, through which it was possible to ventilate and re-oxygenate the patient. A second anesthesiologist used a fibre-optic intubating bronchoscope in order to successfully intubate the patient. While the airway was being established by the second anesthesiologist, a third anesthesiologist set up a propofol infusion to maintain anesthesia.

These three cases in which a cricothyroidotomy kit was mentioned, indicate that there is a desire for a kit in the first case, a need for a kit in the second

Foong.indd 107 22/11/17 16:02

case and in the third case a kit was used successfully. The kit described in this paper is an example that can be used by other centers and may be modified to suit local preferences and requirements.

Institutional standardization of FONA equipment

Evidence suggests CICO crisis may be ten times more frequent in settings outside of the OT (4). Such events often lead to a much poorer outcome with the incidence of permanent harm or death being 30-fold higher in ED and 60-fold higher in ICU compared to the OT (34). In most hospitals, general anesthesia is frequently administered outside the OT setting such as in the ICU and ED. Despite the existence of difficult airway equipment trolleys, a CICO management container/kit may not be available in these departments. This could potentially make assistance difficult in these areas due to unfamiliarity of locations and types of airway equipment. Following discussions with our ICU and ED, institutional standardization of equipment was regarded necessary. These critical care departments subsequently took on the CICO kits with equipment as listed above. Our ICU added tracheal hook to the 'scalpel' compartment as it is a piece of equipment which they are familiar with and find useful in performing tracheostomy. The kits are also available on the 'crash trolleys' that attend medical emergencies in the hospital.

Implication

The drive to review airway equipment for CICO crisis is not limited solely to our hospital. We have been using the custom-made CICO kits in difficult airway courses held in our hospital. This has sparked interest in our critical care community and many have since adopted the CICO kits as part of their standard practice and training. Our approach may serve as a practical guide for implementation of standard practice for CICO management.

This project has also led us to evaluate the focus of our airway training program. Declaring the crisis and decision to embark on infraglottic airway access procedures are crucial in CICO management. Progression to this crucial moment involves a nimble, yet complex decision-making process. This crisis is highly dynamic and unpredictable, and is influenced by context, human factors, experience, patient factors, environment, equipment availability and time pressure (35). There is no 'one size fits all' panacea for managing CICO crises, which makes diagnosis-management difficult to teach. Emphasis should be put on training to increase awareness and to prevent pitfalls of plan continuation error. As a recent editorial precisely pointed out, understanding difficult airway management is a professional responsibility that requires life-long training (36). Repetitive drills and training on difficult airway management and CICO crisis management are not conducive if they are disjointed at the transition phases.

Limitations

We could only test out the CICO kit in a simulated environment due to the rarity of CICO situation. Furthermore, it is difficult to prove that the organized kit would improve patient outcome in a real clinical scenario. Nevertheless we are optimistic of its positive impact in clinical setting given the high-fidelity simulation represents actual scenarios closely. Marshall *et al.* have shown an improvement in Anesthesia Non-Technical Skills (ANTS) using CICO algorithm as a cognitive aid, but it did not lead to a faster performance in technical skills (24). To assess the potential impact of the organized kit objectively, it will be of interest to investigate whether the addition of the CICO kit will result in quicker decision-making and a faster achievement of successful cricothyroidotomy, and hence a faster reoxygenation time as well as supporting ANTS.

Another limitation is the cost of the CICO kits. There is an upfront cost to equip all anesthesia locations and remote locations with the organized kits. This could present as a hindrance in departments with limited budget. This cost is, however, a once-off expense and can be considered minimal in the long run given the durability of the materials used to make the kits. The need for the kits to be replaced is undeniably low due to their infrequent usage. We replace any CICO kit that is heavily soiled with blood or other bodily fluids. Otherwise they can be put through disinfection wash and will eventually be replaced if wearing out. Cost aside, effort should still be made in departments with limited budget to streamline the management of CICO crisis by reviewing their protocol periodically and promoting organization and standardization of airway equipment with low-cost kits.

Conclusion

Difficult airway management is a fundamental skill for all physicians providing airway support. The education and conversation that occurred

Foong.indd 108 22/11/17 16:02

during our process of revising and organising airway equipment have provided an opportunity for anesthesia staff to review their own practice and refresh their emergency FONA competency. It is undeniable that the decision making to transition from supraglottic to infraglottic airway is most crucial in CICO management. Equipment is only one aspect of the multiple factors involved. Along with increased emphasis on training of technical and non-technical skills and rectifying system failure, the most important outcome of the process is raising the institutional preparedness in case of a CICO crisis.

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Foong.indd 109 22/11/17 16:02

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