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Review

Front of neck access to the airway: A narrative review

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A R T I C L E I N F O

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A B S T R A C T

The concept of Front of Neck Access (FONA) covers a large amount of techniques, principles, problems and debates. The aim of this review is to discuss the issue of FONA with special regard to the sole cricothyrotomy, including all technical issues starting from landmark identification to different approaches, either surgical or percutaneous.

Other open questions remain, such as choice of inner diameter, presence of a cuff, potential advantages of Seldinger based techniques, including bougie assisted ones, timing and decision making. Despite being a simple maneuver, cricothyrotomy remains a very complex concept, which should be a core skill of any physician approaching the airway and as simple as it is, it can make the difference between life and death.

Contents

1. Introduction

Every Anaesthesiologist knows that whichever the procedure

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that needs to be performed in patients, it starts with control of airway or awareness that an airway control must be easily achievable.

This concept could sometimes be overestimated, which might more often happen in the two extremes (too few or too much) of physicians' experience, thus resulting in a dramatic scenario if, at any point, airway control fails. The key of safety and success is undoubtfully represented by a clear strategy before initiating any procedure, awareness of available solutions, feasibility of alternative techniques, skill in different techniques and last but not least preparedness through a careful patients preprocedural evaluation [1–6].

The reader might immediately object, at this point, that prediction of a difficult airway has important limitations [7,8] and might fail, either resulting in a high number of false positives (*much ado about nothing*) or (though) low number of false negatives. Starting from the point that the first option is logically preferable to the latter, yet in terms of patients safety, we strongly believe that a careful, multi-parametric [2] and tailored [8] patient's evaluation is the *condicio sine qua non* any procedure should start with, recognizing the logical and statistical principle that the more we study our patients' airways before, the lower the risk we encounter of an unexpected difficulty; and if any should appear unpredictably, for sure it won't be critical, thanks to the *prediction filter*.

Nevertheless, accidents occur, and literature clearly showed that it is mostly due to human factors rather than to technical or skills failure [1,9]. In such a setting, for rare it is or might be, awareness and management of the *Cannot Intubate–Cannot Oxygenate* (CI-CO) scenario must be part of any anaesthesiologist's training, core skills, competencies, preparedness and guidelines [10].

Front of neck access (FONA) is the nowadays mostly used acronym [11] to identify the life-saving procedure to be initiated (early) whenever facing a CI-CO scenario, whereas behind these four letters an entire world of techniques, debates and controversies appears. In attempting to provide a classification of available cricothyrotomy techniques, we might argue that the same terms *FONA* or *Front of Neck Access* could somehow be misleading, as they gather under a single label a series of procedures (percutaneous tracheostomy, surgical elective and emergency tracheostomy and emergency and elective cricothyrotomy [12], both surgical and percutaneous) which are significantly different in terms of indications, technique, timing and aims. In such a way there is certainly a risk of producing a degree of confusion for the not-expert reader.

Aim of this review is to discuss the epidemiologic and technical issues regarding CI-CO, limiting the FONA issue to cricothyrotomy only, and not forgetting the psychological and non-technical issues shadowing the data we observe from clinical practice.

1.1. Epidemiology of CI-CO

Defining a precise incidence of the CI-CO scenario is a hard challenge: apart from classical epidemiological obstacles, such as failed recording of the *near-misses*, reticency and lack of systematic data collection tools, the real problem is that all we know about CI-CO incidence comes from recording of accidents.

Classic data from Benumof reports an incidence of one case over one million procedures [13], and recent evidence addresses CI-CO incidence in the operating room of around 0,0019% [14]. NAP 4 [1] reports an incidence of 1/25000 to 1/5000 with the highest peak for head and neck surgery and with 10 times higher incidence (1/60–1/100) in ICU and even higher in the Emergency Department. From 1.7% to 2.7% [9], and up to 11% of airway management cases in the pre-hospital setting might result in CI-CO [15], and other studies report an incidence from 5/1000 to 5/10000 (up to 21% of failed airway cases) [16] in the ED and 0.24% and 0.15% in the field or in emergency department of military battlefield respectively [17], with a recent retrospective study on about 22000 helicopter-transported patients reporting 0.57% incidence [18]. Recent data from the Danish Anaesthesia Database showed an incidence of emergency surgical airway of 0.06 events per thousand among patients undergoing general anaesthesia, with a higher incidence of 1.6 events per thousand in ear-nose-throat cases and a global evaluation of "satisfactory" airway management in about 37% of cases [19].

The main concern about CI-CO incidence and number of FONA procedures is that we are lacking homogeneous and complete data, we don't have the dimension of the *near-misses*, and finally that we measure the number of cricothyrotomies which have been performed, while we would obtain a picture closer to reality by measuring how many we should have performed. Data from the ASA Closed Claims unmercifully show that more than two thirds of cricothyrotomy were performed too late to change outcome, and that many of them presented serious or life-threatening complications [20]. Attempts to obtain more complete and updated information about CICO incidence and FONA performance were described in a recent paper promoting the use of an app to collect data worldwide [21].

If we look at numbers, we might therefore conclude that CI-CO is rare, and we do also know that the incidence is declining, which addresses new problems such as misconsideration of the need to learn [22] and reduced opportunity for teaching [23,24]. On the other hand, we must not forget that competency in FONA is a core skill [25] and that a CI-CO scenario could occur at any time of clinical practice. In a busy world, it should be considered not less than airbag technology in a car. No one buys a car with an airbag (which is anyway mandatory accordingly to safety regulations) for the possibility he could be carelessly involved in car accident, thanks to the airbag; nevertheless, nowadays, no one would buy a car without an airbag.

1.2. Landmarks and techniques

As with any other invasive technique, FONA requires a learning process integrating the knowledge of regional anatomy and of materials and devices to be used before than proficiency in performing the technique and awareness of indications and timing.

Front of neck access does not rely on a preformed access or pathway, which has to be created in a precise area of the neck, represented by the cricothyroideal membrane (CTM), mostly due to a series of factors.

CTM is the most superficial tract of the patient's airway, the sole pretracheal tissue separating the airway and the skin. In this setting, the largest skin-to-airway distance might be recorded in the obese patient only (in which it could easily overcome 20–30 mm) [26], and more critically in pregnant obese patients (18.0 mm, interval 16.3–19.8 at 95%CI in a recent paper [27]), representing the main obstacle to successful FONA if performed with a pure needle technique or with an inadequately long Seldinger-based set. For such reasons, morbidly obese patients with large neck circumference or poor neck access, should be primarily identified as *no-rescue* thus addressing to maximal attention in the preoperative evaluation and maximal prudence in choice of any not-awake airway securing technique [26], representing those patients in which, if needed, FONA could be performed with double incision technique (preliminary vertical on skin followed by a second one transversally on CTM), as suggested from recent Difficult Airway Society guidelines [11].

A second reason to choose CTM is represented by cricoid cartilage, which appears to be the sole complete cartilage ring in the larynx and trachea, thus offering relative protection against posterior wall lesion in case of (unnecessarily) long needles and scalpels or particularly sharp forceps [28] or bulky sets [29].

Last but not least, CTM remains the preferred FONA site because of quite constant avascularity: cadaver studies clearly showed that either CTM is avascular or, as found in 63% of cases, a cricothyroideal transverse artery has been described to lie horizontally in the upper part of CTM in 93% of cases [30].

Taking account of these anatomical specificities, the *safe* cricothyrotomy area remains located in the lower third of CTM [31]. The extension of this safe area should match with the external diameter of the airway (cannula, tracheal tube or tracheostomy/cricothyrotomy cannula) so to minimize any damage including fracture of laryngeal cartilages [32,33]. Classic cadaveric studies [31,32] indicated an area of about 7.5 mm–10.5 mm in female and 10.0 mm–13.0 mm in male (for an average of 10×8 mm)which could increase up to 20% with head in maximal extension [34]. A recent paper measuring CTM height on tomographic scans by two independent operators [35] revealed a mean height of 7.89 ($\pm$2.21) mm and 7.88 ($\pm$2.22) mm in male patients, and 6.00 ($\pm$1.76) mm and 5.92 ($\pm$1.71) mm in female patients. As a result, any cricothyrotomy cannula should not exceed 8–9 mm of outer diameter to be considered *safe* in terms of potential damage.

If we focus our attention on such a limited safe area, it is not difficult to understand the findings from NAP4 [1] stating that the inability to identify anatomical landmarks of CTM occurred frequently, resulting in the first cause of cricothyrotomy failure, with much more difficulty in obese patients and in females rather than in males, as elsewhere demonstrated [36,37].

No specific technique seems to be reliable to identify CTM [38,39] with best performance being a success rate of 62% [40]. As a further remark, we should not forget that these data are obtained in a non-stress environment so we could expect even worse results in an actual CI-CO scenario especially in physicians aware they are neither skilled nor trained [41].

These considerations might be much more significant for patients with difficult or critical airways such as the obese and/or pregnant patients [42], that is why recent literature suggests an important role for preliminary elective CTM identification and marking with ultrasounds [43,44] whose role is conversely not recommended in the occurrence of ongoing CI-CO [45].

As a conclusion, preliminary identification of difficult cricothyrotomy predictive factors seems extremely important, as part of a multileveled airway evaluation, taking into account that known or rational risk factors are female sex, obesity, a deviated airway (goiter, neoplasms) or a limited excursion of cervical spine, a neck surface pathology (scars, radiotherapy, inflammation) and age less than 8–10 years, due to different laryngeal position during growth and smaller CTM surface [46]. Some authors [47] suggest the acronym SHORT (Close up **S**urgery or **s**car, **H**ematoma or infection, **O**besity, previous **R**adiotherapy and presence of a **T**umor) to make predictive factors more memory-friendly.

1.3. Procedure

Any FONA, once decision is made, starts with proper landmark identification together with patient positioning. Head extension during procedure, which could be achieved with a pillow under the shoulders [11], is someway controversial: on one hand, it allows better exposure of laryngeal cartilages, improving landmark correct recognition, while increasing the size of membrane and CTM-sternal notch distance so as to allow more physical space for manouvers. On the other hand, head extension might distort anatomy and it has been shown not to prove any benefit when compared to a neutral position in terms of success in a recent paper exploring gender related differences in CTM identification [36], so that actually no evidence supports a specific behaviour.

Once CTM is properly identified, including the possibility of pre-procedural ultrasound-based marking [43,44], a successful FONA needs to be based on a stable laryngo-tracheal immobilization. A safe approach suggests the non-dominant hand to fix laryngo-tracheal tract while the second or third fingers are used to mark CTM and address puncture or incision, to be performed with dominant hand. This technique is also known as the *laryngeal handshake* [48], suggesting identification of the hyoid bone and thyroid cartilage while stabilizing the larynx between thumb and middle finger. The index finger identifies the thyroid notch and then moves down the neck along the midline down to the cricoid cartilage, so that the depression immediately above is recognized as CTM. When the thyroid notch is not well palpable as in many women because of different convexity [36], or in children because of small size, it is recommended to identify the sternal notch with the index finger and then moving up along the midline identifying the tracheal rings so as to reach the cricoid ring and CTM in a caudo-cephalic approach.

When there is no opportunity for a clear CTM identification based on recognizable anatomical landmarks, the current evidence supports initiating a cricothyrotomy with a midline 3–4 cm (up to 8 cm in recent DAS Guidelines [11]) vertical incision through skin and subcutaneous tissues over the estimated CTM location, so as to allow a preliminary blunt exploration with the tip of the finger to identify the CTM in order to perform either surgical or percutaneous cricothyrotomy [11,41,49,50].

The role of ultrasound, with different precise probe approaches [51], though important and precious during percutaneous tracheostomy [52], cannot be extended *tout court* to cricothyrotomy during CI-CO. This opportunity has been explored in clinical [53] or experimental [54] settings, showing time consuming results and poor reliability in the emergency setting [55], whereas it has been suggested for preoperative airways evaluation, including preemptive CTM identification [56], with significant reduction (RR = 3) of posterior wall and tracheal damage in an elegant cadaver study if compared with palpation technique [44] and with valuable suggestion to become part of the goals and core skills to be achieved in the future of airway management teaching [57–59].

1.4. Techniques and devices

Conceptually, any FONA technique goes through 3 sequential stages: CTM identification, CTM access and airway device insertion. Once CTM is identified, directly or through a preliminary incision, we could schematically classify cricothyrotomy procedures based on operative technique, or to be more precise, on depth of penetration of eventually used scalpel: surgical (full thickness, entering the airway by scalpel) or percutaneous (sole skin incision before or during procedure), device entering the airway (small cannula over needle or larger Veress-like or trocar-like cannula) and presence or not of a railroading guide (Seldinger or not-Seldinger technique) (Table 1).

A subsequent classification might be performed based on airway device inner diameter, splitting two macro-groups accordingly to the cut-off of 4 mm inner diameter as threshold below which we can grant oxygenation (especially if a high pressure oxygen source is available) or above which we could also grant adequate ventilation [60] [61], with consequent implications on feasibility to perform immediately or with minor delay (time to perform tracheostomy) a not-deferrable surgery (Tables 1 and 2).

As general points, the main differences between techniques might be summarized as follows:

Table 1
Temptative classification of cricothyrotomy techniques for FONA. See text for details. ID: inner Diameter.

Cricothyroidal membrane identification					
Palpation					
Ultrasound					
Pre-incision					
Airway access through the cricothyroidal membrane					
Technique	Distinctive features			Trade name (Manufacturer)	ID (mm)
Surgical (Scalpel based)	Five steps or Standard (Trousseau dilator+tracheal hook)			Surgicric II (VBM, Sulz a. N.,Germany)	6
				Curaplex Emergency Surgical Cricothyrotomy Set (Bound Tree Medical, Dublin, OH, USA)	6.5
				H&H Medical Emergency Cricothyrotomy Kit (Rescue Essentials, Salida,CO, USA)	6
				Melker Emergency Cricothyrotomy set (Surgical) (Cook Medical, Bloomington, IN, USA)	5
	Rapid Four-step (Tracheal hook)			Surgicric I (VBM, Sulz a. N.,Germany)	6
	Three steps (A Stylet or a Bougie)			BACT or Bougie Assisted Cricothyrotomy	≥ 4
				Knife-and-tube // Knife-finger-bougie	≥ 4
Percutaneous (Non-scalpel based)	Narrow bore cannula (Needle cricothyrotomy)			Cricath (Ventinova, Eindhoven, Nederland)	2
				ETAC or Emergency Transtracheal Airway Catheter (Cook Medical, Bloomington, IN, USA)	2
				Ventilation Catheters. Previously named Ravussin Catheters (VBM, Sulz a. N.,Germany)	13G, 14G, 16G
				Surgicric III (VBM, Sulz a. N.,Germany)	2
				The cannula to railroad the guidewire can be used to ventilate	
				Quicktrach (VBM, Sulz a. N.,Germany)[a]	Child 2 Infant 1.5
				Patil (Cook Medical, Bloomington, IN, USA)	3.3
	Wide bore cannula	Seldinger based	Cuffed cannula	Melker (Cook Medical, Bloomington, IN, USA)	5
				Surgicric III (VBM, Sulz a. N.,Germany)	6
			Uncuffed cannula	Arndt (Cook Medical, Bloomington, IN, USA)	3
				Easycric (Teleflex Medical, Athlone, Ireland)	5
				Melker (Cook Medical, Bloomington, IN, USA)	4; 6
				Minitrach II-S (Smiths Portex, Minneapolis, USA)	4
		Non-Seldinger based	Cuffed cannula	Control-Cric and CricKey (Pulmodyne, Indianapolis, USA)	5.5
				PCK (Smiths Portex, Minneapolis, USA)	6
				Quicktrach II (VBM, Sulz a. N.,Germany)[a]	4
			Uncuffed cannula	Airfree (Logumedics Munich, GER)	4.6
				Minitrach II (Smiths Portex, Minneapolis, USA)	4
				Nu-trake(Mercury Medical, Clearwater, FL, USA)	4.5; 6; 7.2
				Quicktrach Adult (VBM, Sulz a. N.,Germany)[a]	4

[a] Same product as *Tracheoquick* (Teleflex Medical, Athlone, Ireland).

1. A cannula less than 4 mm ID provides adequate ventilation with difficulty, unless a high pressure/flow oxygen source is used and adequate expiration pathway/time is granted [60,61].
2. Non-Seldinger procedures are theoretically faster and less time consuming, as CTM puncture is timely coincident with cannula insertion, while paying the due of increased risk on posterior tracheal wall, unprotected by any guide.
3. Seldinger based techniques are theoretically longer though safer, as they allow for separate tracheal puncture/airway identification and cannula insertion, working on the railroading principle over a metal guidewire, hence protecting the posterior tracheal wall, and granting the operator to have one hand free after tracheal catheterization.
4. FONA in pediatrics is an even rarer occurrence, but it is much more challenging, mostly because of smaller CTM dimensions and higher laryngeal position, not underestimating a relative lack of dedicated devices and specific training and experience [62]. Before 2004 the only rules were that written by the American NEMSIS (National Emergency Medical Service Information System) [63], but today it is preferable to suggest the classic surgical procedure (typically performed by ENT surgeons) or alternatively a cannula over needle technique in newborns, infants and toddlers up to 2–3 years old, whereas, above this age, CTM height and tracheal diameter define the size of the device that could be used. The scalpel + pediatric or adult bougie + pediatric tube technique remains more indicated in older children and teenagers, and many commercial sets could be used also in children older than 5 years. Also in pediàtric patients, CI-CO prevention remains of paramount importance.

1.5. Surgical cricothyrotomy

The definition of *surgical airway* is often a source of confusion between different techniques [64]: despite both surgical and percutaneous tracheostomy or cricothyrotomy accessing the airway, indications are completely different, and neither percutaneous nor surgical tracheostomy should ever be addressed to rescue oxygenation in a CI-CO scenario despite the procedure suggested in recent ASA Guidelines [65], as even in expert hands a surgical tracheostomy might take not less than 3–5 min to be performed [66]. The surgical (or *open*) cricothyrotomy is claimed to be the fastest and most reliable method of securing the airway in the emergency setting [67] and the 2015 DAS Guidelines clearly addressed surgical cricothyrotomy as preferred technique for FONA [11]; nevertheless, huge debate is still going on, especially for implications for timing and decision-making of a surgical approach [67].

Different surgical techniques have been described, but all of them initiate with a scalpel incision: due to route of neck (major) blood vessels, and to (inconstant) presence of a small cricothyroideal artery in the upper third of CTM, the scalpel incision is

Table 2
Temptative classification of cricothyrotomy devices based on inner/outer diameter.

Commercial name	ID (mm)	OD (mm)	Oxygenation Ventilation
14G iv cannula-over-needle	1,74	2,2	
ETACS	2	2,5	
Ventilation Catheter (pediatric)*	1,3	2,0	
Ventilation Catheter (adult)*	2,0	2,7	
Surgicric III catheter	2,0	2,7	
Cricath (Ventrain)	2,0	<3,0	
Quicktrach (newborn)	1,5	<2,5	
Quicktrach (children)**	2,0	<5,0	
Arndt	3,0	3,8	
Patil	3,3	4,2	
Melker	3,5	5,1	
Airfree	4,6	5,6	
CricKey	5,2 (c)	<7,0	
Control-Cric	5,5 (c)	<7,0	
PCK	6,0	9,0	
Quicktrach (adults)	4,0	<7,0	
Quicktrach II**	4,0 (c)	<7,0	
Minitrach II and Minitrach II-S	4,0	5,4	
Nu-trake	4,5	<5,5	
Nu-trake	6,0	<7,0	
Nu-trake	7,2	>8	
Melker	4,0	5,9	
Melker	5 (c)	7,2	
Melker	6	8,8	
Easycric	5,0	7,0	
Surgicric I,II,III	6,0 (c)	8,0	
ET Tube	5,5	7,5	
ET Tube	6	8	

*Previously named *Ravussin catheter*; **Same product as *Tracheoquick* (Teleflex Medical, Athlone, Ireland).
Grey: only oxygenation possible; Black: oxygenation and ventilation possible.

recommended to be horizontal and on full thickness above the CTM site. In case of very difficult landmarks [11] a first vertical incision from 4 to 8 cm could be performed from thyroid cartilage towards sternal notch.

Surgical techniques have been classified as *five*, *four* and *three* steps procedures and as *three-steps bougie-aided* (BACT-Bougie assisted cricothyrotomy) surgical techniques.

1.5.1. Standard surgical cricothyrotomy [68]

The CTM is identified via blunt dissection; after a short transverse stab incision in the lower part of CTM, the larynx is stabilized with a tracheal hook at the inferior aspect of the thyroid cartilage while performing cephalad traction. A *Trousseau* dilator is placed in the incision in order to dilate and pass a non-styletted endotracheal tube (ETT). An alternative technique using a fifth finger in place of the *Trousseau* dilator has been described [69], underlining how reliable, fast and kit-independent this approach might be [70]. Some manufacturers offer a complete surgical set including a dedicated cricothyrotomy cannula; other sets combine a modified surgical set with a cricothyrotomy cannula with satisfactory results but on small sample and isolated study [29] (see Tables 1 and 2).

1.5.2. Rapid four-steps technique [71]

CTM is dissected with the scalpel, followed by tracheal hook traction in the caudal direction with one hand while passing the styletted/non-styletted ETT with the other hand.

1.5.3. Three steps 'knife-and-tube' [72]

This approach uses the handle of scalpel to maintain an open access to airway when passing a styletted ETT. Once the blade cuts the CTM, the handle of the scalpel is inserted into CTM incision and rotated 90°, so as to allow ETT passage. An alternative technique [11] suggests providing a horizontal incision with a scalpel and then to rotate it keeping the sharp edge caudally, so to use the same blade as dilator, pulling towards the operator and sliding the styletted ETT along the opposite side of the blade. This approach is suggested in the recent DAS 2015 guidelines as the first line FONA technique [11]. A recent study reports a high first pass success rate for this technique in manikin models of either palpable (44 s) and unpalpable (65 s) CTM, underlining that it is easy to teach and to acquire also in untrained personnel [73]. Other sets come with dedicated forceps acting at same time as scalpel and dilator, with some evidence in cadaver study [28].

1.5.4. Three steps bougie-assisted (BACT) [74]

It is similar to the aforementioned three steps technique, but instead of a styletted ETT, a bougie or tracheal introducer is inserted alongside the vertically oriented scalpel in CTM, either alone (and then cuffed or plain ETT is railroaded above), or with pre-mounted ETT (cuffed or plain). As for *"knife and tube"* technique, also for BACT the minimal suggested scalpel blade size should be larger than usual bougies/introducers diameter [11], so the incision to be wide enough to allow smooth passage of the bougie or introducer (blades 10 or 20 are usually the more appropriate for adult patients). There is no evidence about incision direction (vertical or horizontal), while blade rotation seems to be (prudently, in theory) unnecessary. Particular care should be addressed when advancing and retracting the bougie for any reason when the scalpel blade is in site, as this could result in some damage, including impossibility to remove the bougie from the tracheal tube (Sorbello M, Godoroja D, Margarson M. personal data - submitted).

This technique is claimed to be fast [74], showing higher performance and safety if compared with other techniques (faster execution and a 95% success rate when compared with 18% for the trocar technique) [75]. Another potential benefit of BACT is that it allows for the possibility of changing the ETT size whilst keeping the bougie in the airway [76,77]. Of particular importance, whenever using a stylet-ET or bougie-ET solution, the proper matching of the tube should be warranted, so as to minimize any gap and allow smoother passage of the tube through the CTM. Some authors suggest to couple the bougie with a tapered-ending cricothyrotomy cannula from a set in the market [78].

There is a lack of evidence favouring a specific technique, nevertheless the three steps and the BACT technique seem to be faster and anaesthesiologists are more prone to perform this technique rather than the "*more surgical*" four or five steps [11].

A huge debate is ongoing in literature because of a recent DAS Guidelines message to perform the three steps cricothyrotomy or BACT as the preferential technique for FONA rather than percutaneous techniques, either Seldinger or non-Seldinger based, as they have both been claimed to have poor performance and to be time consuming when compared with surgical techniques.

These results come from interpretation of NAP4 data [1], which clearly showed a very high failure rate for needle cricothyrotomy, a poor performance of percutaneous techniques and a 100% success of surgical technique, but not precisely taking account of who was performing cricothyrotomy (surgeon for surgical and anesthesiologist for percutaneous) and when (if preemptive or during a CI-CO) [4]. With such premises a clear statement or preference could not be expressed based on *Evidence Based Medicine* principles but only on good sense, experience and training.

1.6. Percutaneous cricothyrotomy

Many percutaneous techniques start with tracheal lumen identification by free air aspiration through a (saline filled) syringe, adding the benefit of preliminary confirmation of correct tracheal positioning. The syringe, directly connected to the cricothyrotomy device or connected to a needle/cannula, is advanced through the skin and underlying tissues until bubbles come into the barrel. As a further safety test, lack of plunger recoil might confirm correct placement [68].

Any 2 mm or lower inner diameter cannula is referred as *needle cricothyrotomy*. It is mostly recommended for pediatric (neonates and infants) procedures, and it has long time been considered relatively easy, safe and atraumatic [79]. As confirmed by NAP4 results [1] (showing a success rate of only 37%) and from clinical studies [67], the major limitations of the needle technique are represented by possibility of the small cannula to kink or to impact against the posterior wall [80] and by severe flow limitation represented by the narrow cannula lumen [81]. Unless a high-pressure oxygen source or dedicated flow-multiplier devices [82–84] and adequate gas exhaust and expiratory time are provided, a narrow-bore cannula technique is absolutely inadequate to provide optimal oxygenation and not at all any possibility of ventilation [81,85,86] definitively unveiling the myth of the *restaurant tracheostomy* to be performed with a barrel of a pen [87]. The same 2010 European Resuscitation Council guidelines looked at needle cricothyrotomy as a temporary measure, to be fastly switched to a definitive airway [88], and ASA Closed Claims analysis [20] clearly showed that 89% of needle cricothyrotomy were complicated with pneumothorax, pneumomediastinum, or subcutaneous emphysema when jet ventilation was used, many failed procedures being successfully rescued with a surgical cricothyrotomy.

In summary strong evidence supporting needle cricothyrotomy use is missing, whereas many low evidence studies clearly show failure and complication rates, and potential for delayed reoxygenation [89].

An interesting combination to rescue patients with critical oxygenation has been described for needle cricothyrotomy bridging to Seldinger-based large bore cannula cricothyrotomy [90] and incorporated in some set (Tables 1–2) with promising future options and theoretical advantage of providing early rescue oxygenation followed by effective ventilation.

As a matter of fact, insertion of a wide-bore cannula/tube with an inner diameter empirically fixed as ≥4 mm offers advantages regarding ventilation when compared with a narrow-bore cannula. Adequate minute volumes can be achieved using a conventional breathing system with expiration via the cannula.

On other hand, some studies claim that a reliable ventilation could only be guaranteed with a cuffed tube, as use of an uncuffed tube may lead to gas leakage towards the upper airway [91], so that some authors describe use of supraglottic airways with closed airway conduit to "plug" the upper airways so as to limit any tidal volume leak, especially in low pulmonary compliance patients [92]. There is an ongoing debate on this topic, even if it sounds more academic rather than of clinical impact: presence of a cuff undoubtfully results in larger external diameter and in greater resistance when passing through tissues, coming to the conclusion that a cuffed cannula, although theoretically better for ventilation, is more difficult to insert [93]. On the other side, some studies show that time to insert a cuffed tube is not longer than time to insert a same diameter uncuffed tube, whereas the uncuffed 6.0 mm ID device failed to achieve adequate ventilation if compared with a smaller ID cuffed device [91]. Finally, if we think of cuff role in protecting from aspiration, classic papers showed that cuff diameter must be at least 1.5 times the tracheal diameter for actually preventing leakage and provide adequate protection from aspiration [94] without damaging the wall, which is not a feature of any cuffed cricothyrotomy cannula. Recent debates underlining this limitation suggest that it might be easily surrounded by inflating the tube cuff until leaks disappear, though paying the due of a potentially overinflated cuff, whose danger should be considered in light of the provisional nature of the tube-cricothyrotomy and of the need to switch for a definitive airway [95,96].

Probably, a good sense answer would be that if we choose a small diameter cannula (less than 4 mm) it would be wiser to use a cuffed one, especially if airway obstruction or low chest wall compliance is observed. In other cases, if we use a larger cannula, it would be wiser to spend the increased thickness to favour the cannula ID rather that hypotetic protection from aspiration and sealed ventilation.

Another important difference in the world of cricothyrotomy sets is represented by the principle according to which the cannula is inserted and driven inside the airway: the two options are the Seldinger and the non-Seldinger technique.

1.6.1. Seldinger wire-guided

After CTM puncture and cannulation with needle or small cannula, a metal soft-tipped Seldinger guide is used to catheterize the trachea, then railroading the definitive (large bore) more or less soft cannula mounted over a stiffer, and typically conic shaped, dilator-introducer tightly fitting to cannula inner diameter to facilitate skin penetration and airway entrance. A small skin incision is sometimes useful before inserting the dilator-introducer. Anaesthetists usually find this technique more familiar, and they perceive it somewhat safer as they are used to it thanks to central venous or arterial lines placement [97]. Tables 1 and 2 list the various sets available in the market which are mainly different in diameter and anti-kinking properties of the Seldinger guide, ergonomics of handling, cannula diameter and length, cuff presence and introducer stiffness and length. Fig. 1 shows the theoretical protective effect of a railroading guide on posterior tracheal wall.

1.6.2. Non-Seldinger wire-guided or needle-guided

The methodology behind this group of techniques is based on the same principle concerning narrow-bore devices, that is the principle of cannula over a needle. All these sets use larger cannulas, which sometimes have an outer diameter even superior to the safe 8 mm threshold of CTM (Table 2), though they allow adequate ventilation with standard breathing systems. As a general principle, a railroading guide missing, a considerable force is often required to introduce this type of devices through the skin and CTM with poor control of the velocity and depth of access of the device, which could result in increased risk of damage of the posterior tracheal wall [29,98–100]. An initial scalpel incision could reduce the force required; some devices come with dedicated detachable stoppers, which could anyway over-limit depth of penetration and results in being insufficient in thick necks, as reported in NAP4[1]. Other devices rely on Veress-needle based technology and a penetration-alert system to prevent posterior wall damage, which has anyway been reported due to bulky dimension of the set [97].

On a theoretical point of view, the non-Seldinger based approach has the advantage of being faster [101] as it combines the puncture-dilation-insertion phases, which results for example in being useful and less interfering with chest compression during cardiopulmonary resuscitation [102], but on other hand it offers less control requiring the performing physician to stabilize the trachea until the end of procedure giving back to the operator the feeling of a “semi-blind” procedure.

1.7. Success rate and complications of cricothyrotomy techniques

It is hard, if not impossible, to find out an evidence-based conclusion favouring a certain technique or device in the field of cricothyrotomy. Basing on incidence, any power analysis would suggest unreachable dimension patients' sample; basing on method it would be hard to identify correct endpoint in time to perform rather than on neurologic outcome, and in terms of ethics it would not be feasible to randomize a CI-CO patient for a technique or for another.

In such a field, we need to think critically towards experimental studies, considering for example that a mannequin study showing superiority of surgical technique does not take account of bleeding, or showing faster performance of a non-Seldinger based technique might not allow to identify exerted pressures and eventual tracheal damage.

We need to trust, not a critically, on experts' opinions, basing our choices on personal feedback and adequate training, whichever the technique.

A mannequin study from the authors [103] comparing three Seldinger techniques and one non-Seldinger, clearly showed faster performance for the latter, but higher appraisal and first pass success with the first, with subjective operators' preference on ergonomics and guide-associated perceived safety. Hamaekers and Henderson [99] someway compared large series of various emergency surgical access techniques, coming to confounding conclusions: for example, well trained anaesthetists show a high success rate with needle cricothyrotomy, but reported success rates with different techniques widely vary from less than 50% for needle technique, from 55 to 100% with surgical, from 30 to 100% with non-Seldinger and 60–100% with Seldinger based.

Similarly, a comprehensive meta-analysis of pre-hospital airway control techniques [104] reported that narrow-bore cannula cricothyrotomy has a low rate of success (65.8%) if compared with surgical cricothyrotomy (90.5%) addressing to surgical approach as preferred FONA rescue technique, whereas it is some experts' opinion that anaesthetists could be somewhat reluctant, thus delaying rescue oxygenation, to perform a scalpel technique [4,41].

A recent mannequin study on cricothyrotomy performed by airway-naives, clearly showed a better performance for surgical technique (95%) if compared with non-Seldinger (55%) or Seldinger (50%) technique, nevertheless underlining that the principal cause of observed failure was cannula displacement of non-Seldinger based technique [24].

Finally, in a large and recent systematic review (1405 papers restricted to 24 studies) to compare available commercial kits and traditional surgical or needle techniques [72], on endpoints of success rate and time to secure the airway, conclusions failed to find any statistical difference between all groups, and no technique was proven to be superior on any endpoint. The accompanying editorial [89] of this study interestingly stated that if on one hand there is a high failure rate for needle cricothyrotomy whilst on on the other hand there is currently no clear evidence that any available cricothyrotomy kit is better than a surgical technique, hence

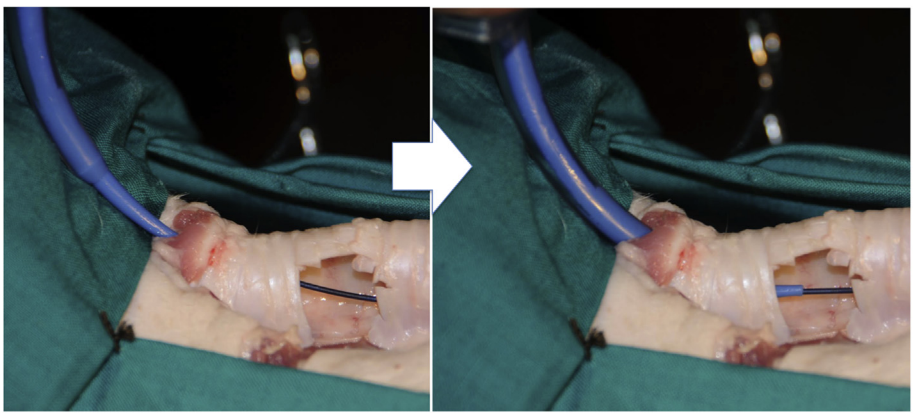

Fig. 1. Animal model of cricothyrotomy: note how the guide might represent the safest railroad system for advancing the introducer-cannula ensemble, allowing maintenance of the correct direction and reducing posterior tracheal wall damage risk.

the latter remaining the more reliable with high success rates up to contrary proof.

Complications are intuitively dependent on the chosen technique for FONA, with wide variations in literature. Posterior wall damage seems to be more frequent with non-Seldinger and cannula techniques, and similarly false route or misplacement; on the other hand, pneumothorax, subcutaneous emphysema and bleeding are more associated with surgical and large-bore cannula (mostly Seldinger) techniques. As indicated by Langvad [72], mean failure rate is around 30%, with different extremes depending on the adopted technique. Apart from specific complications, we might indicate that acute complications range from 0 to 31.6%, for a mean incidence of 15% [60], and long term between 0 and 7.86%, subglottic stenosis being the most common late complication of cricothyrotomy with a 2.2% and a 2.9–5% range in two reviews [105,106] but including a peak of 30% especially in cases of previous repeated intubation attempts [107].

Astonishingly, there is poor evidence and few indications for how to secure a definitive airway after emergency invasive airway procedure such as FONA, with a general tendency, more than a recommendation, to an early switch from cricothyrotomy to a most definitive and secure airway, which could include alternative intubation technique (possibly fiberoptic based, so to allow also a cricothyrotomy control) or conversion to definitive tracheostomy, reasonably within 72 h after cricothyrotomy so to minimize the risk of subglottic stenosis [60,106].

Indications of a faster conversion might be represented by inadequate ventilation, need for prolonged mechanical ventilation including transport or multiple procedures, possibility of easy switch to a different airway and awareness of ongoing complications [60].

1.8. Cannula or scalpel? Surgical or percutaneous?

These questions will probably never find an evidence-based answer, due to low incidence of CI-CO and to impossibility to design randomized controlled trials and adequately powered. On one hand, observational studies for cannula FONA show limited performance, taking account of great variability of techniques and situations, while on the other hand there is some evidence that after adequate training the scalpel technique seems reliable and performing, despite many data come from manikin studies [108]. Undoubtfully, there could be a lack of confidence and certain resistance from the psychological point of view by anaesthetists for a surgical approach for cricothyrotomy [109]: in some authors' perspective, this might result in delay to initiate a surgical FONA thus undermining the benefit of a faster technique such as the surgical [4]. At the same time, approaching the surgical FONA in real life seems to have the limitation of training for anaesthetists and of knowledge (meaning impossibility to help) from surgeons, as from a recent survey [110].

Probably the real answer lies in a different perspective: most of CI-CO situations come from poor planning, lack of strategy, deviation from algorithms, lack of communication and of accessible and known difficult airway carts and sets, so that the debate scalpel or cannula should pass in second line after awareness of importance of human factors and preparedness [4,111], meaning that probably for CI-CO and FONA the non-technical issue is largely more important than the technical one. This is to say that in the end the best cricothyrotomy is the one we succeed to avoid [112]. These observations seem to be supported by a recent study [113] showing that the use of FONA checklists (action cards) in a simulated CI-CO scenario with a cannula technique resulted in a slower but more successful performance, mostly because of correction of non-technical procedural errors. Individual reports, underlining the importance of simple cognitive aids such as the *Vortex approach* do also empower this perspective [114].

2. Conclusions

CI-CO is an airway scenario with really low incidence (but probably more than we measure) but with extremely high mortality and morbidity, and (too) often it occurs unexpectedly, mostly because of underestimated prediction or for judgement and strategical (non-technical) errors.

In such a setting, we cannot exclude that at least once in a career an anaesthetist could be called on to perform a cricothyrotomy [22]. For that day, anyone needs to be prepared, not forgetting that not only CI-CO might occur at intubation phase, but also, and much more dangerously, after extubation [115]; and not falling in false safety belief that powerful reversal agents or newer devices such as video laryngoscopes might solve any situation, because not the first not the latter might solve a mechanical CI-CO or provide oxygenation respectively [116].

Supraglottic airway devices saved many lives and verisimilarly transformed some potential CI-CO in *near misses* [3], but on the other hand they probably contributed to lowering the same awareness of CI-CO occurrence, thus potentially reducing the perception of the need for learning or teaching such a skill [23]. We believe this would be a dramatic mistake.

In the evident lack of evidence in the cricothyrotomy world, our only certainties are represented by few but fundamental concepts.

The best cricothyrotomy is the one we succeed not to perform, through a careful patient evaluation, whichever the setting, as evidence supports that implementation of a comprehensive airway program and has resulted in many benefits, including the number of performed cricothyrotomies in an eleven years' period of study [116].

Secondly, If we need to perform a cricothyrotomy, we need to do it without delay and probably not anymore based on the mere (de) saturation value but rather on an awareness of no other ways left, as sustained by recent *Vortex* [117] and *Spiral* [118] approaches.

Third and finally, we need training, whichever the technique and the setting; powerful tools such as mannequin hands-on [119] and simulation [120] easily [121], successfully and long-lastingly increase and maintain skills and awareness of what in the end is technically a really simple maneuver.

Simple but significant, this procedure can mean the difference between life or death.

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XO no conflict of interest.

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GF inventor of Frova Introducer (Cook Medical, Bloomington, IN, USA – royalties), Percutwist (Teleflex Medical, Ireland – royalties), Easycric (Teleflex Medical, Ireland – royalties), Cricotrainer (VBM Medizintecnik, Germany), Tracheostomy Cannula exchanger (DEAS, Castelbolognese, Italy).

XO: article idea and writing, literature search;

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