EMAC Course

ANZCA
AUSTRALIAN AND NEW ZEALAND COLLEGE OF ANAESTHETISTS

Effective Management of Anaesthetic Crises (EMAC) **Participant Manual**

Third Edition 2018

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EMAC Course Participant Manual

Editor

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Introduction

Welcome to EMAC! Thank you for registering for the course and we hope that you will find it beneficial to your practice of anaesthesia. Instructors and staff of the simulation centre will strive to ensure that you have a rewarding educational experience.

Structure of the Course

The Effective Management of Anaesthetic Crises (EMAC) Course is the only course that is overseen by the Australian and New Zealand College of Anaesthetists (ANZCA). It includes five discrete half-day modules, typically run over three consecutive days.

The modules are usually presented in the following order:

- Human Factors
- Human Factors applied to Cardiovascular Emergencies
- Airway Emergencies: A Human Factors Approach
- Human Factors applied to Anaesthetic Emergencies
- Human Factors applied to Trauma

This course has no exam. There is no assessment. We only ask that you participate to the best of your ability in scenarios and contribute to discussions and learning activities. Participation is a requirement for EMAC certification and occasionally a participant is unable to attend the entire course at one sitting and so needs to come back another time to do so. We accept that all participants are intelligent, caring professionals that are providing the best care to their patients.

The EMAC course is a mixture of:

1. Scenario-based simulations
2. Skill stations
3. Group activities
4. Problem-based learning discussions

How to use this manual

The authors of the five modules have produced this course material to outline the most important information that may assist with management of crises encountered in clinical anaesthesia practice. The manual contains a generic approach, and specific guidelines for management of many emergencies.
There are activities for you to complete prior to the course. Some include trying a specific skill in your workplace and others request that you watch a video.

No-one expects or wants clinicians to memorise every protocol or guideline that is referred to in this manual. We would rather you used cognitive aids during crises. However, we ask that you do read this manual and attempt each activity as you progress through the 5 chapters. **It is likely to take you 2-3 hours to engage with the learning material in each chapter** (i.e. approximately 15 hours in total to read the chapter and linked articles, watch linked videos and complete activities). Please allow yourself enough time to complete this thoroughly.

If you do **not** read this manual and **complete** the activities, you will be at a disadvantage during EMAC.

By reading the manual and attempting the activities; you will derive maximum benefit from the course. The associated documents and video files are best viewed using Google Chrome as your internet browser.

Your safety

Simulation-based education is powerful and sometimes even confronting. EMAC Instructors will attempt to make the clinical setting as realistic as possible. We ask that you try to behave as you would in an actual clinical situation. Unless you are actually stopped by centre staff, please undertake patient care as you would normally with your personal safety, and that of your colleagues, in mind.

Defibrillators at the centre are frequently actual 'live' devices that require safe handling when used. Also, please take care with needles, scalpels and glass ampoules. Gloves and sharps containers are provided. In general, simulation centres are latex-free.

If you have a special need or medical condition, please make it known to the staff.

Real emergencies. If you have a personal emergency, please raise your hand and state that "This is not a simulation – I have a real emergency", to the staff. If there is a fire or other type of environmental emergency, please follow the directions of the simulation centre staff.

Confidentiality

EMAC and other simulation-based courses rely on a high level of confidentiality to be maintained. Unless specifically agreed beforehand, we guarantee that confidentiality will be strictly observed by the EMAC Faculty and staff and we ask that you refrain from discussing the behaviour of other participants, and sharing the scenarios, with anyone, after you leave the course.

Confidentiality Forms: These forms will be distributed at the EMAC course and maintained by the simulation centre. Participants are reminded that it has taken considerable effort to produce realistic scenarios and that it is in the interest of their colleagues that they are not shared with others.
Photography and Videography Release Forms: Completion of these forms allow simulation centres to seek permission from participants to use such material for educational purposes. Please be reassured that images and video will not be used

without obtaining your consent. Further, in the event that you do not give permission for use of your image that appears in any scenario, then those images cannot be used.

Breaks and dress code

Typically, the course runs over three days. Generally, on full days, morning tea, lunch and afternoon will be provided during the breaks. The simulation centre will advise regarding specific arrangements. If you have special dietary requirements, please contact the centre to let them know of your needs.

Participants will be asked to change into **surgical scrubs** during the course. Please wear comfortable shoes.

Please feel free to bring your own **stethoscope**. Your mobile (cell) phone should not be audible during the course and ideally it will be turned off.

More information regarding the specifics of the course for which you have registered, including start times and paperwork that must be submitted, will be provided by the centre running the course.

Tips for working in the simulator during a scenario

Simulation-based learning is enhanced when participants accept that the situation is made as realistic as possible and that you should 'suspend disbelief' during scenarios. A mannequin may not appear to be entirely lifelike but the pharmacology and physiology are quite realistic. Real equipment is used and trained staff fulfil many roles found in a hospital's operating suite or other acute care area. It can be useful to imagine that you are working as a locum in an unfamiliar hospital. Sometimes time is 'compressed' to allow all activities to be completed in the allotted time. Thus, a 30-minute, cardiac-style anaesthetic induction might be less tolerated in the simulation centre than at your cardiac theatre where you work. As in real-life, simulation centre staff may be tired, distracted or less helpful than you expected. You can be assertive in your communication but please remain courteous.

Usually one, or sometimes several, participants are asked to be the primary carer(s) (**First Participant**) of the patient. These patients may be located in the operating theatre or elsewhere in a hospital. You have an opportunity to summon colleagues to assist with management of the patient. Other course participants who are not caring for the patient will be observing from another location. All participants rotate through various roles during the course and will have similar exposure times. During periods of observation, you may be given a written task to complete to assist with the discussion afterwards.

Simulation relies on participants interacting with the simulator, colleagues and other staff. Actual tasks and procedures need to be done. Drugs and anaesthetic agents need to be administered. Simply telling staff that you are giving a particular drug without actually drawing it up and injecting it into an IV line will not be effective. There is a **familiarisation** session at the commencement of the course that will introduce you to the mannequins and theatre environment. This is equivalent to an orientation at a new hospital.

Debriefing after a scenario

Following a scenario, there is a period of discussion and reflection that allows participants to explore behavioural and clinical matters that were observed during the crisis. Both participants and observers will have the opportunity to contribute their perspective during the debriefing activity. Please share the airtime, respect the opinions of others and remain courteous and open to others' comments or suggestions.

Feedback

After each module you will have the opportunity to provide written feedback about the module that you have just completed. There will also be a separate feedback form for the entire course and is usually provided immediately before you receive your certificate.

Some participants will experience an actual real-world crisis after return to their workplace and may wish to let the EMAC Convenor know about their experience. This, and any other type of feedback, is very welcome.

It is normal, and expected, that course participants will reflect on their experiences during EMAC for weeks to months after the course. Occasionally, participants can feel ongoing concern or anxiety about their experience at the EMAC course. If you need to discuss any matters after the course, please contact the EMAC Course Convenor.

Acknowledgement of Copyright

The ANZCA cognitive aid, DAS Guidelines, CAFG Guidelines, ASA Guidelines, Vortex Approach, Simpact Videos and RPH CICO Algorithm are copyrighted material and remain the exclusive intellectual property of the parent organisations/authors who developed them as described in each of the respective source documents. These resources have been included in EMAC in accordance with their respective licensing agreements. The DAS guidelines, Vortex Approach and Simpact Videos are licensed under a Creative Commons Attribution Non-Commercial No Derivatives 4.0 International License.

Disclaimer and your professional development

EMAC course instructors encourage participants to seek further information or clarification on manual content from recommended readings or other peer-reviewed resources. Anaesthesia is a dynamic specialty and EMAC is just one component of your professional development. It is not a substitute for maintaining currency in crisis management and you should consult various organisations and literature to keep yourself up to date. We hope that this simulation-rich course prompts you to seek further courses that offer similar learning methods.

If you find that EMAC is a beneficial course, please do not hesitate to recommend it to your colleagues. Also, if you wish to consider becoming an EMAC Instructor, please discuss it with one of the Faculty.

Participating in a full Effective Management of Anaesthetic Crises (EMAC) course will cover both the CICO and cardiac arrest activities from the emergency responses category. To claim these activities within the CPD portfolio please use the recognition codes provided below:

EMAC CICO recognition code: ER-14-CICO-888
EMAC cardiac arrest recognition code: ER-14-CA-888

Abbreviations and Acronyms

The following terms are used in the EMAC course:

EMAC Supervisor – the ANZCA-approved Instructor responsible for the EMAC course at a particular centre
EMAC Convenor – the EMAC Instructor responsible for an individual course
Module Leader – an EMAC Instructor responsible for a module
First Participant – an EMAC participant initially required to manage a patient
Responder- an EMAC participant summoned to assist a First Participant
Confederate – Simulation Centre staff person acting in a defined role in a scenario

Learning Outcomes

With each chapter of this participant manual, learning outcomes articulate what you should know, or be able to do, after reading the material prior to the course.
By the end of each module of the course, a participant will be able to:

Human Factors

- Interact with the simulated environment in a manner that facilitates learning
- Participate with confidence in a debrief of a simulated event
- Apply non-technical skills outlined in the participant manual in simulated events including examples of effective communication: ISBAR, closed loop communication, team recaps and speaking up.
- Identify cognitive biases and discuss strategies to prevent them.

Human Factors applied to Cardiovascular Emergencies

- Differentiate the features and management of intraoperative cardiac arrest from cardiac arrest in the community.
- Demonstrate the use of the ALS algorithm during an intraoperative cardiac event.
- Recognise and demonstrate the perioperative management of:
    - Myocardial ischaemia & the acute coronary syndromes
    - Cardiac arrest
    - Common cardiac arrhythmias
    - Emergency vascular access
- Demonstrate the use of effective teamwork behaviours particularly, graded assertiveness, team recaps, structured handover, and delegation of areas of responsibility.
-

Airway Emergencies: A Human Factors Approach

- Describe how cognition can be impaired by the stress of emergent situations leading to diminished performance in technical tasks, decision-making and leadership.
- Describe the key features of a cognitive aid designed for use during airway emergencies.

- Outline an integrated team approach to the management of airway obstruction and transition to CICO, including utilisation of a cognitive aid promoting a shared mental model.
- Demonstrate effective communication techniques with the goal of optimising team performance in managing airway obstruction, transition to CICO and CICO Rescue.
- Perform technical components of an integrated CICO Rescue approach, including both cannula and scalpel techniques.
- Discuss the pros and cons of both a cannula-first approach and a scalpel-only approach during CICO Rescue.
- Demonstrate how the cognitive aids, team approaches and CICO Rescue techniques described above, can be incorporated into an overall airway management strategy during a simulated airway emergency.

Human Factors Applied to Anaesthetic Emergencies

- Identify gaps in his/ her understanding of teamwork behaviours, relative to other participants.
- Describe the elements and discuss the application of closed loop communication, perception and/or a 'speaking up' framework.
- Diagnose and manage hypoxia and high airway pressure using a systematic approach.
- Demonstrate the use of the ISBAR framework to arriving helpers.
- Demonstrate hands-off leadership (or unloading the leader) and recapping.

Human Factors Applied to Trauma

- Demonstrate the process of evaluation and resuscitation of a trauma patient in an operating suite.
- Recognise and manage evolving injuries during anaesthetic care of the trauma patient.
- Discuss the importance of teamwork behaviours within trauma teams to optimise patient care.
- Demonstrate the ability to coordinate management priorities and implement effective team behaviours.
- Manage specific problems including airway injuries, intracranial trauma, large volume resuscitation, damage control resuscitation, trauma-related coagulopathy.

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Human Factors

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Introduction

In this first chapter we will discuss Human Factors, what they are, why they're important and give you some tips to improve your skills.

Ideally, you will have practiced these skills for several weeks prior to the EMAC course. If not, we highly recommend you reflect on cases you've been involved with and think about what worked and what could have been done differently to improve the team performance and outcomes.

The Human Factors Module is the core module of the course and the concepts introduced in this chapter will be reinforced throughout the course.

The key concepts covered here are:

- How anaesthesia and indeed all work in health is influenced by the health systems we work within.
- How adverse events occur and what we can do to prevent them.
- Practical aspects of teamwork and communication during anaesthetic crises (Summarised in Table 1).

The first and second sections of the chapter deal with the nature of the healthcare system, the work we do and how adverse events occur.

The second section of the chapter deals with the so-called 'sharp-end' of anaesthesia delivery. We will consider factors from an individual practitioner and team perspective that may prevent or mitigate adverse events and how these can be practiced and embedded into daily practice, not just when crises occur.

Chapter Outline

1. Safety Science as Applied to Anaesthesia
    - 1.1 Systems approach to safety management
    - 1.2 Anaesthesia as a complex system
    - 1.3 Anaesthesia is sociotechnical

2. Why anaesthetic care is usually successful, but occasionally goes wrong
    - 2.1 System vs person approaches to tackle safety issues

Learning Outcomes

By the end of this chapter, and prior to the course, a participant will be able to:

- Describe a systems approach to safety management.
- Identify cognitive biases and performance shaping factors in their own practice.
- Discuss the importance of task management.
- Describe some of the common ways teams can work more effectively, including team leadership, having a shared understanding of the situation, closed loop communication and mutual performance monitoring.
- Describe the components of situation awareness.
- Explain system 1 and system 2 models of cognition in anaesthesia and the role of cognitive aids in system 2 thinking.
- Discuss the concept of 'second victim' effects and strategies to support colleagues after an adverse event.

An Inventory of Teamwork Behaviours in Health
Leaders • Are explicitly identified and ideally have a 'hands-off' role • Ensure all roles are allocated appropriately • Share the mental model with the rest of the team • Prioritise tasks and guides the adaptation to new challenges • Monitor task performance and reallocate resources as required **Followers** • Clarify who has the leadership role if it is unclear • Centralise information to the leader • Off-load tasks from the leader – take a role appropriate to experience • Verbalise clinical interventions to maintain team situation awareness • Ask for team recaps from the leader • Speak up if a possible hazardous inaction/ action is spotted **All team members** • Seek help early • Use structured communication such as ISBAR • Use closed loop communication • Challenge assumptions made during decisions – discuss options among the team • Use a cognitive aid if it's available – have one team member read it aloud • Be alert to task overload in yourself or others. If possible ask for more resources

Table 1. An inventory of teamwork behaviours to practice that will be reinforced in the EMAC course. Adapted from Weller et al 2011.[1]

1. Safety Science as Applied to Anaesthesia

1.1 Systems approach to safety management

Anaesthetic safety has indisputably improved over the last few decades. Bodlander in the 1970s estimated mortality directly related to anaesthesia (in Australia) was 5.9 per 10,000 anaesthetics.[2] By 2008 the mortality related to anaesthesia was less than 0.2 per 10,000 anaesthetics; a thirtyfold reduction despite an aging population, higher proportion of patients with chronic diseases and a higher number of average chronic diseases per patient.

So what has made anaesthesia safer?
Anaesthesia has certainly adopted better drugs, monitoring and safety checks over the last 30 years. These have occurred through:

- Technological 'fixes,' such as introducing non-interchangeable gas supplies with a physical barrier (pin-index system) to misconnections.
- Procedural 'fixes,' such as standardising procedures and introducing minimum standards for central line insertion to prevent line associated infections.
- Educational 'fixes', such as mandating initial training and continuing professional development standards and indeed courses such as EMAC.

Anaesthetic practitioners expect to perform almost flawlessly despite a variety of technical and social factors that challenge optimal performance:

- Less than ideal environmental conditions (inadequate lighting, noise, temperature, ergonomics of equipment)
- Distractions (alarms, phone calls, competing tasks)
- Physical and mental well-being (e.g. fatigue, illness or social issues)

Now read the short article by David Gaba[3]:
Anaesthesiology as a model for patient safety in health care

ACTIVITY
Why is anaesthesia still a model for patient safety in health care?
Give two examples that have made anaesthesia safer since the early 1980s.

As with aviation, the attribution of causes of adverse events has shifted from unreliable equipment to human and team performance issues. Finding ways of improving performance within an imperfect system is the main purpose of the EMAC course.

1.2 Anaesthesia is a complex system

In order to understand how adverse events and patient harm occur, we need to know a little more about our work system.

Anaesthesia is characterised by factors that often make both decision-making and performing actions challenging.

> **ACTIVITY**
> Why do you think decision-making in anaesthesia is challenging?
> (Give two examples)

Refer to Table 2 for factors that make anaesthesia a complex activity, which were originally identified by Orasanu and colleagues.[4] You will recognize some of these in your daily practice.

Features of anaesthesia as a complex system
▪ **Uncertainty** The cause of a problem is often not clear so the 'correct' course of action is also uncertain ▪ **Problems are ill-structured** There is commonly more than one solution and some decisions are interrelated ▪ **Goals are often ill-defined and competing** For example a surgical request for hypotension may compromise cerebral perfusion ▪ **Action-feedback loops are complex** Responses to actions and medications are sometimes unpredictable because of complex and opposing physiological processes ▪ **High stakes** Anaesthesia involves the disturbance of homeostatic processes critical to life (such as oxygenation) and is inherently dangerous ▪ **Decisions are commonly time critical** Actions involved with airway management and perfusion must be undertaken before deterioration and lasting harm occurs ▪ **Organizational constraints exist** Health resources are limited. Equipment might not be available, staffing may be inadequate, there may be pressure to proceed when circumstances are not ideal

Table 2. Features of anaesthesia as a complex system. Adapted from Orasanu et al.[4]

1.3 Anaesthesia is sociotechnical

Anaesthesia is also described as 'socio-technical', which contributes to its complexity as a system. This means the performance of anaesthetists strongly depends on interactions with other people and with technology.

In terms of technology, for instance, the way that information is displayed on an anaesthetic monitor substantially influences our assessment, and hence understanding, of the physiological state of the patient being monitored. A poorly designed monitor might make it more difficult to recognise deviations from normal or trends towards instability. Alarms that are distracting, too frequent or irrelevant may degrade performance rather than inform and augment performance.

Performance of anaesthetists is also facilitated (and limited) by other people on an organisational basis. For example, standards for staffing, equipment and procedures are imposed by your anaesthesia department, your hospital institution, your professional organisation and by government regulations.

In terms of social influences, for instance, anaesthetists work in small teams with surgical and nursing colleagues each defined by their own professional cultures, subcultures and expectations. Effective teamwork is essential in anaesthesia as it improves safety and quality of care and can be enhanced by specific strategies and actions. We will give some strategies for this later in the chapter.

The many cognitive and social roles of the anaesthetist

Cognition or 'thought processes' in anaesthesia are complex. The anaesthetist has to monitor the situation, communicate with others, predict, plan, and prioritise actions. We pattern match with previous situations we've encountered, and compare the present situation with what we expect, drawing from experience.

These different 'modes' of thinking rely upon skill and prior practice to switch among them appropriately, even during routine situations. In non-routine situations with time pressure (a crisis) a lot of the workload is thinking about what needs to be done, but also who could do it and what the priorities are.

2. Why anaesthetic care is usually successful, but occasionally goes wrong

2.1 System versus person approaches to tackle safety issues

First read this landmark article by Dr James Reason, a psychologist from the UK.[5]
Human error: models and management

Reason describes two models of how adverse events occur; one that focuses on the person and one that takes a system approach. Person-based approaches focus on errors that are made at the frontline, regarding these as 'unsafe acts' that need to be eliminated to make the system safer. These unsafe acts are commonly classified as:

- Skill based errors, also termed 'slips' or 'lapses' occur when we are distracted performing familiar tasks such as writing our own name, rather than the patient's name on the form.
- Rule based errors occur when we misapply a commonly used rule (or 'heuristic') such as administering metaraminol for hypotension without taking into account an existing bradycardia.
- Knowledge based errors, occur due to insufficient knowledge or experience such as failure to recognise predictors of difficult intubation or face mask ventilation.
- Violations, occurring as a result of intentional deviations from recommended procedures such as deliberately shortening central venous catheters to reduce redundant length (which may result in embolisation of the guidewire).

By understanding the type of errors occurring in the run up to an adverse event we may be able to understand how the error can be prevented in the future. For example, accidental injection of a muscle relaxant instead of midazolam is a recognised cause of awareness before induction. This might be prevented in many instances by routinely using a 3mL syringe for midazolam and only a 5mL red-barrelled syringe for muscle relaxants. Creating a routine such as this provides tactile and visual cues that make a 'slip' of picking up the wrong syringe less likely.

In contrast, a systems approach takes into account the circumstances in which the person making the error works within. System approaches take a holistic view and look at the broader work environment, equipment and procedures that may contribute to failures. For example, the above-mentioned example of colour coding and labelling of syringes is an example of a systems approach to minimise error.

In the healthcare professions, person approaches are still frequent. It is simpler to *'name, shame and blame'* individuals rather than find out why a problem emerged within an organisation. It perhaps gives a sense of security to the general public, sells newspapers and makes for an easier target for litigation to think there was a single 'bad apple' rather than a complex system failure. It is true that clinicians may be negligent or even malicious in their actions, but this is extremely rare. Most often, violations of protocols and procedures occur because they are either not known at the time, or are perceived to be impractical or inefficient in the context of the work.

ACTIVITY
Take a moment to think about a case you may have seen, or one that's been reported in the media recently. Was it really just a single practitioner involved, or was there a system of care that allowed the adverse events to happen?

Health care organisations 'by law' must have defined processes for investigating and dealing with adverse events.

ACTIVITY
Find out what the procedures exist in your hospital for investigating adverse events when harm occurred (often termed Incident Severity Rating, ISR or SAC 1 and 2 events) and for when harm did not occur (these are the ISR 3, 4, and 5 events).

2.2 Safety barriers in anaesthesia

Reason's Swiss cheese model proposes the presence of multiple imperfect 'barriers' to incidents and promotes the idea that adverse events in anaesthesia always have multiple contributing factors.

ACTIVITY
Recall an incident from a morbidity/mortality meeting or one you have been involved in. What were the barriers to the incident occurring and how did they fail?
Could this have been predicted?

Figure 1. An example of a latent condition – storing medications that look similar in the same location (photo courtesy of Nicholas Chrimes).

A combination of active and latent conditions results in an adverse event. Consequently, this model predicts that errors can be prevented if appropriate barriers or 'defences' are set in place. One example of such a defence is the World Health Organisation (WHO) Surgical Safety Checklist. By requiring operating theatre personnel to confirm that critical steps have been undertaken and to share relevant information, routine use of this tool has substantially reduced morbidity and mortality in surgical patients.[6]

The focus on prevention of failures goes along with a particular view on what ‘safety’ actually means. Defining safety as the absence of risk, and hence preventing things from going wrong in the future by studying errors and implementing barriers has been termed ‘**Safety 1’**.

2.3 A new way of conceptualising safety: Safety 2

Safety 2, or resilience, takes the view that the human is not the weak point in the system, but is the reason why more of the latent conditions described in the Swiss cheese model don’t become active and harm the patient.

Now read the following editorial on resilience in anaesthesia:
Safe anaesthetic care: further improvements require focus on resilience

The resilience view sees safety as a ‘dynamic non-event’: ‘dynamic’ because it is under continuous, timely adjustments by the anaesthetic practitioners, and ‘non-event’ because our successful strategies lead to near misses rather than observable critical incidents.

There are four resilient behaviours used by healthcare professionals[7]:

- *Anticipating the potential*: ‘knowing what might happen’
- *Monitoring critically*: ‘knowing what signals to look for’
- *Responding to actual events*: ‘knowing what to do’
- *Enabling learning from failures*: ‘spreading knowledge of what happened’

Examining why things go well most of the time and the adaptations and strategies used by anaesthetic practitioners to mitigate adverse events, enables us to work more safely within our own complex work systems.

ACTIVITY
Think of the last time you anaesthetised a patient with multiple co-morbidities and it went well. Was it really uneventful? Were there things that you and the team did to prevent potential hazards reaching the patient?

2.4 So what is ‘Human Factors’ again?

ACTIVITY
Write down what you understand by the term ‘Human Factors’?
What does this include?

Now have a look at the definitions listed here on the Australian Health Human Factors website
This page also includes a list of subspecialties of human factors experts.

As you can see Human Factors is more than just the interaction between people, how we form teams and how we communicate. Human Factors isn’t just about preventing ‘human error’ but also how we design systems that humans work in to make sure the human is there for the right reasons. For instance humans perform poorly on vigilance tasks when compared with electronic alarm systems. A method to relieve some of this burden is to create well-designed alarms that detect changes in a patient's status and alert us appropriately.

You can read more about what Human Factors is (and what it isn't) in this article: The science of human factors: separating fact from fiction

And here is an entertaining video made by some engineering students about Human Factors design principles

3. Practical application of Human Factors in Anaesthesia

3.1 Improving your 'Non-Technical Skills'

The remainder of this chapter will look at problems that are commonly encountered in anaesthetic practice and how you can train yourself to guard against them.
Key to this is the idea of Non-Technical Skills (NTS), sometimes called "soft skills".

ACTIVITY
Is there one person that you have worked with that is 'good in a crisis'?
What is it that they do that makes them particularly effective?

Non-technical skills:
"Non-technical skills are the cognitive and social skills that complement technical skills to achieve safe and efficient performance" [8]

In other words, everything else that is in addition to medical knowledge and skills you use for your work. Some anaesthetists are naturally observant, good communicators, and leaders. For the rest of us, the good news is that these 'non-technical skills' can be learned and practiced.

Non-technical skills can be classified and taught in many ways. One early method that is still used is through the 'key points' of Crisis Resource Management as described by Gaba and colleagues. This is an inventory of ideal behaviours originally developed in the aviation industry.[3] Interviews with experienced anaesthetists, analyses of routine work plus simulated and actual crises have also identified non-technical skills that are important in safe effective management of anaesthesia. These have been outlined as the – been formulated into the Anaesthetists Non-Technical Skills (ANTS) framework, shown in Figure 3.

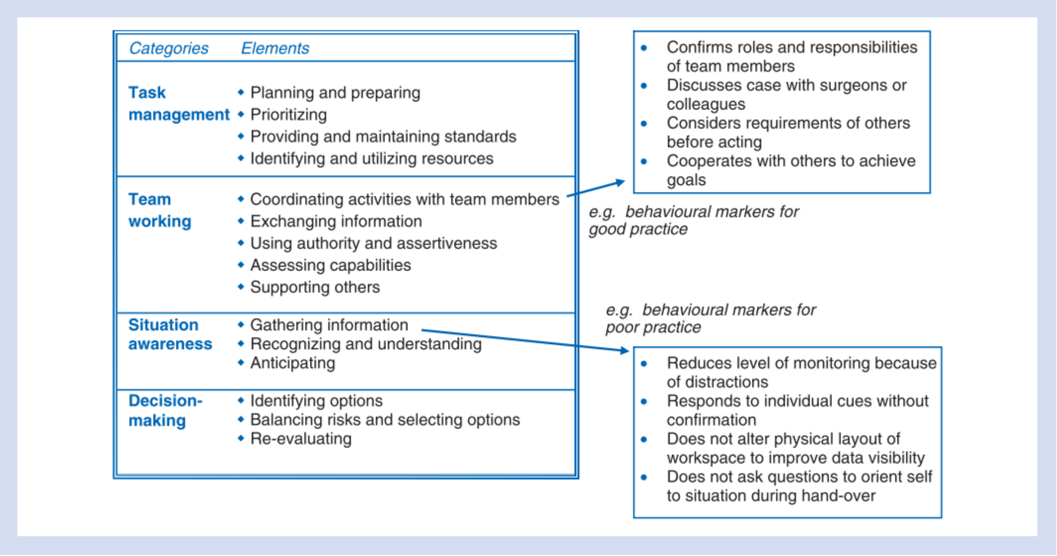


Figure 3. The ANTS framework[9]

The full explanation of the ANTS framework is available here in the ANTS Handbook.

Let's take each of the categories in the ANTS framework and examine how we can improve our non-technical skills; not just in crises but in everyday anaesthesia delivery.

3.2 Task Management

Task management includes planning and preparing, remembering and prioritising jobs to be done, ensuring safety standards are maintained and all resources are utilised.

Planning and preparing

Obviously, part of planning and preparing include the routine checks of the machine and equipment. Remember that the other staff you are working with also need to feel prepared particularly if you are expecting things to be anything other than routine. The current Difficult Airway Society (DAS) guidelines[10] for example, emphasise the importance of a team briefing prior to managing a suspected difficult airway.

Briefing is an activity designed to create a unified or shared mental model of a team's goals, challenges and plans.

An anaesthetic briefing helps the anaesthetic assistant prepare the equipment you might need, particularly during an emergency and may avert specific complications including, as an example, regional anaesthetic blocks on the wrong site / wrong side.

PRACTICE TIP
Have a meaningful briefing with your anaesthetic assistant at the start of a list, and before each case. Include contingency plans even in expected routine cases – after all, 90% of difficult bag-mask and intubation cases are unexpected despite airway assessment.[11]

As we will see later, we may feel reluctant to make some decisions, such as cancelling because of a sense of pressure to proceed ('production pressure'). If you feel that something may not be right you must stop and review your plan. A good example of this is failing to adapt your plan for intubation in the light of clear evidence of potential difficult intubation.

Prioritising

During emergencies, stress can make it difficult to identify priorities for treatment. Furthermore, many team members may be completing multiple tasks in parallel, but even so priorities can still change. For instance, in a trauma case the patient may develop a tension pneumothorax requiring immediate treatment. The team may have to be re-organised to do this quickly.

> **PRACTICE TIP**
> There are often three of four clear priorities in any emergency that can be remembered and easily enacted before help and more resources arrive. In your quiet times, try to think of the first three things you should do for each potential emergency. It might just be a generic "ABC" approach, or you might for example remember "oxygen, adrenaline, remove trigger" for anaphylaxis.

Priorities can be more easily identified if a cognitive aid such as a well-designed checklist or flowchart is visible or can be read out to you while your hands/ brains are full.

Maintaining standards

During emergencies, distraction and stress increases our risk of committing skills based errors such as syringe swaps and blood transfusion errors. Developing safe routines will help to ensure that you do the same thing in times of stress. Don't try to cut corners in emergencies.

Identifying and using resources

Time critical, novel situations generate high physical and cognitive workload. Calling for help early will enable you to mobilise additional resources. Recognising when you and/ or you team members are becoming physically or cognitively overloaded is equally important.

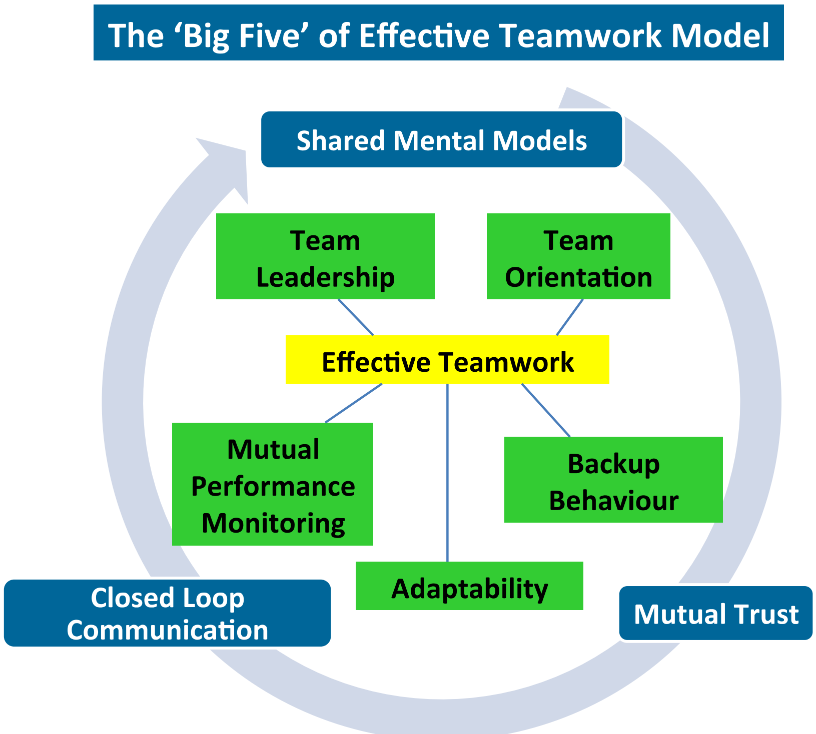
> **ACTIVITY**
> Think of a circumstance where help might not be immediately available such as anaesthesia in a location away from the theatre complex, or at a time when few people are around. How will your call for extra help differ from normal? Who else could assist while experienced help is on the way? What about the timing of the call?

> **PRACTICE TIP**
> Always have a backup plan for additional help. It might just be a phone call for reassurance. In quiet times, think of the worst possible scenario that could happen and mentally assign each team member to a task. Don't forget that the surgical team is a valuable resource with useful skills and use them appropriately to help you do or think.

3.3 Team-working

What is a team?
"A team is two or more individuals with specified roles interacting adaptively, interdependently, and dynamically toward a common and valued goal"[12]

Effective teams in military and other settings demonstrate five components:
1) Clear roles and team orientation
2) Leadership behaviour
3) Monitoring one's own and others' performance
4) Helping one other when required
5) Adapting when situations change (Figure 4)



Adapted from Salas, Sims and Burke, 2005. "Is there a 'Big Five' in Teamwork." Model represents the 'Big Five' behaviours (green) and the Co-ordinating Mechanisms (blue) required for Effective Teamwork (yellow).

Figure 4. A model of critical team skills

These five components (the Big Five)[12] are necessary but not sufficient alone, for high team performance.

Three coordinating behaviours (in blue in Fig. 3) are critical to the Big Five

1) a shared understanding of the situation (mental model) – without this the team may not understand its goals and therefore be of assistance. ISBAR and team recaps which will be described later in this chapter, are information sharing techniques.
2) closed loop communication – you need only think of everyday life for examples of requests which unknown to you, were not heard or not understood – in crises these failures of communication may be life threatening.

3) mutual trust – team members trust that everyone is looking out for, or ‘watching the back’, of everyone else. This fosters an environment where team members feel comfortable to share information, make suggestions, invite input and accept advice.

Sharing the mental model

A useful way of remembering to do this well is the ISBAR acronym which stands for ‘Identification’, ‘Situation’, ‘Background’, ‘Assessment’ and ‘Request/Recommendation’. You may also see other versions of this, such as SBAR (common in the US) and ISOBAR (which includes ‘observations’).
ISBAR can also be used in routine situations such as when handing over to the post anaesthesia care unit (PACU) nurse.

PRACTICE TIP
During quiet times in OR, practice constructing an ISBAR to colleagues for an emergency. Think of an emergency then work out what you would say. The ISBAR format is an easy structure to remember.

Introduction: Who are you and what is your skill mix?
e.g. I’m the senior registrar,

Situation: Why have you called them?
e.g. the problem is hypoxia and I need hands to help.

Background: Usually less is more. Often only the abnormal clinical vital signs and stage of the operation are required during an emergency.
e.g. I have just extubated this very obese patient after a long ureteroscopy and she looks a bit obstructed, and probably is making inadequate efforts. I’ve been assisting her with CPAP via mask for 5 min and we aren’t winning. She was a difficult intubation at the start.

Assessment: This is your diagnosis or differential. If you don’t know what is going on, say that.
e.g. I think this is atelectasis and maybe some sepsis, and that she isn’t going to cope, and that she could be hard to reintubate.

Request/Recommendation: What do you want the help to do?
e.g. I want you to take over leading whilst I focus on the task of intubation.

ACTIVITY
Now watch the following video of an ISBAR handover during an emergency.
How effective do you think this is?
Is there anything you’d add, or anything different you’d do?

Team Leadership

What are the features of an effective leader?

ACTIVITY
Think of a situation where you were in a clinical team with a particularly effective leader.
What did the leader do that made them effective?

One responsibility of the leader is to communicate relevant information, thereby enabling the members to develop a shared mental model: what the problem is, what has happened and what should happen and who should do it in what order. The leader is also the central person to receive incoming information, keep the team situationally aware (see later), and to monitor team performance e.g. all roles are filled and tasks are being carried out.

First the team leader needs to be identified. If you arrive at a clinical emergency and it isn't obvious you may have to ask the room (loudly) who is leading. Congratulations, if there's no reply you might have just volunteered yourself to be that leader!

The leader should stand in a position where they can see the whole room, be seen and have a good overall picture of the situation.

Leadership style may change depending on what is required. If the immediate action required is clear and the problem urgent the leader may be more directive get the tasks done e.g. commencing basic or advanced life support. In contrast, when the situation is less clear or the plan is not working, the patient may benefit from a more democratic style in which team members are consulted in key decisions. This style of leadership encourages team members to share information, and offer opinions.
Leaders are humans, and an effective team anticipates and has strategies for managing error in any of its members. Creating a flat hierarchy and specifically inviting team members to speak up is a useful leadership behaviour to trap or mitigate errors.

Closed Loop Communication
Effective leaders are good at delegation and should followers not volunteer for tasks they can manage (the best option). Clear delegation involves closed loop communication:

- Identify the team member that the task/ role is going to be given to. This should involve their name, eye contact, or if they are standing close and facing away then a hand on the shoulder.
- Giving the opportunity to decline if they feel unable to do it.
- Asking them to report back when the task is done.

PRACTICE TIP
The skill of closed loop communication is incredibly important and needs practice. In theatre, practice wording instructions so that the recipient has the opportunity to decline. For example, "Pete, are you comfortable with <insert task>". You could also try ensuring you have a colleague's attention by gently putting your hand on their arm or shoulder as you ask a question. Like many skills it feels awkward at first but eventually it will become how you communicate. It becomes much more likely you will use these skills in a crisis situation if they are a part of your everyday practice.

A good leader also updates the team with what is happening with regular updates, which we will call ‘team recaps’. This is covered further in the section on situation awareness.

Mutual Performance Monitoring

This is the ability of team members to identify if other team-members, including the leader, are struggling or not performing a task correctly. It is dependent on having a shared mental model so that team members know what is meant to be happening. Part of mutual performance monitoring is awareness of your own ability to manage tasks as a follower. When delegated a task you are unsure about, clarify the task if needed. Even if you understand the task, repeating the instructions back to the leader (or person delegating) helps them understand that you have heard and understood the request. This is closed loop communication, a critical coordinating behaviour.

> **PRACTICE TIP**
> Practice closed loop communication in everyday exchanges in theatre. A response to the surgeon asking for the table to go up should always be “Table going up”. If this is routine and expected they will know if you don’t hear them. Again, it feels odd to repeat back information to start with but quickly becomes part of how you communicate.

Backup behaviour

When mutual performance monitoring identifies difficulties performing an action, inadvertent omission of an action or an incorrect action, team members step in to correct the situation – this is called backup behaviour. Thus a team member may step in to assist with bag-mask ventilation, may volunteer to draw up adrenaline, or may turn off the volatile during cardiac arrest.

Backup behaviours are also useful in preventing fixation on particular solutions to the problem. We’ll talk about this later in decision-making.

> **ACTIVITY**
> Think of a situation where you saw something was wrong, or there was a safety issue and you needed to speak out about it. What stopped you? Why was it difficult?

It’s helpful to have a structure for speaking up when something may be dangerous or may have been missed. This helps break down the barrier of embarrassment, power gradients and a feeling that you need to know everything.

Several structures have been suggested in healthcare without one being clearly superior to another. Common to most approaches is a graded increase in the assertiveness of the concerned person’s advice in the event his or her concern is either not acted upon nor an adequate explanation not given in response.

Just as important as having a structure helping you to speak up, is recognising when someone is trying to speak up to you. Use of key words from a recognized structure may help overcome barriers, so if you hear “I am concerned”, ignore that person at your peril (or really the patient’s peril).

One such structure that we encourage you to use, is the PACE acronym:

PRACTICE TIP
Use the PACE acronym to speak up when you feel uncomfortable.
Probe: a short question or statement (“Are you aware the oxygen saturations are 82%?”)
Alternative (or Alert): What else could be done here? (“We should turn up the FiO_2”)
Challenge: When I’ve seen this before the anaesthetist has turned up the FiO_2. I’m trying to understand why you don’t want to do this now? Usually we also call for more help.
Escalate: Call for help or agreement with others (activates emergency buzzer)

The commonest mistake using PACE is to not move on to the next item and just stick with questions or ‘hint and hope’ statements. It is rare that Challenge or Escalate are required.

Adaptability
With a leader who has an overall view of the situation and can receive and disseminate information, teams can adapt if new information results in a change in priorities. Some changes in priority are planned and predictable but some arise without warning as mentioned in the Task Management section above. An example may be a change of priorities in a trauma patient when new injuries become clear such as the development of a tension pneumothorax. New priorities require a change in the roles and reallocation of resources.

Team orientation
Essentially this is about attitudes. Team members prefer to work as a team because they understand what is required, they expect to monitor each other’s performance and to receive feedback and assistance. A lack of team orientation occurs, at least in part because we don’t commonly train together as an operating room team, or even as an anaesthetic team with anaesthetic nurses/technicians/assistants. Training together helps develop an understanding of others’ roles and capabilities and improves communication among team members.

ACTIVITY
Now watch this video.
While you watch it, see if you can identify the team behaviours discussed in this section.

3.4 Situation Awareness

‘Experts’ seem to be able to grasp the importance of every detail in the midst of the mass of information presented during a crisis. They seem to have ‘eyes in the back of their head’ or the ‘right stuff’ because they are able to establish and maintain what cognitive psychologists call ‘situation awareness’. Situation awareness is the ability to attend, process and reach appropriately to the circumstances. When we 'lose' situation awareness we are often said to be 'fixated'.

Situation awareness isn't just important during the management of crises, it is also important in preventing crises. Understanding the phases of an operation, the surgical requirements and potential effects on the patient's physiology are important to anticipate and prevent problems. Experts acquire this through experience and reflection on their actions. As we will see later on, experts also pattern match the current situation with previous situations to decide on their course of action.

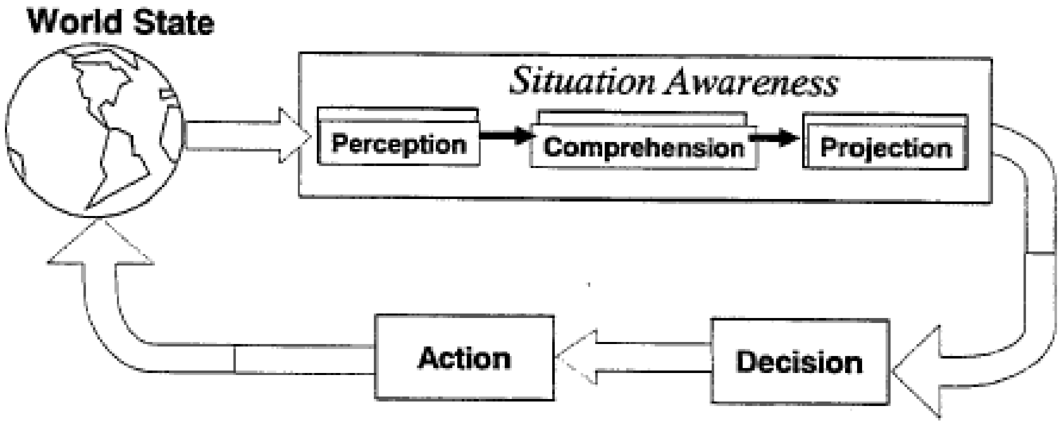


Figure 5. Situation awareness has three main components 1) Perception, 2) Comprehension and 3) Projection[13]

Perception

> **ACTIVITY**
> Watch this video.
> What did you see and what were the assumptions you made?

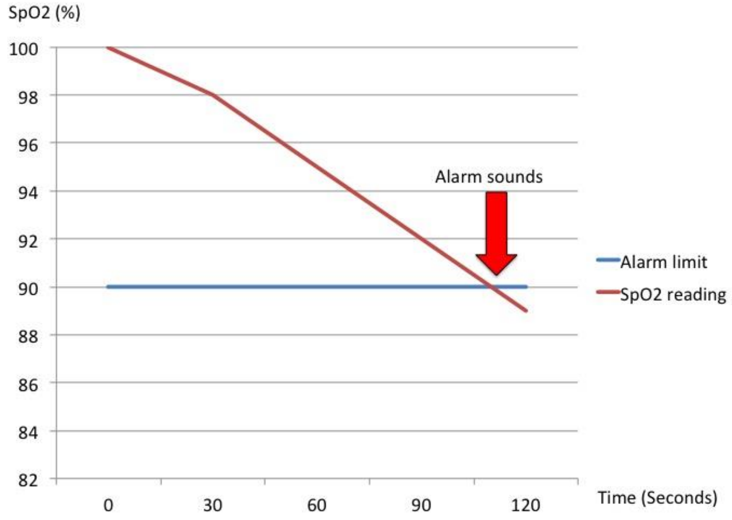
Looking for information is an active process. Eye-tracking studies in driving simulators have shown that drivers often look at cyclists in their mirror but don't consciously perceive them as being there or subsequently undertake actions to avoid them. Merely looking at a patient or monitor might not be enough to give you the information you need, especially if it is difficult to find.

> **ACTIVITY**
> What strategies could you use to improve your perception of changes during anaesthesia?

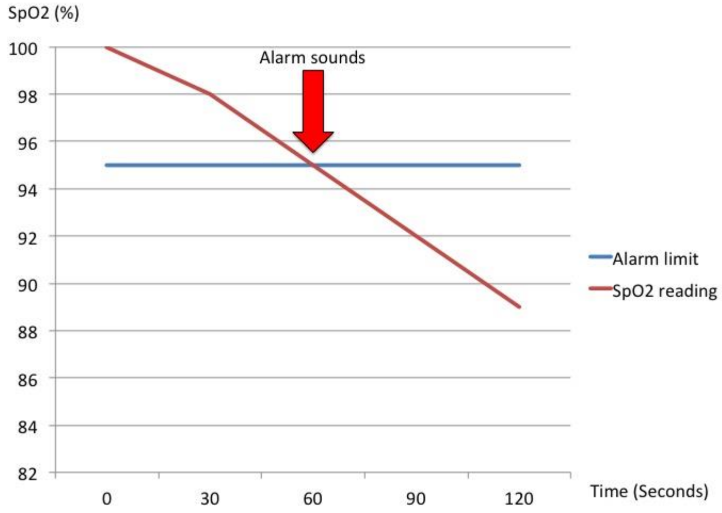
Monitors and alarms

In general humans are poor at vigilance tasks. We are well-adapted to (subconsciously) ignoring a sensory stimulus after a certain time of exposure to it. One way of improving our vigilance is by the intelligent use of monitors and alarms and appropriate intervals for intermittent measurements such as non-invasive blood pressure.

In situation 1 the SpO_2 alarm has been set to a standard 90% resulting in a delayed response to the alarm. In situation 2 the alarm limit has been set to a higher level, allowing an alert to sound when the patient's condition has changed, rather than when a critical problem has occurred. This buys the anaesthetist time to troubleshoot the problem before it becomes an emergency.



Situation 1: SpO_2 alarm limit set to 'default'



Situation 2: SpO_2 alarm limit is changed to a higher level, alerting the anaesthetist to a change in clinical condition.

PRACTICE TIP
Use this active management of alarms by setting the values to when you want to know rather than when there is a problem. It is particularly effective in long cases when vigilance is difficult to maintain and there may be few changes or slow changes in the clinical parameters.

Comprehension

In clinical crises there is often a large volume of information that needs to be gathered and processed in a time-pressured situation. Even as the leader with a hands-off approach it can be difficult to gather all of the information that's needed. One method to improve the information sharing among team members is to intermittently recap the situation. This not only keeps the team mental model up to date with developments, it also has the advantages of inviting ideas about what is going on and suggestions of how to proceed. Furthermore arriving team members will be brought up to speed by a recap.

> **PRACTICE TIP**
> How to do a team recap – remember to keep it succinct!
>
> Try using the ISBAR format or an abbreviated form of it to recap
> Example:
> "I: OK everyone listen up let's just recap.
> S: This is an 81 year-old for hemiarthroplasty, VF arrest and we're on our 3rd cycle of CPR.
> B: She has ischaemic heart disease and had ST changes prior to the arrest. Blood loss wasn't out of the ordinary.
> We've had 2 shocks, 1mg adrenaline, amiodarone next, she's intubated.
> A: Reversible causes: coronary thrombus seems likely but we need to exclude some other causes.
> R: John, please check 100% oxygen and equal air entry. Fluid is running, she isn't cold, ABG being checked. Sylvia can you check the ampoules to make sure no drug errors? Mary can you call the coordinator to get someone here to do a cardiac echo (cardiogram)?
>
> We'll continue CPR, and notify the cardiologist
> Does anyone have anything to add? Anything that we're missing?
> Alright, that's 2 minutes let's get ready for the next shock…

Projection of future state
Many people also find that recapping out loud when leading helps them process events and the implications of new information. A team recap shares the leader's mental model for what might happen next (projected state) and thus set priorities and expectations for the team for the short term. By recapping regularly, progress can be measured against the plan and the team can share their assessment of where improvement has been made.

3.5 Decision making

How are our decisions shaped by the context in which we work?

As referred to earlier in the chapter, there are system factors that may contribute to adverse events occurring. These also affect the way we behave and make decisions by introducing biases and assumptions into our thinking.

Of course, we're not robots and don't think in a cold analytical way. Furthermore, our state of mind may be affected by our physical state.

> **ACTIVITY**
> What physical situations can you think of that might affect your decision-making?

Two mnemonics describe common physical factors that affect our performance:
'HALT'

- Hungry
- Angry
- Late
- Tired

And 'I'M SAFE'

- Illness
- Medication
- Stress
- Alcohol
- Fatigue
  Eating

It may be useful to actively consider the potential for making errors in a particular circumstance. This is termed 'error wisdom' and can be thought of in terms of Self (HALT / IMSAFE factors), Context (e.g. distractions, production pressure), and Task (e.g. complexity of the patient or procedure, unfamiliar setting).
Interruptions have received a lot of attention for their ability to disrupt our cognitive processes and induce errors. Unless the interruption is crucial for the patient's safety they should be ignored until they can be dealt with.
Other factors such as temperature and noise may also affect us. In particular, an easy intervention to help your concentration is to turn off music in theatre. This also has the advantage of improving the ability to communicate during an emergency!

Models of cognition

There are two different models of decision-making in anaesthesia, commonly termed 'Fast and Slow thinking' or 'System 1 and System 2' cognition.[14]

<u>Fast (System 1) thinking</u>

As its name implies, this happens rapidly, almost automatically: A pedestrian steps out in front of us when we're driving and we automatically brake sharply. As we become more experienced our reactions and decisions to situations we encounter commonly become automatic. Examples in anaesthetics include increasing the FiO2 when the saturations start to drop or looking at the surgical site when we hear the sound of the suction, indicating blood is being lost.

<u>Slow (System 2) thinking</u>

This is more deliberate, such as weighing up options for managing the airway, or deciding where to place the intravenous cannula. Even though these decisions take more time, system 2 thinking may still occur in time critical situations to ensure that all of the options have been considered.

System 1 and System 2 thinking both have their place in anaesthesia and both have their advantages and disadvantages.

ACTIVITY
What advantages and disadvantages can you think of for each of the types of thinking systems?

In both systems of thinking it is rare that we truly 'weigh up' the pros and cons of each potential course of action. Most likely we pattern-match against situations we've already experienced and use pre-compiled responses – a process known as 'Recognition Primed Decision making' (RPD).[15] When we make these decisions we commonly make them based on a view of the world that is incomplete using 'heuristics' or 'rules of thumb'.

ACTIVITY
Now read this article by Pat Croskerry, a Canadian Emergency Physician.
The importance of cognitive errors in diagnosis and strategies to minimize them
As you can see from 'List 1' in the article there are a large number of 'cognitive biases' that we bring to our decision making. It is not important to remember these, but it is helpful to consider his 'De-biasing strategies' listed in Table 1 of the article.

We have already mentioned some of Croskerry's de-biasing strategies although they might not be immediately obvious – using team recaps allows a team approach to get more insight, feedback and alternatives. We will now discuss two other strategies – those of cognitive forcing strategies and reducing reliance on memory.

ACTIVITY
What current systematic approaches do you use?
How do you apply them clinically?

The most common systematic approach we all use is the ABC or DRSABC approach but other systems have been tried and are used by anaesthetists.
In the 1990s data from the Anaesthetic Incident Monitoring Study was used to construct a systematic approach that would, if followed correct the majority of critical events under anaesthesia within 60 seconds. Unfortunately, the elements of the 'COVERABCD' acronym[16] were difficult to memorise and it was not widely used.

Cognitive aids and other reminders
Cognitive aids are mnemonics, posters, cards or electronic devices that remind clinicians what to do. A review of the effects of cognitive aids in anaesthetic emergencies demonstrated that they improved the technical performance of individuals during crises. Further research has proven that individual clinicians' team behaviours and the functioning of the team are improved during emergencies if a cognitive aid is used.

ACTIVITY
What emergencies can you think of that have a defined cognitive aid?
Have you seen them being used? Was it effective?

Cognitive aids exist for cardiac arrest, anaphylaxis, airway management and local anaesthetic toxicity. Some are bound together as a book designed to be a comprehensive suite of cognitive aids for all anaesthetic emergencies.
Good cognitive aids are visual reminders of the initial steps required. Detail and evidence may be available as a longer, comprehensive document, but should not clutter the cognitive aid.

Cognitive aids are most effective when they are reviewed and used in a simulated setting prior to being used in an emergency. This familiarity allows the anaesthetist to navigate the aid more effectively and to use the aid as a reminder for actions and how to delegate them.

It has also been shown that when a poster or paper-based cognitive aid is used one team member should be tasked to read out the cognitive aid to the rest of the team. This 'reader' should be a separate person to the leader and act as a prompt for the leader and the rest of the team to prioritise and complete the tasks in parallel.[17]

PRACTICE TIP
Review the cognitive aids available in your institution.
Take time during quiet moments to consider how you would organise the team to fulfil the roles required. Remember to include roles for the leader and reader of the cognitive aid.
Specifically review the cognitive aids that have been endorsed by ANZCA listed in the table below.

A list of cognitive aids for anaesthetic emergencies endorsed by ANZCA

Emergency	Organisation	URL
Anaphylaxis (paediatric and adult)	ANZCA/ ANZAAG	Anaphylaxis Management Guidelines
Cardiac arrest (paediatric and adult)	Australian (ARC) New Zealand (NZRC)	ARC Flowcharts ANZCOR Guidelines
Malignant hyperthermia	Royal Melbourne Hospital	MH Resource Kit
Massive transfusion protocol	National Blood Authority (Australia)	Patient Blood Management Guidelines
Systemic local anaesthetic toxicity	AAGBI (UK)	Management of severe local anaesthetic toxicity

Additional examples of cognitive aids can be found in the Anaesthetic Crisis Manual (paper, or mobile device, http://theacm.com.au) and at www.projectcheck.org).

4. Critical Incidents and the Second Victim

One aspect of perioperative critical incidents that receives little attention is the care for the staff after the event. It is not uncommon to have feelings of anxiety, guilt, shame or inadequacy after a critical incident or death related to anaesthesia. Such feelings are often termed 'second victim' effects and may progress to insomnia, depression, substance abuse, relationship difficulties, post-traumatic stress reactions, avoidance of clinical work or even suicide. Some estimates put the incidence of second victimhood in the health workforce as high as 60%. Given the context of our work, anaesthesia is likely to have one of the highest rates of second victims and the effects may be long lasting with one study suggesting that anaesthetists thought about the death every day for more than a year after the event.

ACTIVITY
Now read this article on the second victim.
Second victims, organisational resilience and the role of hospital administration

What supportive measures can you identify from this article that may help anaesthetists after a critical event?

4.1 Mechanisms to support practitioners after an event

Institutions should have defined procedures to be followed after an event to support staff and identify those who may need professional help.

Immediate actions

Ensure that any device or medication that may have contributed to the event is isolated and removed from the clinical setting. After an unexpected or inexplicable death in theatre many people believe the operations in that theatre should be suspended for the day in order to confirm that there is nothing in the environment such as a machine malfunction that may have contributed.[18] The staff in the theatre should be sent home after a death or significant event if possible, even if they feel they can continue with further cases, as their emotional state may affect the care of the next patient.

Speak to patient and/or relatives

Open disclosure is a legal and moral obligation of the treating practitioner. Each institution will have a policy and a procedure describing how this must be undertaken and with whom. A senior clinician or manager must be involved in this process for serious incidents and it is advisable that another colleague is included for support in most cases. The surgical team should not speak to a family member without an anaesthetist present if the death occurred under, or related to an anaesthetic. National standards exist for open disclosure in Australia and New Zealand.

Speaking to colleagues
The informal ‘tea room debrief’ provides immediate peer support through use of everyday professional and social networks. All too often colleagues have had similar experiences, would have acted in the same way given the situation and can help validate that it was ‘not your fault’. Immediate discussions with the rest of the theatre team can also help them, and you, understand more about the situation and provide a level of support before a formal debriefing can take place. Speaking about the incident with friends and family also helps.

Remember to contact the GP and complete the required documentation. Many operating theatre suites have a folder that helps step through the process to follow if a death occurs in theatre. The process differs between countries and states.

Speaking to a mentor or peer support service
This is a more structured version of the discussion with colleagues. A mentor is someone with whom you have developed a long-standing relationship of support or mutual support and whose opinion you value. They may be able to more objectively look for signs of depression, withdrawal or ongoing problems and refer to formal professional help.

Critical incident ‘team debriefing’
A formal team debriefing led by a trained peer debriefer, e.g. an experienced simulation instructor, may be offered by the organisation to the whole team to help process events. The aim is to provide an opportunity for peer support, and to discuss decision-making, teamwork and systems issues in order to identify potential areas for quality improvement.

A ‘critical incident stress debriefing’ is a particular type of post-incident debriefing led by a trained counsellor and is intended to assist with psychological recovery after a stressful event.

Contacting a psychologist
Seeking professional help with counselling may still be required for some anaesthetists but should not be mandated. Seeking help may be more likely if the anaesthetist believes they contributed to the event.

Following an unexpected death, there is the possibility there may be a coronial inquest or other investigations. These investigations may continue for many years after the event. Ensuring that there is adequate and appropriate support at an early stage using the mechanisms above is an essential way to minimise the stress during these times.

During the EMAC course it is possible that some of the scenarios may raise some uneasy feelings from similar previous experiences. If you feel comfortable to do so, it may assist you to talk through these with course faculty. Finally, do not hesitate to contact the EMAC Convenor following the course if you have any concerns.

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Cardiovascular Emergencies

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Introduction

This chapter is a non-exhaustive adjunct to standard texts and aims to provide a practical guide to cardiovascular crises and emergency vascular access.

Where available, the most recent recommendations by the Australian and New Zealand Committee on Resuscitation (ANZCOR) are cited. In the absence of specific ANZCOR guidelines, the most recent recommendations of the American Heart Association, the American College of Cardiology and the European Resuscitation Council have been used.

It is important to be familiar with the protocols used in the hospital in which you practice, particularly how to call for help out of normal hours.

The module excludes the management of cardiovascular crises or resuscitation in children and pregnant women, mechanical cardiovascular support and the use of pulmonary artery catheters.

Chapter Outline

Learning Outcomes

By the end of this chapter, and prior to the course, a participant will be able to:

- Discuss myocardial ischaemia and acute coronary syndromes, including risk factors, causes and perioperative management.
- Discuss perioperative cardiac arrest including common causes, recognition and management.
- Explain the elements of the Advanced Life Support for Adults algorithm of the ANZCOR guidelines
- Discuss shockable and nonshockable rhythms and when defibrillation should be undertaken.
- Describe the initial management of a patient with life-threatening cardiac arrhythmia, including tachyarrhythmia and bradycardia.
- Discuss the indications for use, synchronization and operation of a cardioverter/defibrillator.
- Discuss the indications and relative contraindications of emergency pacing
- Outline the care of post-arrest patients.
- Discuss the perioperative management of valvular heart disease and hypertensive crises.
- Compare and contrast vascular access options.

1. Myocardial Ischaemia & Acute Coronary Syndromes [1-3]

Coronary artery disease is the leading cause of death in adults in most western countries and, in a general medical context, it is the most common cause of life threatening arrhythmias and cardiac arrest. In the perioperative setting, the situation is complicated by the interplay between underlying condition(s), surgical stress, haemorrhage, coagulation and anaesthesia. Cardiac causes of death, nonfatal myocardial infarction (MI), heart failure, or ventricular tachycardia occur in up to 5 percent of patients 45 years of age or older undergoing in-hospital noncardiac surgery.[4]

1.1 Patients at Risk

ACTIVITY

A 72-year-old man is scheduled to undergo fem-popliteal bypass with graft from his arm. This is an add-on case at the end of an all-day list. Past history: arteriopathy, anterior myocardial infarction 6 months ago treated with drug-eluting stent to left anterior descending coronary artery. Previously he was a 50 pack year smoker, gave up at time of myocardial infarction. Type 2 diabetes

- Medications: Metoprolol 95mg daily, quinapril, GTN spray prn, aspirin, clopidogrel discontinued 2 days ago, metformin, simvastatin, heparin infusion stopped this morning, never reached therapeutic APTT.
- Most recent echo showed anterior dyskinesia with mildly reduced ejection fraction (50%) and grade 1 diastolic dysfunction, consistent with an elevated left atrial pressure. No significant valvular lesions, notably no significant mitral regurgitation.

Do you know this patient's estimated risk of cardiac complications after non-cardiac surgery? What are the primary risk factors?

Refer to the Revised Cardiac Risk Index calculator.

There are several indices of risk factors for perioperative cardiac death or non-fatal myocardial infarction.[5] The Revised Cardiac Risk Index (RCRI) is best known and includes these factors:

- Known coronary artery disease (previous myocardial infarction, previous CABG, or percutaneous intervention).
- History of congestive heart failure or stroke.
- Peripheral vascular disease ± vascular surgery.
- Diabetes mellitus.
- Renal impairment.
- Thoracic, abdominal or supra-inguinal vascular surgery.

Other risk factors not included in the RCRI include:

- Ejection fraction <35%.
- Smoker.
- Hyperlipidaemia.
- Hypertension.

- Non-sinus rhythm e.g. atrial fibrillation.
- Family history (especially sibling).
- Age>70.
- Age<40 and cocaine or methamphetamine abuse.
- Anaemia (Hct<28%).

1.2 Causes of acute coronary events

The causes of perioperative acute coronary events fall into two groups:

1. Those attributed to a mismatch between myocardial oxygen supply and demand; and
2. Those attributable to plaque rupture resulting in acute coronary syndromes.

This distinction is important because their treatments are different.

Myocardial Oxygen Supply and Demand

Supply	Demand
Coronary blood flow Arterial oxygen content	Wall tension Heart rate Contractility

Left ventricular myocardium is perfused during diastole and so the time available for coronary perfusion is inversely related to heart rate. An increase in heart rate increases demand and reduces supply.

Coronary perfusion pressure is usually calculated as aortic root diastolic pressure minus left ventricular end-diastolic pressure. During cardiopulmonary resuscitation (CPR), coronary sinus pressure is used as the downstream pressure in this calculation.

Ventricular wall tension = pressure x radius/2 x wall thickness, and so is determined by both preload (radius) and afterload. Hence, a dilated heart has a greater oxygen demand for the same generated pressure.

Myocardial ischaemia arises when myocardial oxygen demand exceeds supply. Anaerobic metabolism leads to depletion of adenosine triphosphate (ATP), causing systolic and diastolic dysfunction. Local accumulation of anaerobic metabolites may be responsible for pain and arrhythmias.

1.3 Myocardial Ischaemia

Management of Acute Myocardial Ischaemia

Identify at-risk patients and avoid and treat perioperative events that threaten the myocardial oxygen supply/demand relationship.

Reduced Supply	Increased Demand
Reduced Coronary Blood Flow	**Increased Wall Tension**
Tachycardia	Hypertension
Hypotension	Ventricular dilatation
Elevated LVEDP	**Increased Heart Rate**
Reduced Arterial Oxygen Content	**Increased Contractility**
Anaemia	
Hypoxaemia	

Symptoms in the conscious patient:

- Chest pain or sensation of pressure in chest
- Sweating
- Shortness of breath
- Palpitations
- Dizziness / light headedness / fainting

In perioperative patients, myocardial ischaemia may be asymptomatic, and may manifest as reversible electrocardiogram (ECG) changes of the ST segment or T-waves (accepting that there may be false positives, depending on the ECG monitor settings) and haemodynamic perturbations such as:

- Arrhythmias
- Hypotension
- Echocardiographic evidence of systolic dysfunction or regional wall motion abnormalities.

Treatment of Acute Myocardial Ischaemia

Treatment of acute myocardial ischaemia should be tailored to severity of problem:

Optimise haemodynamics

- Reduce myocardial oxygen demand and increase myocardial oxygen supply.
- Normalise blood pressure and ensure adequate coronary perfusion pressure. Consider the use of a vasopressor or inotrope.
- Aggressively manage hypotension or evidence of end-organ hypoperfusion.
- Reduce heart rate. Ensure pain appropriately managed e.g. additional opioid. Consider cardioselective β-blocker e.g. esmolol. Although uncommon in anaesthesia, consider verapamil or diltiazem if β-blocker contraindicated.[1] Target heart rate = 50-60/min for stable ischaemic heart disease.[2]

- Reduce myocardial wall tension – nitrates and avoid/manage severe hypertension.
- Consider afterload reduction, but maintain blood pressure.
- Ensure SpO_2 >90% and avoid hyperoxia.
- Avoid anaemia.
- Ensure normothermia and avoid shivering.
- Consider intra-aortic balloon pump in refractory cases.[1]

- Acute cocaine intoxication stimulates alpha- and beta-adrenergic receptors. Beta-blockade may result in unopposed alpha stimulation, worsening vasospasm, and so nitroglycerine and benzodiazepines are recommended. The recommendations for methamphetamine-induced ACS are similar.[3]

Esmolol

- β_1 cardioselective when infusion rate <300mcg/kg/min. If infusion rate is higher, effect is non-selective.
- Loading dose 250-500 mcg/kg over 1 minute, then infusion 25-50 mcg/kg/min increasing by 25-50 mcg/kg/min every 5-10 min.
- Half-life is 9 min (metabolised by red cell esterase) hence contraindications can be viewed as relative.
- Contraindications to acute β-blockade are bradycardia, AV-block, obstructive airway disease, cardiac failure, hypotension, haemodynamic instability, cocaine induced coronary vasospasm.[3]

Nitrates

- Predominant action is a reduction in preload (wall tension) due to venodilation, thus reducing myocardial oxygen demand.
- Use with severe caution in right ventricular (RV) infarction because marked hypotension can arise due to the effect of venodilation on RV preload.
- Sublingual nitroglycerine 400 micrograms.
- IV glyceryl trinitrate (GTN) 10 mcg per minute via continuous infusion, increasing by 10 mcg per minute every 3-5 minutes, until response (reduction in symptoms or onset of hypotension).[1]
- Systolic blood pressure (BP) should not be titrated below 110 mm Hg if previously normotensive, or reduced by more than 25% if hypertensive.[1]
- Nitrates are contraindicated if 5'phosphodiesterase inhibitors (e.g. sildenafil) administered in previous 24-48 hours[3], so use with caution in these patients as the combination can lead to severe hypotension.

Anti-Platelet Therapy

In the perioperative context, the use of anti-platelet and/or anti-coagulant medications requires careful risk-benefit analysis because of the risk of bleeding, particularly dual antiplatelet therapy (aspirin plus $P2Y_{12}$ receptor inhibitors). Hence, this needs discussion between the surgeon, anaesthetist and cardiologist.

Aspirin

- If not already taking it, aspirin 300 mg, chewed non-enteric formulation for rapid buccal absorption. A lower dose of aspirin (75-160 mg) is acceptable if the risk of bleeding is high.[1] Can be administered by nasogastric tube.
- Contraindications: allergy (esp. if asthma - rare), active bleeding (gut, retina), bleeding disorder.

$P2Y_{12}$ inhibitors (e.g. clopidogrel, ticagrelor).

- Should be considered especially in patients intolerant of aspirin.[2]
- May also be used in the context of plaque rupture.

If myocardial ischaemia fails to respond to therapy, it is important to consider the possibility of myocardial infarction. In this situation, early discussion with a cardiologist and the surgeon is needed to determine treatment and because of the need to consider aborting or minimising the surgery.

The diagnosis of myocardial injury and infarction in the perioperative situation is based on a combination of ECG changes, elevated biomarkers, and clinical suspicion. The ECG may initially be equivocal requiring serial ECG's at 15-30 minute intervals, and biochemical markers may be normal during the first 6 hours after myocardial infarction. With increasing sensitivity of biomarkers, the diagnosis of myocardial injury is becoming more frequent. Elevations of troponin of any level are associated with an increased 30-day mortality rate.[4]

1.4 Acute Coronary Syndromes [1-3,8]

The most urgent priority is determining the need for immediate reperfusion therapy and exclusion of other potentially lethal conditions such as aortic dissection.

Reperfusion therapy is the standard of care for ST-elevation myocardial infarction (STEMI). Thrombolysis is contraindicated after relatively recent surgery because of the risk of bleeding, and so discussion between the surgeon, the anaesthetist and a consultant cardiologist is required, with likely progression to percutaneous coronary intervention (PCI) or medical management as the likely options. PCI requires anticoagulation during the procedure, as well as antiplatelet therapy, and so there is a risk of bleeding after surgery. There are no randomized controlled trials to guide perioperative reperfusion decisions.

The dynamic continuum of acute coronary syndromes ranges from unstable angina/non-ST segment elevation myocardial infarction (UA/Non-STEMI), to ST segment elevation (STEMI) myocardial infarction. Non-STEMI is defined by ST depression or new T-wave inversion and positive biomarkers for myocardial tissue necrosis, in the appropriate clinical setting (e.g. perioperative haemodynamic instability). Unstable angina causes no increase in biomarkers of myocardial injury, and is becoming a less common diagnosis with the increasing sensitivity of biomarker assays.

Treatment of Unstable Angina/Non-STEMI

The goal of treatment is immediate relief of ischaemia and prevention of myocardial infarction and death. In perioperative patients, in the absence of contraindications, options include:

- Nitroglycerine
- Analgesia, but not NSAID
- β-blockers (calcium channel blockers, if β-blockers contraindicated)
- ACE inhibitors
- Aspirin (+/- ADP/$P2Y_{12}$ inhibitor)
- Anticoagulation with unfractionated or low molecular weight heparin

If failed medical therapy (refractory angina, heart failure or worsening mitral regurgitation, haemodynamic or electrical instability) or high risk of major adverse cardiac outcome [high Thrombosis in Myocardial Infarction (TIMI) or other risk score] then early reperfusion may be indicated, same as for STEMI. Early invasive strategy is not recommended if there are extensive comorbidities.

These syndromes are associated with an increase in the risk of myocardial infarction and death and patients require monitored care in an environment where facilities and staff for immediate cardioversion or defibrillation are available. Anaesthetists need to participate in continuous risk stratification, provide initial treatment and co-ordinate the discussion with cardiologist and surgeon, and may need to undertake the transfer to a PCI-capable hospital.

Diagnosis of myocardial infarction in perioperative patients is complicated by the likelihood that there will be no symptoms e.g. in the Poise study 65.3% of patients who had non-fatal myocardial infarction did not experience ischemic symptoms.[5] The diagnosis is thus made on the basis of ECG changes, elevation of biomarkers and clinical signs such as new onset heart failure.

Treatment of STEMI:
The goal of treatment is reperfusion if feasible. Primary PCI is generally considered to be the best option for perioperative patients, accepting the risk of bleeding.[6] ECG criteria are key indicators for urgent angiography +/- reperfusion[3]: ST-segment elevation (≥2mm in 2 contiguous ECG chest leads for men, or in women ≥1.5mm in V2-V3 and/or ≥1.5mm in contiguous chest leads or limb leads) or new left-bundle branch block[7], or evidence of posterior injury (ST depression in ≥ 2 precordial leads).

Time from onset of symptoms to reperfusion is critical. Although the aim should be to achieve reperfusion within 2 hours of first medical contact, the current recommendation is that reperfusion therapy should be administered to eligible patients with STEMI with symptom onset in previous 12 hours. Primary PCI is the recommended method of reperfusion if it can be performed in a timely manner.[7]

In patients with cardiogenic shock, the window of benefit for delayed reperfusion extends up to 54 hours after MI and 18 hours after shock onset. Patients with ongoing unstable angina, or severe heart failure should be considered for delayed reperfusion.[7]

If reperfusion is not undertaken, there is benefit in treating the acute coronary syndromes with both aspirin and β-blockers. They both reduce the risk of myocardial infarction and the risk of death after myocardial infarction.

Temporary circulatory support with intra-aortic balloon pump should be considered prior to revascularization for cardiogenic shock, severe heart failure, or surgical repair of mechanical complications (e.g.VSD, papillary muscle rupture).[7]

Event Management
Ensure that diagnosis is based on more than a three-lead ECG. Declare a crisis, notify the surgeon and discuss with consultant cardiologist. Haemodynamics must be optimised.

Provide medical management and start aspirin early in the absence of contraindications (via nasogastric tube if intubated) and β-blockers should be started. Consider oral ACE inhibitors; they reduce fatal and nonfatal major cardiovascular events after STEMI.[7] The magnitude of clinical benefit is greatest in high-risk subgroups.

Differential Diagnoses of Acute Chest Pain or CVS Collapse

Anaesthetists need to remember that there are other causes of perioperative chest pain or cardiac arrest apart from ischaemia or arrhythmias, and the following causes may need to be excluded:

- Aortic dissection
- Cardiac tamponade
- Pulmonary embolus
- Pneumothorax (tension)
- Oesophageal spasm or rupture
- Pericarditis
- Pneumonia
- Cholecystitis

PRACTICE TIP

Anaesthetised patients with dynamic changes to their ST segments or T-waves (typically inversion) should be treated as angina. Those with non-reversible ST-segment elevation on the 12-lead ECG should be investigated for possible myocardial infarction and evaluated for reperfusion as soon as feasible (this will usually be after the operation). Patients who have perioperative myocardial ischaemia have higher risk of death in the subsequent 12 months and need ongoing cardiological follow-up.

2. Perioperative Cardiac Arrest [8-11]

ACTIVITY

Read a summary of the changes to the Australian and New Zealand Committee on Resuscitation (ANZCOR) Guidelines.

The likelihood of survival and the subsequent quality of life after cardiac arrest are determined by the time taken to restore spontaneous circulation. **The most recent scientific evidence places increased emphasis on the need for high quality and uninterrupted chest compressions during CPR.** This is because effective CPR is required to deliver oxygen and metabolic substrates to the myocardium, and this increases the likelihood of restoration of spontaneous circulation. At best, external cardiac massage provides around 30% of normal coronary and cerebral blood flow[12] and it is a temporising measure used while spontaneous circulation is restored. Vasoconstriction may improve coronary and cerebral perfusion pressure during CPR.[13] Survival after collapse decreases by 7-10% per minute in the absence of bystander CPR, but is 2-3 times better with bystander CPR.[14] Interruptions to chest compression cause a substantial reduction in coronary perfusion pressure and its restoration is not immediate.

During the first few minutes of a ventricular fibrillation (VF) cardiac arrest, chest compressions are more important than ventilation, and the respiratory rate should be 5-6 per minute. Less ventilation is required because pulmonary blood flow is reduced. During prolonged resuscitation, and during resuscitation for asphyxia (typical cause in children), ventilation should be combined with compressions.

Although there are important differences in the aetiology of in-hospital and out-of-hospital cardiac arrest, the initial rhythm is VF or pulseless ventricular tachycardia (pVT) in about 20% of patients, and for these patients the initial treatment is prompt defibrillation. In a further 25% of patients, where the initial rhythm is nonshockable, will subsequently develop VF/pVT during resuscitation.

In adults, an out-of-hospital cardiac arrest is usually due to heart disease.

An unmonitored in-hospital cardiac arrest is usually caused by unrecognised or inadequately treated progressive physiological deterioration with hypoxia and hypotension. The cause must be remedied for resuscitation to be successful, and it is thus important to search for the cause while administering supportive treatment.

A perioperative cardiac arrest usually has a specific cause, which must be remedied for resuscitation to be successful**.** Hence, it is important to search for the cause while administering supportive treatment.

> **ACTIVITY**
> How is cardiac arrest during anaesthesia distinct from cardiac arrest in other settings? Can you list common situations associated with perioperative cardiac arrest?
>
> Read the following article:
>
> Moitra et al (2012) – Anesthesia advanced circulatory life support

2.1 Common causes

The common causes of intraoperative cardia arrest include:[16]

- Pre-existing cardiac, respiratory or renal disease.
- Drug-induced: overdose, suxamethonium-induced bradycardia, anaphylaxis (chlorhexidine, latex, etc.), local anaesthetic systemic toxicity.
- Problems with ventilation and oxygenation.
- Arrhythmia caused by surgical intervention (e.g. vagal stimulation, carbon dioxide insufflation, or insertion of femoral prosthesis).
- High sympathectomy during neuraxial anaesthesia.
- Haemorrhage and hypovolaemia.
- Sepsis.
- Embolic phenomena (thrombi, fat, air or other gas).

2.2 Recognition

In non-anaesthetised and unmonitored patients, cardiopulmonary resuscitation is recommended if the patient is unconscious, not moving and not breathing. Most perioperative cardiac arrests are witnessed and monitored, and it can be difficult to decide when to start chest compressions in a monitored, anaesthetized, hypotensive patient.

<u>CPR should be started if there is any doubt about the presence or absence of a pulse.</u>

2.3 Management [15]

Declare a crisis, notify the surgeon/stop surgery and pack wound.
Then:

- Call for help and a defibrillator.
- Place patient supine and expose the chest.
- Discontinue anaesthetic agents (check that infusions and vaporisers are off).
- Administer 100% oxygen and verify gas composition.
- Institute Advanced Life Support (ALS) algorithm.
- Undertake rapid and complete systematic assessment of the patient, the equipment and drugs, even if the cause is thought to be identified.
- Ultrasound can identify reversible causes such as tamponade, pulmonary embolism, hypovolaemia, and pneumothorax. Sub-xiphoid view is recommended and requires a skilled sonographer to obtain views within 10 seconds.

PRACTICE TIP

Common errors seen during simulation are failure to discontinue anaesthetic agents, failure to administer 100 % oxygen, and failure to provide uninterrupted chest compressions. Anaesthetists tend to inadvertently over-ventilate their patient during a cardiac arrest, and in animal models this is harmful. These errors probably occur in the clinical arena so check these when you go to help someone else manage a crisis.

If it is difficult to decide when to begin CPR, then have a brief discussion with your team to help with the decision process.

2.4 Advanced Life Support Algorithm

ACTIVITY
Refer to the Advanced Life Support for Adults algorithm of the ANZCOR guidelines. What are the only two possible treatment pathways after rhythm has been assessed?

ANZCOR Guideline 11.2 (refer to page 7)

There are only two treatment pathways:

- VF/pVT requires immediate defibrillation.
- Pulseless Electrical Activity (PEA)/Asystole requires immediate thought about causes of cardiac arrest. This is the usual path during anaesthesia.

The remainder of the algorithm is identical for both pathways: chest compression, airway management, ventilation with a compression to ventilation ration of 30:2, i.e. 30 compressions at a rate of 100-120 per minute, followed by two breaths (after intubation: compression rate 100/min, breaths 8-10/ min), venous access [intravenous (IV)] or Intraosseous (IO) and the administration of adrenaline (epinephrine) every 3-5 minutes, and the identification and treatment of reversible factors**.**

Mechanical chest compressors, and devices to measure the adequacy of compression are currently experimental tools that are moving into clinical practice.

PRACTICE TIPS
Don't interrupt compressions to undertake breaths in a patient with an airway device.

Use algorithms as cognitive aids when undertaking CPR.

The defibrillator should be charged during CPR towards the end of the 2 minute loop of CPR to avoid interruptions to compression.

The need to exercise judgment is critical in the perioperative context because the cause of cardiac arrest is likely to include reversible factors.

It is important to be familiar with the protocols used in the hospital in which you practice and how to get help, especially in the middle of the night or during the weekend.

Delegation of responsibility
The leader delegates areas of responsibility and provides regular structured call-outs to recap the situation. In perioperative cardiac arrest there are usually several skilled individuals in the room or vicinity, and so single- or two-person CPR is uncommon. The following areas of responsibility can be delegated:

- Airway/intubation/ventilation.
- Chest compression - person performing compressions should change every 2 minutes. If there is return of spontaneous cardiac output, then the compression person can keep a finger on femoral pulse.
- Monitor and defibrillation, including monitoring the adequacy of compressions.
- IV access and drugs.
- Search for cause i.e. exclude H's and T's. Do not assume myocardial ischaemia as aetiology.

2.5 Shockable Rhythms

If there is a shockable rhythm, immediate defibrillation should be undertaken with the following caveats:

- Interruptions to chest compressions should be minimized.
- CPR should be resumed immediately after each shock, and should continue for 2 minutes before rhythm or pulse are assessed. After successful defibrillation the restoration of effective cardiac output with a palpable pulse takes a few minutes, and CPR should be continued during this time.
- Risks to healthcare workers are electrical shock and spark fire in oxygen-enriched environment. In a patient with an intubated trachea, or with laryngeal mask airway (LMA); keep ventilation system attached to airway device to minimize oxygen concentration adjacent to the cardioversion pads.
- Biphasic defibrillator first shock 120-150J, based on the manufacturer's recommendations. If the manufacturer's recommendation is unknown, then use maximum energy.
- Precordial thump may be of use in first 10 seconds after witnessed VF onset.
- Drugs are adjuncts.
    - Vasopressors improve short-term survival, but there is no placebo-controlled trial showing that any vasopressors increase survival to hospital discharge. The current recommendation is adrenaline (epinephrine) 1mg every three to five minutes, although it should be withheld if a rapid increase in $ETCO_2$ occurs, suggesting return of spontaneous circulation (ROSC), i.e. every second loop of the ACLS algorithm.
    - No anti-arrhythmic drug given during cardiac arrest has been shown to increase survival to hospital discharge. Amiodarone 300 mg is recommended for refractory VF/pVT after the third shock and for haemodynamically stable VT, and other resistant tachy-arrhythmias. Lignocaine 1mg/kg is recommended if amiodarone unavailable.
    - Medications should be administered intravenously or by the intraosseous route, and flushed as appropriate.
- Haemodynamic targets during CPR have not been defined. But the following are worthy of consideration:
    - End-tidal CO_2 should be monitored to confirm adequacy of chest compression and ventilation. $ETCO_2$>20mmHg after 20 min CPR is associated with improved outcome.
    - Aim for diastolic pressure greater than 25 mmHg during CPR to maximize coronary perfusion pressure.
- Extracorporeal CPR (e.g. ECMO, CPB) is gaining popularity and where available, should be considered in reversible situations.

PRACTICE TIP
Charge defibrillator BEFORE giving 'all clear' command, to minimize interruptions to chest compression.

2.6 Non-shockable Rhythms

Non-shockable rhythms are a heterogeneous group of rhythms. Rapid attention must be paid to the differential diagnosis as resuscitation is dependent upon identifying and treating the cause. Initial treatment is CPR and adrenaline (epinephrine).

Pulseless Electrical Activity (PEA)
PEA is cardiac electrical activity in the absence of palpable pulse. There are often weak contractions that can be detected with invasive monitoring or echocardiography. It is often caused by a reversible condition that must be sought and treated. If the initial rhythm is PEA then there is a far greater chance that there is a treatable underlying cause for the cardiac arrest.

Asystole
The pharmacological treatment is adrenaline (epinephrine) and rapid attention must be paid to the differential diagnosis. Pacing is only recommended for:

- Complete heart block, so examine ECG carefully for presence of P waves.
- After cardiac surgery.

2.7 Search for Reversible Causes

ACTIVITY
Before you continue reading, can you recall the 4 Hs and 4 Ts?

If not, refer the ANZCOR Guidelines: https://resus.org.au/guidelines/

The 4 Hs and 4 Ts can be difficult to remember during a crisis. Be sure to use algorithms as cognitive aid when undertaking CPR.

It is important to memorize 4 Hs and 4 Ts (but always refer to the algorithm as a cognitive aid). Do not assume myocardial ischaemia is the aetiology:

- **H**ypovolaemia (the most common cause intraoperatively)
- **H**ypoxaemia
- **H**ypo/or/hyperkalaemia; hypomagnesaemia; hypercalcaemia
- **H**ypo/or/hyperthermia
- **T**ension pneumothorax
- **T**amponade (trauma, renal failure, thoracic malignancy)
- **T**hrombosis (cardiac or pulmonary)
- **T**oxins (including anaphylaxis and overdoses – tricyclic antidepressants, β-blockers, Ca^{++} channel blockers)

PRACTICE TIP
Echocardiography should be considered in the presence of life-threatening cardiovascular instability where the diagnosis is unclear or the response to initial therapy is inadequate, provided the necessary expertise is available to undertake the echocardiographic examination without interrupting chest compressions.

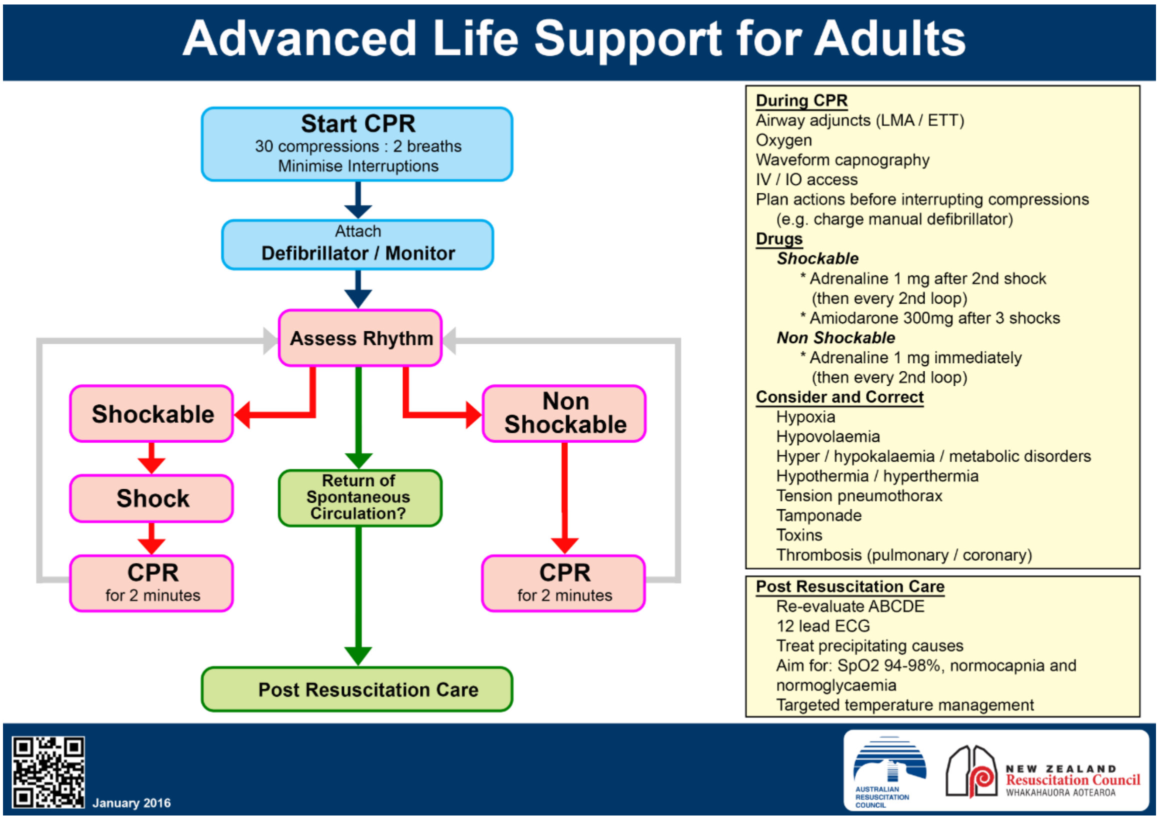

Figure 1. Adult Advanced Life Support Algorithm. NB. It is important to be familiar with the protocols used in the hospital in which you practice.

3. Peri-arrest Arrhythmias[16]

See Tables 1 & 2 and Figure 2.

In this section, an approach to the patient with a life-threatening cardiac arrhythmia is outlined. **Be sure to use a cognitive aid because excessive reliance on memory is a frequent cause of error.** Specific management is dictated by clinical assessment and the need to make timely decisions. Firstly, the anaesthetist needs to determine quickly whether the situation is life threatening and whether the patient needs CPR.

If the patient is unstable with serious signs or symptoms, then urgent and invasive therapy is indicated. Serious signs and symptoms include hypotension (SBP<90 in a conscious patient, but a lower pressure is usually tolerated in anaesthetised patients), heart rate >150 or <40 bpm, reduced level of consciousness, chest pain, congestive heart failure.

Most perioperative arrhythmias have remedial non-cardiac causes such as infection, hypotension, medications, metabolic disorders and hypoxia.[17] These should be sought early and treated. Preoperative ECG may identify predisposing features. Early consultation with a cardiologist is advised.

There are three basic questions:

What is the rhythm? There are two basic possibilities - tachycardia or bradycardia. When looking at the ECG: Is there a p wave, if so what is its relationship to the QRS? Is the QRS morphology normal, what is it width, and is the rhythm regular?

What is the underlying cause? Perioperative arrhythmias generally occur in patients who have heart disease and some other factor that initiates the arrhythmia, including:

- Acute ischaemia
- Sympathetic stimulation
- Drug effects
- Electrolyte imbalance (especially hypokalaemia and hypomagnesaemia)
- Hypoxia, hypercarbia

What is the treatment? This is determined by the clinical urgency and the availability of equipment (e.g. pacemaker for bradycardia). Always address the contributory factors as well as the arrhythmia.

Urgency	Rhythm	Initial Therapy
Serious signs and symptoms	Tachycardia	Electrical therapy - Cardioversion
	Bradycardia	Select the most readily available of: • Electrical therapy – Pacing • Drugs
Unstable but not immediately life threatening	Tachycardia	Reverse cause Consider drugs
	Bradycardia	Reverse cause Consider drugs

Table 1. Simplified Approach to Arrhythmias

3.1 Tachyarrhythmia with a pulse [9,16]

A cardiology opinion should be sought, although emergency treatment should not be delayed.

Tachyarrhythmias are usually differentiated on the basis of site of origin as supraventricular (SVT) or ventricular (VT). This distinction is important because ventricular tachycardia may degenerate into VF, whereas SVT is less hazardous, and in stable patients the treatments are different.
Both VT and SVT shorten diastole thus reducing coronary perfusion, and this may precipitate myocardial ischaemia.
Contributory factors should be sought and corrected. Failure to do so reduces the likelihood of sustained cardioversion:

- High circulating catecholamines.
- Hypokalaemia (if K^+<3.6 give K^+ at rate of 20 mMol per hour) with continuous ECG monitoring and then check it.
- Hypomagnesaemia (assume Mg^{++} low if K^+ low, give 8 mMol slowly over 10 minutes), and repeat if necessary. Mg^{++} is indicated for torsades de pointes and digoxin toxicity.

Haemodynamically unstable

Unstable patients with tachyarrhythmia (irrespective of supraventricular or ventricular origin) should be cardioverted. Shock should be synchronised with the R wave to minimize the risk of inducing ventricular fibrillation. If cardioversion fails then treat with amiodarone and then have further attempt at cardioversion. Because of the risk of stroke, caution should be exercised when considering cardioversion of fast atrial fibrillation (AF) if the duration of AF unknown. In this instance, an initial trial of vasopressor therapy is reasonable.

Haemodynamically stable with wide-complex tachycardia and a regular rhythm
Most patients will have VT and should be treated as such. Some will have SVT with bundle branch block. Stable VT can be treated with amiodarone 300mg initially, over 20-60 min. Some will have SVT with bundle branch block, if uncertain, consider administering adenosine first.

Haemodynamically stable with narrow-complex tachycardia and a regular rhythm
After excluding sinus tachycardia, most patients can be assumed to have supraventricular tachycardia (AV nodal re-entry tachycardia, or AV re-entry tachycardia/WPW or atrial flutter). These are uncommon in the peri-arrest situation unless there is underlying heart disease. Vagal stimuli such as Valsalva manoeuvre (ask awake patient to blow plunger up 20 mL syringe, carotid massage <5 sec.) will terminate about 25% of episodes of paroxysmal SVT. Failing those, administer adenosine as a 6mg rapid bolus, escalating to 12mg, which can be repeated every 1-2 min. This is successful in 90-95% of SVTs, or will slow atrial flutter allowing identification of flutter waves. If adenosine is contraindicated or fails without showing exposing atrial flutter, then administer verapamil or diltiazem. Adenosine may rarely trigger dangerously fast ventricular response in WPW.

Haemodynamically stable with an irregular tachyarrhythmia
Usually atrial fibrillation (AF) irrespective of QRS width, although occasionally this will be atrial flutter with variable AV block. Wide complex arises when there is bundle branch block.

New onset perioperative AF is usually caused by an underlying condition, e.g. sepsis, endocrine problem, pulmonary embolus. If the patient is clearly unstable, they should be cardioverted, accepting the risk of stroke. If not unstable, they should not be cardioverted without prior anticoagulation or transoesophageal echocardiography (TOE) to exclude atrial thrombus, unless the duration of atrial fibrillation is less than 2 days. If new onset (<48 hr), cardioversion may be safer for perioperative patient because it may allow anticoagulation to be avoided. Consultation with cardiologist is important. Ventricular rate control in atrial fibrillation is most commonly with β-blockers. In critically ill patients and those with severely impaired left ventricular (LV) systolic function, intravenous amiodarone can be used, and calcium channel blockers are relatively contraindicated due to their negative inotropic properties.[18]

Target rate is unclear, there being no long-term difference between patients with <80 at rest and <110 at rest. In patients with AF of >48 hr (or unknown duration) and requiring immediate cardioversion, concurrent anticoagulation with heparin should be considered because of atrial hypokinesia and risk of thrombus formation.[19]

Antiarrhythmic medications are not benign
Every antiarrhythmic that is administered unsuccessfully will add to myocardial depression and can be pro-arrhythmic (classic example is quinidine causing torsades de pointes). Acknowledging that all the antiarrhythmic medications can be pro-arrhythmic, verapamil has very specific and narrow indications (SVT known with certainty to be supraventricular in origin, and in absence of pre-excitation) and should be probably not be used without discussion with a cardiologist. Digoxin, amiodarone and nondihydropyridine Ca^{++} channel antagonists such as verapamil should all be avoided in pre-excitation.

	Wide Complex Tachycardia	Narrow-Complex Tachycardia (regular rhythm)	Atrial Fibrillation
First Choice	Amiodarone Mg++ for torsades	Adenosine for SVT	Esmolol for rate Amiodarone for rate and rhythm
Second Choice	Lignocaine	Amiodarone Esmolol	Ca++ blocker Amiodarone Magnesium Digoxin

Table 2. Simplified Antiarrhythmic Choices

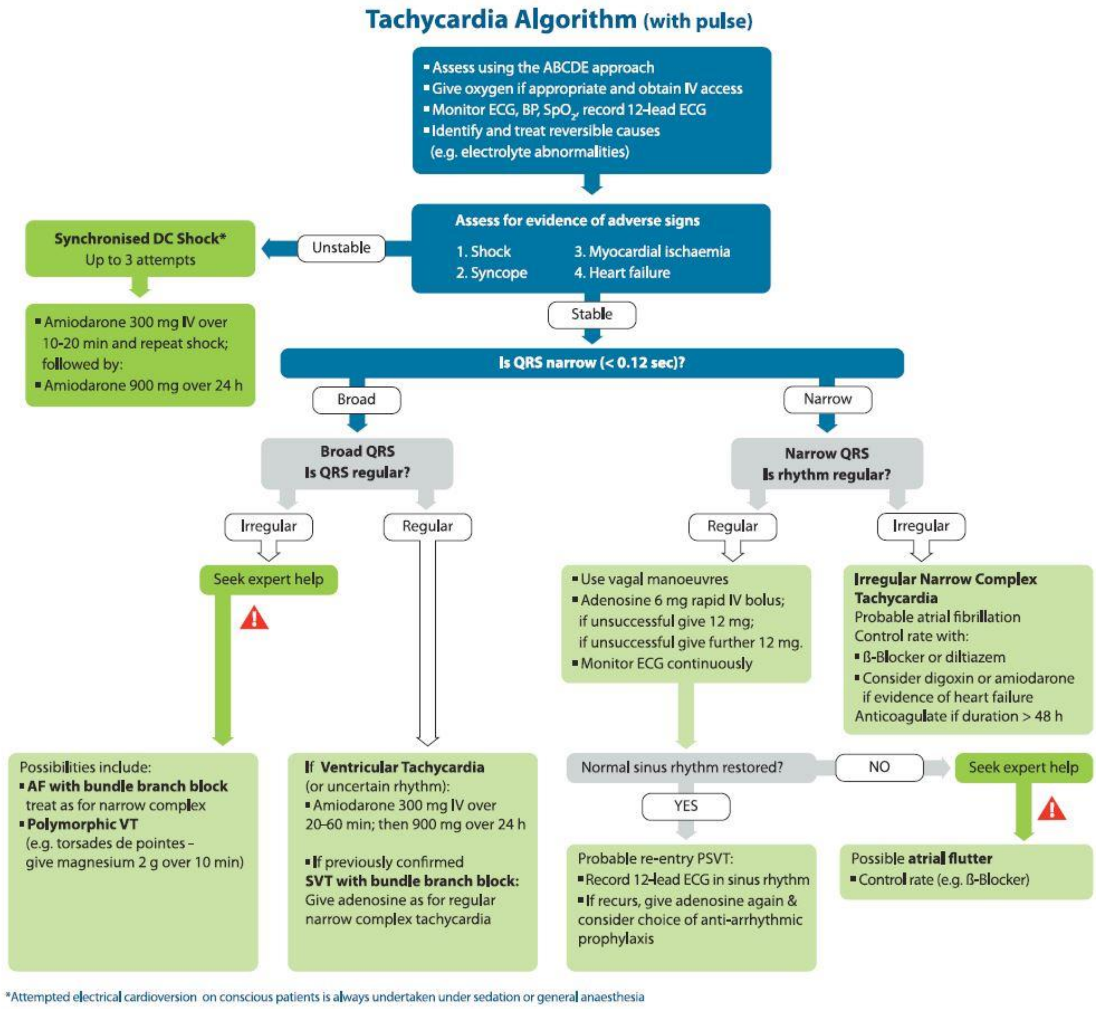

Figure 2. European Resuscitation Council algorithm for tachycardia with pulse.[16] NB. It is important to be familiar with the protocols used in the hospital in which you practice.

3.2 Cardioverter defibrillator[16,20]

A defibrillator is a device that delivers a controlled electric shock to terminate a cardiac arrhythmia. It is thought that if a sufficient portion of the cardiac tissue is rendered temporarily unexcitable, then the uncoordinated waveform that perpetuates the VF will be extinguished and normal electrical activity will resume. Cardioversion is the same principle, but with the use of a synchronised shock applied to a rhythm other than VF. Cardioversion requires less energy and 70-120 J biphasic is the most common initial energy, except for atrial fibrillation where a larger initial shock, 120-150 J biphasic, is recommended.

Defibrillator Features and Operation
Unsynchronized mode is usually the default setting. Modern defibrillators are biphasic, with manufacturer-specific energy recommendations. This is because the required energy varies depending upon the specific waveform of discharge.

Maximise current flow through the heart
Optimise transthoracic impedance: good contact with chest wall, appropriate size of electrode and end-expiratory timing (air in the chest increases the impedance), bone is a poor conductor and should be avoided.
With regard to electrode placement, the anterior electrode should be placed right parasternal, below the right clavicle and apical electrode is midaxillary line at level of nipple. It does not matter which electrode (apex/sternum) is placed in either position. The long axis of the apical pad should be orientated in a cranio-caudal direction to minimise transthoracic impedance.

Synchronisation
The shock should be synchronised to occur with the R wave of the electrocardiogram. VF can be induced if a shock is delivered during the relative refractory period. Some defibrillators re-set to the default asynchronous mode after delivering a shock and need to be re-set to the synchronised mode for subsequent synchronised shocks. Where there are problems with synchronisation using pads only, attaching ECG leads and synchronise to an appropriate lead (usually lead II) can be helpful. If there is a delay in synchronisation, then use an unsynchronised shock.

Indications
A cardioverter/defibrillator is preferred over antiarrhythmics if unstable, HR>150, or failed drug therapy. Indications for use include:

- Broad complex tachycardia and atrial fibrillation require large energy shock: Biphasic 120-150J.
- Atrial flutter and supraventricular tachycardia require lower energy: Biphasic 70-120J.
- Pulseless VT treated as VF (asynchronous defibrillation).

> **ACTIVITY**
> What are some of the potential hazards to patients and health care workers when using a cardioverter/defibrillator? How can they be minimised?

Hazards to Patient
Choose the minimum effective energy as it could cause damage to the patient's heart. Initial shock energy reflects a compromise between probability of success and risk of harm. The shock energy should be increased if a shock fails to terminate the rhythm. If the defibrillation is effective but the arrhythmia recurs, then the problem is recurrence, not failure to defibrillate and so re-shock with the same energy. Address the underlying cause and add an antiarrhythmic drug. Be sure to differentiate failure to defibrillate from rapid reversion to VF.

Electrical induction of VF may occur with asynchronous shocks.

Damage to implanted pacemakers or defibrillators may also occur. Try to avoid defibrillation directly over implanted devices.

Fire risks may apply more in the simulation environment than during patient care where stick-on pads are invariably used. It is an oxygen-enriched environment. Leave breathing system attached to airway device. Metallic medication patches can cause arcing and burns or fire risk.

Hazards to Healthcare Workers
Give clear warning of impending shock delivery. This risk to healthcare workers has probably been over-stated in the past.

Procedure for Defibrillation
It is essential to be familiar with the equipment in your own hospital. Defibrillation/cardioversion will be practiced at a skill station.

	Wide Complex or Atrial Fibrillation	**Narrow-Complex or Atrial Flutter**
Biphasic	120-150 J	70-120 J
Monophasic	200 J	100 J

Table 3. Simplified first shock energy settings[14,16]

3.3 Bradycardia[16] (see Fig 3.)

Bradycardia may be absolute (e.g.<60 beats per minute) or relative (inappropriately low in the physiological context). Bradycardia may be 'normal' in the extremely fit individual, and may be secondary to some other process, e.g. raised intracranial pressure, or hypertension from accidental overdose of a vasopressor. Mechanism is either reduced sinoatrial node firing rate, or failure in the conducting system, and can have cardiac or non-cardiac (e.g. drug toxicity) cause. Perioperative bradyarrhythmias are usually caused by medications, electrolyte disturbances, hypoxaemia or ischaemia. The treatment for symptomatic bradycardia, irrespective of cause, includes stopping vagal stimulation and then the critical decision is whether to pace or to use drugs.

- Initial treatment must be accompanied by a search for cause (e.g. hypoxaemia).
- Drug therapy is atropine 600 mcg repeated every 3-5 min. to a total of 3 mg (algorithm says 500mcg doses, but is manufactured as 600 mcg ampoule).
- If initial response is satisfactory, re-evaluate to consider risk of asystole. The risk of asystole is higher if: recent asystole, Mobitz II AV block, complete heart block with wide QRS, or ventricular pauses >3 seconds.
- In absence of response to atropine, isoprenaline (isoproterenol) (5mcg min^{-1}), adrenaline (epinephrine) (2-10mcg min^{-1}), dopamine (2-10 mcg kg^{-1} min^{-1}) are recommended second line medications. In anaesthetic practice, ephedrine or adrenaline (epinephrine) may be easiest in unexpected situation.
- Third-line drug therapies include aminophylline, glucagon (if β-blocker or Ca^{++}-blocker overdose).
- Unstable symptomatic patients should have transcutaneous cardiac pacing, atropine and/or adrenaline (epinephrine), as a bridge to transvenous pacemaker. Pacing should be available for stable patients where there is a perceived risk of asystole.

Sinus bradycardia, First Degree Block & Mobitz Type I Second Degree Block

- Rarely symptomatic.
- All of these may be caused by excessive vagal stimulation, especially if patient receiving digoxin, β-blocker, verapamil.
- Second Degree Block has intermittent failure of A-V Conduction. Mobitz Type I block is generally benign and asymptomatic. Block is usually at A-V node, with a normal His-Purkinje System. There is a progressive increase in delay between P and QRS, until a QRS complex is missed, causing an irregular QRS rhythm.

Sick Sinus Syndrome

- Alternating bradycardia and tachycardia.
- Treatment – combination of antiarrhythmics and permanent pacemaker.

Mobitz Type II Second Degree Block

- More ominous than Mobitz Type I.
- Intermittent failure of A-V conduction with loss of QRS complex; without progressive increase in delay between P and QRS. Irregular QRS rhythm.
- Usually caused by myocardial infarction or chronic degeneration of conduction system.
- May progress unexpectedly to third degree heart block. Symptomatic patients should be referred to a cardiologist for permanent pacing.

ACTIVITY
How do you differentiate between Mobitz type I and type II blocks?

Third Degree Block

- Total failure of A-V conduction. Block is usually below A-V node and involves total block through both bundles, hence wide QRS. Regular QRS rhythm.
- This is an unstable rhythm that is associated with extreme bradycardia and episodes of ventricular asystole.
- Usually caused by myocardial infarction or chronic degeneration of conduction system.

3.4 Emergency Pacing

Indications

- Haemodynamically unstable bradycardia (hypotension, altered mental state, angina, pulmonary oedema). Especially if unresponsive to drug therapy.
- Bradycardia with pause dependent ventricular rhythm (risk of ventricular tachycardia or ventricular fibrillation).
- Cardiac arrest secondary to drug overdose, acidosis, electrolyte disturbance or other reversible process.
- After cardiac surgery.

Relative Contraindications

- Severe hypothermia (risk of triggering VT and VF, these are also more difficult to treat).
- Brady-asystolic arrest >20 minutes (futility - patient is already dead).

<u>Transcutaneous Pacing</u>

This is the first choice in emergency cardiac care. Most modern defibrillators have transcutaneous cardiac pacing capability and the recommended output is more or less twice the output of a standard peripheral nerve stimulator and there is no significant bystander risk (in contrast to cardioversion/defibrillation).

- Apply standard defibrillation pads. The anterior electrode is placed to the left of sternum at the cardiac apex. The posterior electrode is placed immediately behind the anterior electrode, to the left of the spine, but may be placed laterally (in the standard defibrillation position) if moving the patient is difficult. Remember the goal is to deliver current to the heart.
- Initiate pacing. Default rate is typically 80 per minute. In an emergency it is better to select a fixed rate as the first choice (if you use a demand pacing mode, and the ECG becomes disconnected, then there may be a delay with pacing). Increase the output until capture is achieved, typically 65-100 milliamperes (mA) in adults with unstable bradycardias (most transcutaneous cardiac pacing systems have an output current of 0-200 m Amps). Pace at 10% above capture threshold.
- <u>Check that the pacing current is triggering the ventricle to depolarise.</u> You should see a wide QRS complex and a broad T wave.
- <u>Ensure mechanical capture</u>**,** i.e. pulse synchronous with ECG.
- Additional pharmacological inotropic support [e.g. adrenaline (epinephrine) infusion] is often needed in addition, to produce adequate cardiac output.

Complications of Transcutaneous Pacing

The pacemaker current has a duration of 20-40 milliseconds and this current may conceal the underlying rhythm. <u>This may cause the operator to fail to recognise either non-capture or underlying ventricular fibrillation.</u> Pain from electrical stimulation of skin or muscle may make this difficult in the conscious patient, hence carefully administered analgesia and sedation may be required. Tissue damage can occur with prolonged use.

<u>Fist Pacing</u>

If atropine is ineffective and transcutaneous pacing is not immediately available, fist pacing can be attempted while waiting for pacing equipment. Give serial rhythmic blows with the closed fist over the left lower edge of the sternum to pace the heart at a physiological rate of 50–70 beats min^{-1}

Specific force recommendations are not included in the ALS guidelines. Presumably it should be similar to a precordial thump where the recommendation is for a sharp impact from a height of about 20 cm, followed by immediate retraction of the fist to create an impulse-like stimulus.

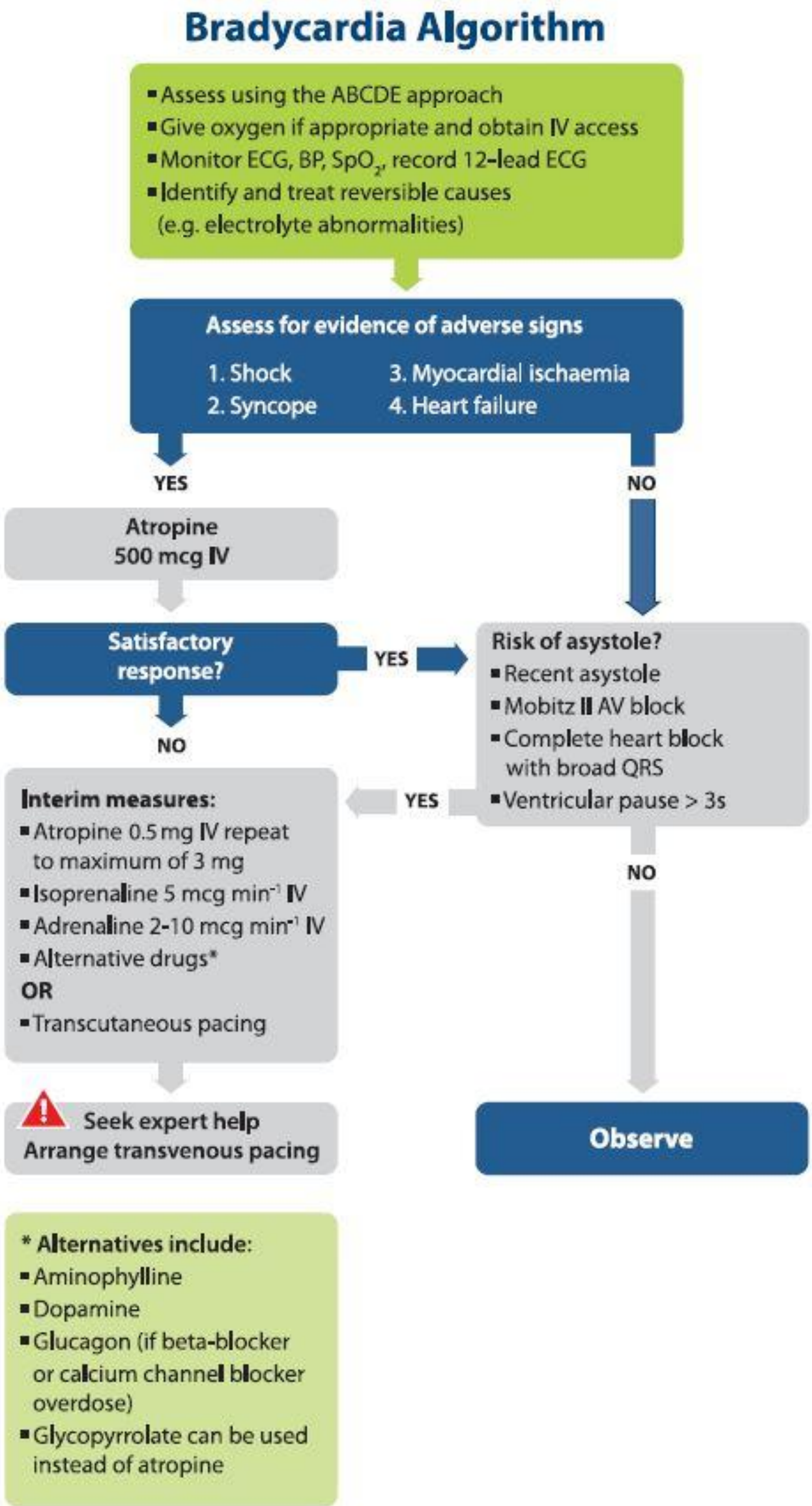

Figure 3. European Resuscitation Council bradycardia algorithm.

4. Post Resuscitation Care[10,21]

Although some patients do awaken rapidly after cardiac arrest, this is difficult to determine in the intraoperative cardiac arrest. It is thus reasonable to leave the trachea intubated after all intraoperative cardiac arrests (except very brief ones), and to undertake post-resuscitation care in the intensive care unit.

The immediate goals of post-resuscitation care are to:

- Identify and treat precipitating causes.
- Assess and mitigate ischaemia-reperfusion injury to multiple organs.

In practice this means optimising cardiopulmonary function and systemic perfusion, especially to the heart and brain, and to institute measures that may improve long-term, neurologically intact survival.

Global Review

Post-arrest patients will frequently have haemodynamic instability and ABCD problems are common contributing factors and should be actively pursued through secondary survey and repeated re-evaluation.

<u>Secondary Survey and initial management</u>

Airway	Ventilation R=L
Breathing	Paralyse, sedate, target SpO_2 94-98%, normocarbia
Circulation	IV access, monitoring (vital signs, urine output, invasive monitoring). Verify placement of all catheters and cannulae with X-ray
Diagnose Cause	12-lead ECG to rule out STEMI, electrolytes, (Na^+, K^+ , Ca^{++}, Mg^{++}, blood gases), drug screen, glucose. Consider echocardiogram
Treatment Complications	CXR (fractured ribs, pneumothorax, tracheal tube), consider tamponade.

Cardiovascular Care

After ROSC a 12 lead ECG should be obtained to rule-out STEMI and the potential need for immediate re-perfusion. This is relatively unlikely in perioperative patients, compared to patients with out-of-hospital cardiac arrest.

The severity of myocardial dysfunction in the post-resuscitation period is related to the duration of global myocardial ischaemia, the underlying cause, and the extent of the systemic inflammatory response. Inotropes or vasopressors are usually needed, at least transiently, to treat the hypotension from systolic dysfunction. Volume loading may be needed to optimise preload in context of impaired diastolic relaxation.

There are no internationally agreed haemodynamic targets. Avoidance and correction of systolic BP<90 mmHg, or MAP<65 mmHg have been accepted as reasonable, taking into account patient's normal blood pressure, and aiming for adequate urine output (1ml $kg^{-1}h^{-1}$) and normal or decreasing plasma lactate.

Respiratory Care [22]

The patient may be hypoxaemic secondary to gross V/Q mismatching and should be ventilated with 100% oxygen until the oxygenation and ventilation are stable and verified. Subsequently, maintain oxygen saturation 94-98%, avoiding hyperoxia and ventilate to maintain normocapnoea, and avoid hypocapnoea.

Neurologic Care

Early neurologic assessment is an unreliable indicator of ultimate recovery of cerebral function. The earliest assessment for poor prognosis should be at 72 hours. Targeted temperature management (32°-36°C) is recommended for adult patients who remain unresponsive after ROSC. It is reasonable for this to be maintained for at least 24 hours. Avoidance of hyperthermia is essential. Seizures or other forms of epileptiform activity occur in 12-24% of patients who are comatose after ROSC. Continuous EEG monitoring is recommended and this is an intensive care unit (ICU) issue, not an immediate perioperative concern.

The benefit of any specific target range for blood glucose are uncertain. Tight glucose control increases the risk of harmful hypoglycaemia and is not recommended. Target less than 10mmol.L^{-1} and avoid hypoglycaemia.

Any associated cerebral oedema is rarely associated with increased intracranial pressure. Cerebral autoregulation is impaired in at least 35% of patients, providing argument in support of maintaining blood pressure close to normal for that patient.

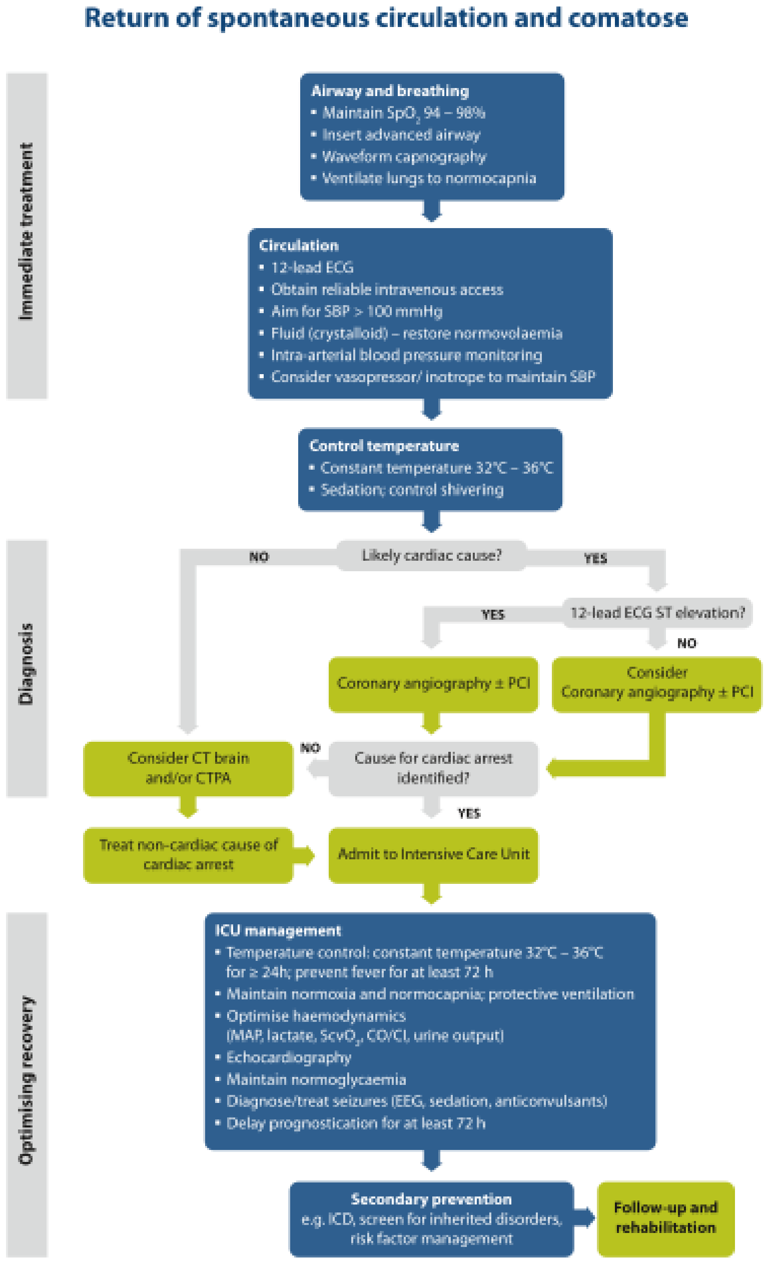

Figure 4. European Resuscitation Council Post arrest care algorithm.

5. Crises with Valvular Heart Disease [4,23]

Significant valvular heart disease increases cardiac risk for patients undergoing noncardiac surgery. Diagnosis is crucial for the perioperative management of patients with valvular heart disease undergoing noncardiac surgery. Diagnosis will usually require echocardiography.

Valvular intervention before elective noncardiac surgery is effective in reducing perioperative risk for adults who meet standard indications for valvular intervention (replacement and repair) on the basis of symptoms and severity of stenosis or regurgitation.[4]

5.1 Aortic stenosis

Aortic stenosis is the most common valvular heart disease in the elderly; affecting 2 – 9% of adults over the age of 65 and 50% of patients also have coronary artery disease.[24] In general, asymptomatic patients with severe aortic stenosis and preserved ventricular function can safely undergo moderate risk, noncardiac surgery, provided there is appropriate monitoring and perioperative haemodynamic management. Risk is related to transvalvular maximum velocity, and left ventricular size and function. The rate of complications is much higher in patients with undiagnosed severe aortic stenosis.[24]

The mechanism of major adverse cardiac event is related to hypotension and tachycardia resulting in a decreased coronary perfusion pressure, and development of arrhythmias or ischaemia. Patients with aortic stenosis or hypertrophic cardiomyopathy may develop myocardial ischaemia without having coronary artery disease.

Because of reduced ventricular compliance, a high filling pressure is required and maintenance of preload is desirable. Hypotension may cause a dramatic reduction in coronary perfusion and should be treated aggressively with an α-agonist. Sinus tachycardia or atrial arrhythmias should similarly be treated aggressively, aiming for a heart rate of 50-60.

5.2 Mitral stenosis

Patients with symptomatic mitral stenosis or regurgitation carry an increased risk of perioperative congestive heart failure.[17] As with aortic stenosis, the main goals during the perioperative period are to avoid tachycardia and hypotension, and to maintain intravascular volume at a level that ensures adequate flow, but without causing acute pulmonary oedema.

Percutaneous mitral balloon commissurotomy may be an option. Mitral valve disease is associated with pulmonary hypertension and atrial arrhythmias (especially atrial fibrillation). Tachycardia is poorly tolerated in severe mitral stenosis because of limited time for atrial emptying (left atrial pressure rises further) and left ventricular filling is compromised.

5.3 Aortic and mitral regurgitation

Left-sided regurgitant lesions are better tolerated than stenosis. Both are associated with LV volume overload. Preload should be maintained because the LV has increased size and compliance and excessive afterload should be avoided to maintain cardiac output and reduce the regurgitation volume. Tachycardia is useful to optimize forward flow.

In aortic regurgitation, a critically low diastolic pressure in the presence of high left ventricular end-diastolic pressure, can threaten coronary perfusion.

5.4 Hypertrophic cardiomyopathy (HCM) [25,26]

This disease is more common than previously recognized (1:500) and is frequently undiagnosed. Dynamic left ventricular outflow tract (LVOT) obstruction occurs in 2/3 of patients with this diagnosis. The condition is particularly relevant during perioperative care because LVOT obstruction may be provoked by increases in contractility, reduction in preload, or a decrease in ventricular volume. A patient with HCM who sustains acute haemorrhage resulting in systemic hypotension and tachycardia may develop dynamic LVOT obstruction, and the situation is likely to be aggravated by the administration of adrenaline (epinephrine). Negative inotropes (typically β-blockers) are the mainstay of treatment. Vasodilators will worsen the LVOT obstruction and any associated mitral regurgitation. Patients who do not have dynamic LVOT obstruction may decompensate due to diastolic dysfunction. Paroxysmal atrial fibrillation may be poorly tolerated and may cause acute deterioration.

6. Hypertensive Crises[27]

The perioperative risk attributed to hypertension is related to the extent of pre-existing hypertension-induced end-organ damage, and complications directly attributable to the effects of hypertension on heart, brain, and surgical sites (e.g. increased haemorrhage and threats to vascular anastomoses.) Patients who have poorly treated severe hypertension (e.g. BP>180-209/110-119) have an increased risk of intraoperative cardiovascular lability and perioperative myocardial ischaemia.

Therapy for perioperative hypertensive crises should be directed at the underlying cause of the acute hypertension and the related morbidity.

ACTIVITY
What are the most common causes of severe intraoperative hypertension?

Read the following article:
Paix et al (2005) – Crisis management during anaesthesia: hypertension [28]

Immediate treatment:[29]

- Stop the surgery until BP control is achieved.
- Exclude measurement error (repeat the measurement, correct cuff size, ensure the transducer has not fallen to the floor).
- Treat the cause (e.g. deepen the anaesthesia, check that the ventilation and oxygenation are adequate, check that this is not the response to intracranial hypertension in head injured patients. Consider uncommon problems such as malignant hyperthermia, phaeochromocytoma or autonomic hyperreflexia if chronic spinal cord injury).
- Consider invasive monitoring and specific antihypertensive therapy such as vasodilators and β-blockers. Check that usual antihypertensives have been administered. Caution should be exercised if administering β-blockers without vasodilators in this context, because of the risk of precipitating acute left ventricular failure.

Subsequent investigation should be considered to exclude rare and unexpected conditions such as thyroid storm, phaeochromocytoma, and other endocrine causes of hypertension.[29]

7. Emergency Vascular Access

The traditional EMST/ATLS approach has been to undertake two attempts at peripheral venous cannulation, and failing that to undertake peripheral venous cut-down. The use of venous cut-down is now uncommon because the complication rates of cut-down are similar to femoral vein cannulation and central vein cannulation (although the complications here are more serious).

When caval injury is a possibility, IV access should be above or below the diaphragm, depending on site of injury. Cervical injury is a relative contraindication to internal jugular. With chest injury, place the central line on same side as the chest injury to avoid injury to good lung. If using a vascular access sheath (such as a pulmonary artery catheter sheath) for rapid infusion, ensure that all valves are capped to avoid air entrainment.

When used with a pressure infusion system, an extravasated IV line can cause a compartment syndrome. Failure to respond to IV therapy should provoke a search for an extravasated IV line.

7.1 Vascular access options

Peripheral vein

- Percutaneous - procedure of choice.
- Cut-down should be delegated to someone with surgical expertise – long saphenous, cephalic, basilic, median cubital. Almost never needed in the current era.

Central vein

- When peripheral sites not available.
- Low complication rate with experienced personnel and use of ultrasound.
- Life threatening complications include haematoma, haemo/pneumothorax, hydrothorax, cardiac tamponade, air embolus, and arrhythmia.
- Complication rate increases with each needle pass and success is very unlikely after 5 needle passes.

Femoral vein

- Cannulation has fewer immediate complications than other central veins and can be undertaken concurrently with airway management, and compressions. Increased risk of line sepsis is debated.

Intraosseous (IO)[30]

- The device must be flushed before use, and a lignocaine bolus (2mL of 2% lignocaine) is recommended to reduce pain with infusion.
- IO devices can be for the same purposes as a peripheral or central line.
- Pharmacokinetics are similar to central venous access and any drug can be administered by this route. In animal models, and in humans, they have been used to administer adrenaline (epinephrine), sodium bicarbonate, calcium chloride, hydroxyethyl starch, 50% dextrose in water, lignocaine, blood, colloid and other fluids.
- Can be used in all age groups. During WW2 they were standard equipment for use in adults, although recent use mostly in preschool children (less than 6 years). Specific equipment is now commercially available for use in adults, and IO route is accepted

by the European Resuscitation Council and the American Heart Association as an alternative form of IV access in adults.[31-33]

- Tracheal administration of drugs no longer recommended, IO is preferred.
- Because the tibial site can easily be accessed without interfering with CPR, it may be the best site.
- Modern devices (e.g. power drill) allow rapid access, high success rate on first attempt, with a typical insertion time of 1-2 minutes.
- Can be used to draw laboratory tests, but laboratory needs to be warned that it is a marrow specimen.
- Rapid infusion in adults is feasible, but there is concern regarding risks of fat embolus, extravasation, and compartment syndrome and so the safety of large volume infusion is unclear.
- Contraindications: Fracture or recent intraosseous attempt in same extremity because of risk of fluid extravasation, compartment syndrome or vascular injury in target extremity, acute infection at insertion site, orthopaedic hardware at insertions site, inability to identify landmarks. There have been reports of significant injury with sternal with use of the EZ-IO®.

ACTIVITY
Please read the following:
Paediatric Intraosseous Access
Intraosseous Access

Then view the following videos prior to attending the EMAC Course.

1. Overview
2. Tibia
3. Humerus
4. Errors
5. RIC Lines

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Airway Emergencies:
A Human Factors Approach

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Introduction

Good practice in anaesthesia is underscored by careful planning and preparation, early recognition of problems and know-how regarding effective team interventions. A well-prepared anaesthetist has an overall airway management strategy for each patient prior to commencing anaesthesia. This strategy comprises three levels of planning, as follows:

1) The ***primary plan*** is the preferred anaesthetic technique, reflecting best practice according to available evidence and tailored to the patient's needs.
2) It is also practical and worthwhile to plan for a small number of contingencies. These include failure of the primary plan and complications for which there is a reasonable index of suspicion. ***Contingency plans*** can also be tailored to the known needs of the patient and surgery.
3) Numerous problems can potentially develop during anaesthesia, which are unanticipated. These evolve to airway emergencies if not rapidly resolved. While it is not practical to formulate tailor-made plans for each of these, over-reliance upon intuitive problem solving may contribute to sub-optimal management. ***Emergency plans*** are simple pre-rehearsed responses, often supported by cognitive aids designed to prompt good decision making and establish a shared mental model.

The main focus of this chapter is the third level of planning; becoming familiar with and rehearsing emergency plans for the unanticipated difficult airway. It is beyond the scope of the chapter to address specific techniques relevant to primary and contingency planning for anticipated difficult airways, such as acute presentations with airway swelling, trauma and/or

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bleeding. Similarly, while airway assessment is essential for planning, it is well covered elsewhere[2] and will only be briefly addressed in this chapter.
Unanticipated difficulty can occur with any of the three modalities of the upper airway management: facemask ventilation (FMV), supraglottic airway (SGA) insertion and tracheal intubation. Difficulty with tracheal intubation is an inconvenience and can generate anxiety, but is in most cases not a genuine emergency unless it is accompanied by upper airway obstruction with an inability to deliver oxygen via one of the other modalities. If this situation is not managed well, and sometimes even despite it being managed well, the outcome can be a 'can't intubate, can't oxygenate' (CICO) event.

The period leading up to CICO has been labelled *'Transition'* to CICO and can be defined as being *the period from when CICO is first explicitly identified as a possible outcome to the point where either alveolar oxygen delivery is definitely restored via effective upper airway rescue, or CICO is declared and CICO Rescue initiated*. Effective management of *transition* requires concurrent optimisation of upper airway rescue and active preparation for CICO Rescue. This will be a major focus of this chapter.

A recent report published by the Australian and New Zealand College of Anaesthetists' Airway Management Working Group (ANZCA AMWG) explores aspects of 'best practice' in relation to CICO 'transition' as well as examining the incidence, impact and aetiology of CICO[1]. The report contains several key findings and recommendations of which the following two are arguably the most important. First, that while the large majority of incidents involving difficult airways are resolved without CICO eventuating, sufficient evidence exists to suggest anaesthetists, and other clinicians, are not well prepared to prevent and manage them. Second, the report provides evidence that management of airway emergencies is far more frequently compromised by human factors rather than technical expertise. These include a combination of poor judgment, flawed decision making and loss of situational awareness.

The results of the 4th National Audit Project (NAP4), a collaboration of the Association of Anaesthetists of Great Britain and Ireland (AAGBI) and the Difficult Airway Society (DAS), support this assertion that human factors play a significant role in determining the outcomes of airway emergencies.[3] The authors of the study state:

> *"Elements of poor planning, poor judgement, (and) deviations from recognised algorithms…were seen throughout the reports submitted to the project".* [3 (p112)]

Our approach to the unanticipated difficult airway is broadly organized into two phases:

1. Management of upper airway obstruction and 'transition' to CICO
2. Management of the CICO event. CICO Rescue is the term which will be used to describe the performance of any cannula, scalpel or guidewire cricothyroidotomy or tracheotomy technique aimed at achieving access to the trachea for oxygen delivery after CICO has been declared.

Chapter Outline

1. Being prepared for the unanticipated difficult airway – The need for a strategy, not just a plan
    - 1.1 Airway Assessment
    - 1.2 Algorithms
    - 1.3 Algorithms as foundation tools
    - 1.4 Cognitive aids as implementation tools

2. A review of airway outcomes - Is the unanticipated difficult airway poorly managed?
    - 2.1 NAP4
    - 2.2 ANZCA Report on transition to CICO

3. Human Factors concepts central to airway management
    - 3.1 The need for 'Hand's Off' Leadership
    - 3.2 'Fast' vs 'Slow' thinking
    - 3.3 Competency as a motivator
    - 3.4 Shared mental models

4. Managing upper airway obstruction, transition to CICO and CICO Rescue effectively – What are the barriers and how can we overcome them?
    - 4.1 Prevention of CICO
    - 4.2 Priming for CICO
    - 4.3 Permission to perform CICO Rescue
    - 4.4 Puncture: CICO Rescue performance
        - 4.4.1 A 'Cannula-First' Approach utilising both cannula and scalpel techniques
        - 4.4.2 The DAS 'scalpel only' CICO Rescue Approach

Learning Outcomes

By the end of this chapter a participant will be able to:

- Describe how stressful emergency conditions impair cognitive processes leading to errors and diminished performance in technical tasks, decision-making and leadership.
- Describe the key features of a range of ANZCA-recommended emergency airway algorithms and cognitive aids.
- Demonstrate an integrated team approach to the management of airway obstruction and transition to CICO, including utilisation of a cognitive aid promoting a shared mental model.
- Employ effective communication techniques aimed at clarification of leadership and team member roles, sharing information, prompting action, declaring CICO and mobilising resources for CICO rescue.
- Perform technical components of an integrated CICO Rescue approach, including both cannula and scalpel techniques.
- Discuss the pros and cons of both a cannula-first approach and a scalpel-only approach to CICO Rescue.
- Incorporate the cognitive aids, team approaches and CICO Rescue techniques, described above, into an overall airway management strategy during a simulated airway emergency.

> ***NOTE***
> The activities and simulation sessions that comprise the airway module on day 2 of the EMAC course rely on the participant arriving with a firm working knowledge of:
> i) optimisation techniques for upper airway rescue during airway obstruction; and
> ii) a range of CICO Rescue techniques including both cannula and scalpel techniques.
>
> It is essential that Section 4 of this chapter, which covers these topics, is read and the activities completed prior to attending the airway module.

A glossary of terms is provided in Appendix 1.

In this chapter, the term 'oxygenation' or 'alveolar oxygen delivery' is used in preference to 'ventilation' to emphasise that the goal is always oxygenation rather than delivering normal minute volumes. This is particularly important during CICO Rescue. It is worth emphasising, however, that during upper airway rescue the definitive indicator that alveolar oxygen delivery is occurring is the presence of end-tidal carbon dioxide ($ETCO_2$).

1. Being prepared for the unanticipated difficult airway – The need for a strategy, not just a plan

Mortality data presented in the abovementioned ANZCA AMWG report highlight suboptimal assessment and primary planning as contributing to the majority of cases of death from CICO. This emphasizes the importance of carefully considered primary plans. However, even when an appropriate primary plan has been developed, all airway management techniques have a failure rate, and even meticulous selection of a carefully considered primary airway plan, including access to the latest technology, does not guarantee success. Thus, while the process of careful airway assessment followed by selection of an appropriate primary airway plan is laudable, airway assessment should be seen not just as a tool for identifying the best possible primary airway plan, but also as a stimulus for selecting and mentally road-testing a series of back-up plans to be utilised in the contingency of the primary plan failing.

In other words, anaesthetists should be encouraged to always ask themselves the following question*…"what is the plan if this plan fails?"* in order to develop an airway *strategy*.

"A strategy is a coordinated, logical sequence of plans, which aim to achieve good gas exchange and prevention of aspiration. Anaesthetists should approach airway management with strategies rather than plans"[3 (p8)]

The process of developing an airway strategy is not only relevant prior to initiation of airway management but also whenever an unanticipated airway emergency has occurred, and effective upper airway rescue has led to alveolar oxygen delivery being re-established. These are crucial moments when the patient is no longer at imminent risk of critical desaturation and time exists to explore additional management options. When this occurs there is an opportunity to reassess the existing strategy in the light of new information or altered priorities that may have arisen during airway instrumentation undertaken to that point.

1.1 Airway assessment

The ANZCA AMWG recently released an airway assessment resource designed to assist anaesthetists in the process of airway assessment.[2] This document includes a comprehensive review of airway literature and existing guidelines. The resource recommends an approach of developing an overall airway strategy rather than limiting the focus of assessment to the formulation of the primary plan. The resource encourages the anaesthetist to consider the following questions during the process of airway assessment:

Specific airway overview questions[2]
1. Is there documentation regarding previous airway difficulty?
2. What is the impact of surgery on the airway?
3. How difficult is bag and mask ventilation?
4. How difficult is it to place a supraglottic airway device?
5. How difficult is it to intubate the patient?
6. How difficult is it to perform an Infraglottic airway?
7. What is the aspiration risk?
8. Is there any altered cardio-respiratory physiology?
9. How easy will they be to extubate?

The resource can be accessed through the following link:
ANZCA Airway Working Group: Airway Assessment

PRACTICE TIP
Begin each airway assessment with a provisional strategy in mind encompassing both the primary plan and contingency plans in case difficulty is encountered. Perform your airway assessment with a view to testing the viability of your airway strategy.

For example - if FMV is part of your contingency plan in case of difficulty with intubation during a rapid sequence intubation, ensure that your airway assessment includes a specific focus on identifying predictors of difficulty with FMV.

1.2 Algorithms

The ANZCA AMWG reviewed a selection of established emergency algorithms addressing airway obstruction and transition to CICO for common themes. These algorithms included the Difficult Airway Society (DAS) guidelines[4], The American Society for Anaesthetists (ASA) algorithm[5], the Canadian Airway Focus Group Difficult Airway Algorithm[6] and the Vortex.[7]
Key features that were considered to contribute to an algorithm's effectiveness included:

1. Easily accessible to all members of the team and embedded in everyday routine practice, such as case briefings.
2. Representing airway assessment, decision to induce general anaesthesia and CICO as related events.
3. Presenting upper airway rescue as three pathways or lifelines: FMV, ETT and SGA.
4. Provision of clinical criteria for declaring CICO, for example, maximum number of attempts at endotracheal intubation and extent of peripheral oxygen desaturation (although this second criterion is controversial).

5. Inclusion of prompts (as questions, reminders or practice points) for steps at high risk of faulty decisions, omission or delay. These will be discussed further in the *Cognitive aids as implementation tools* section, below.

Recently several authors have attempted to draw a distinction between i) relatively information-dense, comprehensive algorithms and ii) the simpler cognitive aids designed for use in real-time emergencies. [8,9] The more complex algorithms such as the ASA and DAS algorithm have been categorized as *foundation tools*, and may be considered more appropriate for the learning, preparation and planning phase of airway management.[8] The simpler, pared-back decision support tools such as the Vortex or the recently-released ANZCA CICO Transition cognitive aid[1], may be better suited to use during an airway emergency to support the implementation of an emergency plan. These have been categorized as *implementation tools.*[8]

1.3 Algorithms as *foundation tools*

1. **The DAS Guidelines**

The Difficult Airway Society guidelines for the management of unanticipated difficult intubation[4] is an exemplar of a planning tool that incorporates three levels planning; primary, contingency and emergency, as part of a complete airway strategy. They observe human factors principles in their simple layout and by highlighting a “stop and think” opportunity when oxygenation becomes possible.[10,11] They also incorporate new devices (videolaryngoscopes) and techniques (NO DESAT[12] and THRIVE[13] nasal delivery of oxygen) into the guidelines. An overview of the DAS guidelines is provided in the Figure 1, below.

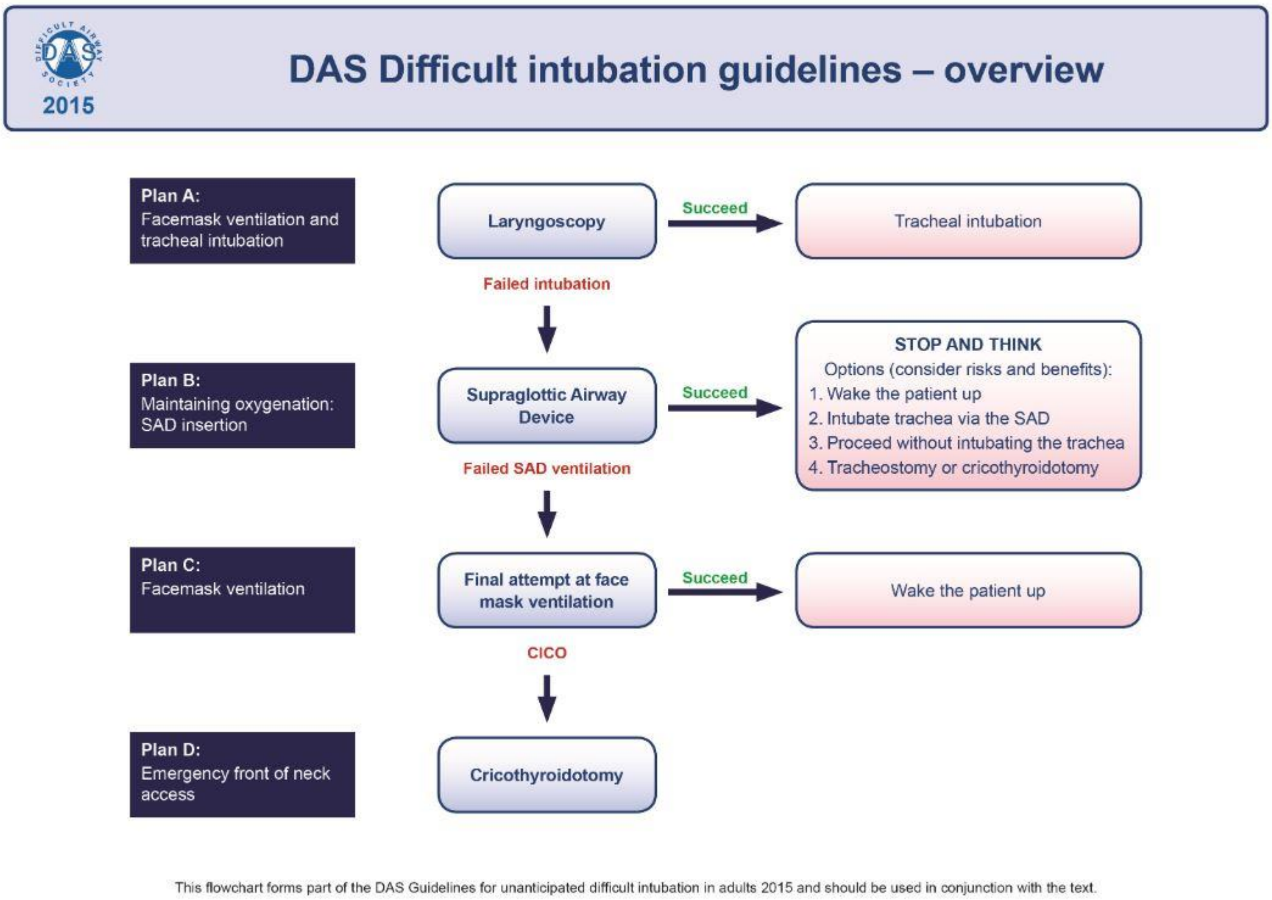

Figure 1. DAS overview

For the reasons outlined above, throughout this chapter the DAS guidelines will be considered a *foundation* tool for use *prior* to an airway emergency, while the use of a simple *implementation* tool (cognitive aid) that is context independent will be advocated for use *during* management of airway crises. This is consistent with the approach encouraged by the DAS Guidelines.[14]

2. Other *foundation tools*

The ASA algorithm and the Canadian Airway Group Difficult Airway Algorithm are shown below. Similar to the DAS guidelines, their complexity and the inclusion of considerable text is likely to limit their utility as a decision support tool during a crisis. While each of these algorithms has specific strengths worthy of discussion, they are not widely utilised in the countries where EMAC is delivered, and will not be discussed further.

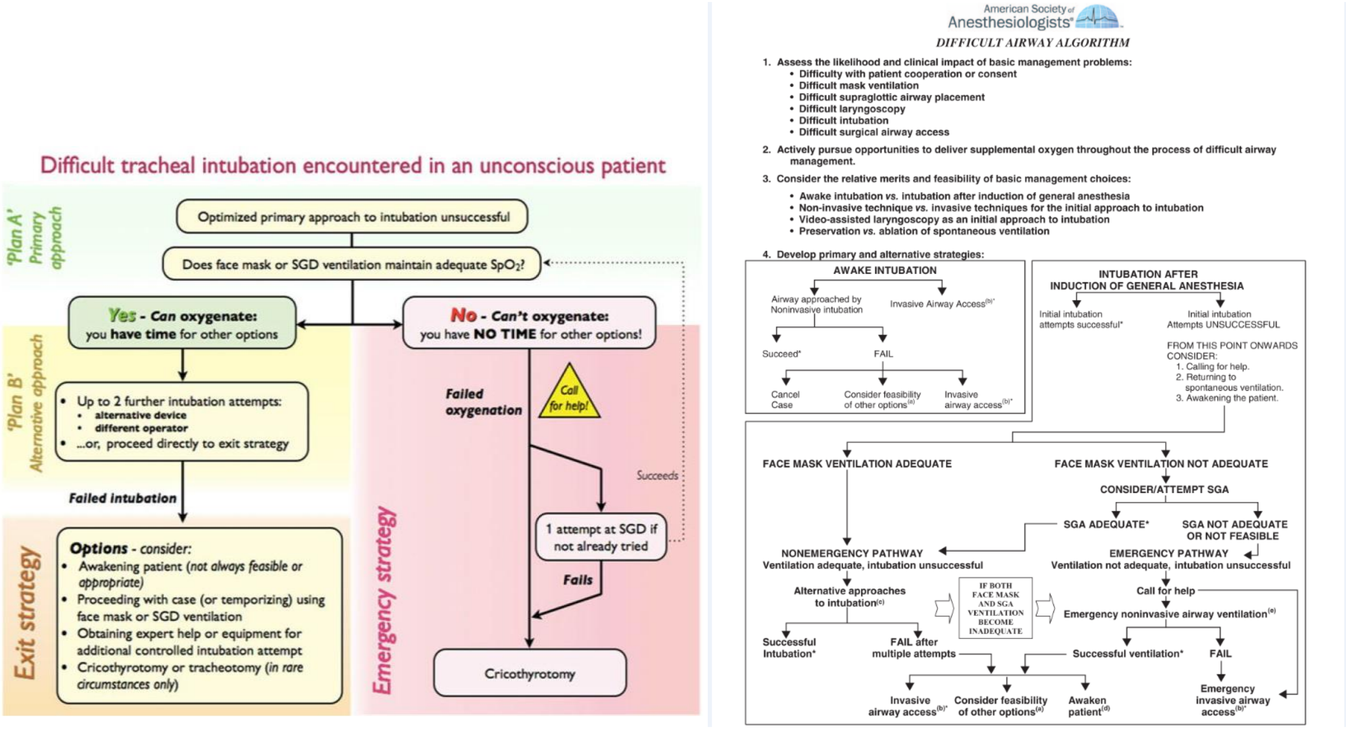

Figure 2. Canadian Airway Focus Group Difficult Airway Algorithm & the American Society of Anaesthetists Algorithm

1.4 Cognitive aids as *implementation tools*

Time-critical situations cause impairment of cognition and recall, which can limit the effectiveness of content-rich foundation tools in these situations. Simplified cognitive aids are designed to be used *during* the emergent situation, and as such require different properties to the foundation tools described above. In his literature review of existing cognitive aids for use during emergencies Marshall identified a number of properties of the ideal cognitive aid[15], including:

- Prompting recall of the available options
- Preventing omissions of viable options, deviations from best practice and failures to progress when an option is exhausted
- Presentation in a simple format to allow use during an emergent situation
- Supported by prior training to ensure familiarity with the tool
- Promotion of team coordination

Here we present two examples of cognitive aids designed to address these needs by supporting decision-making with a view to: i) preventing CICO where possible; ii) preparing (priming) for CICO Rescue early in the transition process; and iii) declaring CICO and commencing CICO Rescue in a timely manner.

Regardless of the examples presented here, it is important that you are familiar with any cognitive aids for airway management in use at your hospital.

1. The ANZCA transition to CICO cognitive aid

As described earlier, the ANZCA AMWG in their review of existing algorithms and decision-support tools for use during airway obstruction and transition to CICO, identified a number of useful prompts that an implementation tool should provide. These are shown in Box 1, below.

Box 1: <u>Useful prompts during upper airway rescue</u>

- Consider awake intubation/tracheostomy in high-risk patients.
- Attempt all three upper airway rescue pathways: FMV; ETT; LMA.
- Call for help.
- Attempt to deliver oxygen via an upper airway rescue pathway at all times.
- Awaken the patient if feasible.
- Mobilise resources for CICO rescue when two supraglottic pathways are unsuccessful.
- Declare CICO when all three upper airway rescue pathways are unsuccessful.
- Initiate CICO rescue immediately CICO is declared.
- Team members should be encouraged to speak up at any time if concerned.
- Use specific criteria to guide extubation and monitor carefully afterwards.

These points were used as the basis for the design of the ANZCA Transition to CICO Cognitive Aid, shown below. Although badged as a cognitive aid, by virtue of its inclusion of large amounts of supplementary information, in particular that relating to airway assessment, this tool appears to be addressing more of the learning, preparation and planning aspects of a *foundation tool*, and moving away from the ideal properties of an *implementation* tool, described earlier.

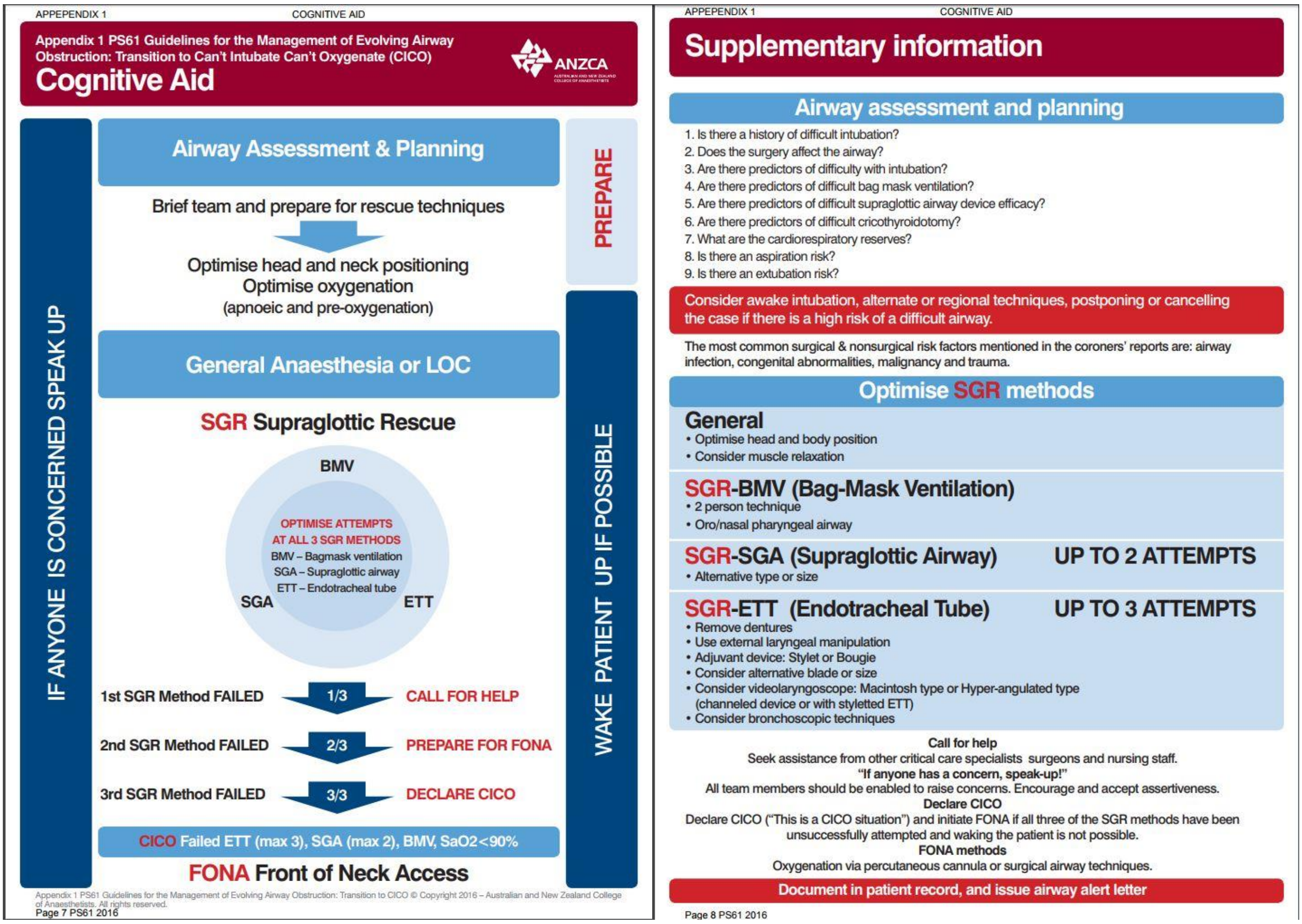

Figure 3. The ANZCA Transition to CICO Cognitive Aid

2. The Vortex tool

The Vortex tool is the central component of the broader Vortex Approach - a system designed to help clinical teams perform under pressure by providing a simple, consistent template that can be taught to all clinicians involved in advanced airway management, regardless of the context in which airway management takes place. The Vortex does introduce some non-standard language, discussed later, particular around areas of airway management where existing language is ambiguous or poorly defined. This suggests that it is likely to produce optimal results in situations where entire teams are trained around this approach.

The key components of the Vortex Approach are:

1. The Vortex Tool
2. The CICO Status Tool
3. The Green Zone Tool

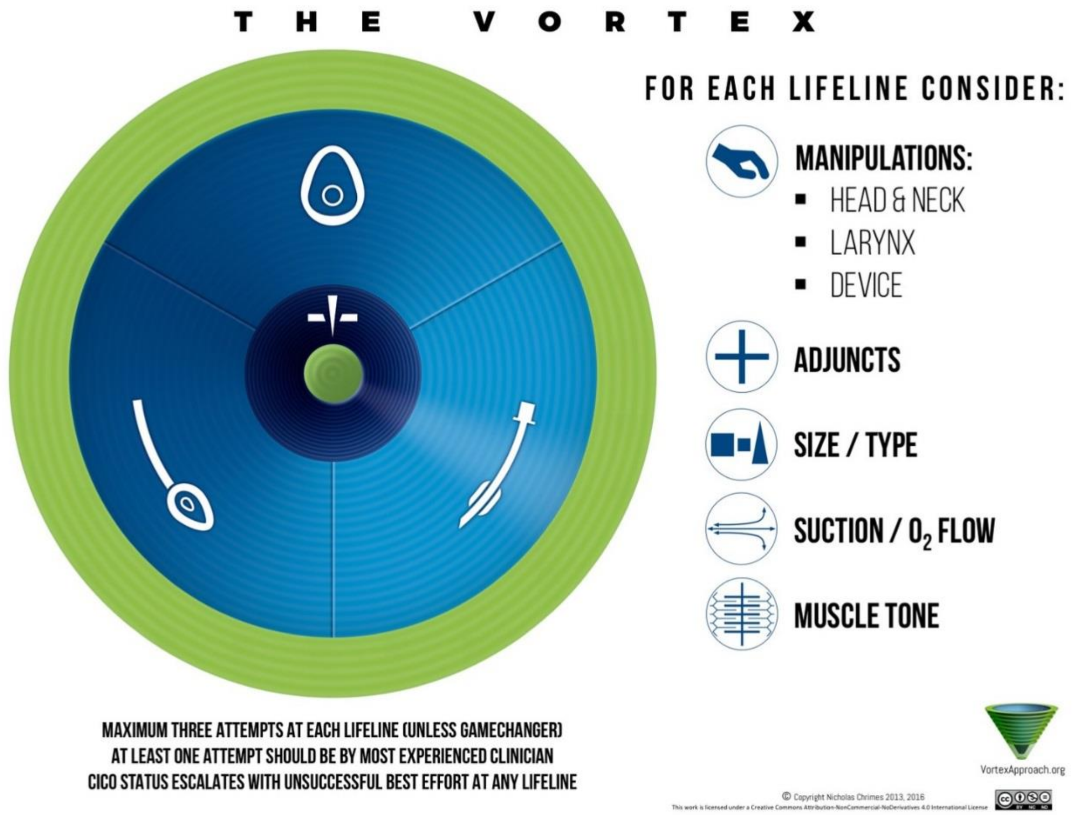

Figure 4. The Vortex Tool

The Vortex tool (above), the Vortex Approach, and the ANZCA Transition to CICO Cognitive Aid will be discussed in more detail in later in the chapter in *Section 4: Managing the transition to CICO and CICO Rescue effectively – What are the barriers and how can we overcome them?*

2. A review of airway outcomes – Is the unanticipated difficult airway poorly managed?

2.1 NAP4

Human factors, and in particular poor decision making, frequently contributed to suboptimal airway management in the NAP4 reports.[3] The authors concluded that airway management was poor in approximately half of anaesthetic cases in which serious airway complications occurred and that the commonest causal factor was poor judgment. Amongst the many failures of individual or team non-technical skills (NTS) that were identified during review of the cases, the following were felt to have occurred during the real-time management (as opposed to the assessment and planning phase) of the airway emergencies:

- lack of clarity of team structure
- poor leadership
- failures of communication
- failures to cope with the stressful environment
- failures to formulate, communicate and implement back-up plans
- fixation error involving failure to desist from a primary plan when it was not working.

These failures in NTS manifested as fundamental errors in management such as:

- Repeating attempts at tracheal intubation well beyond the recommended number
- Failing to attempt upper airway rescue with a SGA prior to performing CICO rescue
- Failing to perform CICO rescue when it was clearly indicated.
- Omitting administration of muscle relaxation and/or deepening anaesthesia where it was considered likely to have solved or at least improved the problem.

Analysis of the NAP4 data suggested that human factors contributed to just over 40% of serious complications, and had been directly causative in a quarter of cases. Interestingly, in a *post-hoc* analysis of a sample of the reported NAP4 cases, Flin and colleagues used a structured interview process to identify causative human factors in a range of domains.[16] These interviews revealed that human factors had in fact played a causative role in all of the cases reviewed.

One of the comments recorded from an anaesthetist interviewed in the above study serves to highlight the effect of cognitive biases (discussed in more detail later in the chapter) on decision making – in this case the experience of countless numbers of 'uneventful' cases leading up to this one very difficult case. The consequence in this case is fixation error:

"I really think it was sort of locked in my head that this was not going to be anything other than a straightforward case… I found it quite difficult at the time getting my head round what had happened and working out what the problem was". [16 (p.821)]

The Elaine Bromiley Case

The list of NTS failures described in the NAP4 study bears an uncanny likeness to those identified as having contributed to the poor outcome in the high-profile Elaine Bromiley case.[16] In that seminal case the possible consequences of losing situational awareness during an airway emergency are clearly highlighted. Not only did the anaesthetists involved in this case fail to recognise the seriousness of the situation and the duration that the patient was exposed to hypoxia, but they also failed to recognise the significance of the times where they were able to oxygenate the patient – these were an opportunity to stop, stabilise the patient, and calmly consider all available options including the possibility of waking the patient. The importance of identifying these opportunities as a means of preventing a CICO event will be emphasized later in this chapter when effective management of CICO transition is explored.

For those not already familiar with the case, the independent report, including the coroner's verdict[17], can be found via the link below:
The Case of Elaine Bromiley (report)

The video outlining the case details and the human factors issues contributing to the outcome[18], can be found via the link below:
Just a Routine Operation

2.2 ANZCA report on transition to CICO

As already mentioned, the ANZCA AMWG recently produced a comprehensive review of the literature on transition to CICO titled *Transition from supraglottic to infraglottic rescue in the "can't intubate can't oxygenate" (CICO) scenario*[1]. In Part One of the report, the impact of CICO transition on mortality and patient safety is reviewed; including the evidence indicating that the 'transition' process is sub-optimally managed. Sources of evidence include audits, adverse event databases, the ASA Closed Claim data, coroner's reports and research studies. The key points, excluding those relating to assessment and planning, are as follows:

- Declaration of CICO and performance of CICO Rescue may be delayed or not occur at all. This is often associated with persistent, excessive attempts at upper airway rescue
- Viable modalities of upper airway rescue, such as LMA insertion, are frequently completely omitted
- Anaesthetists often lack the technical knowledge and skill to implement an effective CICO Rescue strategy
- Organisational preparedness for CICO events is frequently inadequate, including an absence of training, protocols, cognitive aids and equipment to support prevention of CICO, and performance of CICO rescue.

In Part 3 of the report, the role of human factors and non-technical skills in managing the transition to CICO is explored. Anaesthetists' vulnerability to cognitive error and impairment is described in detail, and the importance of teamwork, cognitive aids and effective training in mitigating this vulnerability discussed. The following section will expand upon these concepts.

3. Human Factors Concepts Central to Airway Management

Later in the chapter the core elements of effective management of a time-critical airway crisis will be identified. At the same time, the barriers to effective management that contribute to the errors and sub-optimal performance commonly seen within each of these elements will also be explored, along with the tools and behaviours that we believe can combat and overcome these barriers. Before that, however, it is worth expanding on a couple of key points that were raised in the Human Factors chapter (Chapter 1) that provide some insight into specific aspects of time-critical airway emergencies that make them particularly vulnerable to errors and impaired performance.

These are:

1. The need for 'Hand's Off' Leadership
2. 'Fast' vs 'Slow' thinking
3. Competency as a motivator
4. Shared mental models

3.1 'Hands off' leadership

During an unanticipated difficult airway, almost by definition, the anaesthetist is going to be highly engaged in technical tasks at the time the crisis declares itself. It has been well established that when we receive incoming cognitive stimuli deemed to be important, for example, cues that that airway management is more difficult than anticipated, most or all of our cognitive capacity will be directed towards managing the technical problem, at the expense of reasoning and communication.[19] This may contribute to many of the commonly seen failures during management of airway crises, particularly those around loss of situational awareness, poor task prioritisation, and failures to identify and establish clear leadership. This highlights not only the importance of calling for help, but also having the tools and language to rapidly communicate the key aspects of the crisis to the arriving members to allow a shared approach to problem-solving and identification of priorities.

ACTIVITY

Watch these two short videos, Handover 1 and Handover 2, depicting the stage of an airway crisis when help arrives.

What question did the responding anaesthetist ask in the "Handover 2" video that ensured optimal team structure? What did this move to 'hands off' leadership achieve?

3.2 Cognition under stress – fast (System 1) and slow (System 2) thinking

The dual-process model of cognition has evolved from the work of Nobel-prize-winner Daniel Kahneman.[20] The key features of this model can be summarised as follows:

System 1 decision making (frequency gambling)	System 2 decision making
• Rapid, effortless, instinctive • Tends to occur sub-consciously. • Relies heavily on pattern recognition and/or heuristics (mental "rules of thumb") to allow fast and frugal decision making. • Prone to biases and errors	• Slow, effortful, • Difficult under stress • Logical, systematic, • Error resistant • Requires significant cognitive "band-width" which in turn requires slowing down off-loading tasks, etc.

Due to the time-critical nature of airway crises, we will almost certainly default to System 1 decision making in these situations.[21] An example of how this type of decision making can be flawed or biased in the domain of airway management would be the decision to persist with multiple attempts at intubation, using various blades of a video-laryngoscope, despite dangerously low oxygen saturations and an inability to oxygenate (ventilate) the patient. In retrospect it is easy to see that this is a mistake, but in the midst of an airway emergency our experience tells us that it is exceedingly unusual for intubation with a video-laryngoscope to be unsuccessful. The heuristic (mental shortcut) we may adopt in the midst of this stressful situation is *"Video-laryngoscopy has always worked before, therefore it will work now".* Repeated previous successes with the video-laryngoscope has biased our thinking. We can replace these unhelpful heuristics with helpful ones (thereby de-biasing our thinking) by utilising simple decision-support tools[22] that prompt us with the available options and optimisations but force us to desist from these when they are exhausted and to acknowledge and prepare for worst case scenarios.

The slower but more robust System 2 decision making is likely to be difficult to implement in the time-critical situation of a 'can't oxygenate' airway crisis. The opportunity to be "systematic" occurs at moments when the time pressure is suspended – the times when confirmation of adequate alveolar oxygen delivery is possible. This is the case even if these 'can oxygenate' moments are achieved with a 'rescue' airway device, for example, an LMA, that was not the intended device of the primary airway plan.

It is therefore critical during an airway crisis to recognise the opportunities to slow down, in order to create the necessary cognitive bandwidth for systematic thinking. This is the rationale behind both the 'Stop and Think' prompt of the DAS guidelines, discussed earlier, and the 'Green Zone' of the Vortex Approach, which will be discussed in the next section. Purposeful 'slowing down' strategies such as these are recognised as an important defence against errors and resultant poor outcomes in the operating theatre environment.[23]

3.3 Competency as a motivator

In chapter 1 the idea was introduced that the anaesthetist exists as part of a complex system involving interactions with other people and complex technology. Within that system the anaesthetist has a strong need to: i) understand what is happening around them; and ii) maintain a sense of feeling and appearing competent. In their book examining human factors in the critical care setting, St Pierre and colleagues explain how clinicians maintain an understanding of the ever-changing situation around them through the adoption of mental-models which are rapidly formed utilising an existing catalogue of past experiences[24]. When an incorrect mental model is adopted, particularly in a high-stakes situation, the need to maintain 'understanding' of the situation leads to a tendency to disregard or ignore incoming information that contradicts the adopted set of assumptions. Recall the statement from the interviewed anaesthetist from NAP4:

"I really think it was sort of locked in my head that this was not going to be anything other than a straightforward case… I found it quite difficult at the time getting my head round what had happened and working out what the problem was"

Compounding this subconscious desire to preserve a sense of understanding of the situation is the fear of appearing incompetent to one's peers. Airway management is an essential component of anaesthetic practice, and is the area of medical care in which anaesthetists are thought to be, and expected to be, experts. When problems arise during airway management it is likely that a complex array of emotions, such as guilt, shame or fear, will accompany the failure to anticipate the difficulty, and the ongoing inability to resolve the problem.[25] These feelings and emotions serve to further bias decision making and increase cognitive impairment.

Again, to overcome the effects of these unhelpful emotions and fears, cognitive forcing strategies are needed to systematise the clinicians approach and de-bias their thinking.[25] These can include decision-support tools (cognitive aids) and utilisation of a team approach to establish and maintain a shared mental model of the situation. By sharing the problem, including their understanding of it, the clinician can utilise the team to identify the biases and blind-spots in their reasoning. This is the idea of *mutual performance monitoring* that was introduced in the Human Factors chapter.

3.4 Shared mental models to optimise team performance

All of us will have benefited in our careers from times when our anaesthetic assistant, or colleague, has made helpful, timely suggestions that have helped us to avoid or retrieve a difficult clinical situation. Earlier, the Human Factors chapter introduced the idea that a key requisite for ensuring this type of effective team-work is the establishment of a shared mental model.

The shared mental model allows team members to:

- predict what equipment or assistance might be needed into the future
- make suggestions on how best to achieve the key management priorities
- identify when there are errors or biases in the airway operator's or team leader's thinking.

The utilisation of a simple, effective cognitive aid that is understood by all members of the team managing the airway crisis can ensure a shared mental model of the situation is established. One remaining element in the chain between a shared understanding of the management approach and a shared understanding of the situation is a commonly understood language that allows rapid, effective communication of the situation during an airway crisis.

Later in this chapter a set of key terms and phrases to be utilised during an airway crisis to rapidly establish a shared understanding of the situation, promote recall of possible management options and force consideration of, and preparation for, worst case scenarios will be proposed.

4. Managing Upper Airway Obstruction, Transition to CICO and CICO Rescue Effectively – What are the Barriers and How Can We Overcome Them?

The earlier sections of this chapter have attempted to provide some insight into the barriers to effective management that exist with regard to time-critical airway emergencies, and the kinds of errors that can occur as a result. Some of the solutions to overcoming these barriers have also been touched upon. At the outset of this chapter we defined Transition to CICO as being *the period from when CICO is first explicitly declared as a possible outcome to the point where either alveolar oxygen delivery is definitely restored via effective upper airway rescue, or CICO is declared and CICO Rescue initiated*. Effective management of this transition therefore requires the concurrent pursuit of two key goals: i) efficient optimisation of upper airway rescue; and ii) physical and psychological preparation for the timely performance of CICO Rescue.

The problem with conceptualising this process of CICO transition is that CICO events are only identifiable as CICO events after exhaustion/completion of upper airway rescue attempts - i.e. it is only identifiable as a CICO event in retrospect. When difficulty with alveolar oxygen delivery is first encountered we have no way of knowing whether the situation will culminate in a CICO event. Experience tells us it rarely does. With this in mind, it is easy to understand why the two key goals of CICO transition might be approached with less urgency and rigor than might be reasonably expected in these situations. In the absence of a metaphorical crystal ball, allowing us to know at the outset which of these situations are CICO events and which aren't, a robust comprehensive approach to unanticipated airway obstruction is required to ensure the key goals of CICO transition are managed effectively.

Four key elements of effective transition to CICO have been described[14], and are schematically represented in Figure 3, below. These elements will now be examined in detail including the barriers to effective management that exist and how these are overcome.

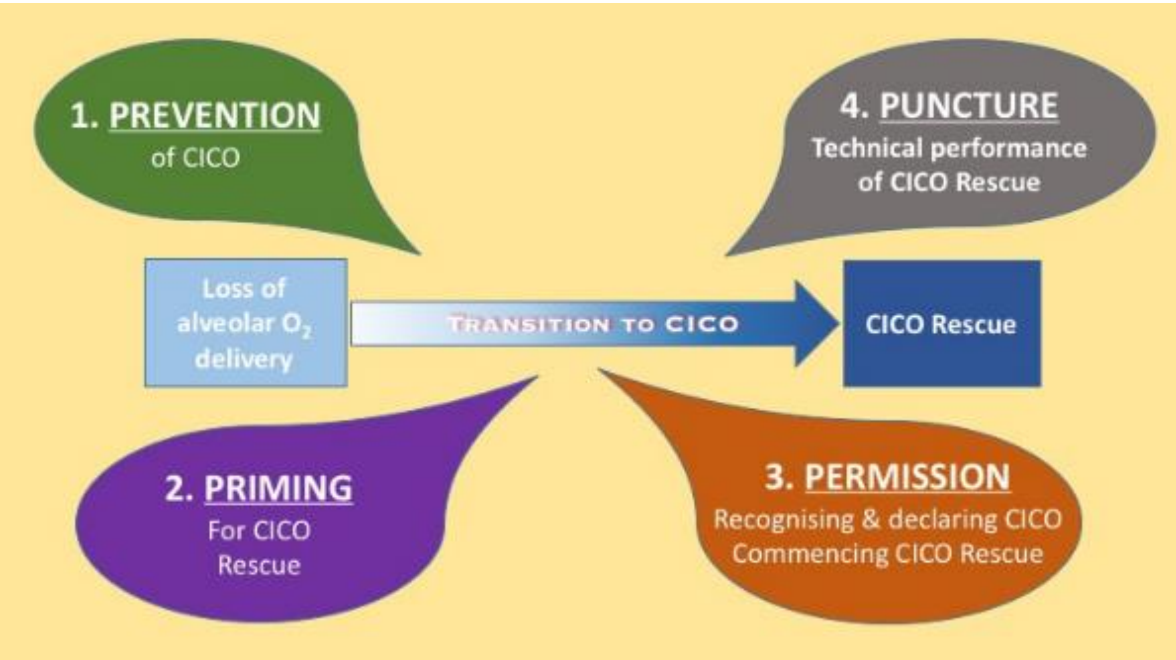

Figure 5: Elements of effective management of CICO Transition

4.1 PREVENTION of CICO

"Just over half of cases did not have an attempt at rescue with a SAD before attempting the emergency surgical airway. Importantly there were cases where a SAD was placed and provided a good airway after the cricothyroidotomy had been performed, demonstrating that emergency surgical airway could have been avoided in at least a proportion of these patients." [3 (p108)]

It is a statistical reality that not all difficult airways can be predicted[27]. Unfortunately, within this cohort of unanticipated difficult airways, there are a concerning number of cases that proceed to CICO Rescue where the CICO event could otherwise have been prevented.[1,3]

The preventable cases tend to involve either failures of i) *Omission*: a failure to attempt or optimise aspects of upper airway rescue when ventilation is impossible, or ii) *Persistence*: a failure to desist from attempting airway instrumentation when alveolar airway delivery is possible – thereby transforming a *'can't intubate, CAN oxygenate'* situation into a CICO situation. While stress clearly plays a contributory role in both of these situations, they do, in fact, evolve from different underlying mechanisms, and as such require different strategies to ensure they are effectively addressed. The barriers to effectively preventing CICO and the possible solutions are outlined in Table 1, below.

1. PREVENTING CICO		
Barriers to effective management	**Errors commonly seen**	**Solutions**
Omission • Inability to recall all three upper airway rescue pathways or optimisation strategies for each of these ▪ Reliance on decision-support tools not suited to real-time use in emergent situations Persistence ▪ Failure to recognise alveolar oxygen delivery (ventilation) is occurring ▪ Failure to recognise opportunities afforded when alveolar oxygen delivery is occurring – slowing down to think, re-oxygenate, gather resources and plan	• *Declaration of CICO without an attempt at LMA insertion* • *Declaration of CICO without administration of muscle relaxants to optimise upper airway lifelines* • *Repeated attempts at direct laryngoscopy instead of waking the patient or performing asleep fibreoptic intubation*	• **Contingency planning (e.g. DAS guidelines)** • **Cognitive aid** used in real-time • **Hands-off leadership** ▪ **Slowing Down to Think** when alveolar oxygen delivery is restored ▪ **Communication** Use of key **terms and phrases** by team members to promote a shared metal model ▪ **Capnography** As a definitive indicator of alveolar oxygen delivery

Table 1. Preventing CICO.

How can a cognitive aid assist *prevention* of CICO?
Earlier we introduced two cognitive aids as example of *implementation tools*, intended for real-time use during an unanticipated airway emergency. Aspects of each of the tools have been designed specifically to overcome the abovementioned problems of *omission* and *persistence*[8].

Both tools highlight the fact that there are only three upper airway rescue pathways (referred to as 'lifelines' in the Vortex approach) by which alveolar oxygen delivery can be established and confirmed: FMV, SGA and ETT. Exhaustion of an upper airway pathway as an option, referred to as completion of a 'best effort' in the Vortex approach, without being able to restore alveolar oxygen delivery mandates moving on to the next pathway or lifeline.

The circular arrangement of the three lifelines on both tools means that these tools can be used regardless of which airway management modality difficulty was first encountered with, and that the airway operator can attempt to utilise the remaining lifelines in whatever sequence is judged most appropriate in the clinical circumstances. Importantly, this allows these tools to be used is in situations where endotracheal intubation is not the primary plan – unlike clinical guidelines written explicitly for the situation of difficult intubation. Both tools are shown again, below.

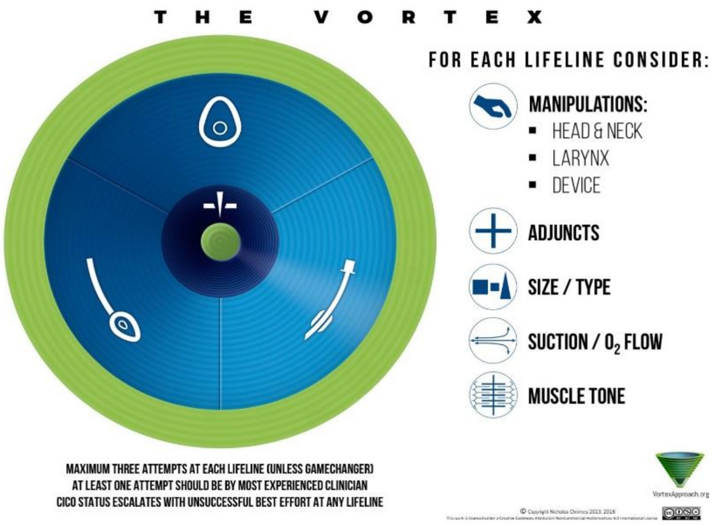

Figure 6.
The Vortex Tool

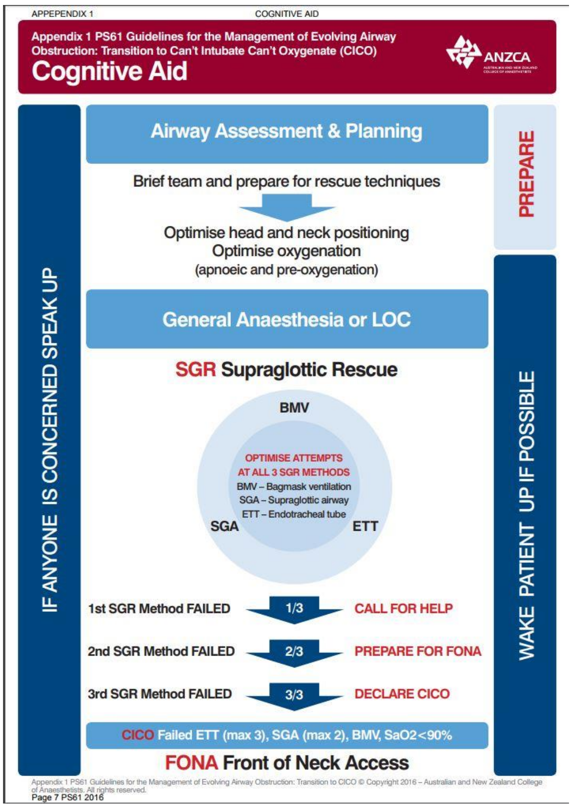

Figure 7. Front page of the ANZCA Transition to CICO tool

In keeping it ‘conceptually’ simple these tools seek to prevent the commonly seen errors of *omission* such as forgetting to attempt insertion of an LMA when FMV is impossible.

Both tools attempt to prevent getting stuck at a particular pathway or lifeline by limiting the maximum number of attempts at each pathway. They also both include prompts designed to ensure that optimisation strategies are employed if initial attempts at a pathway or lifeline are unsuccessful. In this way, other common errors of *omission* can be avoided, such as forgetting to deepen anaesthesia or administer muscle relaxants where laryngospasm and/or muscle tone are contributing to the inability to oxygenate the patient.

The Vortex model prompts five categories of optimisation that may be applied to improve success at re-establishing alveolar oxygen delivery (entering the Green Zone) via any of the lifelines (Figure 8, below).

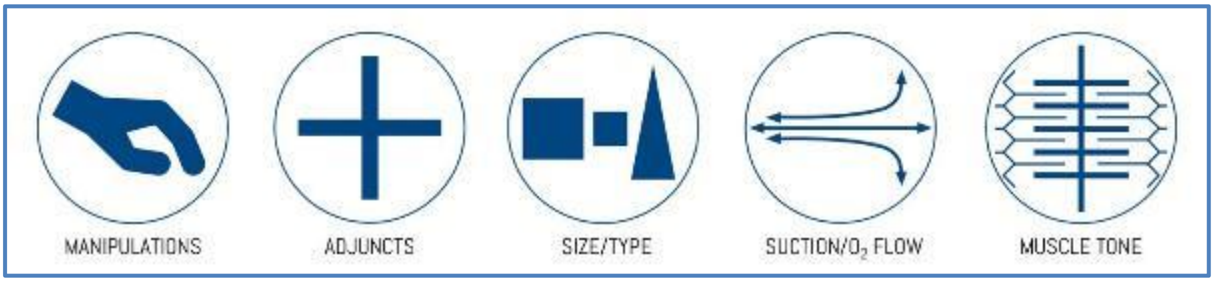

Figure 8. Vortex optimisation prompts for upper airway *lifelines*

These five categories apply equally to each of the three lifelines. The specific interventions within each category are discussed in more detail on the website at VortexApproach.org. Categorising optimisations in this manner allows the entire team to track which interventions have been implemented by the airway operator and to offer suggestions in a structured manner.

The ANZCA Transition to CICO tool has optimisation prompts listed under each of the upper airway rescue pathways, which are referred to on the tool as supraglottic rescue (SGR) methods as well as a heading of general prompts. These are found on the reverse side of the tool, and are shown in Figure 9, below.

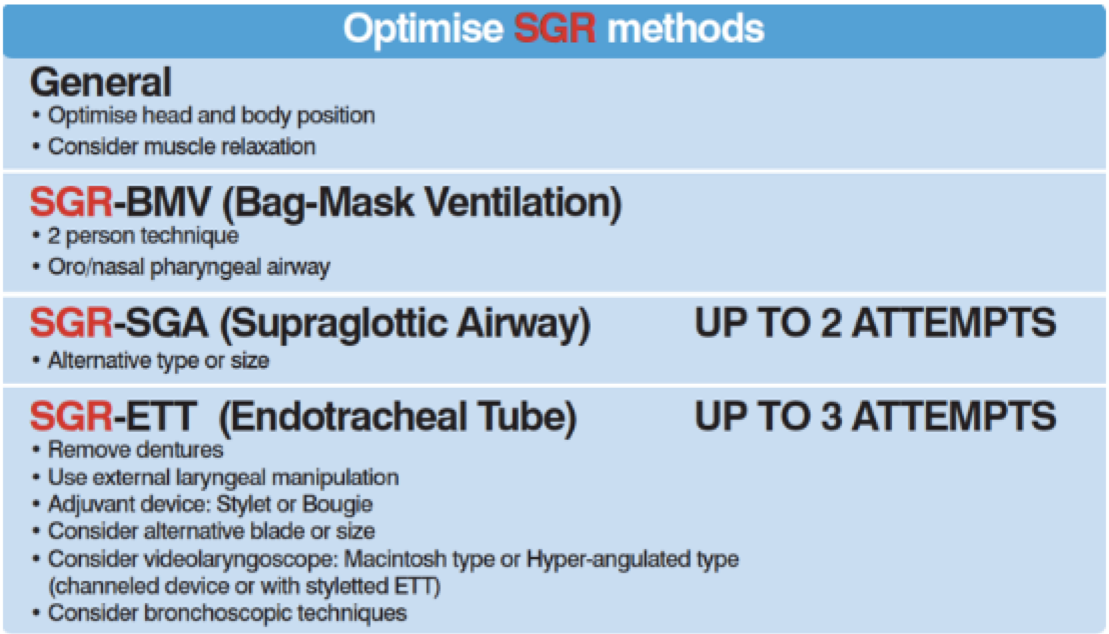

Figure 9. ANZCA Transition to CICO optimisation prompts. SGR = supraglottic rescue.

The Green Zone

The Vortex Tool possesses one important feature that is not addressed in the ANZCA Cognitive Aid, which is a type of cognitive *'slowing down'* strategy[23], mentioned earlier in the chapter. Confirmation of adequate alveolar oxygen delivery using any of the three lifelines, results in outward movement into the circumferential 'Green Zone'. The Green Zone emphasizes the relative safety of the 'can oxygenate' situation, encouraging the team to step out of 'crisis mode' and slow down. It prompts recognition of the opportunity to re-oxygenate, gather resources and develop a strategy that arises whenever alveolar oxygen delivery is able to be established. The idea of climbing out of the relative 'panic' of the vortex onto the 'safe' horizontal surface of the green zone is illustrated on the lateral three dimensional representation of the vortex, below.

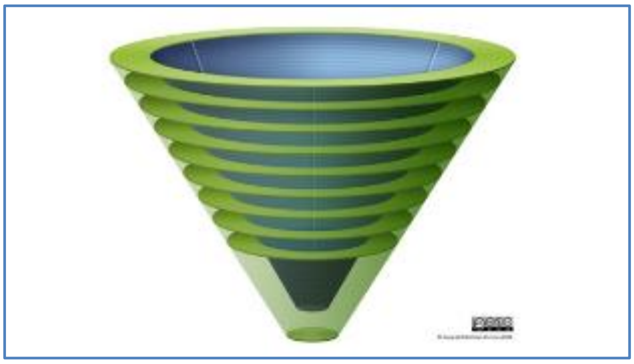

Figure 10. Lateral view of the vortex

In this way, errors of *persistence* can be avoided, such as returning to repeated attempts at intubation or SGA insertion and potentially transforming the 'can oxygenate' situation into a CICO situation. This important concept of *forced cognitive slowing* is similarly addressed in the 'stop and think' prompt of the DAS foundation tool.

Key terms & phrases to assist *prevention* of CICO

Whether the team managing the airway crisis constitutes just the anaesthetist and the anaesthetic assistant or a horde of responders following declaration of a crisis, the imperative to rapidly establish a shared mental model of both the situation and the management priorities applies. Where practicable, the first step in this process will be to establish 'hand off' leadership.

For each element of CICO Transition there are pivotal pieces of information that will rapidly align the team's understanding of the situation and the immediate management priorities. These can be concisely shared in the form of key terms & phrases, or requested in the form of standard questions. Some examples of these that may aid in the *prevention* of CICO by avoiding errors of omission or persistence are provided, below:

Question/Statement	Alternative
"Would you like me to coordinate?"	*"Would you like me to take the airway so that you can team lead?"*
"Can you oxygenate (ventilate) the patient"	*"Are you stuck in the Vortex?"*
"Have you ever been able oxygenate?"	*"Have you been in the Green Zone with any lifeline?"*
"We have got end-tidal CO_2"	*"We are in the Green Zone"*
"Have you optimised everything with facemask, LMA or intubation?"	*"Have you had a completed best effort at any lifeline?"*

ACTIVITY

Imagine you have encountered a difficult intubation and impossible mask ventilation during a category 2 Caesarean section, but have rescued the airway with a classic LMA.

What are your options at this point? What factors would influence your choice?

Click here to read more about the options available in the Green Zone, and to view the Vortex Green Zone Tool

4.2 PRIMING for CICO rescue

"For a surgical airway to be successful as a rescue option, it must be instituted early in the management of the difficult airway. Prompt calls for the appropriate equipment and personnel may save lives" [3 (p38)]

The concept of 'priming' for CICO Rescue refers to an escalation in readiness to perform CICO Rescue that occurs in real time during an evolving airway crisis.[29] It is distinct from any preparation that occurs prior to the initiation of airway management. Priming is crucial to ensure that airway management teams are poised to perform CICO Rescue immediately when CICO is declared without any additional delay during which patients may be exposed to ongoing hypoxia. The traditional way of approaching upper airway rescue and transition to CICO involves implementation and optimisation of upper airway rescue in isolation, followed by declaration of CICO and commencement of preparation for CICO Rescue. This is depicted in the diagram below.

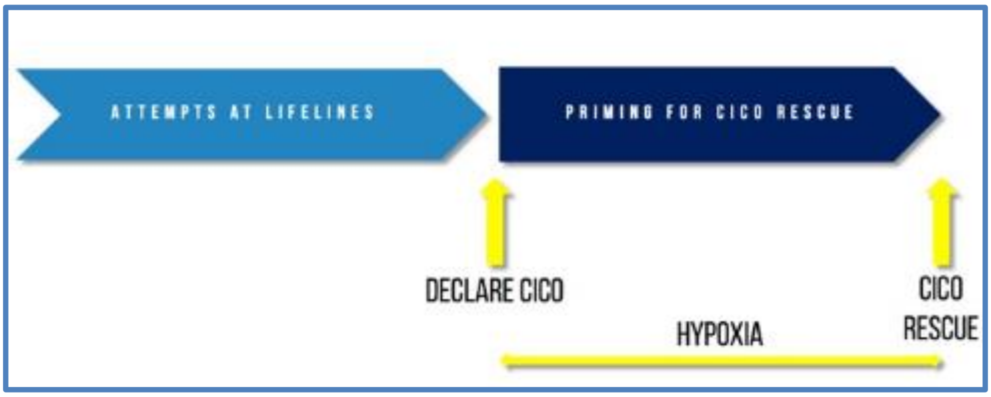

Figure 11. Inefficient priming for CICO Rescue

If, instead, *priming* is instigated early following recognition of difficulty with alveolar oxygen delivery, and occurs in parallel with attempts at upper airway rescue, the period in which the patient is likely to be exposed to hypoxia can be reduced. This is an example of planning for failure and represents one of the final steps in repeatedly asking the question *"what is the plan if this plan fails?"*. Efficient priming for CICO Rescue is depicted in the diagram below.

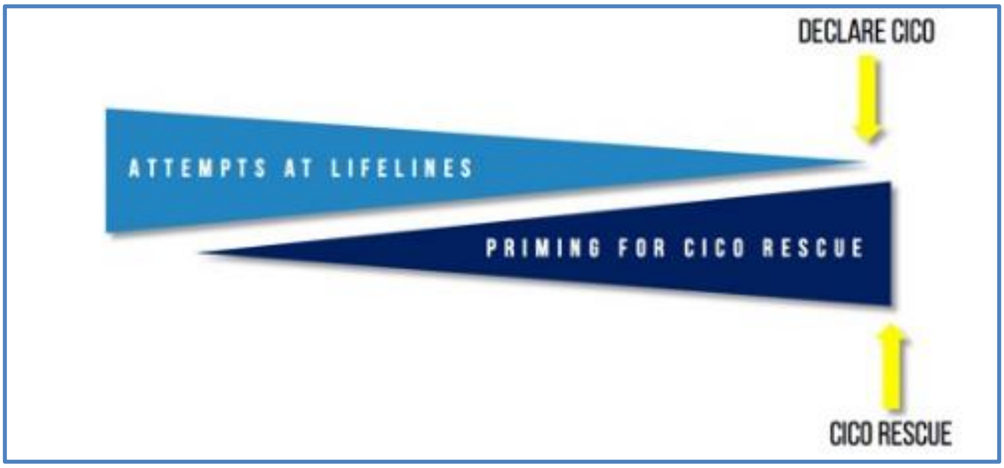

Figure 12. Efficient priming for CICO Rescue

Priming for CICO Rescue serves the additional purpose of preparing the airway operator and the team for crossing the significant psychological barrier of declaring CICO and committing to CICO Rescue (see next point – *Permission to perform CICO Rescue*).

Table 2 outlines the barriers to effective *priming* for CICO Rescue and how these can be overcome.

2. PRIMING for CICO RESCUE		
Barriers to effective management	**Errors commonly seen**	**Solutions**
▪ Fear of being seen to have 'overreacted' if CICO Rescue is mentioned but is ultimately not necessary. ▪ Insidious onset of airway emergencies, lack of a clear trigger to escalate the level of care. ▪ Confirmation bias and fixation error – "CICO doesn't happen to me" ▪ Stress, loss of situational awareness and task fixation	• *Failure to prepare for CICO Rescue despite exhaustion of most or all of available upper airway lifelines.*	▪ Use of a **Cognitive aid** in real-time ▪ **Point-of-care CICO kits** in a visible location ▪ **Hands-off leadership** ▪ **Communication & Training** Use of key **terms and phrases** by team members to promote a shared mental model

Table 2. Priming for CICO Rescue.

How can a cognitive aid assist in *priming* for CICO Rescue?
Both the Vortex Tool and the ANZCA Cognitive Aid promote *priming* for CICO Rescue by anchoring a distinct escalations in readiness to identifiable end-points during upper airway rescue – in both cases the end-points are completion or exhaustion of a pathway of upper airway rescue.

By conceptualising the process of upper airway rescue as consisting of three distinct pathways or 'lifelines', a cognitive aid allows the completion or exhaustion of a pathway to be used as a trigger for *priming* for CICO Rescue. In this way the level of preparedness to perform CICO Rescue is progressively raised when exhaustion of a pathway is recognised and declared.

The Vortex Approach refers to this level of preparedness as the 'CICO Status'. An adjunctive decision support tool, the 'CICO Status Tool', shown below, links the completed 'best effort' to the actions that should occur with each escalation in CICO status.

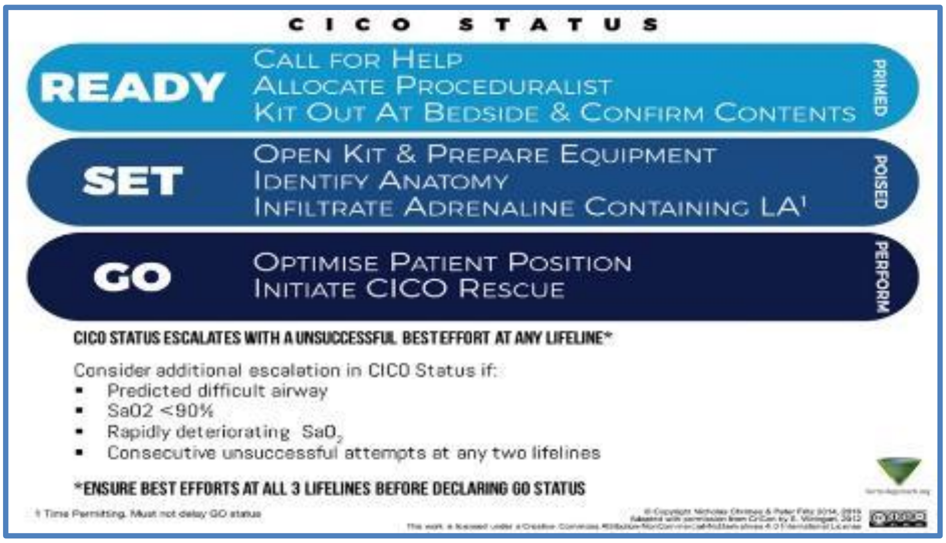

Figure 13. The Vortex CICO Status Tool

The ANZCA Transition to CICO tool promotes *priming* in a similar three-step process of escalation. Adopting a structured and standardised approach to *priming* distributes responsibility for escalation across the team. This serves to alleviate any 'anxiety' of the individual clinician at being seen to be over-reacting. It therefore helps reduce the barriers to timely declaration of CICO.

Point-of-care CICO Kits

Having CICO equipment at the point-of-care (i.e. in each theatre) may also promote effective *priming*. There is the obvious advantage of the equipment being on hand and ready to be checked, opened and prepared. Less obviously, having clearly labelled CICO equipment in a visible location in the theatre can serve as a reminder that CICO is a possible outcome early in the evolving crisis. This may be the useful heuristic needed to prompt the team to prime for CICO rescue – in a sense the kit can act as a cognitive aid in itself.

Key terms and phrases to assist *priming* for CICO Rescue

Question/Statement	**Alternative**
“That is a completed best effort at Facemask/ LMA/Intubation”	*“Have you had a completed best effort at any of the lifelines?”*
“Let’s prepare for CICO Rescue”	*“Let’s raise the CICO Status to ready/set/go”*

ACTIVITY

Consider again the hypothetical situation of the Caesarean section where during RSI the initial attempt at intubation has been difficult and facemask ventilation has been impossible despite a completed best effort.

What should the CICO Status be if you were utilising the Vortex Approach?

Click here to read more about the concept of *priming* and CICO status

4.3 PERMISSION to perform CICO Rescue

"Task fixation (failure to accept attempts at tracheal intubation should be abandoned), and reluctance to diagnose CICV and proceed to rescue techniques until too late have been frequently documented in cases of CICV" [3 (p107)]

Earlier we presented evidence that CICO rescue is frequently performed too late[1, 2] or not at all[10] despite being clearly indicated. This highlights how difficult it is for clinicians, and in particular anaesthetists, to desist from upper airway rescue and move to CICO Rescue.

Providing *permission* to perform CICO Rescue involves establishing a shared agreement that initiating this confronting procedure is a legitimate course of action in the circumstances. Three factors contribute to providing the team with permission to initiate CICO Rescue. First, there must be *recognition* by a member of the team that a CICO situation exists. Second, this information needs to be *communicated* to the team in a clear and understandable way. Third, the team must have a collective *willingness* to commence CICO Rescue. The barriers to recognizing and declaring CICO, and commencing CICO Rescue are outlined in the table, below.

3. PERMISSION – Recognising and declaring CICO & committing to CICO RESCUE		
Barriers to effective management	**Errors commonly seen**	**Solutions**
Recognition ▪ Inability to define completed "best effort" at an upper airway lifeline ▪ Lack of a clear trigger for CICO Rescue – including over-reliance on SpO_2 as a decision prompt ▪ Confirmation bias and fixation error – *"CICO doesn't happen to me"* Declaration ▪ Guilt: responsibility for creating situation ▪ Pride/Fear: reflection on own competence Willingness to commence ▪ Lack of familiarity with technical aspects of CICO Rescue ▪ Confronting nature of performing CICO Rescue	• *Persisting with repetitive attempts at upper airway rescue despite exhaustion/ optimisation of all upper airway rescue pathways*	▪ Use of a **Cognitive aid** in real-time ▪ **Priming for CICO rescue** ▪ **Communication** clear declaration of CICO by team members ▪ **Training in CICO Rescue** Creating a 'brand' for CICO in the workplace ▪ **C1CO Pathway** Cannula-first pathway provides less confronting 'entry point' into CICO Rescue ▪ **Point-of-care CICO kits** in a visible location

Table 3. Recognising & declaring CICO and Committing to CICO Rescue.

How can a cognitive aid assist in *recognising* CICO or *committing* to CICO Rescue?

An effective cognitive aid will assist with *recognition of CICO* by providing a clear trigger for declaration of CICO and will facilitate *committing* to CICO Rescue by prompting teams to prepare for this eventuality while concurrently optimising upper airway rescue attempts. In this way the 'spectre' of a possible CICO event is raised and considered early and preparation for performance of CICO Rescue already well underway by the time upper airway rescue lifelines are exhausted.

As already discussed, the Vortex Approach promotes *recognition* of a CICO event by providing a definition of CICO that is closely linked to recognisable endpoints during upper airway rescue – *'An inability to confirm adequate alveolar oxygen delivery following completed best efforts at all three upper airway lifelines'*. It also allows the team to track completion of best efforts at each of the three upper airway and therefore easily recognise when CICO Rescue is required.

The ANZCA Cognitive Aid utilises a similar three-tier *priming* process, and assists in recognition by mandating declaration of CICO once all three modalities of upper airway rescue are completed.

Other strategies for overcoming the psychological hurdles to declaring CICO and commencing CICO Rescue

It is important to minimize the previously discussed psychological barriers to declaring CICO. Besides having a clear definition of CICO and a cognitive aid assisting recognition of CICO, this will be best facilitated through training that involves creating a 'brand' for CICO within the workplace such that all members of the team understand what CICO is, how it can be prevented and how it should be managed. Now that the easily verbalised term 'CICO' (*Ky-Koh*) has become internationally accepted (replacing the difficult-to-articulate 'CICV'), the anaesthetic community worldwide is a step closer to having the shared language for use in this high-stress situation.

The final hurdle to performing CICO Rescue is overcoming the reluctance of anaesthetists to move from a domain of relative comfort (management of the upper airway) to one of relative unfamiliarity (CICO Rescue). It has been suggested that this reluctance stems from the confronting nature of performing an invasive, unfamiliar procedure such as CICO Rescue.[30,31] To overcome this, it is important that i) the technique(s) recommended for CICO Rescue lie within the skillset of the anaesthetist, ii) the equipment is immediately available and supports the recommended technique(s), and iii) regular training in these techniques is provided.

There is strong evidence to suggest anaesthetists prefer to commence CICO Rescue with a cannula technique.[3,32] For this reason the CICO Rescue strategy proposed in this chapter incorporates both cannula and scalpel techniques (see next section – *'Puncture'*). This philosophy is supported by ANZCA who have taken a position that all anaesthetists should continue to be trained in both cannula and scalpel techniques.[33] We recognise that this is an area of significant controversy and the pros and cons of the various approaches to CICO Rescue are outlined in a table included as appendix 4.

Key terms and phrases to assist with *permission* to perform CICO Rescue

Question/Statement	Alternative
"Have you exhausted all options with Facemask, LMA and Intubation?"	*"I have had a completed best effort at each of the lifelines"*
"Is this a CICO?"	*"This is a CICO, we need to perform CICO Rescue"*

4.4 PUNCTURE: CICO rescue performance

"Of the 58 cases, the anaesthetist defaulted to a surgical colleague to perform the emergency airway in 33 and attempted rescue themselves in 25. Only nine of these 25 anaesthetic attempts were successful" [3 (p108)]

Puncture refers to the technical aspects of the performance of CICO Rescue. The results of the NAP4 audit with regards to anaesthetist's performance of CICO Rescue are far from reassuring. Much of the subsequent discussion about the possible underlying causes for this poor success rate has focused on a suggested inferiority of cannula techniques for CICO Rescue. This largely ignores a number of significant confounding factors, the most significant of which are the facts that almost all the successful scalpel-based procedures were performed by experienced Ear-Nose-Throat (ENT) surgeons, and were often performed when oxygenation was possible. Accounting for these factors it would be equally valid to conclude that when a clinician, unencumbered by the emotional overlay of having caused an airway crisis, performs a procedure in which they are trained, in a situation where the patient is not at imminent risk of hypoxic harm, they will perform better than one who is undertaking an unfamiliar procedure during a time critical emergency which they feel responsible for creating.

With regard to the choice of a cannula-first versus a scalpel-only approach to CICO Rescue, it is worth highlighting ANZCA's position (at the time of publication of this manual), on CICO and front of neck access (FONA), which is another term for CICO Rescue:

> *"The college does not "mandate" one approach to FONA over the other. Both are part of CICO training, and individual circumstances will likely direct a preference for one over the other (including department and individual training, patient factors, and the presence of surgical assistance)"* [33]

4. PUNCTURE - CICO Rescue performance		
Barriers to effective management	**Errors commonly seen**	**Solutions**
▪ Lack of familiarity with technique ▪ Lack of availability of equipment ▪ Inadequate priming for CICO Rescue ▪ Inappropriate technique for context or equipment ▪ Stress - impaired recall of technique, impaired motor skills	▪ *Inability to insufflate through cannula (use of low-pressure source)* ▪ *Barotrauma with insufflation (incorrect equipment or insufflation technique)* ▪ *Surgical emphysema (failure to confirm correct placement of cannula)* ▪ *Inability to access trachea (selection of wrong technique)*	▪ Training aligned to an algorithm eg **C1CO pathway or DAS FONA approach** ▪ **Technical proficiency** in both cannula and scalpel CICO rescue techniques ▪ **Role Allocation** of CICO Rescue to appropriate team member ▪ **Point-of-care CICO kits** with associated training to ensure familiarity and proficiency

Table 4. CICO Rescue Performance

What is clear from the NAP4 report is that failures were frequently a function of either inadequate training or a lack of availability of, and familiarity with, the CICO Rescue equipment. Specifically, the successful placement of a cannula was on numerous occasions followed by utilisation of equipment for oxygen insufflation that has been demonstrated to be ineffective or even dangerous in the setting of CICO with complete upper airway obstruction[34,35]. This indicates a need for institution-specific protocols incorporating safe equipment, located at the point-of-care, and supported by team-based training.

Recognising that internationally there is strong ongoing debate regarding the optimum approach to CICO Rescue, the EMAC airway module is going to focus on an approach that incorporates both cannula and scalpel techniques. A table outlining the pros and cons of a *scalpel-only* approach (as advocated for in the DAS guidelines), vs a *cannula-first approach* incorporating both cannula and scalpel techniques (as outlined, below) is included at appendix 4. The DAS FONA algorithm is shown, and briefly discussed at the end if this section.

4.4.1 A 'cannula-first' approach utilising both cannula and scalpel techniques

In 2009, Heard and colleagues published an algorithm and an accompanying description of techniques for the management of CICO events.[36] Their article described an institution-specific (Royal Perth Hospital) approach with a training program and point-of-care equipment customised to their CICO algorithm. Recognising that anaesthetists have a reluctance to declare CICO and commit to CICO Rescue, the Royal Perth Hospital (RPH) approach specifies a 'cannula first' primary step to minimise this reluctance to commit. Importantly, the approach includes contingencies in case of failure of the primary cannula step, and details how to rapidly convert a cannula into a cuffed airway. The RPH CICO Rescue algorithm is shown in Figure 14.

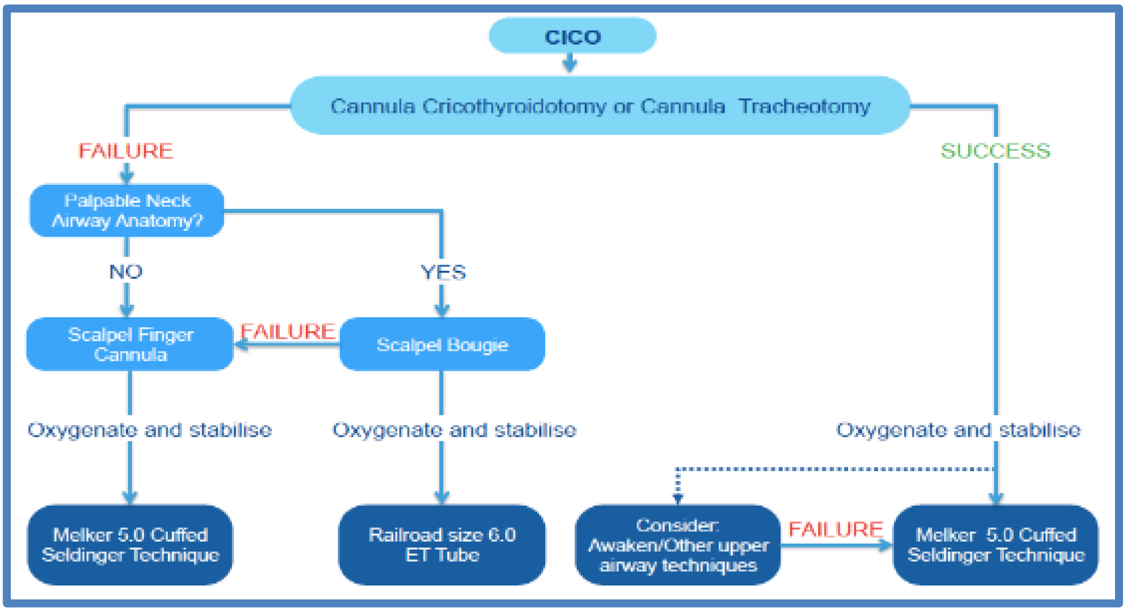

Figure 14. RPH CICO Rescue Algorithm, modified from Heard, Green and Eatkins.[35]

The RPH CICO Rescue algorithm is one of the algorithms recommended by ANZCA[37] as being suitable for use in CICO Rescue, and the RPH approach, incorporating point-of-care equipment and training to support the algorithm, has been adopted by many Australian hospitals. We have selected this approach for EMAC as a model for teaching CICO Rescue techniques as it ensures that all EMAC participants gain training in both cannula and scalpel techniques. We recognise, however, that the approach and techniques that each EMAC participant ultimately adopts will depend on the protocols and equipment available in their workplace. The ‘cannula-first’ approach is primarily designed for institutions equipped with CICO packs, including a means of rapidly delivering oxygen via a cannula, at or near the point of care. Institutions without these packs are more likely promote a scalpel-only approach such as that outlined in the DAS guidelines.

The trigger for the development of the RPH CICO Rescue Algorithm was an airway related death at RPH in 2001, where the ensuing recommendations in the coroner’s report[38] included improvement in training in the management of what we now refer to as Can’t Intubate, Can’t Oxygenate (CICO) scenarios.

The algorithm and the techniques described in the article were the result of four years of observed CICO management under realistic, stressful conditions in a wet lab, incorporating an anaesthetized, live animal model. Thousands of subsequent observed performances have allowed the RPH airway group to continually improve and refine the effectiveness and safety of these techniques.[35] A simplified version of the RPH algorithm called the Cannula 1st (C1CO) Pathway, more suitable as a real-time *implementation* tool to aid decision making during a CICO event, is shown, below.

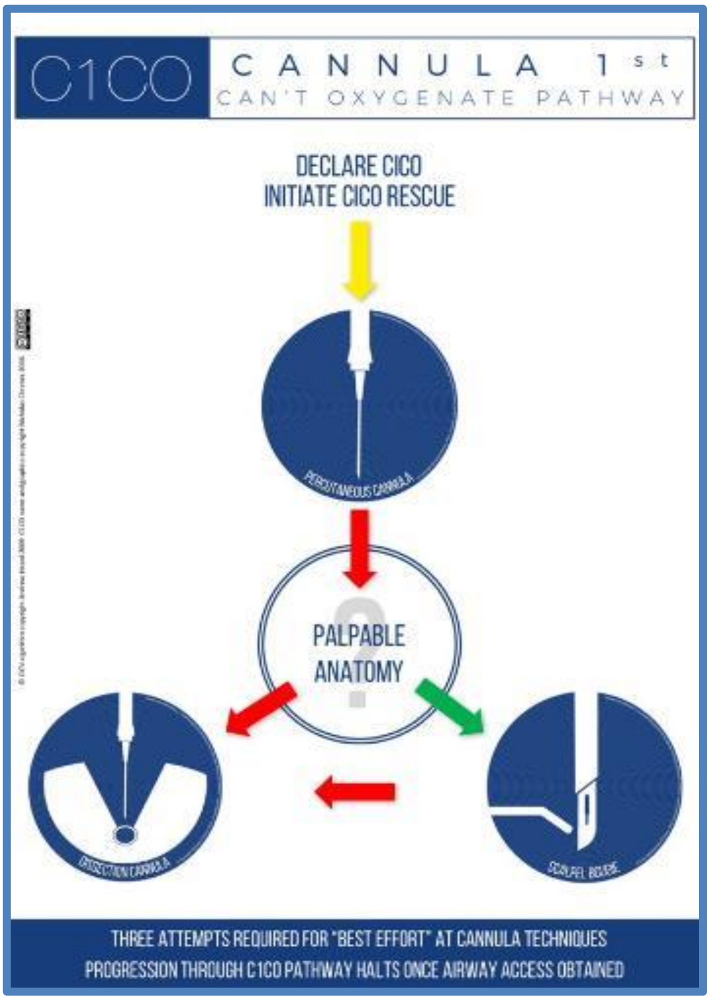

Figure 15. The C1CO Pathway, courtesy of
Nicholas Chrimes and Andy Heard

The C1CO/RPH pathway incorporates cannula, scalpel, and combined techniques deployed from least to most invasive. It is an example of a strategy – “a series of logical plans” that acknowledges that, like all procedures, sometimes the primary plan (in this case cannula insertion) will fail.

The probability of two techniques failing in series is intrinsically lower than the probability of either individual technique failing. This is supported by the results of the NAP4 study, where despite anaesthetist-led attempts failing in a significant proportion of the 56 cases involving CICO Rescue, many of these were rescued by surgeon-performed attempts, with ultimately only three patients dying from failed surgical access.
The pathway stipulates cannula first on all occasions, taking into account i) the significant psychological barriers to commencing CICO Rescue (previously discussed), ii) the need to remove the uncertainty of choice at the first step, and iii) the fact that the likelihood of success of a scalpel technique is not diminished by the presence of blood in the airway, while the converse is not true.

It is of course essential that any techniques recommended have a high likelihood of success. The data from the RPH Airway training lab demonstrates similar success rates and time to first oxygenation for cannula and scalpel-bougie-tube techniques when performed by anaesthetists in the live animal model.[35]

Performance of CICO Rescue using the RPH approach potentially involves utilisation of the following techniques:

1. Cannula cricothyroidotomy/tracheotomy
2. Controlled rate insufflation
3. Guidewire conversion
4. Scalpel bougie
5. Dissection cannula

The following section outlines when these techniques should be utilized, and provides links to videos demonstrating each of the techniques. Detailed descriptions of each of the techniques can be accessed by clicking the links provided. In some instances the title on the video is not consistent with the updated terminology used in this chapter.

NOTE
It is essential that all the videos embedded in this section are viewed prior to attending day 2 of the EMAC course.

A walk through the RPH 'Cannula first' CICO Rescue pathway.
Following declaration of CICO, the patient should be positioned for maximum neck extension and a laryngeal handshake attempted[39]

1. Cannula cricothyroidotomy/tracheotomy
The cannula insertion technique utilised will depend on whether the anterior neck anatomy is palpable or not.

ACTIVITY
Watch video 1. Cannula technique and video 2. Cannula technique non-palpable neck anatomy

A detailed description of the cannula techniques can be found here

2. Controlled rate insufflation
It is important to understand that the potential for morbidity with the cannula technique lies not with the cannula insertion, but rather with the delivery of oxygen through the cannula. To minimise the chance of barotrauma or delivery of subcutaneous oxygen, a number of key points relating to the cannula technique must be emphasised:-

- Confirmation of intra-tracheal placement of the cannula (aspiration of air through the cannula) is critical
- The objective is oxygenation, not ventilation
- The trigger for repeat insufflation should be anchored to a decline in saturation
- Controlled rate insufflation is a temporising measure only, and rapid conversion to a definitive airway should follow
- Jet insufflation with high-pressure/high-flow devices such as the Manujet device are frequently implicated in barotrauma injuries and should be avoided wherever possible
- A fit-for-purpose, medium-flow oxygenation device such as the Rapid-O_2 device, ENK device or Ventrain should be available at the point-of-care.

The cannula insertion technique and associated controlled rate insufflation strategy advocated by the RPH CICO algorithm addresses all of these points.

ACTIVITY
Watch video 3. Controlled rate insufflation technique

A detailed description of the Controlled rate insufflation technique is provided here

3. Melker/Guidewire conversion
In some cases, cannula cricothyroidotomy is all that will be required, allowing safe, minimally invasive oxygenation until the arrival of experienced assistance or additional equipment enables either i) successful intubation from above, ii) waking of the patient with the cannula left in situ, or iii) formal surgical airway by a surgeon. If, however, these options are not available, the insertion of a cannula provides the conduit for a guidewire-assisted conversion to a definitive airway. The Melker kit is one example of how this could be performed.

ACTIVITY
Watch video 4. Guidewire conversion technique

A detailed description of the guidewire conversion technique is provided here

In the event that the primary cannula technique fails, a scalpel technique should be performed. The specific technique performed depends upon whether the anterior neck anatomy is palpable.
4. Scalpel bougie
If there is palpable anatomy (either cricothyroid membrane or trachea) then a scalpel-bougie-tube technique is indicated.

ACTIVITY
Watch video 5. Scalpel-bougie technique

A detailed description of the Scalpel-bougie technique is provided here

5. Dissection cannula
If the anterior neck anatomy is impalpable, the recommended progression is to perform a Dissection Cannula technique with rapid re-oxygenation followed by guidewire conversion.

ACTIVITY
Watch Video 6. Dissection-cannula technique

A detailed description of the Dissection-cannula technique is provided here

It is important to note that the DAS guidelines recommend an alternative scalpel approach for impalpable anatomy[4], the *'scalpel-finger-scalpel-bougie'* technique, described later. This technique may be a better option for clinicians working in an environment where the means to jet insufflate is not immediately available. This technique was, however trialled by the RPH Airway Group in 2005 but found to have a low success rate in their live animal model with impalpable anterior neck anatomy.[40]

The importance of equipment availability

CICO is a time-critical emergent event. As such, the argument has been made for making the equipment required to perform CICO Rescue available at the point of care[41]. That is, that it should be available in every theatre and location where anaesthesia is administered, not just on Difficult Airway trolleys. This should be in the form of a CICO equipment pack, to avoid having to locate or assemble the various pieces of equipment. Stocking CICO Rescue equipment packs in the Emergency Department, Intensive Care Unit, and on ward MET/code blue/cardiac arrest trolleys should also be considered. An example of a point-of-care CICO pack is displayed below.

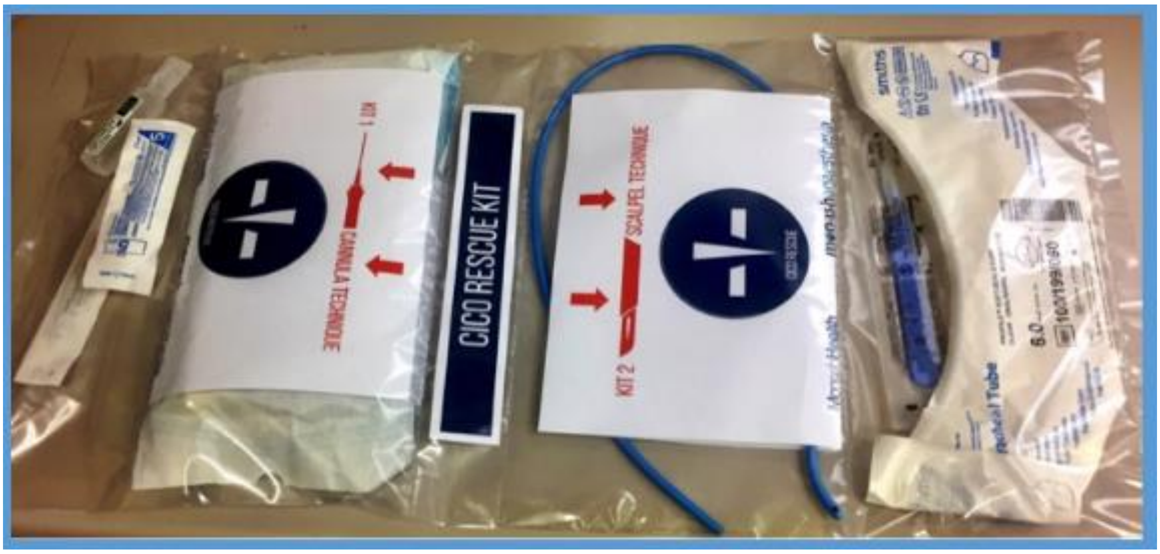

Figure 16. An example of a point-of-care CICO Kit

The presence of a CICO equipment pack in every location where anaesthesia is administered ensures that it is immediately available for clinical use, should the crisis arise. An important additional benefit of a prominently displayed CICO equipment pack is as a visual prompt that may remind the anaesthetist, or any other team member in the room, that CICO Rescue techniques may need to be undertaken, and encourage their timely use.

Aside from the Melker device for guidewire conversion, all of the equipment required to implement the 'cannula first' CICO Rescue approach is inexpensive. The Melker device remains affordable enough to keep in stock in a location known to relevant staff and close enough to any anesthetising location that it can be obtained within a few minutes (such as on a Difficult Airway Trolley), so that a cannula can be converted to a cuffed airway utilising a guidewire conversion technique after emergency re-oxygenation has been undertaken.

The reasonable price of the equipment used in the RPH CICO Rescue approach also allows regular training to occur utilising the same equipment, which is essential for any CICO rescue strategy to be employed successfully.

To assist any EMAC participants who might be interested in setting up point-of-care CICO packs in their own departments we have provided some additional photos of examples of CICO packs from other Australian hospitals (Appendix 2), along with a full list of the equipment required in a pack to effectively implement the C1CO pathway (Appendix 3).

4.4.2 The DAS ‘scalpel-only’ CICO rescue approach

As already mentioned, the DAS approach to what they call Plan D - emergency *Front of Neck Access* (FONA) advocates scalpel-only techniques, except where a clinician has expertise in a cannula technique and jet insufflation[4]. The pros and cons of this ‘scalpel-only” approach are outlined in the table in Appendix 4. The *‘Cannula first’* approach outlined above is designed for institutions with the equipment to deliver flow-regulated jet insufflation at the point of care. Institutions without readily available CICO equipment supporting both cannula and scalpel techniques would be better served by being familiar with, and training to, a *‘scalpel-only’* approach such as that suggested by DAS, whose *Failed intubation, failed oxygenation in the paralysed, anaesthetised patient* flowchart is shown, below.

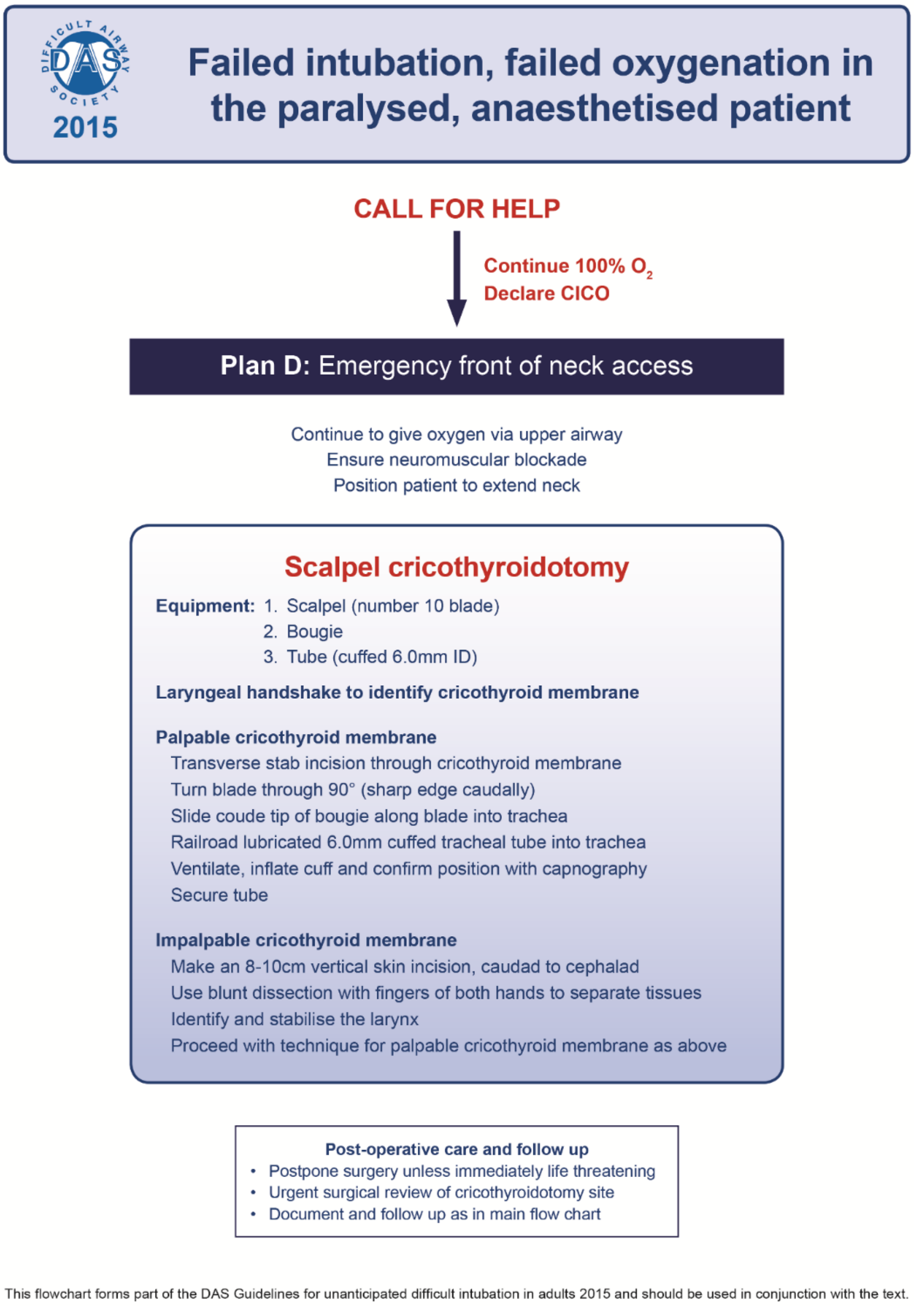

Figure 17. The DAS *Failed intubation, failed oxygenation in the paralysed, anaesthetised patient* flowchart

For the patient with palpable anterior neck anatomy the DAS approach utilises a scalpel-bougie technique identical to that described in the previous section. For the patient with impalpable anterior neck anatomy the DAS guidelines advocate a Scalpel-finger-scalpel-bougie (SFSB) technique. Similar to the dissection-cannula technique shown in Video 6, above, the SFSB technique involves an 8-10cm vertical incision down to the depth of the strap-muscles, followed by blunt dissection with the fingers of both hands until the structures of the airway can be palpated. At this point the technique deviates from that of the dissection-cannula technique by then reverting to the scalpel-bougie technique, shown in Video 5, above.

One major concern with the SFSB technique described in the DAS guidelines is that when the airway structures lie a considerable distance from the neck surface there will be limited ability to manoeuvre the curved coude tip of the bougie into the small incision in the airway[40].

This potential limitation with the technique is illustrated in figure 18 below, and is the main reason that the dissection-cannula technique (described earlier) was adopted as the preferred technique for non-palpable anterior neck anatomy in the RPH 'Cannula-first' approach.

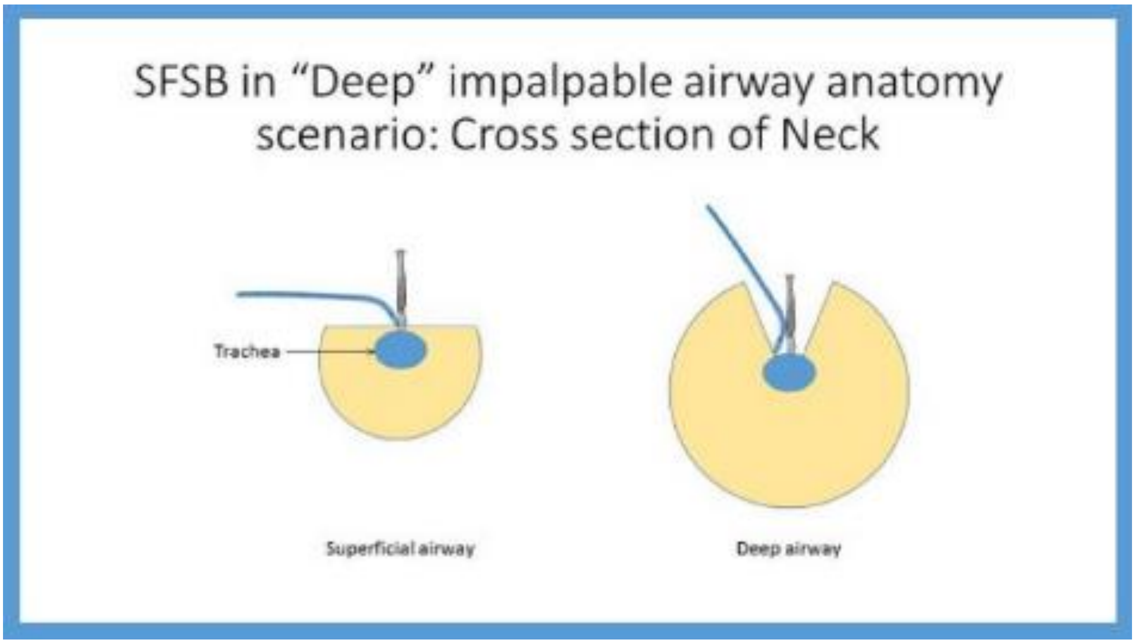

Figure 18. Limitations of the Scalpel-finger-scalpel-bougie technique with deep airway structures. Courtesy of Andy Heard and Scott Douglas

Additional features of the DAS CICO Rescue approach include an emphasis on ensuring adequate paralysis, positioning of the patient, and continuous attempts at oxygen delivery via the upper airway. They also provide prompts and explicit advice with regard to post-operative care and follow up.

5. Summary

This chapter has endeavoured to provide insight into how human factors impact airway management, and particularly their role in the time critical situation of airway obstruction, CICO transition and CICO Rescue. The barriers to effective management of these time-critical emergencies have been explored and a number of potential solutions explored. These include i) preparation and planning tools for constructing a robust airway strategy, ii) cognitive aids to support team work, decision making and situational awareness during a crisis, iii) the use of key terms and phrases to rapidly establish a shared mental model of the situation and the management priorities, and iv) an approach to CICO Rescue that is supported by training and immediately available equipment.

The airway module on day 2 of EMAC will build upon these concepts with a brief recap of the key points followed by hands-on workshops practicing the skills and utilising the tools already described in this chapter. The module will culminate in a series of airway scenarios requiring these tools and skills to be integrated into an effective team approach to these airway crises.

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Appendix 1 - Glossary

CICO (pronounced *ky-koh*)	1. A failure to deliver oxygen as a result of upper airway obstruction (at or above the level of the glottis), not relieved by all reasonable attempts at upper airway rescue[1] 2. An inability to confirm alveolar oxygen delivery (i.e. ventilation) following completed best efforts at all three upper airway lifelines[7]
CICO Transition	Explained in the chapter introduction, above,
CICO Rescue	CICO Rescue is an umbrella term used to describe any emergency cannula or scalpel cricothyroidotomy/tracheotomy technique. It has been adopted in preference to the many other terms applied to this procedure (emergency surgical airway, emergency front-of-neck access, invasive airway access, infraglottic rescue, etc.) because the term CICO (to describe can't intubate, can't oxygenate situations) has now become so widely recognized, that any procedure used to solve the problem should be linguistically coupled to it to promote cognitive association. Unlike the other terms applied to this procedure, CICO Rescue is simple, intuitive, precise, unintimidating and inclusive of both cannula/scalpel techniques performed on either the cricothyroid membrane or trachea.
CICO Status	A term borrowed from the Vortex Approach that indicates the level of concern for CICO and preparedness to perform CICO Rescue.
Upper airway lifelines	A term used to describe the three broad modalities of upper airway rescue that can be utilized when difficulty with oxygen delivery is encountered – Face-mask ventilation (FMV), Supraglottic airway (SGA) insertion, and Endotracheal tube ETT) insertion.
Green Zone	A concept outlined in the Vortex Approach that refers to any situation in which adequate alveolar oxygen delivery can be confirmed (typically by detection of $ETCO_2$) and the patient is no longer at imminent risk of critical hypoxia. In effect, this term denotes it is a "can oxygenate" situation. This provides the clinical team with time to pause and consider the opportunities available to them before further instrumenting the airway. These opportunities include re-oxygenating the patient, assembling resources and developing a strategy.
Cannula-first CICO Rescue (C1CO)	The C1CO abbreviation refers to a simplified representation of the Royal Perth Hospital CICO algorithm discussed in the chapter

Appendix 2 - Additional examples of point-of-care CICO kits.


HM


CICO PACK TWO
SCALPEL TECHNIQUE
CICO PACK ONE
NEEDLE TECHNIQUE


1A
1B
Needle Technique
NEEDLS
CICO
SCALPEL
2
Scalpel Technique

Appendix 3 - Equipment list for Point-of-Care CICO Kits

1. Cannula technique/Jet Oxygenation
   - 14G Insyte Cannula (preferably x2)
   - 5mL syringe
   - Normal Saline 10mL (preferably x2)
   - Rapid-O_2 jet oxygenation device (or Enk flow modulator)

2. Scalpel bougie technique
   - Size 10 blade safety scalpel
   - Frova bougie
   - Size 6 internal diameter cuffed endotracheal tube

Optional additions
- 15mm Rapi-fit connector for Frova bougie
- Green gauze

Required in central location (e.g. in difficult airway trolley) for guidewire conversion following rapid re-oxygenation
- Melker Cuffed Emergency Cricothyrotomy Catheter Set (Seldinger)

N.B. The ‘Rapid O2’ device can be purchased from the following distributor in Australia -
Meditech Systems Asia Pacific Pty Ltd
Unit 3, 29 May Holman Drive
Bassendean, WA 6054
Australia
Tel: +618 6162 9911

Appendix 4 – Pros and cons of a *'scalpel-only'* vs a 'cannula-first' CICO Rescue approach

	Pros	Cons
Cannula-first technique	• Anaesthetists prefer cannula techniques compared with scalpels[32], and they lie within the skill-set of the anaesthetists, which therefore poses less of a barrier to committing to CICO Rescue • Success of a cannula technique is impacted by presence of blood in the airway – therefore it is easier to progress from cannula to scalpel than from scalpel to cannula • A failed cannula insertion does not limit the success of subsequent scalpel attempts, as evidenced by the high overall survival of patients when cannula CICO Rescue fails[3] • Data from live animal models demonstrates similar success rates and time to first oxygenation for cannula and scalpel-bougie tube techniques when performed by anaesthetists[35] • In the NAP4 audit, success rates for needle cricothyroidotomy was 52% compared to 37% for scalpel technique when comparing only anaesthetist-performed procedures[3]	• Cannula techniques had a high failure rate in NAP4 and recent • Jet-ventilation in the emergency CICO situation has a high rate of barotrauma[41] and/or subcutaneous emphasaema[3] • Only really viable in institutions with point-of-care or immediately available CICO kits, including medium-flow oxygenation devices (e.g Rapid-O2 or Enk flow modulator) • There are no clinical reports of successful use of the Rapid-O2 device[8] • Cannula insertion does not provide a definitive airway, and additional decision-making +/- further intervention is required once the patient is re-oxygenated • Requires technical skill in a number of techniques which may hamper decision-making and performance in an emergency situation • Limited human evidence to support safety and success of cannula techniques
Scalpel-only technique	• High success rates with scalpel techniques demonstrated in pre-hospital[42-44] and military[45] setting, with superiority over cannula techniques demonstrated in one meta-analysis[44] • Simple technique that is easy to learn with a high success rate amongst novices in cadaver studies[46, 47] • Provides a definitive airway with protection against aspiration, minimal risk of barotrauma, and the ability to monitor end-tidal CO2, without the need for further steps. • Only requires familiarity with one set of techniques	• Places complete reliance on success of single method, rather than utilising a strategy with a contingency plan for failure • Most successful scalpel-based procedures in NAP4 were performed by experienced ENT surgeons, while success rates were low (37%) when performed by anaesthetists.[3] • A review of the Danish anaesthesia database (all patients in a 6-year period) demonstrated a success rate of 50% (3 out of 6) with emergency surgical airways[48] • The scalpel-bougie techniques reported in different papers are not consistent with regards to the actual technique used • The requirement to use a scalpel may present a mental barrier to anaesthetists, potentially delaying them from declaring a CICO situation • Limited human evidence involving hospital-based anaesthetists

49.
Hyperlinked files

CICO Rescue #1 – Cannula Technique (palpable anterior neck anatomy)

Percutaneous Cannula Technique *(palpable anterior neck anatomy)*
The cricothyroid membrane is the preferred location but the technique can also be performed on the trachea.

- Position the patient – maximum (safe) neck extension. Push the pillow up under the shoulders or remove it entirely, and/or lower the head extension of the operating table.
- Assemble the cannula-syringe apparatus:
  - Aspirate 2mL of saline into the 5mL syringe,
  - Attach the syringe to the hub of the cannula trocar,
  - DO NOT loosen the cannula from the trocar (increases risk of false positive air aspiration).
- Position yourself – on the opposite side of the patient to your dominant hand (right handers stand on the patient's left and vice versa).
- Perform laryngeal handshake – place your non-dominant hand on the neck with a "v" formed between the thumb and the fingers. Identify the lateral edges of the airway and stabilise it between the thumb (on the proximal edge) and the 3^{rd}-5^{th} fingers (on the distal edge). Identify the cricothyroid membrane (or the midline of the trachea) with your index finger.
  - If no airway structures are palpable, use *Impalpable Anterior Neck Anatomy Modifications* as described below.
- Hold the syringe as is commonly done for central venous access – place fingers around the barrel flange and the plunger to allow "aspirate as you go" during insertion.
- Insert the cannula at a shallow angle to the skin (30-45^{o}) in a caudad direction and pull back on the plunger to create a vacuum as soon as the tip of the trocar is through the skin.
- Advance the cannula whilst pulling on the plunger until air is aspirated.
  - Advancement should be smooth – "jigging" promotes separation of the cannula from the trocar leading to false positive aspiration of air.
- As soon as air is aspirated, cease advancing the cannula.
- Move the non-dominant hand to stabilise the cannula at the hub.
- With the dominant hand, release the plunger (ensure no recoil) and stabilise the hub of the trocar.
- Advance the cannula off the trocar and into the airway with the non-dominant hand, and DO NO LET GO.
- Detach the syringe from the hub of the trocar (dispose of trocar safely), expel the air from the syringe, attach it to the hub of the cannula, and perform a rapid check aspiration of air.
  - Failed check aspiration may occur if the cannula is kinked or is abutting the posterior tracheal wall. With the syringe still attached, slowly withdraw the cannula until air is freely aspirated.
- Attach Rapid-O_2 device and reoxygenate the patient as per *Jet Oxygenation Technique* as described below.
- If the first attempt fails to locate the trachea during insertion, DO NOT aspirate on withdrawal (unacceptably high risk of false positive air aspiration between the cannula and the trocar).
- Withdraw the cannula-syringe apparatus together, and repeat the attempt.

If unsuccessful after a maximum of 3 attempts or 60 seconds, proceed to *Scalpel-Bougie Technique* as described below.

CICO Rescue #2 – Cannula Technique (impalpable anterior neck anatomy)

Percutaneous Cannula Technique *(impalpable anterior neck anatomy modifications)*

- The laryngeal handshake is by definition impossible, but use the technique to identify the middle of the neck with the index finger of the non-dominant hand. If USS is immediately available (or preoperative imaging has localised the trachea) this could be used to identify the insertion point.
- Insert the cannula-syringe apparatus at 90º to the skin to maximize the chance of finding a deep trachea, using the same "aspirate as you go" technique.
- If/when the trachea is located by aspiration of air, reduce ("flatten") the angle of insertion and advance a few more millimetres BEFORE advancing the cannula off the trocar (as per *palpable neck anatomy*). Perform check aspiration and oxygenate the patient.
- If the first attempt fails to locate the trachea during insertion, DO NOT aspirate on withdrawal (unacceptably high risk of false positive air aspiration between the cannula and the trocar).
- Withdraw the cannula-syringe apparatus together, and reinsert 1cm laterally to the first insertion point. If the second attempt fails, reinsert 1cm laterally on the other side of the first insertion point.

If unsuccessful after a maximum of 3 attempts or 60 seconds, proceed to *Dissection Cannula Technique* as described below.

CICO Rescue #3 – Controlled-Rate Insufflation Technique

Controlled Rate Insufflation Technique

Jet Oxygenation is undertaken after successful insertion of a cannula into the trachea, whether *Percutaneous Cannula Technique* (palpable or impalpable) or *Dissection Cannula Technique*. Successful check aspiration of air from a cannula must be demonstrated before commencing jet oxygenation to confirm that the tip of the cannula is in the trachea. An appropriate device (such as a Rapid-O_2) must be available to safely oxygenate via a cannula. Intravenous 3-way tap devices or the Manujet must not be used.

You should deliver a 4 second/1000mL initial rescue breath, followed by 2 second/500mL subsequent breaths guided by SpO_2 measurement. These volumes are suggested for an "average adult". SpO_2 guided oxygenation minimises the risk of thoracic trauma and cardiovascular instability caused by excessive jetting. If SpO_2 is unmeasurable, jetting reverts to being time-based.

1. Ensure Rapid-O_2 is attached to a 4 bar oxygen source (wall pressure or cylinder with regulator) with 15L/min flow.
    a. Anaesthetic machine oxygen outlets may have different driving pressures and are often uncalibrated above 10L/min.
    b. Flow rates of less than 15L/min make detection of an obstructed cannula extremely difficult.
2. Connect Rapid-O_2 to the hub of the cannula (do not attach too tightly – it will need to be removed if Melker conversion is undertaken).
3. Occlude the open limb of the Rapid-O_2 T-piece with your thumb for 4 seconds, counting out loud (eg, "one Mississippi, two Mississippi…") to enhance correct timing.
    a. Look first at the neck to ensure no swelling occurs, then at the chest to visualise its rise.
    b. Significant pressure felt by the thumb identifies obstruction. This may be simple kinking (resolved by carefully withdrawing the cannula) or may signify the cannula is not in the trachea. If necessary, confirm tracheal placement by repeat aspiration of air via a syringe.
4. Wait for a rise in oxygen saturation whilst noting the time (some find it helpful to restart counting out loud. *There will be an appreciable delay* but they should BEGIN to rise within 20 seconds. There are 3 possible scenarios:
    a. If SpO_2 is recordable and does begin to rise within 20 seconds, wait for and note the peak SpO_2. Deliver a 2 second/500mL jet only when the SpO_2 falls by 5 percentage points from the peak (ie if a peak SpO_2 of 92% is achieved, jet again when SpO_2 falls to 87%) and assess for response.
    b. If SpO_2 is recordable but does not begin to rise within 20 seconds, deliver a 2 second/500mL jet at the end of the 20 second wait and again assess for response.
    c. If SpO_2 is unrecordable altogether, deliver a 2 second/500mL jet every 30 seconds.
5. All subsequent breaths (whether SpO_2 guided or time based) are of 2 seconds duration, counted out loud to enhance correct timing.
6. Plan for the next step of airway management.
    a. If jetting is providing adequate oxygenation and there is no risk of aspiration, further attempts to secure the airway via the mouth (or nose) could be considered if there is a "game changer".
    b. In all other circumstances, initiate plans to convert the cannula to a cuffed airway as soon as possible (see *Melker Conversion Technique*).

CICO Rescue #4 – Melker Conversion Technique

Melker Conversion Technique

After initial rescue oxygenation via a cannula, a cuffed, wide bore airway can be secured if required using a Seldinger technique. It can be performed wherever a cannula has been successfully inserted, whether through the cricothyroid membrane or the trachea. This describes the technique for a 5.0mm Melker and there may be differences in technique if you use an alternative device. Note that other sizes of the Melker airway are NOT cuffed.

1. Positioning (of the patient and yourself) remains the same as for *Percutaneous Cannula Technique* described above.
    a. Position the patient – maximum (safe) neck extension. Push the pillow up under the shoulders or remove it entirely, and/or lower the head extension of the operating table.
    b. Position yourself – on the opposite side of the patient to your dominant hand (right handers stand on the patient's left and vice versa).
2. Deliver a 2 second/500mL jet of oxygen at an appropriate time (see *Jet Oxygenation Technique*) and then immediately commence Melker conversion process.
3. Detach the Rapid-O_2 whilst maintaining the position of the cannula with your non-dominant hand.
4. With your dominant hand, feed the soft end of the Melker guidewire into the cannula.
5. Remove the cannula and hold the wire with your non-dominant hand.
6. Stabilise the wire, take a scalpel in your dominant hand and advance it along the wire with the cutting edge facing in a caudal and anterior direction, making a stab incision through the skin. (Note this step is not required when converting a cannula in a *Dissection Cannula* scenario as the skin has already been incised.)
    a. A size 10 scalpel (as recommended for the *Scalpel-Bougie Technique*) is more effective than the scalpel provided in the Melker kit itself.
7. Move the wire in a circular motion to confirm that there are no skin tags between the wire and the incision.
8. Pick up the Melker in the dominant hand. The appropriate way to hold the Melker is difficult to describe. The key objectives to holding the Melker are to ensure that the introducer/dilator does not slip back creating a "step" between it and the airway, and that it is held so that the curvature matches the appropriate final position in the trachea.
9. Feed the wire into the proximal opening of Melker introducer until it emerges from the distal end.
10. Stabilise the trachea with the non-dominant hand. You should NOT have anyone hold/apply counter traction to the wire.
11. Advance the Melker over the wire and into the airway in a predominantly cephalocaudal (NOT antero-posterior) direction, until the stabilising flanges abut the skin (or anterior trachea, in a *Dissection Cannula* situation).
12. Inflate the cuff, then remove the introducer and wire together.
13. Connect to circuit or self-inflating bag and oxygenate. Confirm correct placement with capnography. Secure the Melker airway in place.

CICO Rescue #5 – Scalpel-Bougie Technique

Scalpel-Bougie Technique

The *Scalpel-Bougie Technique* should be attempted if the *Percutaneous Cannula Technique* fails (after 3 attempts or 60 seconds) when anterior airway anatomy (cricothyroid membrane and/or trachea) is palpable. The cricothyroid membrane is the preferred location but the technique can also be performed on the trachea. If anterior airway anatomy is impalpable, proceed to the *Dissection Cannula Technique*.

1. Positioning (of the patient and yourself) remains the same as for *Percutaneous Cannula Technique* described above.
    a. Position the patient – maximum (safe) neck extension. Push the pillow up under the shoulders or remove it entirely, and/or lower the head extension of the operating table.
    b. Position yourself – on the opposite side of the patient to your dominant hand (right handers stand on the patient's left and vice versa).
2. Perform laryngeal handshake – place your non-dominant hand on the neck with a "v" formed between the thumb and the fingers. Identify the lateral edges of the airway and stabilise it between the thumb (on the proximal edge) and the 3^{rd}-5^{th} fingers (on the distal edge). Identify the cricothyroid membrane (or the midline of the trachea) with your index finger.
    a. If no airway structures are palpable, the *Scalpel-Bougie Technique* is inapplicable. Proceed to *Dissection Cannula Technique* as described below.
3. With a size 10 scalpel in your dominant hand, make a horizontal stab incision through the cricothyroid membrane (or anterior trachea) with the sharp edge of the blade towards you.
4. Apply gentle traction toward you then rotate the blade 90 degrees clockwise so that the sharp edge of the blade is now directed caudally.
5. Hold the scalpel low (close to the blade) and gently pull towards you, ensuring that it stays perpendicular to the skin surface, so that a triangular hole opens up. Be careful that the blade doesn't slip out of the airway at this point.
6. Without releasing the scalpel, change hands so that your non-dominant hand is now holding the scalpel.
7. Take the bougie in your dominant hand, holding it near the coudé tip, and with the bougie orientated parallel to the floor and perpendicular to the long axis of the trachea, with the coudé tip pointing towards you and down.
8. Push the coudé tip against the scalpel blade so that it is guided into the hole. You will feel a slight pop as it enters the trachea.
9. Rotate the bougie so that the blunt end is pointing upwards and cranially, and the coudé tip is angled caudally and anteriorly.
10. Remove the scalpel.
11. Advance the bougie gently (it should only require fingertip pressure) and confirm tracheal placement by feeling clicks against tracheal rings, or "hold up" at an appropriate depth (neither too shallow (paratracheal) or too deep (oesophageal)).
    a. If inserted further than 10cm before tracheal placement is identified, withdraw to 10cm at the skin.
12. If a 15mm Rapi-Fit connector is available, attach to the bougie and oxygenate using the anaesthetic circuit or a self-inflating bag.
    a. If connected to gas analysis, CO_2 should be detected.
    b. DO NOT attempt to oxygenate via a bougie using a Manujet or any other high pressure device.
13. Load a size 6 ETT onto the bougie.
    a. If available, a size 5.0 Melker fits snugly over the Frova bougie and reduces the risk of hold up during insertion.
    b. Larger ETTs increase the risk of hold up during insertion.
14. With your non-dominant hand, stabilise the trachea and with your dominant hand advance the ETT whilst continually rotating it from before it abuts the skin until after it has entered the trachea.
15. To avoid endobronchial intubation, only advance the ETT until the black line (if the ETT has one) is at the skin. DO NOT remove the bougie yet.
16. Inflate the cuff.
17. If there is no black line on the ETT, gently withdraw it until resistance (from the cuff abutting the wall of the trachea) is met.
18. Remove the bougie.
19. Connect to circuit or self-inflating bag and oxygenate. Confirm correct placement with capnography. Secure the ETT in place.
20. If the technique is not successful after 2 attempts or 60 seconds, proceed to *Dissection Cannula Technique*.

CICO Rescue #6 – Dissection-Cannula Techniques

Dissection-Cannula Technique

The *Dissection Cannula Technique* is the final and most invasive technique to rescue a CICO scenario. It should be undertaken if both the *Percutaneous Cannula* and *Scalpel-Bougie* Techniques fail in a patient with palpable anterior airway anatomy, or if the *Percutaneous Cannula Technique* fails in a patient with impalpable anterior airway anatomy. The cricothyroid membrane remains the “preferred” location but by this stage of a CICO event the first airway structure identified should be cannulated.

1. Positioning (of the patient and yourself) remains the same as for *Percutaneous Cannula Technique* described above.
    a. Position the patient – maximum (safe) neck extension. Push the pillow up under the shoulders or remove it entirely, and/or lower the head extension of the operating table.
    b. Position yourself – on the opposite side of the patient to your dominant hand (right handers stand on the patient’s left and vice versa).
2. Assemble a new cannula-syringe apparatus and set it down within easy reach:
    a. Aspirate 2mL of saline into the 5mL syringe,
    b. Attach the syringe to the hub of the cannula trocar,
    c. DO NOT loosen the cannula from the trocar (increases risk of false positive air aspiration).
3. Identify the midline of the anterior neck as well as possible.
4. “Tension” the skin by spreading it apart using the thumb and index finger of the non-dominant hand.
5. With the scalpel in the dominant hand make a longitudinal, caudal-to-cranial, 8-10cm incision through the skin and superficial fat (preferably down to depth of the strap muscles).
6. Using fingers of both hand, separate and blunt dissect to below the strap muscles and continue until the airway is identified.
    a. The thyroid and cricoid cartilages may be identified.
    b. The trachea has a knobbly feel AND you can “get behind it”.
    c. The cervical vertebrae have a knobbly feel but you can’t “get behind” them.
    d. Other anterior neck structures (sternocleidomastoid muscles, large vessels) can be “got behind” but they are not knobbly.
7. Stabilise the airway with your non-dominant hand.
8. Take the cannula-syringe apparatus in your dominant hand and insert into the airway as described in the *Percutaneous Cannula Technique*.
9. Oxygenate the patient as described in the *Jet Oxygenation Technique*.
10. Convert to a Melker as described in the *Melker Conversion Technique*, except that no further scalpel incision should be necessary (step 6 can be omitted),

Managing Anaesthetic Emergencies

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Introduction

As outlined in chapter 1, anaesthetists are occasionally involved in time critical and high stakes events in a complex system, where the cause of the physiological derangement is not immediately obvious. Management and diagnosis must be prompt and concurrent, yet we know cognition is impaired under time pressure.

This chapter builds on strategies introduced in chapter 1 to improve team management.

Chapter Outline

1. Something isn't right here – an immediate response
2. Something still isn't right - could it be something else?
3. Helpers arrive – getting the best from them
4. The team forms and performs
5. Recapping
6. Cognitive aids
7. References

Learning Outcomes

By the end of this chapter, and prior to the course, a participant will be able to:

- Outline an immediate response to generic critical events such as hypoxia, hypertension, hypotension, high airway pressure, high $ETCO_2$, low $ETCO_2$.
- List advantages and disadvantages of systematic approaches.
- Give an example of published cognitive aids for anaesthetic emergencies.
- Discuss two barriers to declaring a leader or taking on the role of leader in a critical event.
- List the elements of ISBAR when used as a succinct structure to brief arriving helpers.
- Describe how recapping by a leader assists the individual and team to diagnose and manage critical events.

1. Something Isn't Right Here – An Immediate Response

Although the number of things that can go wrong perioperatively seems unlimited, critical events tend to present in a limited number of ways: the most frequent difficulties are hypoxia, hypotension or hypertension, ventilation or rhythm disturbances.

> **ACTIVITY**
> Think about your immediate approaches to the generic problems above. How structured are they? When was the last time you used one?

ABC (Airway, Breathing, Circulation) is widely used in healthcare as an immediate response that helps us prioritise. In a world where the proliferation of acronyms may be confusing, it is commendably simple and memorable, it is widely applicable and it can help us make progress in diagnosis and management even in a state of panic. The DRSABCD of basic life support[1] you have been taught throughout your training incorporates ABC for this reason.

It is worth thinking through how the anaesthesia context affects the ABC approach. Rather than a spontaneous problem, the patient has been administered or is receiving anaesthesia medications, and surgical or anaesthetic manoeuvres may be in progress.

Have you ever come to help at a cardiac arrest in the OR and found the patient still receiving a volatile agent or a remifentanil infusion? It is easy in the stress of the moment 'not to see' and thus to omit important actions.

For this reason, some anaesthetists train themselves to scan Machine/ Airway/ Breathing/ Circulation/ Surgical field regularly during routine anaesthesia. When a non-routine event occurs, they will automatically and often unconsciously conduct the same scan pattern, gathering information and detecting anomalies.[2]

As an example, a drop in blood pressure prompts a scan of the monitor; we glance at the ECG to confirm rhythm, and SpO_2, volatile, and capnography traces are briefly tracked. The rapid scan continues to the airway, chest movement, and surgical events in progress, and generally back to the fluids and drug infusions.

> **ACTIVITY**
> What is your own scan pattern during routine anaesthesia?
> This may take some working out and self-monitoring of your eye tracking as it rapidly becomes automatic during training. Does it include fluids and infusions?

Most often we rapidly match a pattern we have seen before and unconsciously invoke fast (system 1) thinking or recognition primed decision making (refer to Chapter 1) to guide our actions. For example, the drop in blood pressure may match our pattern for subarachnoid block combined with general anaesthesia, and we increase the vasopressor almost on autopilot.

Less experienced staff may be slower to make a decision and act: their ‘library’ of patterns is smaller, they may not be able retrieve a pattern to match and System 2 thinking may be required.

Due to time constraints the information we draw on to pattern match may still be incomplete, so we commonly ‘play the odds’ to help decide on a course of action. Common things do occur commonly and thus this strategy, also called frequency gambling, generally rewards us by solving the problem. Despite the pejorative associations of ‘gambling’, this strategy is valuable to our daily functioning in anaesthesia.[3]

2. Something Still Isn’t Right - Could It Be Something Else?

Less often in daily practice, perturbations in patient physiology are not immediately corrected by our automatic scan and system 1 response. A conscious and deliberate systematic approach is the right strategy here to reduce the chance of missing important information: in hypoxia, is the FIO_2 dialled up, the tube in the trachea rather than the right main bronchus, the cardiac output sufficiently supported?

Some examples of schemata for systematic approaches are given in the Appendix, and you have also worked through approaches to tachycardia/ bradycardia / the obstructed airway in previous chapters.

ACTIVITY
Compare your own memorised approaches to those listed in the Appendix.
Have we (or you) omitted something that should be there?

Some anaesthetists start with the patient in this detailed systematic approach e.g. in hypoxia, assess airway device position, chest movement and breath sounds. A downside to this sequence is that you may become distracted by an equivocal finding in the chest or something that takes time to check, so forgetting to scan the machine early for an adequate FIO_2. Generally, a machine-to-patient sequence allows you to exclude equipment problems quickly and move on without the risk of forgetting something simple.

PRACTICE TIP
Keep yourself well-rehearsed for your systematic approach by invoking it whenever parameters are not routine, rather than reserving it for dire emergencies.

From reading chapter 1 you are aware that cognitive biases influence us and thus fixation errors may occur: we continue with an incorrect diagnosis despite evidence to the contrary and thus implement an inappropriate plan. A typical cognitive bias at work here is premature closure in which we accept a diagnosis before it is fully verified: ‘when the diagnosis is made, the thinking stops’. Feeding into this problem is confirmation bias in which we discount information which does not support the diagnosis, and that when we have invested time and resources into managing a specific diagnosis we may struggle to let it go. Recognising a fixation error is occurring is very difficult for those whom it is affecting, and often glaringly obvious with hindsight at the subsequent morbidity and mortality meeting.[4]

> **ACTIVITY**
> Watch this amusing video.

> **PRACTICE TIP**
> A hallmark of fixation is perseveration: if you find yourself or see someone else doing the same thing repeatedly without making progress, think "could something else be the cause here?" Ask your team or call for new help to think through the problem.

3. Helpers Arrive – getting the best from Them

When called to assist a colleague, a normal tendency is to scan the scene and monitors and make our own diagnosis within a few seconds, especially if the colleague is task and/or cognitively overloaded and does not immediately brief us. Be aware of this tendency in yourself; our instant diagnosis may be wrong because we have incomplete information, we may institute actions that have already failed, or we may assume that other treatment actions have already been completed. For example, you may conclude adrenaline is required for profound hypotension, draw it up and give it a dose before finding out a large dose has just been administered.

> **ACTIVITY**
> Think about the last time you were called in urgently to help a colleague. How easy was it to know what had already happened, what the working diagnosis and plan was, and how to help?

ISBAR was presented in chapter 1 as a succinct way to brief helpers so they are up to speed with what the primary problem is, what led up to it, what you have done, what you think the cause is and what your plan is.

It worth considering some elements of ISBAR in a little more detail.

I - identification. In critical events, the identification is not of the patient but of your own skill mix. A helper will process your ISBAR information differently if you are a junior trainee on your first night duty, compared with the interpretation if you are a Fellow in the subspecialty involved.

S – situation. This should be very brief and avoid drawing helpers into an anchoring bias, in which the group locks onto salient features too early and does not adjust this initial impression in the light of later information.[4]
For example, avoid stating that the situation is asthma, or that there is major blood loss. Stating that you have high airway pressures at induction, or that the problem is hypotension is less likely to lead your helpers into a "groupthink" fixation error should you be incorrect in your diagnosis.

B – background. Include what you have done so far. Keeping this succinct may be challenging. Remember helpers can always ask for more background after the initial ISBAR.

A – assessment. Often we call for help because we are uneasy and don't know what is going on. Stating exactly this is perfectly valid in the A of ISBAR, and indeed very important for helpers to know.

R – response. You may want the helper as a pair of hands and ask them to perform a specific task, you may want them to think through the issue with you, or you may need them to do both. Sometimes you want them to lead. This is the time to say these things explicitly. Remember that if you want them to lead, you must give them sufficient information to do so effectively – ISBAR is a means to do this.

PRACTICE TIP

Next time you need to make someone else aware of a situation and of your plan, even if it is non-medical or relatively routine, try using an ISBAR structure. You may discover you naturally use one.

Phoning the rosterer to ask to be rostered off on a particular day and offer your suggested contingency plan would be a simple example.

Similarly, listen critically to people who contact you: the PACU nurse will often use a classic ISBAR when informing you your last patient is hypotensive and he/she wants to increase fluids.

4. The Team Forms and Performs

In the past decade the importance of a leader in anaesthetic critical events has become accepted. Without an obvious leader many of the teamwork behaviours listed in the Inventory in chapter 1 become impossible or less effective.

Your own experience is probably that explicit identification of a leader is not yet routine in anaesthesia events, although it is common in emergency departments and intensive care units.

ACTIVITY
Think about the barriers to declaring a leader and/ or taking on leadership yourself in a critical event at which you were present.

As a helper, there are barriers to stepping up such as steep hierarchies or feeling we won't know enough, and we may consider the procedural anaesthetist will want to 'own the patient'. Some anaesthetists consider their OR hierarchy is flat and then feel self-conscious declaring a leader. As the procedural anaesthetist, we may also feel we have caused the problem, and this emotional guilt response may impair our ability to lead.

What really matters is that a leader emerges rapidly to facilitate the team behaviours and performance, and the leader is obvious to those arriving later.

In Emergency Department and Intensive Care Unit, leaders usually make themselves obvious by standing at the foot of the bed and may also wear an identifying jacket or similar. Anaesthetists generally have to make a conscious and often uncomfortable effort to move away from the head of the patient to the overview position. Active followers make a major contribution to effective teamwork by asking "Who is leading?" and then off-loading tasks from the leader while reminding them to be hands-off.

Airway events present a special challenge to transfer of information and declaration of leadership because the procedural anaesthetist is almost always task loaded with physical airway manoeuvres as well as the huge cognitive load. The cognitive aids presented in chapter 3 are a strategy to aid sharing the mental model under extreme time pressure.

It may be that the leader is the most experienced airway person in the room and must take on the physical role at the head end. In these cases, leadership must at least temporarily pass to another team member (not necessarily an anaesthetist) until the original leader can regain situation awareness.

5. Recapping

A feature of hospital acute care teams is that arrival of helpers is usually staggered. Later arrivals will not get the initial ISBAR and can be unsure what is happening or how to help or even if they are required. In a large team, the rapid questions and responses among its members often lead to a spiral of increasing noise levels.

Regular recaps by the leader, sometimes called huddles[5], address both these problems. A suggested structure for a recap is given in chapter 1. Remember to ask for input at the end of a recap, this gets the whole team crosschecking your thinking, is an important de-biasing strategy and makes your team adaptable as events unfold. It can be hard for a task loaded leader to remember to do a recap. Suggested triggers to a recap are:

1) you are asked for a recap by the team;
2) new helpers join the team;
3) there is a natural pause in action e.g. the airway is rescued by a SAD and you can stop and think; or
4) you are not sure what to do next.

6. Cognitive Aids

These include the immediate response (see Section 1 above), and more detailed schemata in your head (see Section 2 above, and Appendix) which you rehearse from time to time.

There was a time when needing to check written information was seen as a sign of inadequacy and indecision: fortunately for our patients and for us, written cognitive aids are rapidly becoming acceptable and indeed expected in healthcare.[6] With the promulgation of airway difficulty, anaphylaxis, malignant hyperthermia (MH), and local anaesthetic toxicity guidelines by the College[7], referring to a written cognitive aid is nearing 'a standard of care' expectation.

ACTIVITY Review the ANZCA and ANZAAG guidelines on perioperative anaphylaxis management. This is a package for use in crises. Where is it in your department?

Crisis checklists, as these may be called, are aide-memoires to make sure we remember 'silly stuff' - critical but sometimes forgotten steps.[8] You and the team may well have undertaken many steps to manage the situation by the time the crisis checklist is opened up: they are 'do-read' checklists, not 'read–do'.

Some requirements for effective use in critical events are presented in chapter 1, including being user -friendly, familiar to the team and preferably read aloud by a reader. Checklists on your personal electronic device are worth having, but a version that can be shared visually or audibly with the OR team enhances their de-biasing value and facilitates sharing the mental model.

ACTIVITY
Take a look at this guide to designing a checklist used by the 'project check' team.[9] A checklist for use under time pressure requires a specialised process of design and formatting, and it should be tested iteratively to ensure it is usable.

In summary, cognitive aids with systematic approaches, memorised or written, assist us with diagnosis and management in multiple ways:

- prevent 'freezing under fire', when stress prevents us making any progress.
- encourage systematic gathering of information and repeated re-evaluation of the situation.
- are comprehensive.
- reduce the cognitive load when trying to think and act at the same time.
- may be rehearsed mentally or in a simulated situation to achieve a streamlined performance.

There are downsides however:

- you have to be able to remember it (or access it immediately) to use it.
- working through a cognitive aid may delay effective treatment.
- it is possible to choose the wrong cognitive aid for a given situation, e.g. tachycardia algorithm instead of anaphylaxis.
- it won't work for problems 'not in the manual'.

ACTIVITY
Look back at the Inventory of Teamwork Behaviours at the start of chapter 1 (Table 1). At this stage of the course many will have been manifested by participants in scenarios.

Ensuring you have (or are) a leader who 'stands back and verbalises' will transform the robustness of the teamwork process when non-routine events occur.

7. Summary

Core knowledge and skills are still basic requirements for effective crisis management. In addition to rehearsing for uncommon events, this chapter explores further how to behave in a non-routine event, and to think about how we think. The scenarios provide an opportunity to practice and evaluate new strategies.

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Appendix 1
Examples of schemata for systematic approaches to undifferentiated problems

1. Hypoxia

Initial response ABC

- treat and diagnose simultaneously, don't assume artefact

Systematic approach

O_2 supply ⬇	Pressure gauges, flow meters, FIO_2, vaporizer housing
Anaesthetic machine ⬇	Ventilator: VT, rate, airway pressures, capnography
Circuit ⬇	Connections, one-way valves, filter
Airway ⬇	Exclude obstruction in unintubated airway, filter, airway device. Check for secretions. Pass suction catheter and/or bronchoscope down ETT and make sure it goes beyond distal tip of ETT
Ventilation ⬇	Exclude endobronchial intubation, with auscultation or bronchoscope, look and listen for bilateral chest expansion, adequacy of minute ventilation, bronchospasm, recheck airway pressure, exclude pneumothorax
Lungs ⬇	Gas exchange problem: aspiration, pulmonary oedema, bronchospasm, consolidation, atelectasis. Pulmonary embolism - air, thrombus, fat
Blood ⬇	Circulation: low cardiac output, anaemia: reduced O_2 carriage, high O_2 extraction and decreased mixed venous saturation
Tissue uptake	Increased metabolism (sepsis, thyroid crisis and MH)

2. High airway pressure

May present in different ways

- problem ventilating the patient (e.g. decreased compliance in breathing bag, poor chest expansion, reduced breath sounds, reduced expiratory tidal volume, abnormal ventilator sound, high airway pressure alarm)
- hypoxia secondary to hypoventilation
- circulatory collapse due to high intrathoracic pressure (e.g. occluded expiratory limb, tension pneumothorax)

Systematic approach

Gas supply ⬇	Check O_2 bypass/ flush/ other high pressure gas source
Anaesthetic machine ⬇	Ventilator/ bag switch
Circuit ⬇	Obstruction to expiration in circuit, ventilator, scavenger system, PEEP valve setting? Exclude circuit and machine problem by disconnecting and ventilating with self-inflating bag
Airway ⬇	Exclude obstruction: filter, airway, ETT, secretions, foreign body. Pass suction catheter or bronchoscope down ETT and make sure it goes beyond distal tip of ETT
Lungs ⬇	Bilateral chest expansion and breath sounds? (endobronchial intubation, bronchospasm, aspiration, pulmonary oedema, atelectasis)
Pleural cavity ⬇	Pneumothorax, haemothorax
Chest wall ⬇	Inadequate muscle relaxation, opioid induced chest wall rigidity, malignant hyperthermia, obesity, pressure applied to chest wall by surgical team or equipment
Surgical procedure	Raised intra-abdominal pressure, surgical intervention, position

3. Hypotension

A frequent unintended event in anaesthesia, most commonly resulting from relative overdose of anaesthetic agents (both intentional and unintentional), other medication error, hypovolaemia or central neural blockade.

Initial response ABC

- treat and diagnose simultaneously, don't assume artefact.

Systematic approach

Hypovolaemic ⬇	Blood loss, fluid deficit
Cardiogenic ⬇	Contractility, rate, dysrhythmia Volatile anaesthetic agent, beta-blocker, other negative inotrope
Distributive ⬇	Vasodilation: drugs, sympathetic block, sepsis, anaphylaxis
Obstructive	High intrathoracic pressure, tamponade, pulmonary embolus, surgical compression

4. Hypertension

Generally due to surgical stimulus or pre-existing hypertension, context may suggest a neurological cause. However may be a response to hypoxia/ hypercarbia, medication error, or phaeochromocytoma.

Initial response ABC

- treat and diagnose simultaneously, don't assume artefact.

Systematic approach

Pre-existing hypertension ⬇	Treated, untreated ? medications taken
Sympathetic reflex ⬇	Inadequate anaesthesia Is the anaesthetic agent actually being delivered? Vaporizer leak, IV infusion disconnection/ error Hypoxia, hypercarbia: check SpO_2, $ETCO_2$ Cerebral event: raised ICP, cerebral ischaemia, vasospasm
Sympathomimetic effect ⬇	Exogenous: accidental drug administration? Endogenous: e.g. phaeochromocytoma
Surgical	Aortic clamp

5. Increased $ETCO_2$

Respiratory depression, laparoscopic surgery and inadequate ventilation settings are common causes. Bear in mind that $PaCO_2$ maybe markedly higher than $ETCO_2$.

Initial response ABC
Systematic approach

Inhaled/ exogenous CO_2	Check capnography trace for return to baseline (soda lime exhausted, incompetent valves, rebreathing) Insufflation with CO_2? $NaHCO_3$ iv?
Hypoventilation	Respiratory depression, mechanical load, ventilator settings, airway pressures, obstruction
Increased production	Fever, seizures, malignant hyperthermia, hyperthyroidism

6. Decreased $ETCO_2$

No $ETCO_2$: exclude oesophageal intubation, accidental extubation.
$ETCO_2$ may considerably underestimate $PaCO_2$ if ventilation is to unperfused lung, e.g. severe hypotension, pulmonary embolism .

Initial response ABC
Systematic approach

Circuit	Air entrainment (leak), dilution with circuit gases (sampling problem)
Airway	Oesophageal intubation, accidental extubation
Ventilation	Ventilator settings, overenthusiastic hand ventilation
Gas exchange	Pulmonary embolism, cardiac failure/arrest, severe hypotension
Decreased production	Hypothermia, hypothyroidism, decreased metabolism

Management of Trauma

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Introduction

The intra-hospital resuscitation and management of the multiple injured patient can be divided into three phases: initial resuscitation; definitive management; and ongoing care and recovery.

The boundaries between these phases may be blurred considerably. Trauma victims may require anaesthesia and surgery whilst still in the resuscitation phase – in particular, damage control procedures, occult or evolving injuries may cause acute deterioration during definitive management or subsequent care. Thus it is imperative that anaesthetists have a systematic approach in the assessment and management of the trauma victim at all stages of management, as well as strategies to deal with specific trauma-related anaesthetic issues.

This module outlines principles that are well covered in the *Early Management of Severe Trauma* (EMST) course convened by the Royal Australasian College of Surgeons (RACS). This module does not attempt to replace this course - completion of EMST is highly recommended for anaesthetists who may be involved in the management of trauma patients. As discussed in the previous chapters, a shared mental model and common language are critical aspects in the practice of effective teams. Both EMST and its nursing twin *Trauma Nursing Core Course* (TNCC), teach a standardised approach to trauma patients - all participants of trauma teams are strongly encouraged to complete these courses to facilitate sharing the same framework and language.

Good trauma teams exemplify many of the effective leadership and team behaviours described in chapter 1.

It should also be noted that although not all anaesthetists work in a trauma centre, it is an expectation that all anaesthetists are familiar with trauma management principles as acutely injured patients may still present unexpectedly at any hospital with an Emergency Department.

As the field of trauma is one of continual evolution, keeping up to date with current practice is essential. Several useful web resources include the following websites:
Trauma.org
NSW Institute of Injury and Trauma Management

Chapter Outline

Learning Outcomes

By the end of this chapter, and prior to the course, a participant will be able to:

- Discuss the intra-hospital resuscitation and management on the multi-injured patient, including initial management, definitive management and ongoing care and recovery.
- Apply human factors principles in trauma team management.
- Employ the use of protocols and checklists in the context of trauma.
- Describe the accepted practice/protocols for transferring trauma patients in their hospital.
- Discuss the management of large volume resuscitation in trauma.
- Discuss the aesthetic implications of airway, chest and intra-cranial trauma.

1. Initial Management

The initial assessment of the trauma patient includes the following elements[1]:

1. Preparation
2. Triage
3. Primary Survey
4. Resuscitation
5. Secondary Survey
6. Continued post-resuscitation monitoring and re-evaluation
7. Definitive care

The primary and secondary surveys should be repeated frequently to identify any change in the patient's status that indicates the need for additional intervention.[1]

The management of the severely injured patient requires a rapid identification of management priorities based on their injuries, vital signs and mechanism of injury.
A brief review of the steps involved in the reception of severely injured is as follows:

1.1 Preparation

The prior determination, training and resourcing of a few selected Trauma emergency departments as the receiving centres for a large area, rather than all hospital Emergency Departments being a reception area for trauma patients, has been consistently shown to be associated with better patient outcomes.

Flash Teams

In 2012, Tannenbaum et al[2], coined the phrase 'flash teams' to describe teams in which membership turns over quickly, with 'peripheral' individuals (for example the intensive care, anaesthetic and surgical team members) coming and going, whilst 'core' team members (for example the Emergency Department medical and nursing staff) are more likely to remain constant. Based on their analysis, they suggest the following recommendations for team-based practice with dynamic teams:

- Team leaders need to choose and allocate team members using criteria that optimises team formation by ensuring members are qualified to participate, and can work well together.
- Creation of role clarity, and guidance for team leaders in how to create a sense of team identity.
- 'Quick-start' protocols and 'join-in-progress' protocols that allow teams to form quickly, and to ensure new members that join an already functioning team are brought up to speed quickly and seamlessly.
- Explicit identification of the obligations of people with specific, high-value skills to avoid overloading them.

Given the data, it is hardly surprising that team dynamics during an intubation in the Emergency Department are less than ideal. In an environment with a documented airway complication rate of 30%, anaesthetists may arrive feeling uncomfortable. Reasons for this include working with different teams, an unfamiliar environment, challenging situations,. and alternate or additional expectations of their role. It seems we have created a number of obstacles to successful team performance before we've even considered a critically ill patient needing airway management using unfamiliar equipment in a sometimes hostile environment!

Use of protocols to guide decision-making

The wisdom behind the development of procedures, protocols and checklists is well established in literature; including publications such as the Risk Management Standard[3] and the British Standard on Crisis Management.[4.] What is not always clear is the role these systems take in the crisis leadership domain.

The use of systems to empower the crisis leader has been widely accepted in other industries. In the aviation industry, the use of checklists in the cockpit is seen as a vital tool to allow the crew to make informed and rapid decisions. In the military, a protocol-driven, immediate response to an unexpected situation is seen as a means to get the organisation to a starting point for decision-making, even in the absence of direct leadership.

The Advanced Trauma Life Support algorithm for doctors is based on a similar process:

A Airway maintenance with cervical spine protection
B Breathing and ventilation
C Circulation and haemorrhage control
D Disability: Neurological status
E Exposure and Environmental control

In this case, rather than formulating an immediate action in preparation for a leader's decision, it provides a guide for both the team and the team leader. It also roughly equates to the anticipated priorities of treatment for the patient where the most life threatening conditions are identified and treated first. Not every trauma patient presents in this way of course, but the 'ABCDE' checklist covers most situations, most of the time, and allows decisions, and therefore positive control, to continue even in the absence of overwhelming stress, confusion, conflicting ideas and paucity of information. The effectiveness of such systems in the management of trauma patients is evidenced by the fact it has been formally adopted in over 60 countries.

In each of these cases, a system of standard operating procedures (military), algorithms (medical) and checklists (aviation) are used in a very particular way but all with the same principle: they assist the crisis leader to make decisions.

Multidisciplinary training of trauma teams has also been shown to be beneficial in improving patient outcomes. Prior notification of the arrival of patients by ambulance services and allowing the entire trauma team to be ready to receive the patient is an instrumental component in optimising preparation. Assigning roles within the team and team members gowning with appropriate personal protective equipment should also be performed prior to the receipt of a patient.

ACTIVITY
How is the Trauma Team response activated in the Trauma hospitals you have worked in? Which clinical specialties are notified and which attend? What are the essential team roles which are allocated and who assumes the role of the Team Leader?

Conversely, how is the response to a trauma organised and managed in smaller hospitals where human and physical resources are limited?

1.2 Triage

This process is a distribution of resources to *achieve the greatest good for the largest number of casualties.* If sufficient resources are available, the patients with life-threatening or multiple injuries will be treated first. However, if the number of casualties exceeds the capacity of the facility or staff then those casualties with the greatest chance of survival with the least expenditure of time, equipment and staff are managed first.

Prehospital handover
The value of an accurate description of the environment and mechanism of injury cannot be overestimated. A brief summary of the mechanism of injury as well as pre-hospital management can provide important information, but should not take priority over management of immediately life threatening injuries. Pre-hospital teams may have a system of handover of clinically relevant material. Almost all ambulance services in Australia and New Zealand use a version of:

I - Identification of patient
M - Mechanism of injury or Medical complaint
I - Injuries or Information related to complaint
S - Signs and Symptoms
T - Treatment and Trends

A - Allergies
M - Medication
B - Background
O - Other information

PRACTICE TIP
If possible try not to interrupt the pre-hospital clinician whilst they handover. Listen and save any questions to the end.

ACTIVITY
What is the accepted practice for handover from ambulance staff to the Trauma Team in the hospital where you work (i.e. prior / during or after transfer of the patient from the ambulance stretcher to the hospital bed)?

1.3 Primary Survey

The primary survey is a rapid initial assessment, the goal of which is to rapidly identify and manage correctable injuries that pose an immediate threat to the patient's life, for example

- Airway obstruction
- Chest injuries with compromise of the breathing or circulation
- Severe internal or external haemorrhage

During this phase the team should be determining the destination and next course of management for the patient.

A systematic approach is essential so that life-threatening conditions can be ruled out, hence the ABCDE approach:

A Airway maintenance with cervical spine protection
B Breathing and ventilation
C Circulation with haemorrhage control
D Disability: neurological evaluation
E Exposure of the patient for a full examination and environmental control

> **PRACTICE TIP**
> Asking the patient for their name and what happened is a rapid way of assessing A, B, C and D in a conscious patient.

> **PRACTICE TIP**
> It is imperative to note that life-threatening injuries are identified and managed simultaneously (i.e. the ADBCDE approach is not a linear process), the initiation of treatment may occur in parallel with history-taking / examination occurring. In a well-staffed trauma team, various team roles are delegated with team members relaying any salient findings back to the team leader.

Airway and cervical spine

Airway assessment is usually easily assessable and correctable and hypoxia will cause significant morbidity or mortality unless promptly managed. The assessment should include the following aspects:

- Is the airway patent?
- Can the patient speak and breathe freely?
- Are there any signs or symptoms that the airway is obstructed, or is likely to become obstructed?

It is important to assume that in the presence of blunt trauma a cervical spine injury has occurred until excluded by appropriate radiological and clinical examination (refer to Appendix 1). Careful consideration should be given to cervical spine protection in trauma patients particularly those with a significant mechanism of injury, midline pain, head trauma or focal neurological deficit.

The International Liaison Committee of Resuscitation (ILCOR) guidelines have concluded that there is no evidence that C spine collars in the acute setting actually reduce C spine injuries and there is considerable evidence that they cause significant morbidity. Some jurisdictions have thus discontinued their use in a pre-hospital context.

The approach to using hard *vs* soft collars varies from state to state but the principles of in-line stabilisation and prevention of cervical spine manipulation during airway manoeuvres remains the same. If cervical spine protection is hindering management of a compromised airway then priority should be given to airway management.

The patient's head and neck should be maintained in the neutral position. In adults, this is usually with a folded towel (3-5 cm) under the occiput, i.e. the patient's head should not be lying flat on the bed.

> **ACTIVITY**
> Find out what the current practice is with regards to cervical spine protection and the use of hard / soft collars in your state / location by the ambulance and retrieval services.

If there is a major problem with the airway then this should be addressed before moving onto Breathing and Ventilation. Sometimes this requires intubation, but sometimes a simple airway adjunct will suffice until the primary survey is completed. If intubation is needed most Emergency Departments now have checklists for intubation.

> **ACTIVITY**
> 1. Does your Emergency Department have a checklist for intubation?
> 2. Does it make sense to you?
> 3. What equipment is available for the management of the anticipated and unanticipated difficult airway / intubation?

Breathing and Ventilation

If oxygenation or ventilation is inadequate consider:

- Commencing bag / mask ventilation.
- Identification and management of potential causes of inadequate oxygenation / ventilation, for example, drainage of a large tension pneumothorax or large haemothorax. In this initial phase, drainage of these can occur via a needle, finger thoracostomy or tube thoracostomy.
- If the primary cause for hypoxia / hypoventilation is neurological, intubation of the patient may be indicated.

> **PRACTICE TIP**
> Lung ultrasound is more specific than CXR in diagnosing a pneumothorax.

> **PRACTICE TIP**
> Intubation and positive pressure ventilation can unmask or aggravate a pneumothorax. Be vigilant for signs of tension pneumothorax such as high airway pressures, sudden hypotension, or loss of cardiac output. Do not wait for investigations before treating these.

Circulation and haemorrhage control

Assess the circulation, by checking the presence of pulses, finger SpO_2, warmth in the peripheries and manual blood pressure. Monitoring including blood pressure (non-invasive ± invasive), ECG and pulse oximetry will supplement the vital signs. If inadequate, then consider the possibility of significant haemorrhage.

The mnemonic PLACES may help:

P	Pelvis - is a binder on? Has it been correctly applied and at the appropriate level?
L	Long bones.
A	Abdomen – eFAST may help to diagnose intra-abdominal bleeding.
C	Chest – a CXR is useful in determining bleeding within the chest.
E	External – control with tourniquets where possible.
S	Scalp – especially in children.

Establish at least two large bore peripheral IV cannulae (14 or 16G) or an intraosseous needle if IV insertion is unsuccessful. Blood should be taken for haematological and biochemical investigations and the Massive Transfusion Protocol (MTP) activated.

Consider administering Tranexamic Acid (TXA) if this has not already been given within 3 hours of the injury occurring. This is usually given initially as 1g over 15 minutes followed by a subsequent 1g infusion over 8 hours. TXA is a synthetic derivative of the amino acid lysine, and acts as an anti-fibrinolytic by inhibiting the conversion (or activation of plasmin from plasminogen) activation of plasminogen to plasmin. Note:

- The benefit of tranexamic acid is greater if given early[5]
- NNT 125 (RR 0.68) for death from bleeding if given within 1 hour
- Benefit is seen up to 3 hours post-injury
- Causes harm if given later than 3 hours

As a team, you will need to consider whether to start replacing fluids or treat the patient with permissive hypovolaemia. In any case use fluids or blood for both diagnosis and treatment by administering 250 -1000 mL boluses and assessing the response, i.e. change in perfusion indexes such as heart rate, peripheral warmth, ABG results or blood pressure. Permissive hypotension, damage control resuscitation and haemodynamic endpoints will be discussed later in this chapter.

The patient's response to initial fluid resuscitation can be used to determine subsequent fluid therapy. Patients who respond rapidly to an initial fluid bolus and remain haemodynamically stable are classed 'rapid responders' with minimal blood loss and are unlikely to need further fluid or blood. 'Non-responders' to initial fluid therapy who remain haemodynamically unstable are likely to have significant blood loss, will require large volumes of blood replacement and urgent surgical control of bleeding.

'Transient responders' are those who respond well initially but subsequently deteriorate. These patients are likely to have ongoing bleeding and require blood replacement and surgical intervention. ATLS[1] uses the terms 'rapid', 'non' and 'no responders' to guide crystalloid vs blood for initial fluid therapy. Rapid Responders receive X-matched blood if needed, transients receive type-specific blood if required, and non-responders receive O negative blood if urgently required (refer to Appendix 2).

If the patient is extremely unstable damage control thoracotomy, laparotomy or pelvic packing may occur at this point during the assessment and management of 'Circulation' in the Primary Survey. In this situation progression to 'Disability' will only occur once haemorrhage is controlled and the patient is stabilised.

ACTIVITY
1. How is the MTP activated in your hospital? What are the blood products which arrive in your first, second, third etc. packs?

2. Read the CRASH-2 Trial[5] regarding the evidence for using TXA in the context of Trauma.

3. Read the following article: Rolf Rossaint et. al. (2016) - The European guideline on management of major bleeding and coagulopathy following trauma: fourth edition.[6]

4. The National Blood Authority has an excellent website with several e-learning modules - one of these is about the blood management in patients with critical bleeding. Complete the module accessed via the BloodSafe website.

Disability

Rapid assessment of level of consciousness using the AVPU score:

- A Awake
- V Responding to verbal commands
- P responding to painful stimuli
- U unresponsive

A score of P or U corresponds to a Glasgow Coma Scale (GCS) score of 8 or less and suggests a need for definitive airway management and protection. Assess the pupils for symmetry and assess for the presence of unilateral peripheral neurological signs. Blood glucose level should also be checked.

PRACTICE TIP
Prior to tracheal intubation of a trauma patient it is useful to establish their GCS score, the presence and symmetry of upper / lower limb movement and pupils. These findings and the grade of view on laryngoscopy should be documented in the patient's notes

Exposure

The patient should be fully undressed and an active search made for significant injuries. Although a complete examination is required it is critical to avoid hypothermia as this is associated with poorer outcomes in trauma patients. Therefore, after the examination has occurred the patient should be immediately covered by a forced air warming device (this is preferable) or warm blankets if the former is not available.

1.4 Resuscitation

It should be re-emphasised that assessment and resuscitation of the trauma patient is a parallel process and occurs concomitantly. The immediate resuscitation of the trauma patient consists of management of hypovolaemia, oxygenation and haemorrhage control. During resuscitation continual re-evaluation of the 'ABCDEs' is undertaken. If clinical deterioration occurs then the primary survey should be recommenced.

At this stage, urinary and nasogastric catheters can be inserted if indicated. (please note, an orogastric catheter should be inserted if contraindications to nasogastric catheter insertion are present). X-rays (AP chest and AP pelvis) are useful early on, whilst radiological investigation of other injuries can be delayed until after the secondary survey is complete.

1.5 Secondary Survey

The secondary survey is the systematic evaluation of the patient including history and physical examination.

The secondary survey is only undertaken when the primary survey is completed, resuscitation is well under way and the patient's vital signs are normalizing.

History

The AMPLE mnemonic suggested in the EMST course provides a useful summary of the patient's history:

A Allergies
M Current Medications
P Past medical history / Pregnancy
L Last meal
E Events / Environment relating to injury history

Physical Examination

This should be undertaken in the form of a full secondary survey. The need for further investigations will be determined as a result of this review. However, they may need to be delayed until initial, urgent surgical or radiological procedures have been undertaken. Determining the relative priorities for operative treatment, detailed radiological investigations, and transfer to other areas for definitive care requires collaboration and input from all senior staff managing the patient. These procedures should not interrupt the ongoing resuscitation and continuous re- evaluation of the patient.

Log Roll

The patient will need to have their back examined during the patient assessment. If there is any possibility of a spinal injury this must be performed via a log roll. The timing of a log roll can be as follows:

1. During Circulation in the primary survey, particularly in a penetrating trauma patient, where visualising potential entry and exit wounds are crucial or where large volume blood loss is suspected from the back.
2. During Disability in the primary survey, particularly if a spinal injury is suspected.

3. When transferring a patient from the ambulance stretcher onto the hospital bed.
4. During the secondary survey in all other patients.

Watch this following video that demonstrates the how a log roll should be performed.

ACTIVITY
We have discussed in detail above the process involved in the initial assessment and management of the trauma patient in Emergency Department. Have a think and make some notes about how you might approach assessing a trauma patient who suddenly arrives in theatre for an emergency operation - how will you rapidly assess the patient, how many additional people will you require (both the minimum and optimal number) to assist you manage the patient?

2. Evolving Injuries

The early response to injury is a dynamic process. Continual and repeated review of the patient's general condition with primary and secondary surveys is essential. Ongoing concealed blood loss can occur, particularly with pelvic fractures. Acute brain swelling can diminish the potential for long-term neurological recovery.

3. Hand-Over of Care

Multiple transfers of management occur for the trauma patient. In-hospital transfers can involve both resuscitation / critical care teams (emergency medicine, anaesthetic, intensive care) as well as subspecialty surgical teams. The ISBAR approach to handover should be used (refer to the Human Factors modules for more information on this approach).

A verbal summary and thorough written documentation are both critical elements in optimising patient care and preventing further injuries and complications occurring.

ACTIVITY
What examples of teamwork behaviours from chapter 1 can you identify in Trauma / Trauma Team management? Try and describe at least 5.

4. Management of Large-Volume Resuscitation

4.1 Resuscitation end-points

Traditionally, the adequacy of fluid resuscitation is assessed via normalisation of blood pressure, heart rate and urine output. However, suboptimal tissue perfusion persists in a significant number of patients with multi-system trauma even after the normalisation of blood pressure, heart rate and urine output. A number of alternate endpoints have been studied, the most practical being serum lactate, base deficit and gastric mucosal pH levels. There is evidence to suggest that the normalisation of one or all of these parameters as early as possible within the first 24 hours following injury significantly improves survival in severely injured patients. Despite this, fluid resuscitation should not in any circumstances prevent the definitive treatment of injuries.

4.2 Large volume resuscitation in trauma

Patients who are hypovolaemic (greater than 50% blood loss) following severe trauma are at a high risk of developing multiple organ system failure and death The triad of acidosis, coagulopathy and hypothermia is associated with significantly increased mortality in this patient subgroup. Furthermore, aggressive attempts to normalize haemodynamic parameters prior to control of haemorrhage have been shown to worsen outcome (especially in penetrating trauma to the torso).[7]

Whilst the optimal algorithms for fluid resuscitation, blood product replacement, and the use of inotropes and/or vasopressor are yet to be determined, the evidence suggests that resuscitation of the shocked trauma patient should be considered in two phases.

Initial resuscitation prior to control of haemorrhage should be limited to keep systolic blood pressure (SBP) 70 - 90 mmHg, depending on age and pre-existing pathology. This is known as ‘permissive hypotension’. In the context of intracranial injuries the target SBP should be slightly higher (approximately 100 - 110 mmHg) to facilitate adequate cerebral perfusion.[8] A urine output of 0.5mL/kg/hr can be used as a guide to fluid replacement.[1]

There is evidence that crystalloid solutions may potentiate cellular injury caused by haemorrhagic shock and therefore blood products should be commenced earlier than normal. To this end Massive Transfusion Protocols (MTPs) have been developed and should be used. This has been shown to both reduce blood product usage and improve patient outcomes. It is important that anaesthetists are familiar with the process of the MTP response within their institution and the blood product components present within the consecutive packs made available.

5. Anaesthetic Implications of Airway Trauma[9, 10]

The overall incidence or Traumatic Airway Injury (TAI) is low - approximately 0.4% for blunt and 4.5% for penetrating airway trauma.[11] The presenting signs and symptoms for blunt TAI differs to that of penetrating TAI. Of particular note, patients with blunt TAI have a higher associated Injury Severity Score and rate of mortality.

ACTIVITY How is the Injury Severity Score calculated?

Despite the low incidence of TAI in trauma patients, an early and fastidious airway assessment is necessary as presenting features may be subtle and overshadowed by other more obvious injuries.

5.1 Blunt laryngeal trauma[12]

Mortality rates of all airway injuries range between 15-40%. Death is usually the result of associated injuries including aspiration (blood and recurrent laryngeal nerve injury), intrapulmonary haemorrhage, frank airway disruption and laryngospasm. Intubation may cause further trauma and failed attempts may precipitate complete airway disruption and/or obstruction.
Diagnosis requires a high index of suspicion. Patients may be asymptomatic for 24-48 hours, and may have distracting injuries.

High risk mechanisms include:

- Direct anterior neck trauma
- Steering wheel or dashboard in motor vehicle accidents
- 'Clothes-lining' injuries in motorcycle or bicycle accidents
- Other direct blows to the neck
- Severe flexion / extension injuries, crush injuries e.g. attempted hanging

The mechanism may predict the site of injury.

Direct blow

- Laryngeal or cricoid cartilage injury is more likely to occur.
- Comminuted fractures of the thyroid cartilage cause separation of the epiglottis from the larynx.
- Fractures of the lateral portion of the thyroid cartilage may create false passages and fragments may obstruct intubation attempts.

Extension / flexion injuries

- Tracheal tears or laryngotracheal separation may occur.
- Most commonly occurs at cricotracheal junction where connective tissue is weak.
- The airway may still be held in close approximation by the peritracheal tissue and infrahyoid (strap) muscles during negative pressure ventilation. The severed ends may be dislodged on attempts to pass a tracheal tube.

Major diagnostic criteria suggestive of significant airway injury include:

- Dyspnoea
- Subcutaneous emphysema
- Stridor
- Inability to tolerate the supine position.

The presence of major criteria has been suggested by some as an indication for immediate surgical tracheostomy under local anaesthesia. Please note that cricothyroidotomy is usually contraindicated in these patients as the lesion is usually below the first tracheal cartilage.

Minor criteria include:

- Local swelling & tenderness
- Hoarseness
- Dysphagia
- Haemoptysis

Assessment

Investigations:

- *Computed Tomography (CT)*. Regarded as investigation of choice by many, this assesses integrity of larynx, condition of cricoarytenoid joints and endolaryngeal tissue not seen on fibreoptic endoscopy. Note that CT is inadvisable in the presence of a major diagnostic feature.

- *Laryngoscopy*. Direct flexible nasolaryngoscopy/bronchoscopy allows evaluation of cord movement, laryngeal mucosa & airway lumen with a lessened risk of worsening any cervical spine injury. Bronchoscopy may allow securing of the airway more distal to the injury, or endobronchial intubation if necessary. Topical local anaesthetic should be used with caution due to a potential risk of aspiration. Indirect laryngoscopy may cause coughing / gagging & further compromise the airway.

- *Cervical spine and chest X-rays* may show subcutaneous (in particular cervical emphysema) and extrapleural air (pneumothorax or pneumomediastinum) and other associated injuries. Subcutaneous emphysema is seen in 85% of patients with tracheobronchial injury.

> **PRACTICE TIP**
> The presence of a pneumothorax in association with a large ongoing air leak following tube thoracostomy is pathognomonic for a bronchial disruption.

Airway management

Management should be considered on a case by case basis and is dependent on the likely injury and skills of the managing team. If one or more major diagnostic features are present, management should proceed in theatre with surgical assistance immediately available.

Options are:

- Tracheal intubation under general anaesthesia – use of a tube at least one size smaller than usual has been suggested (if not used, one should at least be immediately available.
- Although an Inhalational induction avoids the use of positive pressure ventilation there is the risk of aspiration in the non-fasted, trauma patient. Intravenous induction may be necessary in the confused / uncooperative patient.
- Awake fibreoptic intubation.
- Rigid laryngoscopy and bronchoscopy – may allow intubation distal to the site of injury.

Blind nasal intubation and percutaneous tracheostomy may exacerbate pre-existing injuries and are not advised.

Be aware that:

- Cricoid pressure may dislocate fractured cricoid cartilage or entirely disrupt a partial tracheal transection.
- Positive pressure ventilation can exacerbate air leaks and worsen air dissecting around structures / surgical emphysema.
- Creation of false passages can occur during intubation attempts.
- Failed attempts at passage of a tracheal tube through a fractured portion may cause complete dislocation and obstruction.
- Cricothyroidotomy may be useless in cricoid cartilage or distal trachea injury
- If facilities are available, helium-oxygen mixture (Heliox) may buy time in the **non-hypoxic** patient.

PRACTICE TIP
Management of blunt laryngeal trauma should involve an ENT surgeon where possible. If the patient is stable, and any significant airway interventions plans these should occur in the operating suite.

ACTIVITY
Read this article from Australasian Anaesthesia:

Peady (2005) - Initial Airway Management of Blunt Upper Airway Injuries: A Case Report and Literature Review

5.2 Airway burns[13]

A significant number of deaths from burns are secondary to respiratory complications arising from the inhalation of toxic products of combustion.

The injury of greatest concern in the acute management of airway burns is that of thermal injury to the upper airway as this may result in rapidly progressive oedema and obstruction.

Signs suggestive of inhalational burns:

Major

- Hoarse voice
- Brassy productive cough Stridor
- Facial, oral pharyngeal burns / oedema of face & mouth

Minor

- Singed nasal hairs
- Carbonaceous sputum or oropharyngeal carbon

Although flash burns may cause superficial burns to the face and lips and do not usually cause an upper airway burn, the patient should still be assessed for the signs outlined above.

Management

Major signs are highly suggestive of laryngeal injury and early intubation must be considered. Although maximal swelling usually occurs 12 - 36 hours after injury, pharyngeal and laryngeal oedema may develop rapidly (over minutes) following inhalational burns to cause complete airway obstruction. Orotracheal intubation may rapidly become impossible, necessitating a surgical approach through a now anatomically distorted airway.

Correction of fluid losses in burns patients with large volume resuscitation may also increase airway swelling, therefore, if the airway is starting to show signs of swelling consider limiting the IV fluids until after it is secured. This was a significant learning point from the 2001 Bali bombings.

Be aware that:

- Inhalational injuries may be associated with carbon monoxide poisoning.
- Burns may be associated with drug or alcohol intoxication or psychiatric disturbance.

6. Anaesthetic Implications of Chest Trauma

Major chest trauma to a large artery, vein or bronchus is often fatal on the scene. Only 15% of these patients require an operative intervention. The remainder of patients may need volume replacement, ventilation, chest drains and analgesia.

The chest X-ray (CXR) is an essential and vital source of information and needs to be carefully and systematically evaluated. Major airway injury is suspected when there is surgical emphysema in the neck, mediastinal air or pneumopericardium on the CXR. If airway disruption is suspected, fibreoptic visualization with a bronchoscope / nasendoscopy should be considered prior to intubation / intermittent positive pressure ventilation (IPPV).

> **PRACTICE TIP**
> It is important to consider the urgency of intubating the patient in this situation. If possible it is preferable to perform intubation of these patients in theatre.

Chest drains should only precede the CXR if the patient is deteriorating rapidly. Chest tube insertion should be performed by surgical incision followed by blunt plural dissection. Keeping the pleural cavity empty will help to seal off air leaks. Thoracotomy is not usually needed unless the blood loss is more than 1500 mL initially or more than 200 mL/ hour for two hours. A larger volume of blood than this suggests the injury is not just one or two intercostal vessels but potentially something more significant.

Cardiac tamponade most commonly results from cardiac laceration following a penetrating wound. It is characterised by distended neck veins (may not be present in a hypovolaemic patient), hypotension and a shocked patient. The diagnosis may be confirmed on FAST ultrasound. Needle pericardiocentesis is of little use as the blood in the pericardium is usually clotted and may result in laceration of the ventricle or coronary arteries. Urgent transfer to an operating theatre for thoracotomy is the management of choice.

Emergency Department thoracotomy is a drastic procedure with limited utility. It should be reserved for patients who are *in extremis* and appropriate surgical expertise should be immediately available.

7. Intra-cranial Trauma[6, 14]

About 50% of trauma deaths are associated with Traumatic Brain Injury (TBI). Early management of TBI should be directed toward minimising progression of injury in the at-risk brain. Specific aims for the anaesthetist are to:

- Minimise secondary insults
- Detect neurological deterioration during the management of other injuries
- Seek neurosurgical advice to aid effective decision-making
- Undertake specific neuro-resuscitative measures when required

Secondary injury can result from a number of causes. Specific management requirements to minimise this occurring include consideration of the following:

- Hypotension is strongly associated with a poor outcome in TBI. A single systolic pressure below 90mmHg is associated with a doubling in mortality. Although a SBP > 90 mmHg has previously been the recommended SBP target, the most recent guidelines for the management of severe TBI advises higher targets (i.e. maintaining a SBP at ≥100 mm Hg for patients 50 to 69 years old or at ≥110 mm Hg or above for patients 15 to 49 or over 70 years old. The recommended Cerebral Perfusion Pressure (CPP) target is between 60-70 mmHg).[8]
- Hypoxia, hyper/hypocapnoea and hyper/hypoglycaemia are also associated with poor outcomes, however an adequate SBP is considered to be the most important factor in preventing secondary injury in TBI.[15]

7.1 Management strategies for TBI

Fluid resuscitation

Warm non-glucose containing isotonic crystalloid solutions are preferable for intravenous administration in patients with TBI. Normal saline is considered the crystalloid of choice to avoid hyponatremia developing as this is associated with the development of cerebral oedema. Glucose-containing IV fluids should be avoided.

In some patients who have a combined haemorrhagic and intracranial injury managing haemodynamic targets may be difficult. If the patient is still bleeding and requires permissive hypotension to manage their blood loss, (for less than 2 hours whilst active measures at stopping the bleeding are occurring typically with surgical or radiological intervention), then this desire to maintain CPP cannot be achieved.

The theoretical risk of large volumes of fluid worsening cerebral oedema does not seem to be supported in clinical practice, although there may be some benefit in use of hypertonic saline in TBI as it increases circulating volume and reduces ICP. There is insufficient evidence to support the use of one vasoactive agent above another if fluids alone are insufficient to maintain arterial pressure. Normal saline should be used as the crystalloid of choice in order to avoid hyponatremia which is associated with cerebral oedema. Glucose-containing solutions should be avoided for the same reason. Coagulopathy may increase intracranial bleeding and therefore should be managed aggressively.

Ventilatory control
Hypoxia, hypo- and hypercapnoea are all viewed as avoidable secondary insults. SpO_2 should be maintained above 90% and $PaCO_2$ between 35-40 mmHg. Patients with a GCS score of <9, who are unable to maintain their own airway or respiratory parameters or patients with higher GCS score who are requiring CT scanning or other investigation / intervention are candidates for intubation and controlled ventilation. This should be performed in a manner so that hypotension is avoided.

Glycaemic control
Hypoglycemia should be corrected and hyperglycaemia avoided, however, optimum targets are yet to be defined. Hyperglycaemia directly causes secondary brain injury by inducing parenchymal metabolic acidosis and through the overproduction of reactive oxygen species. A single episode of BSL > 11.1mmol/L is associated with a 3.6-fold increase in hospital mortality.

Monitoring
During prolonged procedures to treat other injuries to the trunk or limbs it is important to monitor for deterioration. This may require placement of an Extra Ventricular Drain (EVD) by a neurosurgeon.

Specific neuro-resuscitative measures can temporarily delay the effect of a rising ICP. Head up positioning [20 degrees] and adequate muscle relaxation optimise cerebral venous pressure. Hypertonic Saline (HTS) 3-4 mL/kg, 7.5% or mannitol infusion [0.5 – 1 gram/kg] and / or acute hyperventilation may also be indicated in some situations to provide a short-term reduction in ICP. All these should be regarded as a bridge to urgent neurosurgery.

Steroids
Steroid administration is not recommended for improving the outcome or reducing ICP in patients with severe TBI. Moreover, steroids may be harmful after TBI (as seen in the CRASH trial which was prematurely halted due to a greater mortality in the steroid group).

ACTIVITY
Read the summary Guidelines for the Management of Severe Traumatic Brain Injury (4th ed.), released in August 2016.

8. Transfer

Transfer of trauma patients is often required, either for further investigation or management to occur. It should be performed using the appropriate model in the jurisdiction where you work and should involve senior clinician handover of care. It is important for the team to have discussed prior to transfer the appropriateness of the destination the patient is being transferred to in the context of whether the patient is stable or unstable (e.g. a haemodynamically unstable patient is inappropriate to be transferred to the CT scanner)

ACTIVITY
What is the process for trauma patients to be transferred in your institution (i.e. which clinicians are involved, what equipment is brought on the transfer?

9. Imaging in the Trauma Setting

The role of imaging in acute trauma is a continually developing field. Currently a combination of ultrasound, X-ray and CT scans are routinely used.

9.1 EFAST (Extended Focused Assessment with Sonography in Trauma)

EFAST is now part of the primary survey in major trauma centres and consists of 6 ultrasound views of the torso:

1. Left; and
2. Right 2nd rib interspace in the mid-clavicular line to ascertain the presence of a pneumothorax
3. RUQ
4. LUQ
5. Pouch of Douglas

   These views are to ascertain the presence of fluid and look at the 3 dependent areas of the abdomen with the patient lying supine.

6. Subcostal view of heart - this view is to determine the presence of pericardial fluid.

There are accredited courses which need to be completed before a person can diagnose abnormalities on a EFAST scan.

ACTIVITY
Watch these videos on EFAST and lung ultrasound:

EFAST Instructional Video

Ultrasound for Pneumothorax Case Study

9.2 X-ray

X-rays should be completed in parallel with the secondary survey, unless they are indicated as part of the primary survey. It is regarded as standard practice that two X-rays are routinely taken in the multi-trauma patient, namely, an anteroposterior (AP) chest and pelvic X-rays.

PRACTICE TIP
Note that X-rays:
- should not prevent resuscitation efforts.
- should not involve moving the patient from the resuscitation bay.
- should be referred for specialist radiological opinion if any doubt remains as to the presence of pathology.

Other required X-rays (especially those of limbs) are routinely performed during and following the secondary survey.

Refer to Appendix 3 for further information regarding X-rays.

9.3 CT

The role of CT in the initial investigation of trauma patients is also evolving. The salient points of note with regards to CT include the following:

1. Most trauma centres have protocols in place to rapidly perform non-contrast Head and Neck CT, then 'neck to mid-thigh' contrast CT angiography followed by a delayed film if required. This can all be routinely performed in 10 minutes.
2. The clarity and detail with modern CT scanners is highly detailed.
3. Most trauma centres have one of these scanners in close proximity to the resuscitation bay with an anaesthetic machine, monitoring and full resuscitation equipment in the room.
4. Most trauma centres have protocols for the entire trauma team to accompany the patient to the CT scanner for this procedure.

As such, many patients are having CT scans during the resuscitation phase of their initial assessment.

There is still however a definite place in the unstable patient for proceeding to OT directly and most trauma centres have a 'Code Crimson' or 'Red Blanket' protocol for this.

ACTIVITY
What are procedures and protocols for 'imaging' acute trauma in your hospital?
Does your hospital have a protocol for moving a patient directly to OT and if so, what is your role in that protocol?

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Appendix 1
Clearing the cervical spine[16]

The diagnosis of an unstable spinal injury can be difficult, and a missed spinal injury may have devastating long-term consequences. 5-10% of patients with a traumatic brain injury (TBI) have an associated unstable cervical fracture. Therefore, in trauma patients, spinal column injuries should be presumed until it is excluded.

Clearance of the cervical spine in trauma patients is one of the most contentious issues in trauma care and should not be the sole responsibility of the anaesthetist. The pre-requisites for clearing the cervical spine are:

- GCS score of 15.
- no intoxication.
- no distracting injuries.

together with the following normal examination:

- no midline tenderness.
- FROM.
- no referable neurological deficit.

In the acute phase of trauma management, the focus should be on appropriate spinal immobilisation, rather than spinal clearance. Imaging of the spine should not take precedence over lifesaving therapeutic and diagnostic procedures. Initially a rigid cervical immobilisation collar may be used, however these are likely to cause pressure related injuries, so should be changed to a more anatomically correct collar as soon as possible, preferably within four hours.

The cervical spine may be clinically cleared in hospitalised patients if the following conditions are met:

- Normal alertness.
- No drug or alcohol impairment.
- No midline cervical tenderness.
- No focal neurologic deficit.
- No significant ‘distracting’ injury.
- Pain free range of active movements.

If these conditions are not met, then cervical spine immobilization is indicated until the neck can be cleared by radiological evaluation. Guidelines and protocols vary between institutions depending on expertise and facilities available, and may include CT scan and/or MRI. Practitioners should familiarize themselves with guidelines relevant to their own institution. (General guidelines are available in the bibliography section).

Appendix 2:
Processing of Emergency Blood Requests

The following is an outline of the electronic processing of emergency blood requests which is the routine procedure in most major hospitals in Australia and New Zealand.

ROYAL PERTH HOSPITAL EMERGENCY BLOOD REQUESTS

Urgent
Blood required urgently- no current group and screen: Emergency issue of blood.
12 x O Negative uncross-matched units are available immediately.
Sample received: Sample is centrifuged for 5 minutes. Blood grouping test takes 2 minutes to perform- give **group-specific** blood if required urgently.

Semi-urgent
Blood is required –Clinicians inform lab that they will wait, however they will inform lab if situation changes and emergency blood is required.
Sample received: Sample is spun for 5 minutes. Group and antibody screen takes 25 minutes.

Antibody screen	
No antibody detected	Antibody detected
Blood is electronically issued	Determine antibody specificity (30 mins)
About 30 seconds to label unit	Compatible units available, crossmatch time: 30 mins
	If no compatible units available - order from Red Cross (if urgent : 20 mins to arrive, then 30 mins to crossmatch)

Total time for cross-matched units if antibody detected for the first time is about 90 minutes (screen, identification, crossmatch). Approximately 1 in 100 transfusions will result in an antibody being made.
In WA the Red Cross has an antibody register to which all transfusion labs (private and public) have access. Whenever a lab detects an antibody, it gets added to the register. When we receive a sample for testing, we check the register to see if the patient has been registered as having an antibody (and all government labs have their transfusion computers connected so we can see complete testing and transfusion history for any patient who has been tested by a government lab that does cross-matching in WA).
In an emergency situation, if we can get a name and a date of birth, we automatically check the antibody register, as O Neg units may not be suitable.

Susan Finch, Chief Scientist, Transfusion Medicine, Royal Perth Hospital (October 2016)

Appendix 3
Viewing of X-Rays

There are many different approaches to viewing X-rays which may be valid. Experienced clinicians use their own approach. However, the following is just one such approach.

X-rays should always be examined on a viewing box or computer screen and the following features should be sought:

- Correct orientation of film or view.
- Name of the patient
- Date of the film

These factors, often overlooked in the busy resuscitation period, are important as often multiple patients' X-rays are viewed at the same box. Following on from this 'The ABCDE approach' can be used.

1. *Adequacy of the X-ray*:
    - Technical factors: adequate penetration of the film
    - Patient factors: are all the anatomical features included?

2. *Bones:*
    - Look for any lucency to indicate fractures by carefully following the outline of each bone (e.g. rib or vertebrae)
    - Look for fragments of bone.
    - Look for alignment of bones (particularly important in the C-spine)

3. *'Cpaces' and other soft tissues*

4. *Diaphragm and Disc spaces* in the CXR and C-spine respectively.

5. *Extras:* This refers to additional equipment often placed in the patient such as nasogastric and endotracheal tubes.

Chest X-ray

Look for the following features:

1. *Adequacy:*
    - Penetration of the film should such that the disc spaces of the lower vertebrae can be seen through the cardiac shadow.
    - The entire chest wall and both costo-phrenic angles should be visualised.
    - Rotation of the film can be assessed by comparing the distance between the clavicles and the spinous processes.
    - In the trauma setting often an AP rather than a standard PA film is obtained.

2. *Bones:*
    - Initially the humerus, clavicles and scapula on both sides are inspected. Thereafter the ribs on each hemi-thorax are individually traced looking for

fractures. Fractures of the upper three ribs are associated with cardiac, aortic and bronchial injury.
- Rib fractures are associated with a haemothorax and pneumothorax.
- Lastly the vertebrae are inspected.

3. *Spaces and soft tissues*
   - The mediastinal structures are examined from top to bottom
   - The trachea should be centrally placed.
   - In a child the thymus may give an appearance of a widened mediastinum.
   - The aortic arch should be uniform and clear.
   - Widening of the mediastinum may indicate a traumatic rupture of the aorta.
   - The cardiac shadow should lie 2/3 in the left hemi-thorax. AP films tend to exaggerate the size of the heart. Displacement of the heart is either due to the mediastinum being pushed across (e.g. tension pneumothorax) or being pulled (e.g. collapse of a lung).
   - A globular shaped cardiac shadow may indicate a haemopericardium or pericardial effusion.
   - The lung fields should be individually assessed and then compared to each other.
   - Lung markings must be seen to the edge of the lung fields.
   - The soft tissues surrounding the chest may contain foreign bodies or subcutaneous air indicating a pneumothorax.

4. *Diaphragm:*
   - The right diaphragm is normally situated above the left.
   - Blunting of the costo-phrenic angles may indicate a haemothorax, pleural effusion or diaphragm rupture.
   - The appearance of stomach or small bowel in the chest indicates diaphragm rupture.

5. *Extras:*
   - Endotracheal tube should be placed in the trachea above the carina.
   - Nasogastric tubes in the left hemithorax indicate a ruptured diaphragm.
   - ECG leads and intercostal drains may be seen.

Complete EMAC Participants Manual

Change control register

Version	Author	Date	Sections Modified
3.2	Various	June 2017	Created
3.3	B Peace	Jan 2018	Cardiovascular Emergencies: hi-res images replace low-res (mostly throughout) Airway Emergencies: hi-res images replace low-res (mostly throughout)
3.4	B Peace	Feb 2018	Airway Emergencies: New links to the following videos: Handover 1, Handover 2, Guidewire 4. Correct pagination throughout and inclusion of a Contents page.