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CURRENT OPINION

A proposed system for standardization of colour-coding stages of escalating criticality in clinical incidents

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Purpose of review
This article proposes a standardized framework for colour-coding states of criticality in clinical situations and their respective escalated responses.

Recent findings
The first level is a *green* zone representing a *'safe' space (to proceed)*, where any hazards are controlled, latent or undetectable. The second is an *amber* zone, where hazards are known to be present, but one can *proceed with caution* and increased vigilance, and where defences are used to prevent escalation to a crisis. In the *red* phase – a state of *crisis* – a hazard is realized, clear and present. This is a time to decide what actions are required to mitigate the threat. Next, a *blue* phase refers to a *life-threatening emergency*, where the system is unstable, harm is evident and compounding upon itself, and immediate rescue action is needed to avert an irreversible outcome. Finally, *dark grey* represents the *aftermath,* where the situation has either stabilized or progressed to its final outcome, a time to reflect and learn.

Summary
A standardized colour-coding system for assessing and responding to escalating levels of criticality has implications for clinical practice and adverse event reporting systems.

Keywords
adverse event, clinically stable, colour-coding, criticality, risk analysis

INTRODUCTION

The effect of colour on affect and perception of meaning has been an established research stream in semiotic psychology for many decades. Semiotics is the study of signs and meaning; a *sign* being a substituted representation (or 'representamen') of another object in order to convey an idea (or 'interpretant') of some aspect of that object [1–3]. For example, the colour green may be used as a representamen of an object such as a leaf or a sapling, with the intention to connote nature ('green energy') or immaturity ('the green intern') as interpretants. A sign can be an *icon* (a stylised facsimile, e.g. a 'trash-can' icon at the bottom of a computer screen), an *index* (e.g. a weather vane is an index of wind direction because the wind physically turns the vane) or a more abstract *symbol* (e.g. the swastika as a symbol of totalitarian fascism).

Although the association of signs with certain emotions, ideas or events may seem fixed to Western observers, these are by no means universal. For example, prior to the twentieth century, the swastika was a traditional symbol of well being and prosperity across the Indo-European world, and remains so in many non-European cultures [4]. In Chinese cultures, red is associated with joy and good fortune rather than danger [5]; in parts of South America, yellow is the colour of death [6], etc.

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KEY POINTS

- Semiotics influence behaviour and colour has semiotic significance.
- The state of criticality of clinical systems may be generally classified into five qualitatively distinct and escalating phases depending on the stability of the system and the nature of threats to that system; each phase is denoted by a different colour.
- With each phase of criticality, there is a different priority for clinical action.
- Each phase is context sensitive, and may differ in different environments or with different clinical teams.
- A clearer understanding of the state of criticality in a given situation may help practitioners identify and communicate the right course of action at the right time, both in retrospective analyses and in real-time clinical management.

Thus, the interpretants of colour are acquired or learned rather than innate, subject to social and cultural contexts, and reinforced by repeated exposure or indoctrination.

GREEN - YELLOW/AMBER - RED

A key example of applied colour semiotics is the ‘green-amber-red’ system used in traffic lights, whose correlate meanings are ‘go-caution-stop’ respectively. Its origins stem from the nineteenth century, in the early days of British rail; initially ‘go’ was white (the ‘all clear’ colour), green was ‘caution’ and red was ‘stop’ [7]. White was deemed unsafe after drivers confused stars or other stray lights for white ‘all-clear’ signals; for reasons unclear at that time, green became ‘go’ and yellow became ‘caution’. In 1920, the first four-way three-colour road traffic light tower was installed in Detroit, apparently inspired by the UK rail signalling system [8].

Studies later found that red is the first colour to be distinguishable by the human eye from all other colours in low light conditions [9]. This affirmed red as the preferred colour for the most restrictive signal instruction: ‘stop’. For ‘go/all clear’, a colour was needed towards the opposite end of the visible spectrum (e.g. indigo or violet) to distinguish it from red; however, as the emitting wavelength was made shorter, a greater light intensity was required to make it visible in daylight, at a greater cost. Green was the familiar compromise and officially became ‘go’; and yellow, equally distinguishable from both green and red, was chosen as the intermediate ‘proceed with caution/prepare to stop’ colour.

In 1967, the red-yellow-green colour signal scheme officially became the US national traffic standard [9]. Shortly after, the United Nations began working actively via the Vienna Convention of Road Signs and Signals to standardize traffic light colours across the globe [10]. Over time, the association between ‘green-amber-red’ and ‘go-caution-stop’ has become virtually global, although there are exceptions. In Japan, the ‘go’ light is by government decree blue-green, to justify the traditional Japanese word *ao* ascribed to it, which is ‘blue’, a relic of a time when the Japanese only had one word for both colours [11,12].

BLUE, BLACK AND GREY

’Code Blue’ has in most western healthcare settings become synonymous with cardiopulmonary arrest and emergency resuscitation. The coining of this term is attributed to pioneering Kansas cardiologist Hughes Day, who was inspired by the observation that most patients with severe physiological impairment of the respiratory or cardiovascular system were cyanotic [13,14]. Thus, the colour blue acts as a semiotic *index* of a state of cardiopulmonary collapse that requires immediate intervention to prevent an irretrievable negative outcome.

In western cultures, black, the colour traditionally worn at funerals, is a symbol of death, gravity and finality (e.g. ‘fade to black’). The colour grey has a number of interpretants: not only uncertainty (e.g. ‘a grey area’), but also age and experience (‘grey hairs’) as well as intelligence (‘grey matter’).

Colours can influence performance. Xia *et al.* [15] found that when volunteer individuals were asked to perform detail-oriented tasks, such as checking the correct spelling of an address, they performed simple tasks better when text was set against a red background, but performed more difficult tasks better when performed against a blue background. The researchers suggested a possible reason was that red, being associated with danger, raised the general level of arousal of individuals, which was beneficial for the simple task but degraded performance of the more difficult task, because it tipped them over the crest of the Yerkes-Dodson arousal-performance curve [16,17].

COLOUR CODING IN ANAESTHESIOLOGY AND CLINICAL SAFETY SYSTEMS

In clinical contexts, skin colour is often used as a sign (or, in more specific semiotic terms, an *index*) of disease states: not only blue for hypoxia (see above), but also yellow for jaundice, white for shock/anaemia, black for ischemia/gangrene, red for bleeding/

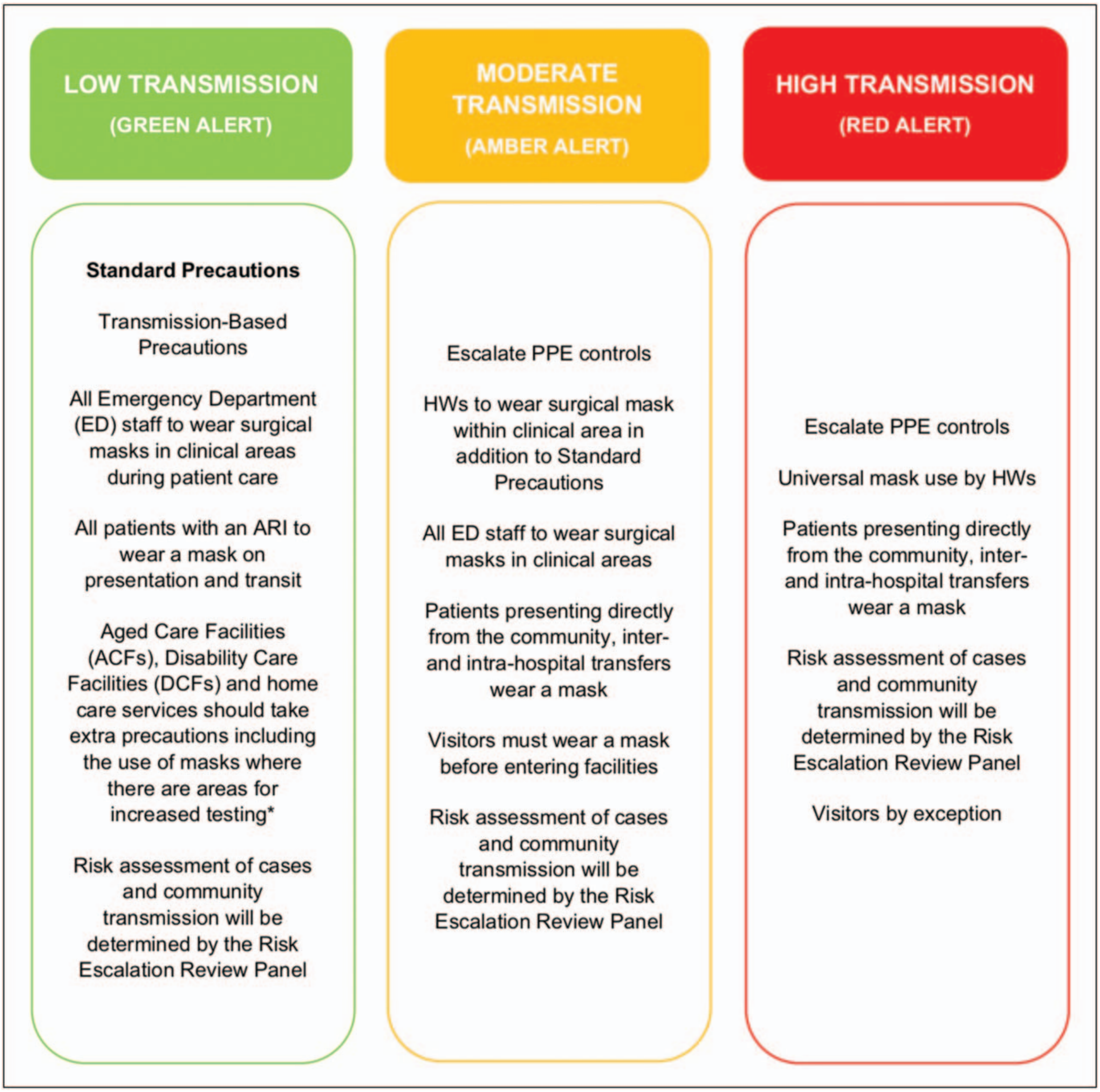

FIGURE 1. An escalating colour-coded response matrix for COVID-19 infection. Developed by the NSW Clinical Excellence Commission; Adapted with permission.

inflammation, etc. Colour-coding is now an established feature of anaesthesiology practice, for example to identify medical gases [18] and in medication labelling [19,20]; however, in these instances, the colours used seemingly have no semiotic value other than to distinguish different entities from each other.

Colour-coding modelled on the modern traffic light system is frequently used to distinguish safety, caution and danger. In healthcare, red, yellow, amber and green in various gradations have traditionally been used in risk assessment matrices such as the Severity Assessment Code used by Australian health authorities to assist with root cause analysis [21–23].

A typical example of the use of traffic light colours to represent escalating criticality and response is the New South Wales COVID Risk Matrix [24]. This matrix uses green-amber-red colour coding to align hospital response measures with the risk of community transmission and onward spread of the virus (see Fig. 1). In all these examples, the colour change reflects a gradient of severity of a parameter (risk or community transmission) rather than qualitatively different states.

In clinical practice, the traffic-light model can also be seen in, for example, coding drawers in difficult airway trolleys [25] and coding levels of urgency for Caesarean section [26]. In these

Color	State/Priority	Description	TEMs	DefCon Status	ASA Grade
GREEN	Routine, Safe *Avoid Hazards* Proceed; 'Business as Usual'	System stable Threats controlled or undetected	Avoid	5 Peacetime Troops practising away from public view	I Normal
AMBER	Non-Routine *Trap Deviations* Slow Down; Check; Watch	System stable Threats present but unclear	Trap	4 Increased vigilance Troops in the streets	II Mild systemic disease
RED	Critical *Mitigate Threats* Stop; Confer; Decide	System stable Threats present and clear	Mitigate	3,2 Force Mobilisation Jets in the air	III Severe systemic disease
BLUE	Complex Critical *Rescue from Harm* Do the Drill	System unstable Harm occurring and compounding	('Undesirable Aircraft State')	1 State of War	IV Constant threat to life; Critically Ill
BLACK	Catastrophic *Learn from Outcome* Debrief; Reflect; Analyze	System in collapse Outcome irreversible	(Crash)	['Zero'] Defeat; Apocalypse	V (VI) Moribund (Brain Dead)

FIGURE 2. The ErroMed model compared with various threat assessment models. Adapted with permission.

examples, escalating colours (green to yellow to red) also denote situations of escalating severity.

DISPLAY OF INFORMATION FOR CRITICAL INCIDENT ANALYSIS TOOLS

At present, there is no generally accepted colour-coding system for critical incident analysis tools. Reason's Swiss Cheese diagram [27] depicts yellow slices, although the colour confers no conceptual meaning apart from being the same colour as cheese. The red arrow trajecting through the Swiss cheese holes may signify danger but seems more stylistic than semiotic.

The ErroMed model of error management [28,29] was influenced by Helmreich's Threat and Error Management (TEMs) model [30], the US military's Defence Readiness Condition (DEFCON) classification system [31] and the American Society of Anaesthetists' ASA grading system [32]. The three classification systems are compared in Fig. 2.

In TEMs, pilots are taught to 'avoid' 'trap' and 'mitigate' errors in order to prevent an 'undesirable aircraft state' and, ultimately, an aviation accident. The TEMs model has also been adapted in the USA for anaesthesiology practice [33]. Colour does not feature prominently in the model, although in at least one graphical depiction 'avoid' is yellow, 'trap' is amber and 'mitigate' is red [34].

The US DEFCON coding system, introduced in 1959, was used to define graduated states of military readiness to threats of attack on US soil [31]. The state of readiness declared was thus a surrogate for the perceived level of threat. The colour levels from peacetime (Defcon 5) to state of war (Defcon 1) are blue-green-yellow-red-white. There is an unofficial 'DefCon Zero' (no colour), denoting a nuclear apocalypse. Note that this coding system defines not only escalating levels of threat but also the priorities for action related to each level.

Most anaesthesiologists are familiar with the ASA grading system of physical status, first described in 1941 [35] and formalized in 1963 [36]. ASA grade has been used for years as a surrogate predictor of perioperative risk, although it only grades disease severity and does not account for other performance shaping factors (e.g. task, operator and environmental factors) [37,38]. In 1980, ASA grade VI (for brain-dead patients) was added [39]. No colours are associated with this grading system.

In the ErroMed model [29], colour is used to denote both a state of criticality and the priorities of action. Green denotes a 'routine' or 'safe' state, where the priority is to proceed, while *avoiding* known hazards. Amber denotes a 'nonroutine' state where an abnormality is detected, but it is as yet unclear whether this represents an imminent threat. The priority is to increase vigilance in order to *trap* and check deviations from the norm, and to proceed with caution. Red is a 'critical' state where a clear and present danger is identified, which may or may not already be causing harm; the priority is to make decisions to *mitigate* the threat. Blue is an unstable 'complex critical' state of life-threatening emergency, where harm is not only occurring but is compounding on itself; the priority is to *rescue* the patient from irreversible harm. Black is a state of 'catastrophe'; the operators have lost control of the outcome, which is now irreversible. The priority is to reflect and *learn* from the event.

'CRISIS' VS. 'EMERGENCY'

Note that in this paradigm, a clear and present threat triggers a *crisis* (from the ancient Greek word for 'a time for making decisions'); this is not the same as an *emergency* (a time of instability requiring immediate action). In anaesthetic practice, these phenomena often arise simultaneously (e.g. in anaphylaxis, sudden cardiac arrest, etc.), but not always (e.g. in delayed inhalational thermal injury, or paracetamol overdose). For patients who are critical but still stable, there may be time to pause, confer and prepare for an emergency situation, in order to avert escalation into a situation from which there may be no good outcome. Distinguishing 'crisis' from 'emergency' may be counter-intuitive to most clinicians trained in traditional 'crisis management' (which is in effect mostly 'emergency and crisis management'). Nevertheless, it is especially evident when facing nonlinear/exponential phenomena such as the spread of the COVID-19 pandemic (see Fig. 3) where, in the absence of an overt emergency, the difference between prompt and delayed

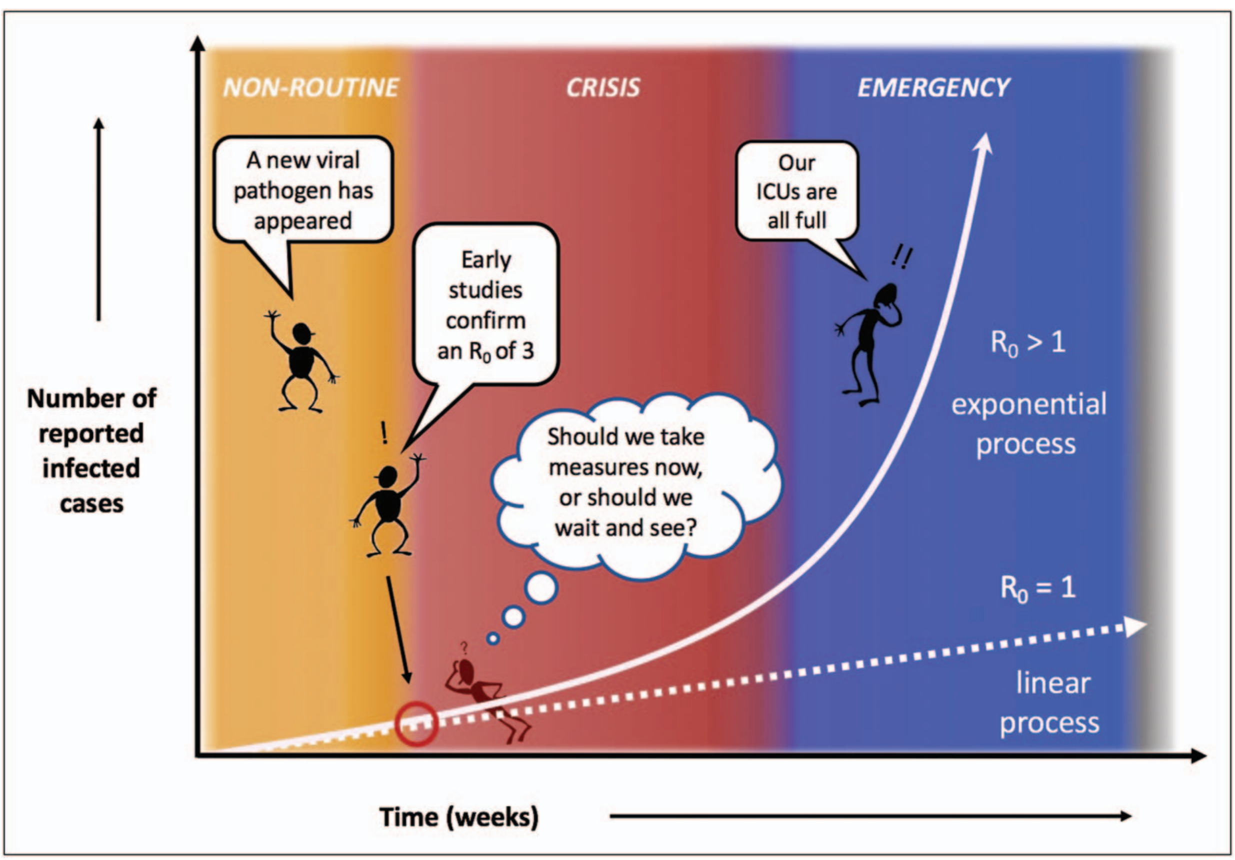

FIGURE 3. An example of 'crisis' vs. 'emergency' in a nonlinear process (Original).

measures can be stark [40]. The same logic would apply to proactive early management of an infected wound, an aggressive malignancy, etc.

DISCUSSION

The colour coding of incident evolution – from a 'routine' or 'safe' state through a non-routine state to a crisis, and thence through emergency management to a final outcome – has been incorporated into a Bowtie analysis model [41▪▪]. This diagram consists of five zones and is designed to map and simplify the complexity of crisis and emergency management. The model recognizes that in most cases, a critical incident has been in evolution long before it becomes clinically apparent.

The *green* zone is a space that is 'safe' or 'safe to proceed'. In this state, known latent factors and hazards are routinely under control. The aim is to stay in the green zone or to return to the green zone by *avoiding* these hazards.

The *amber* zone is where abnormalities that constitute potential threats are detected early to *trap* the anomaly using both proactive and reactive strategies. The planned procedure continues, but usually at a slower pace, with heightened vigilance and caution to prevent a crisis.

In the *red* zone, a hazard is realized, and a threat is clear and present. It is a time of *crisis* for the clinician to stop what is routine, to evaluate and make decisions to *mitigate* the threat. The clinician might assume an initial presumptive diagnosis or differential diagnosis at this point, but the diagnosis might change as the crisis evolves. For instance, hypotension is common in response to induction of anaesthesia, but might reflect the early stages of anaphylaxis which is less common. In many clinical situations, the complication manifests by rendering the patient unstable (see below); in this case, the crisis (red) and the emergency (blue) coincide. However, on occasions wherein the patient is still stable, but the clinician judges that a life-threatening emergency appears inevitable, a period of crisis precedes the emergency, and there is the opportunity to mitigate potential harm by acting in anticipation: calling for help, marshalling equipment, starting preemptive treatment, etc.

Up to this point in the model, the system under examination has been stable. For the purposes of this model, 'clinical stability' is defined as *the ability of a complex adaptive clinical or physiological system to maintain indices of functions essential to its homeostasis within defined 'normal' bounds within a given time horizon*. Stability is context sensitive: for example, a patient in respiratory distress with pneumonia may be deemed 'unstable' at home but 'stable' in a hospital ward on oxygen and intravenous antibiotics; or 'unstable' on a ward despite this treatment, but 'stable' in an ICU on life support. A patient under cardioplegia for open heart surgery, with continuous perfusionist support and monitoring, may be regarded as being in a state of 'stable'

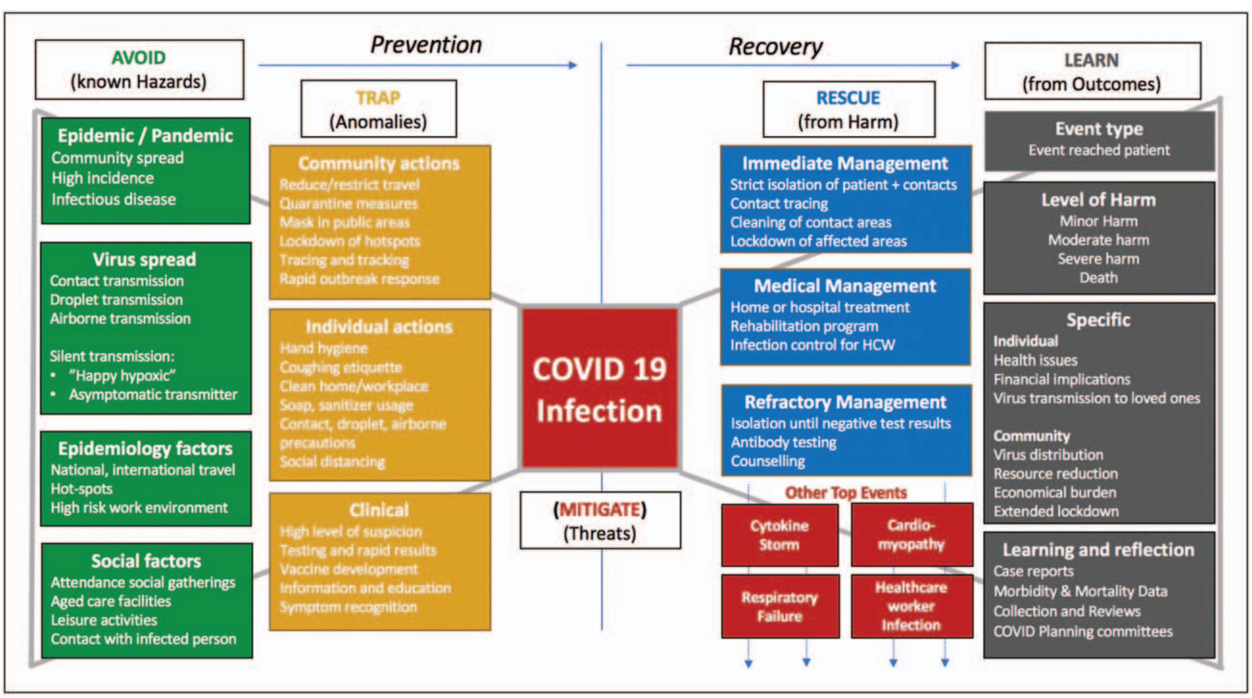

FIGURE 4. An example of a colour-coded Bowtie diagram. Adapted from with permission from [41▪▪].

cardiac arrest (for about an hour). In these situations, the various clinical support systems form part of the complex adaptive system in question, redefining the context. In the *blue* zone, essential homeostatic mechanisms have been disrupted, and the system is now unstable; it represents the worst realization of a clinical risk, a life-threatening *emergency* where harm is occurring and compounding upon itself, requiring immediate action to *rescue* the patient from permanent harm. The further one proceeds in this phase without rescue, the more complex and chaotic it becomes, to the point where the operators lose the ability to control the outcome (a catastrophic 'grey' zone). In the proposed blue zone, there are four stages. Immediate management is the treatment of physiological parameters, while the diagnosis might be presumed or unclear. Definitive management is treatment based on a diagnosis or differential diagnosis. If the first two steps fail to be effective, then refractory management is invoked which has two parts: review other possible diagnoses and escalation of treatment. The final stage of management is postemergency management, which might involve an ongoing treatment plan and/or transfer to intensive care or to another hospital. The cognitive load in the *blue* zone is immense and is best managed through better emergency planning: the development of drills, checklists, algorithms, cognitive aids and their rehearsal through simulation. In this sense, planning may be regarded as the distribution of the cognitive load of an emergency over time.

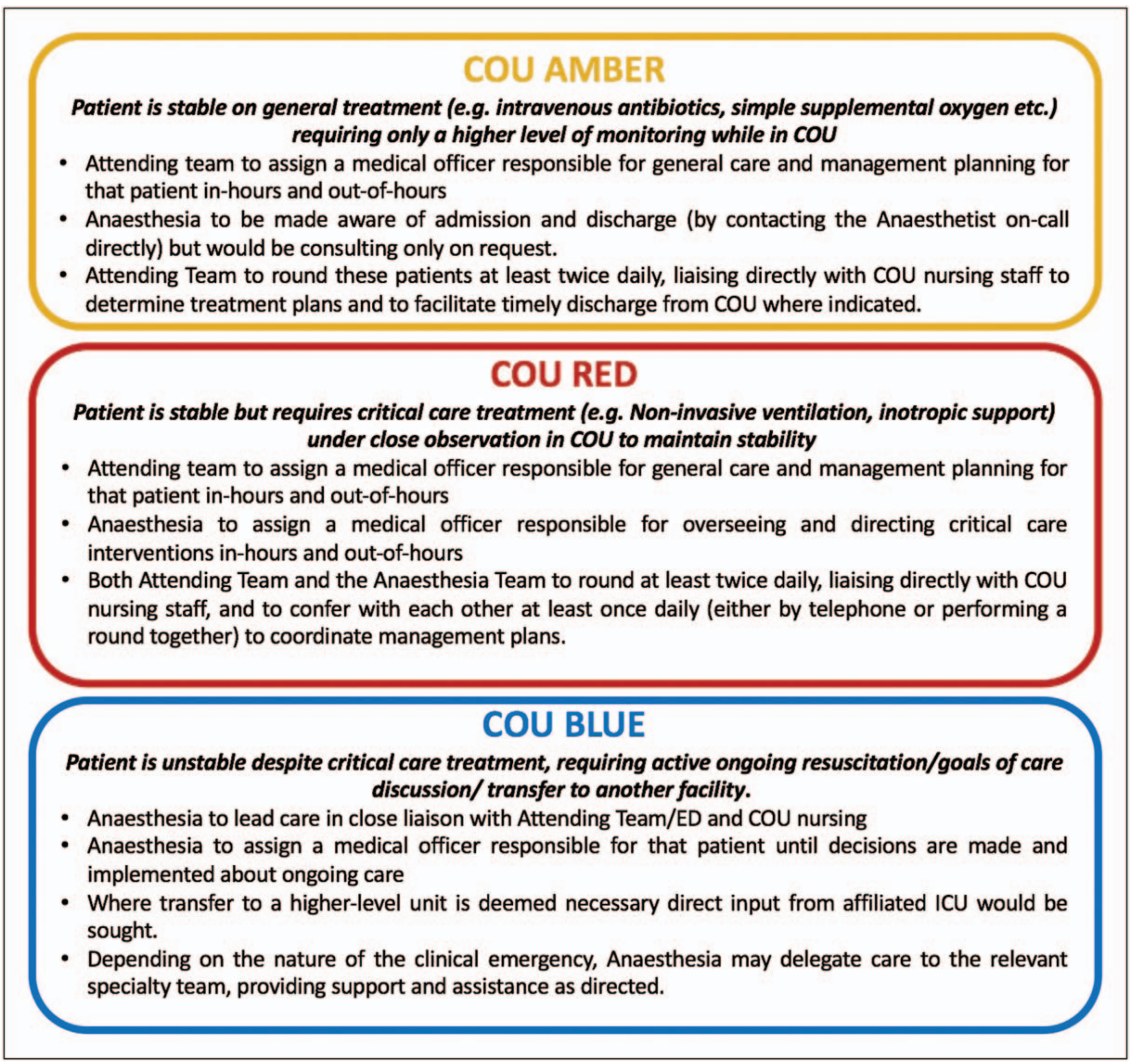

FIGURE 5. Use of the colour-coding model to stratify criticality of patients in a Close Observation Unit (Original). Note that the escalating categories not only denote increasing severity but also qualitatively different critical states and different modes of management.

The final *grey* zone categorizes the possible outcomes of the incident, which might vary from a return to the green zone with no harm right through to the possibility of a fatal outcome. Grey was chosen over black to encourage a focus on wisdom rather than finality; in this zone, while the actors can no longer influence the outcome for a given patient, they can seek to improve outcomes for future patients. It is therefore a time to salvage, to reflect and to *learn*.

Note that as the definition of clinical stability is context-sensitive, so too are states of criticality; what is 'red' or 'blue' for one environment or for one team may be 'amber' or even 'green' for another, depending on available resources, expertise and other performance shaping factors prevailing upon a given clinical situation [42,43].

The 'Bowtie' method of analysis [44,45] currently used by ANZTADC in its WebAIRS incident reporting system [46,47] has adopted this colour-coding scheme [41■■]. This system promises to be intuitive and complete; it groups and summarizes all essential aspects of anaesthetic incident reporting. An example of a Bowtie diagram (applied to COVID-19 as the Top Event) is given in Fig. 4.

A second potential application of the model is in the stratification of patients in Close Observation Units (COUs). A COU provides an intermediate level of care between a general ward and an ICU [48]. In smaller hospitals where no intensivist is available to run a closed-style unit, the practical day-to-day medical governance of an open-style COU can be quite challenging, especially ensuring effective coordination and communication between critical care teams and attending medical and surgical teams. This can be facilitated by assigning one of three levels of critical illness to the patient based on initial/ongoing assessments, consistent with the colour-coding model (see Fig. 5).

Another potential application would be as a rapid shorthand for getting a theatre team on the same page about the criticality of a clinical situation (e.g. 'We are Amber; we need to take it slow and keep an eye on x'; 'We are Red; let's take a minute to confer and make a plan'; 'We are Green, let's go'). The model could also be used to teach trainees to look beyond the emergency management of complications and to think about how to prevent them, as well as how to recover and learn from them. This would inculcate an expert's situational awareness of anaesthetic complications, in keeping with Klein's observation that experts have the ability to see both anomalous details and the big picture at the same time, as well as the ability to see the past, present and future as one [49].

CONCLUSION

The impact of colours on perception and task performance depends on social cultural contexts. The authors advocate a colour-coded system for staging states of escalating criticality in an evolving clinical event. The colours connote not just states of escalation but also different management priorities for each level. The first three zones, green (routine), amber (nonroutine) and red (critical), follow the semiotic traffic light paradigm with which most readers would be familiar, to the point where a critical event occurs. To these two extra zones are introduced: blue (complex critical) to denote a rescue phase from which recovery might be possible, and dark grey (aftermath), to indicate a final phase of reflection and learning. The authors encourage the reader to use this framework to improve patient safety.

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Conflicts of interest

The authors declare no other conflicts of interest.

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Dr. Yasmin Endlich is Director of Extended Global Medical Training, which is a not-for-profit organization that supports medical learning and teaching in low-income countries and rural Australia.

The diagrams shown in this review are examples only and are not a complete set of risk assessment and management recommendations for COVID-19.

Dr. Yasmin Endlich and Dr. Martin Culwick are members of ANZTADC.

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■ of special interest
■■ of outstanding interest

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