

SPECIAL ISSUE

The Vortex: a universal ‘high-acuity implementation tool’ for emergency airway management

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Abstract

Factors influencing performance during emergency airway management can be broadly divided into issues with preparation and those with implementation. Effective design of resources that provide guidance on management requires consideration of the context in which they are to be used. Many of the major airway guidelines do not specify whether they are intended to be used during preparation or implementation and may not take the context for use into account in their design. This can produce tools which may be not only ineffective but actively disruptive to team function in an emergency. The Vortex is a novel, simple, and predominantly visually based cognitive aid, which has been specifically designed to be used in real time during airway emergencies to support team function and target recognized failings in airway crisis management. Unlike the major algorithms, which are context specific, the Vortex is flexible enough for the same tool to be applied to any circumstance in which airway management takes place, independent of context, patient type, or the intended airway device. This makes the same tool suitable for use by emergency physicians, intensivists, paramedical staff, and anaesthetists. The Vortex contains many of the recognized features of an ideal cognitive tool and may be effective in reducing implementation errors in emergency airway management. Experimental evidence is required to establish this.

Key words: airway management; crew resource management, healthcare; emergencies; emergency treatment; human engineering; medical errors; patient safety

Factors influencing performance during emergency airway management can be broadly divided into those relating to preparation and those relating to implementation (Fig. 1). Clinician preparation includes all aspects of training, experience, consultation, and planning. Even appropriately prepared clinicians, however, can make basic errors during emergency airway management.^{1–3} Rather than reflecting a lack of skill or knowledge required to manage a situation, these errors often involve clinicians becoming cognitively overloaded in situations of stress.^{1–8} This compromises their ability both to evaluate the situation and to recall available rescue strategies. Impaired decision-making, fixation, omission, or failure to act are recognized consequences.^{1–6 9} Such errors are often compounded by an inability of clinical teams to function effectively.^{1 3 4} Psychological barriers to abandoning the various upper airway techniques in favour of invasive techniques,

such as emergency cricothyroidotomy, may further reduce performance.^{10 11} Rather than necessarily involving failure to prepare, these issues represent a problem with implementation of the airway plan, although preparation and implementation issues may often coexist within the same clinical situation.¹⁰

Tools providing guidance on appropriate management can be used during either the preparatory or implementation phases to assist with performance of a task.⁴ The taxonomy outlined in Fig. 2 has been coined for this article to improve clarity when discussing these tools. Guidelines, protocols, and procedures can be considered ‘foundation tools’, which help to explain the task (and the underlying theory) before the event to promote understanding or memory. In contrast, the term ‘cognitive aid’ specifically refers to ‘implementation tools’, intended to prompt the user during performance of the task.^{2 4 6 7}

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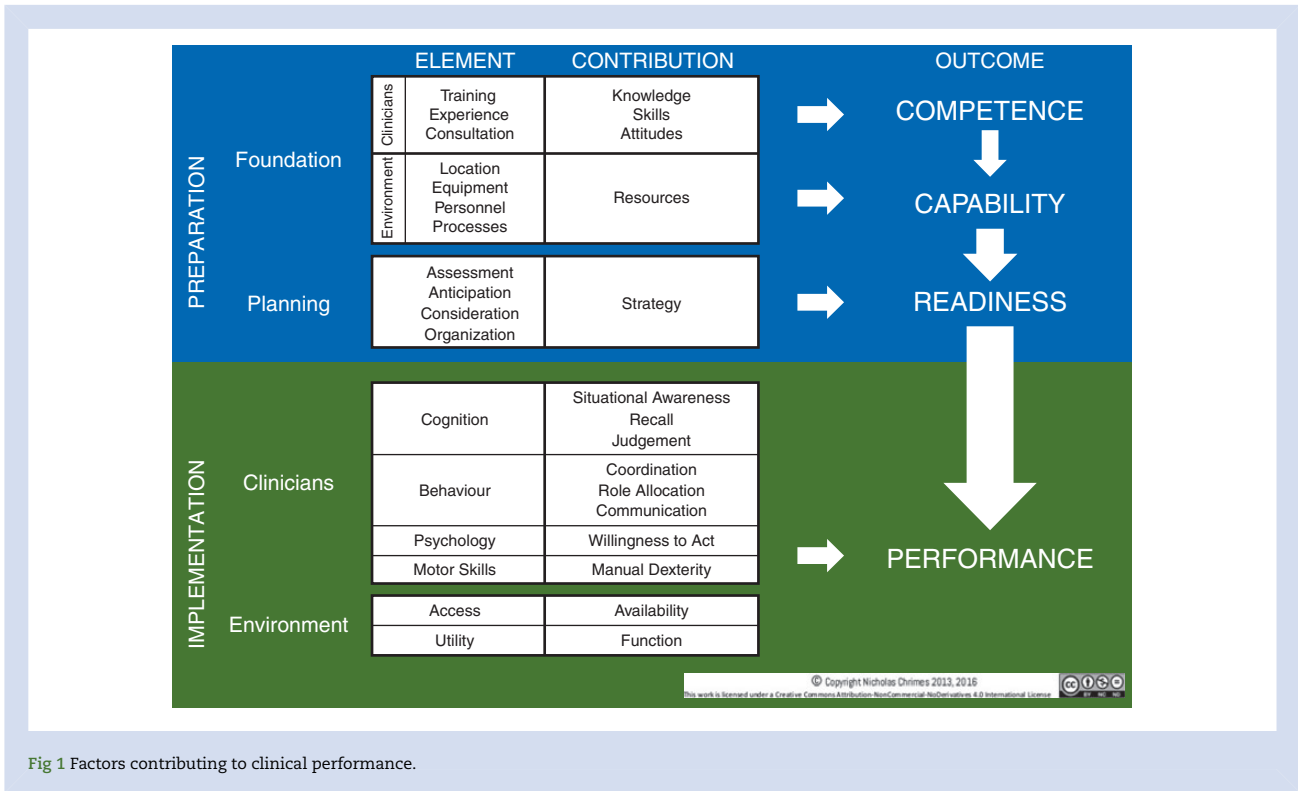


Fig 1 Factors contributing to clinical performance.

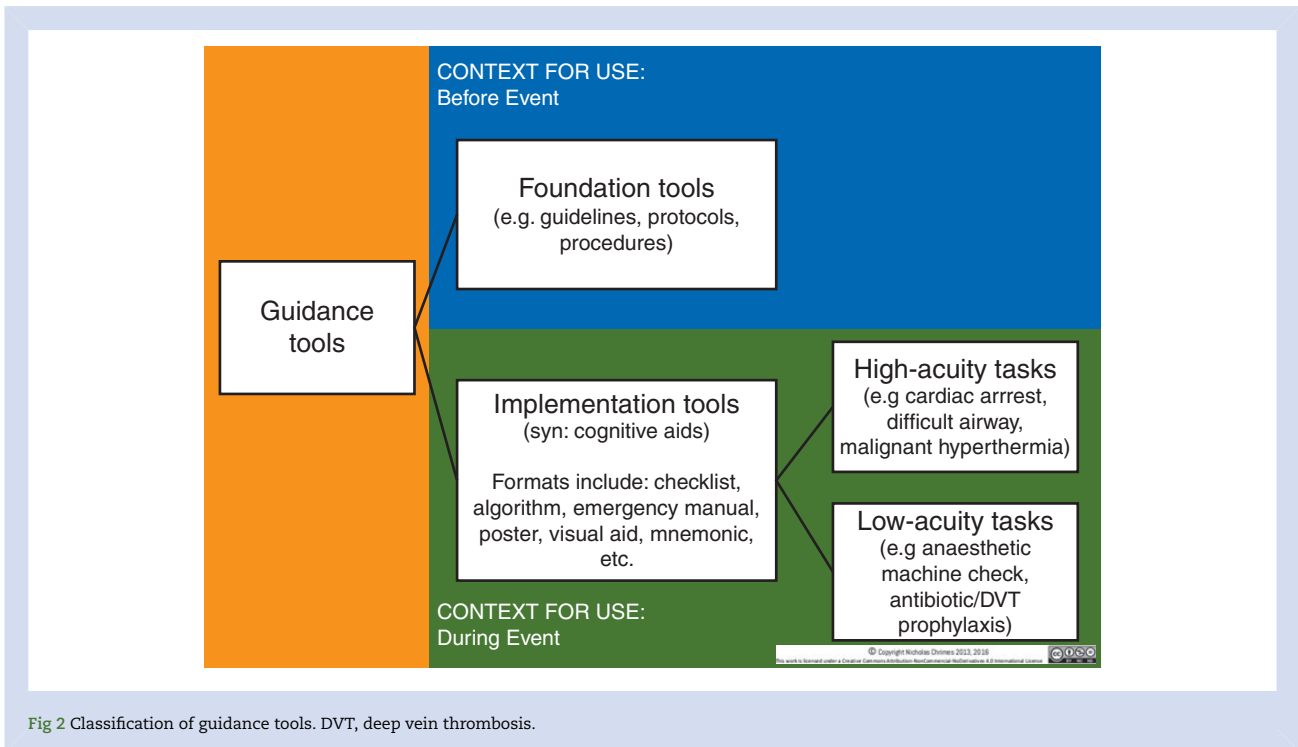


Fig 2 Classification of guidance tools. DVT, deep vein thrombosis.

The effectiveness of guidance tools is dependent upon both their technical content and how that content is presented. The design requirements of guidance tools differ significantly depending on the context in which they are to be used.^{4 6 7}

Well-constructed implementation tools have the potential to facilitate team situational awareness, improve communication, prompt decision-making, and guide key actions.^{2 6 12 13} If poorly designed, however, implementation tools also have the potential

to impair performance and cause harm.⁶ Foundation tools will typically be too detailed or complex to refer to during performance of a task.^{4, 6} Likewise, implementation tools intended for low-acuity tasks will have different design requirements from those intended for use during high-acuity tasks.^{2, 4, 6} Despite this, not all difficult airway guidance tools specify whether they are intended to be used to lay a foundation or referred to during implementation.⁴ In anaesthesia, even tools intended for use during implementation are largely developed with content as the major focus, without necessarily addressing the human factors considerations needed to enhance their utility in a particular context.⁶

The 2015 Difficult Airway Society (DAS) guidelines explicitly state that they are intended for use as a foundation tool, while acknowledging the Vortex as having a purpose distinct from their own.⁵ The Vortex is a 'high-acuity implementation tool' designed to support teamwork and decision-making during the high-stakes, time-critical process of managing an airway emergency.^{14, 15}

Development

Using grounded learning theory, based on more than 15 years of clinical experience in anaesthesia and exposure to hundreds of simulated crisis events as a simulation instructor, the author created the Vortex to address a perceived deficit in the existing guidance tools for emergency airway management. The concept was to provide a single, consistent implementation tool that could be used during an airway crisis by inter-professional teams across all specialties involved in advanced airway management. Designing an implementation tool for this purpose demands that it is presented in a way that enables it to be used in real time by teams of potentially highly stressed individuals. It also requires that the same tool is flexible enough to be capable of being applied to all circumstances in which advanced airway management takes place, independent of the context, the patient type, or the primary intended airway device.

The information-dense, text-based presentation of the major airway algorithms,^{5, 16–19} despite being technically accurate, makes it more difficult for teams to use the information within them during the stress and uncertainty of an evolving airway emergency.^{2, 4} The major airway algorithms also tend to provide context-specific guidance. Separate algorithms have been developed to apply to adult,^{5, 17} paediatric,¹⁸ and obstetric^{17, 19} patients. Complicating matters further is that most of these algorithms exclusively address the circumstance in which the primary intended airway is an endotracheal tube^{5, 16, 17} but not the common situation in which the primary intended airway device is a supraglottic airway or even face mask ventilation.¹ The resultant multiplicity of algorithms and their inability to be applied directly to a large proportion of situations in which airway crises arise may increase the cognitive load associated with their use. This has the potential further to reduce their utility as implementation tools during an airway crisis.²⁰

A simple, low-content, predominantly graphic design is recognized to make a guidance tool more suited to real-time use during crisis situations.⁴ To maintain such a design, the Vortex makes two assumptions. The first is that the tool will be used by clinicians who are already competent to perform advanced airway management independently. As such, its role is to prompt implementation of previously learned knowledge and skills. The Vortex is not intended to teach clinicians or compensate for deficiencies in training, experience, consultation, or planning. The expectation is that the tool should prompt a clinical team with the options for airway management and facilitate shared situational awareness. Given these prompts, preparatory activities should have provided

clinicians with the basis to make a judgement on the best course of action to take in a given context and the technical skills for implementing it. The second assumption the Vortex makes is that teams have been trained in its use before the occurrence of an airway crisis. Familiarity is recognized as being important for a crisis management implementation tool to be effective^{6, 7} and removes the need for it to include complex explanatory detail.

The context-independent nature of the Vortex also allows the same tool to be used in any clinical situation in which an airway crisis might arise. Avoiding the need to choose between multiple algorithms may improve familiarity and recall under stress, further enhancing utility as an implementation tool.

The prompts provided by the Vortex address factors recognized to impair implementation of airway management, including the following: failure to consider all available techniques for achieving airway patency; failure to consider all the strategies available for optimizing success at each of these; excessive airway instrumentation; failure to recognize the significance of achieving alveolar oxygen delivery; failure to recognize the 'can't intubate, can't oxygenate' (CICO) situation; lack of priming for emergency front-of-neck access; delayed implementation of emergency front-of-neck access; and impaired teamwork.^{1, 3, 4, 10, 11}

Description

Overview

The Vortex is based on the principle that there are three 'non-surgical' techniques to establish a patent airway: use of a face mask, a supraglottic airway, or an endotracheal tube. If a best effort at each of these three upper airway 'lifelines' is unsuccessful, then airway patency must be restored by initiating 'CICO rescue' (emergency front-of-neck access). Rather than the traditional algorithm-based design, the Vortex uses a simple graphic that depicts the upper airway lifelines as three zones arranged in a circular fashion around a central area representing CICO rescue (Fig. 3). If a 'best effort' at any of the three lifelines is unsuccessful, this mandates spiral movement inward to the next lifeline. The circular arrangement of the three lifelines means that airway management can commence with any lifeline and proceed between the remaining ones in any sequence according to what is judged most appropriate in a given context. This more accurately depicts real-world practice than the rigid sequence mandated by an algorithm.⁴ Inability to establish alveolar oxygen delivery after best efforts at all three lifelines culminates in arrival at the central zone, representing the need to initiate CICO rescue.

Best efforts

According to the Vortex model, achieving a best effort at any upper airway lifeline may involve up to three attempts (although the minimal possible number should be used). Not all attempts in pursuit of a best effort at a particular lifeline have to be completed before initiation of the first attempt to establish an alternative lifeline. Consistent with clinical practice, best efforts at multiple lifelines may progress in parallel, with sequential attempts alternating between optimizing different lifelines.⁴ Movement around the Vortex thus tracks the sequence in which best efforts at each lifeline are completed, rather than the sequence in which individual attempts to achieve this are undertaken.

Any repeated attempt at a lifeline must incorporate optimizations that have not previously been implemented. Five categories of optimization are presented on the tool to prompt consideration of the available options for maximizing the likelihood of

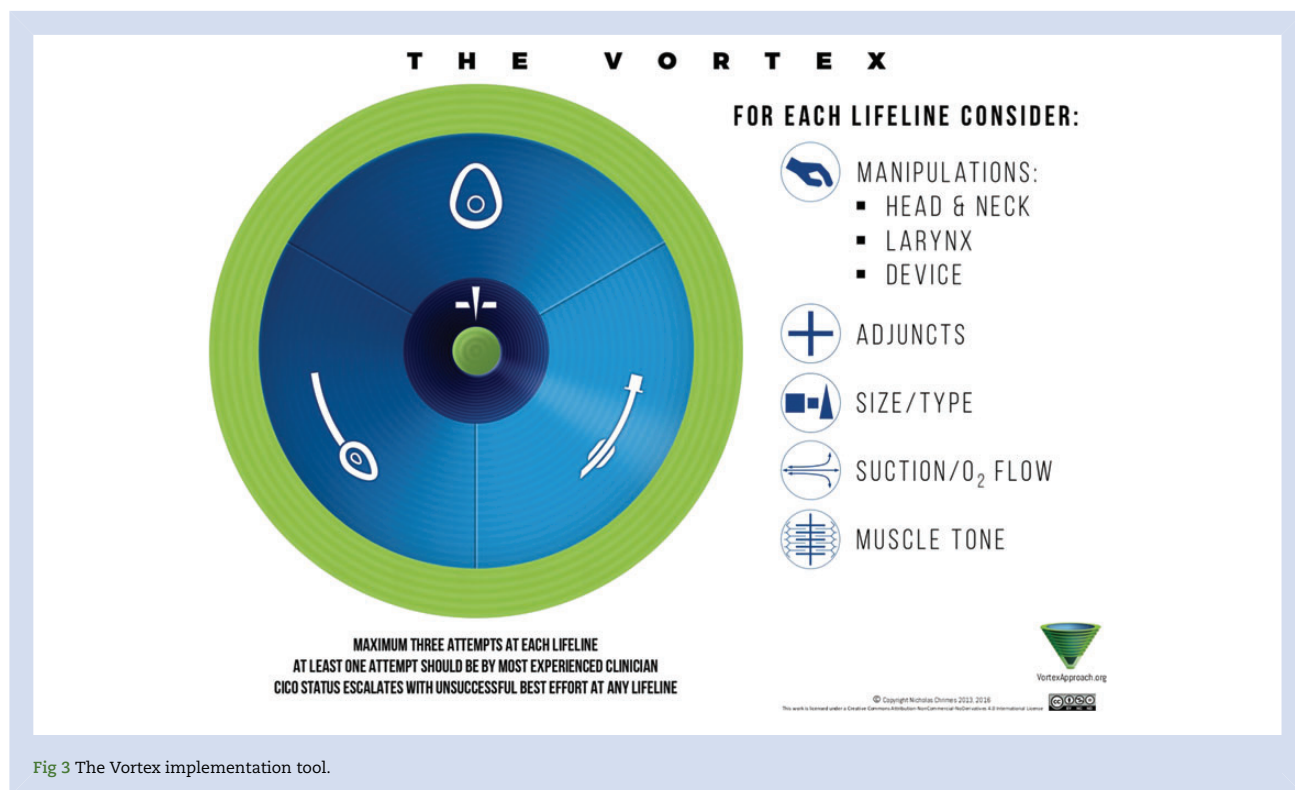


Fig 3 The Vortex implementation tool.

achieving airway patency with any of the three lifelines. The specific interventions relevant to each individual lifeline under these headings are taught to clinicians as part of training with the implementation tool. Exhaustive implementation of all these interventions would be both time consuming and inappropriate. What constitutes a best effort and a reasonable number of attempts to achieve it is a context-dependent decision. The category headings serve only to prompt consideration of the available options. This is important from two perspectives: firstly, it facilitates efficient achievement of a best effort, maximizing the chance of timely success with each lifeline; and secondly, it provides a defined end point to optimization and promotes team recognition of the need to move on to a different technique when a best effort has been unsuccessful. Ultimately, if all three lifelines are unsuccessful, it provides the team with permission to initiate CICO rescue.

The green zone

Inability to achieve alveolar oxygen delivery after a best effort at any lifeline mandates spiral movement towards the centre of the Vortex. In contrast, confirmation that adequate alveolar oxygen delivery is being achieved (typically by obtaining an end-tidal carbon dioxide trace in combination with maintenance of adequate oxygen saturation) results in movement outwards into the circumferential 'green zone' at the perimeter of the tool. The green zone is also visible in the centre of the tool, representing the ability of CICO rescue to restore alveolar oxygen delivery when all upper airway lifelines have been unsuccessful.

Entry into the green zone, via any technique, signifies a crucial point in airway management, during which the patient is no longer at imminent risk of critical desaturation. Acknowledging this situation of relative safety can potentially arrest the momentum of repeated airway instrumentation that might convert

the 'can oxygenate' situation into the 'can't oxygenate' situation. Declaration of being in the green zone by any member of the team provides a cue to consider the opportunities this provides: the opportunity to restore patient oxygen saturations and alveolar oxygen stores, the opportunity to assemble resources (equipment, personnel, and location), and the opportunity to make a plan. Planning options are divided into the following three broad categories: the first is to maintain the lifeline by which the green zone has been achieved (and either proceed or 'wake' the patient); the second is to convert the lifeline to a preferred technique to maintain airway patency without intending to leave the green zone (e.g. use of an Aintree catheter or performance of a surgical airway); and the third is to replace the current upper airway lifeline with a different one (e.g. interrupt face mask ventilation to re-attempt intubation). This last option involves deliberately leaving the green zone and relinquishing the technique by which alveolar oxygen delivery is being achieved. The appropriateness of each of these options varies according to the context. Considerations to assist in this decision are highlighted as part of training and prompted in the moment using a separate implementation tool (Fig. 4). Whichever option is selected in the green zone, planning should always include preparation for the contingency that airway patency is lost. This should include a strategy to complete best efforts at any remaining upper airway lifelines and an appropriate level of priming to perform CICO rescue.

Can't intubate, can't oxygenate status

Declaration that a best effort at any lifeline has been unsuccessful mandates an escalation in the 'CICO status'. This specifies predefined actions for obtaining help and priming the team to perform CICO rescue, according to a three-tiered ready-set-go set of criteria outlined on a separate adjunctive implementation

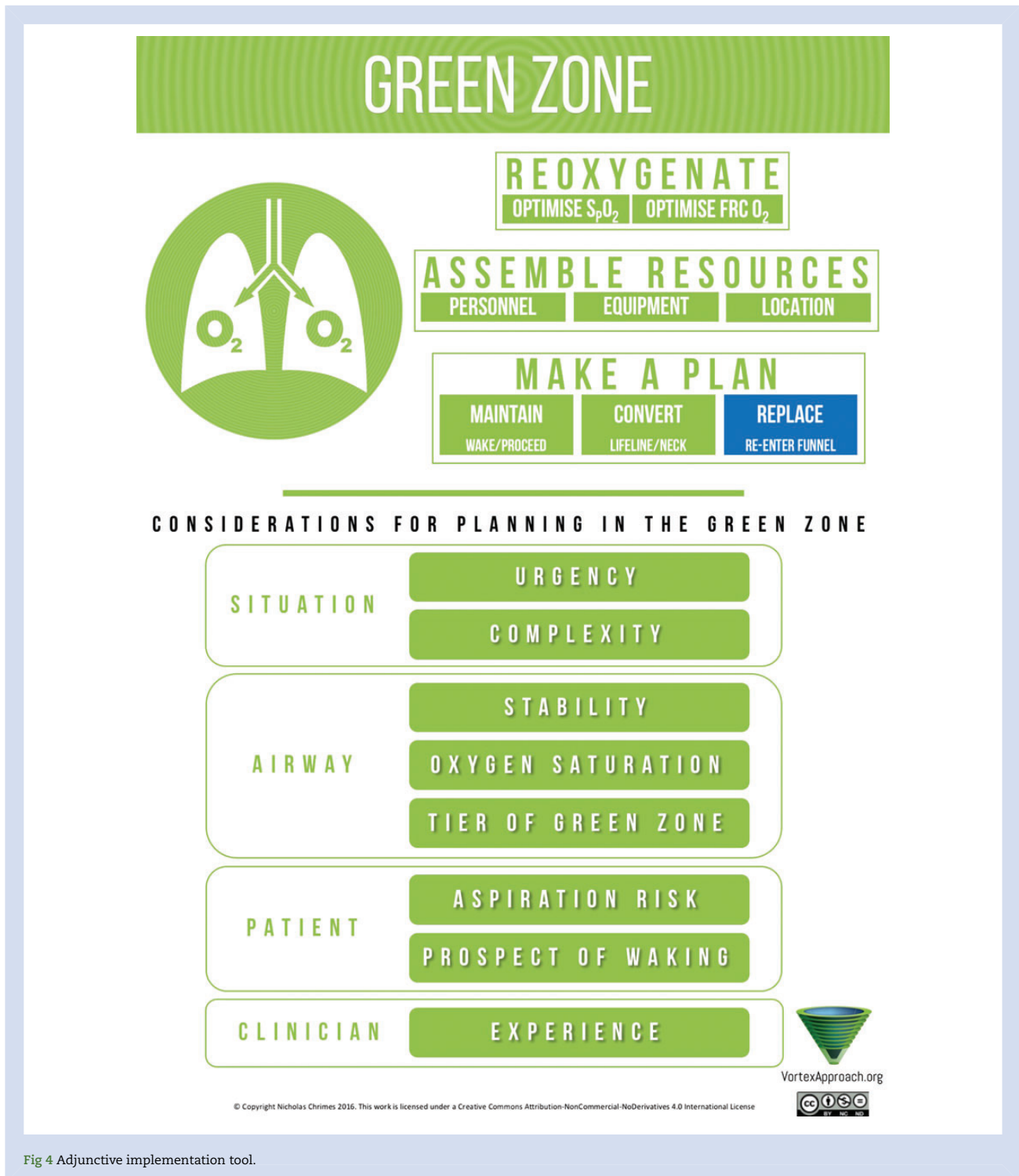


Fig 4 Adjunctive implementation tool.

tool (Fig. 5). The CICO status thus serves to facilitate early transition to CICO rescue by integrating both practical and psychological priming for this confronting procedure in parallel with successive unsuccessful attempts to establish airway patency via the upper airway lifelines. Team leaders may also trigger an additional escalation in CICO status according to other recommended criteria or their own clinical judgement, but CICO status

should not reach 'go' until a declaration is made that best efforts at all three lifelines have been unsuccessful.

Conceptual imprinting

The circular graphic on the Vortex implementation tool is intended to represent looking down into a funnel. Narrowing of



Fig 5 The 'can't intubate can't oxygenate' (CICO) status implementation tool.

the funnel implies the diminishing time and options available as one spirals deeper into the Vortex and the inevitability of needing to initiate CICO rescue once best efforts at all three lifelines have been unsuccessful. The deepening blue colour lower in the funnel suggests imminent hypoxaemia if airway patency is not restored. These visual cues are intended to promote team situational awareness. The pattern of concentric rings in the circular CICO rescue zone at the bottom of this funnel deliberately evokes the visual perspective of looking down the lumen of the trachea, with the 'shard' icon penetrating its wall. This creates an additional graphic prompt for initiating CICO rescue. The juxtaposition of the central green zone with the bottom of the funnel is intended to balance the inherent conflict associated with performance of CICO rescue: it is undesirable if avoidable but essential when indicated. Although it is important to reinforce that CICO rescue is an invasive procedure to be used as a last resort in airway management, in isolation this concept and the bottom-of-the-funnel metaphor could be interpreted as intimidating and implying failure of the clinician. This potentially creates a psychological impediment to proceeding to CICO rescue that might delay or deter performance of this procedure when it is required. If best efforts at all lifelines have been unsuccessful, CICO rescue is a crucial intervention to make the patient safe. The visibility of the green zone at the bottom of the funnel is intended to convey this path to safety and to encourage clinicians to proceed in this circumstance.

A supplementary illustration used for training (a 'foundation graphic' which is not part of the implementation tool) shows the lateral aspect of the Vortex in three dimensions to demonstrate the funnel concept (Fig. 6). In this three-dimensional image, the area where alveolar oxygen delivery cannot be confirmed is represented by the interior of the funnel. The sloping surface inside the funnel reinforces the need to implement best efforts efficiently to restore airway patency via each of the upper airway lifelines in order to avoid clinical deterioration. In contrast, the green zone encompassing the funnel (enabling it to be visible both inside and outside the funnel on the implementation tool) comprises horizontal surfaces, emphasizing that it represents an opportunity to pause and plan.

Using the visual metaphor of a funnel provides a 'conceptual imprint' to convey these additional aspects, obviating the need for the implementation tool itself to make explicit reference to

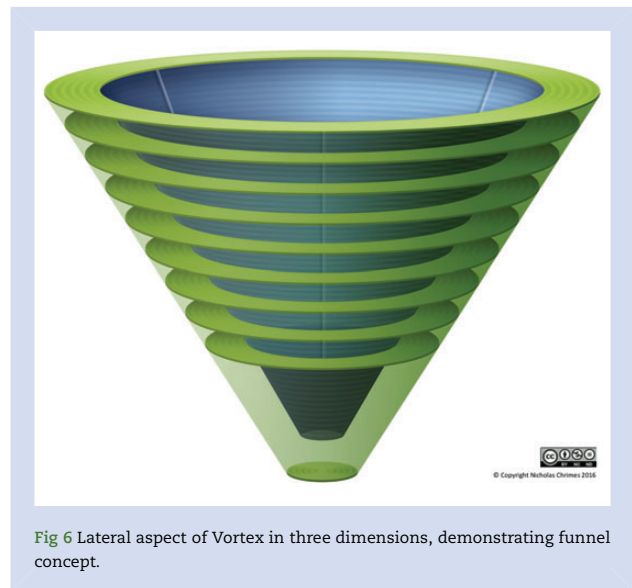


Fig 6 Lateral aspect of Vortex in three dimensions, demonstrating funnel concept.

them and allowing it to maintain a simple, low-content interface. The conceptual imprinting process is supplemented by the vivid nature of the name 'Vortex', which affords a concise mechanism for some of these imprinted concepts to be expressed further verbally, as in the example below. Moreover, the Vortex moniker and its associated logo create a 'brand', exploiting strategies used in marketing to heighten memorability. This has the potential to enhance awareness and recall of the implementation tool and its underlying concepts which augments the utility of the tool, during the stress of managing a challenging airway.

Critical language

The emphasis of the Vortex is on team performance rather than performance of the individual clinician. The Vortex creates a common template for airway management that is intended to facilitate team situational awareness. Cardiac arrest management includes verbal declarations, such as 'no pulse' or 'shockable rhythm', which convey critical moments of situational awareness to the clinical team. These create a shared mental model and assist team members in anticipating the next steps in management. Such critical language is known to be important to enhancing teamwork and minimizing error, particularly between clinicians from different clinical backgrounds.⁸ In addition to the graphic tool, the Vortex introduces standardized terminology, such as 'completed best effort', 'in the green zone', 'CICO status', and 'sucked into the Vortex'. This provides an analogous lexicon to facilitate airway crisis management.

Discussion

The design requirements of a guidance tool for airway emergencies differ according to whether the intention is for it to be used before or during the occurrence of an airway crisis. An effective high-acuity implementation tool must address not only the specific technical factors known to impair clinical performance but also the human factors that make it able to be used in situations of stress.^{6,7} The Vortex implementation tool has been developed with consideration of these principles to create a novel, simple, visually based tool, which is better suited for real-time use in an emergency than the traditional high-content, text-based

decision algorithms.⁴ The Vortex should not be considered an alternative to these algorithms but a complementary tool, intended to facilitate implementation of the principles they advocate, and assist clinical teams to perform under pressure.

The primary purpose of the Vortex is to avoid the CICO situation by facilitating efficient implementation of best efforts at each of the upper airway lifelines and encouraging recognition of the significance of achieving alveolar oxygen delivery, even when this has not been achieved by the primary desired method. It also prompts early priming for CICO rescue as an airway scenario evolves and gives teams permission to implement this in the rare situation where all three upper airway lifelines are unsuccessful and CICO is declared.

Another distinguishing feature of the Vortex is that it has been designed to be flexible enough to be applied universally to all episodes of airway management. This single tool can be used by all clinical teams who deal with airways, not only in anaesthesia but also in emergency medicine, intensive care, pre-hospital, and other resuscitation settings. By providing a common template across specialties, the Vortex may be particularly beneficial in enhancing teamwork and communication when these diverse groups of clinicians come together at short notice to manage airway emergencies.

Although designed to be referred to during an unfolding airway crisis, previous familiarity and training in use of the Vortex tool is required for it to be used effectively. The Vortex implementation tool is only one aspect of the broader 'Vortex Approach', which provides complementary foundation material using the same language and concepts, supported by an inter-professional team training programme.^{14 15} Even the implementation tool itself is not restricted to being used during an unfolding emergency. It can also be used in a lower acuity setting as a format for clinicians to plan airway management for a particular patient, enabling them to make decisions and brief the team in advance. This might include anticipating the sequence in which upper airway lifelines will be attempted, the optimizations to maximize their potential for success, and the definitive end points of a completed best effort. This provides teams with the opportunity to clarify strategy and ensure availability of resources before embarking on airway management. In addition, use of the implementation tool as a template for planning routine management would be expected to enhance familiarity and reinforce the Vortex model, with potential improvement in the ability to recall and use the tool in an emergency setting. Given the simplicity of the implementation tool and the conceptual imprinting provided by the visual metaphor of the funnel, it is conceivable that sufficient familiarity could ultimately lead to the physical representation of the Vortex becoming irrelevant in the emergency setting. Instead, the tool could be seen in the mind's eye of clinicians, which is recognized to be an ideal feature of an implementation tool.²⁰

The Vortex exhibits many features of an ideal implementation tool.^{6 20} A recent report on transition to CICO rescue identifies the potential of the Vortex directly to target human factors affecting team performance and protect against fixation and omission errors in an airway crisis.⁴ Anecdotal use of the Vortex during real airway emergencies supports this idea,²¹ but experimental research is now needed to establish its validity.

Declaration of interest

All intellectual property relating to the Vortex is owned by the author and is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License.

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