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## **Failure to Rescue following Emergency Surgery:**

### **A FRAM Analysis of the Management of the Deteriorating Patient**

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#### **ABSTRACT**

**BACKGROUND:** Failure to rescue (FTR) denotes mortality from post-operative complications after surgery with curative intent. High-volume, low-mortality units have similar complication rates to others, but have lower FTR rates. Effective response to the deteriorating post-operative patient is therefore critical to reducing surgical mortality. Resilience Engineering might afford a useful perspective for studying how the management of deterioration usually succeeds and how resilience can be strengthened.

**METHODS:** We studied the response to the deteriorating patient following emergency abdominal surgery in a large surgical emergency unit, using the Functional Resonance Analysis Method (FRAM). FRAM focuses on the conflicts and trade-offs inherent in the process of response, and how staff adapt to them, rather than on identifying and eliminating error. 31 semi-structured interviews and two workshops were used to construct a model of the response system from which conclusions could be drawn about possible ways to strengthen system resilience.

**RESULTS:** The model identified 23 functions, grouped into five clusters, and their respective variability. The FRAM analysis highlighted trade-offs and conflicts which affected decisions over timing, as well as strategies used by staff to cope with these underlying tensions. Suggestions for improving system resilience centred on improving team communication, organisational learning and relationships, rather than identifying and fixing specific system faults.

**CONCLUSION:** FRAM can be used for analysing surgical work systems in order to identify recommendations focused on strengthening organisational resilience. Its potential value should be explored by empirical evaluation of its use in systems improvement.

**Keywords:** Failure to Rescue; Emergency Surgery; Patient Safety; FRAM; Resilience Engineering

# **1 INTRODUCTION**

## **1.1 The need for systems approaches in patient safety**

It has been over twenty years since the publication of two key reports in the US and the UK, respectively, which highlighted the extent of widespread and potentially avoidable patient harm (Department of Health, 2000, Kohn et al., 2000). Numerous international studies have provided evidence suggesting that around 4% - 12% of hospitalised patients will experience an adverse event, and about half of these are thought to be preventable given current medical knowledge (de Vries et al., 2008). However, even though these reports and studies helped to spark significant interest and investment in patient safety research, the actual improvements achieved in practice have fallen short of expectations (Wears and Sutcliffe, 2019). Among the reasons for this shortfall is the overly narrow focus on a few specific strategies and interventions, such as incident reporting systems, the use of standardisation, and the introduction of non-technical skills training (Mannion and Braithwaite, 2017).

Slowly but steadily there is the realisation that most patient safety issues cannot be addressed meaningfully through simplistic and reductionist approaches alone. This is reflected in a growing interest in systems approaches, which are thought to be better suited for understanding and improving modern complex healthcare systems. Examples include the increasingly popular SEIPS model (Systems Engineering Initiative for Patient Safety) (Carayon et al., 2020, Holden et al., 2013) and STAMP / STPA (Systems Theoretic Accident Model and Processes / Systems Theoretic Process Analysis) (Leveson, 2012), which have been applied across a diverse range of healthcare settings and patient safety problems (e.g., (Carman et al., 2021, Kaya, 2021)). In this paper we report the application of another emerging systems approach – the Functional Resonance Analysis Method (FRAM) (Hollnagel, 2012) – to study the management of surgical patients at risk of deterioration.

## **1.2 Failure to rescue as a surgical quality indicator**

Failure to recognise and respond to acute deterioration of patients, or, “failure to rescue” (FTR), is a well-known and intractable problem, which affects hospitals worldwide (Ghaferi and Dimick, 2015). Silber and colleagues define FTR as the conditional probability of patient death following a surgical complication (Silber et al., 1992). FTR has been proposed as an alternative metric for surgical quality as opposed to mortality rate (Silber et al., 2007), because it is more tightly linked to postsurgical complication rates (Ghaferi et al., 2009b, Ghaferi et al., 2011), rather than patient factors. Across surgical settings, FTR rates have

been found to range between 8% - 18% (Johnston et al., 2015b, Portuondo et al., 2020). Considering the large number of surgical procedures carried out each year, these figures represent significant, potentially preventable patient harm.

FTR has been linked to lack of clinical experience, high workload, overconfidence, communication problems, equipment and logistical bottlenecks, delayed referrals and transfers, and difficulties in locating senior doctors due to competing priorities (Peebles et al., 2012, Johnston et al., 2015b, Burke et al., 2020, Wakeam et al., 2014b, Callaghan et al., 2017, Donohue and Endacott, 2010). Strategies for reducing FTR events were summarised in a recent systematic review (Burke et al., 2020), and include higher nurse staffing levels and a higher percentage of nurses educated to degree level (Blegen et al., 2013, Rafferty et al., 2007). Trigger tools such as the UK National Early Warning Score (NEWS2) are widely used (Royal College of Physicians, 2017), but not universally found to improve outcomes (Bedoya et al., 2019, Donohue and Endacott, 2010). Improvement efforts also include the use of clear standardised escalation and communication protocols, Rapid Response Teams (RRT), and a focus on safety culture (Ghaferi and Dimick, 2015, Johnston et al., 2015a, Johnston et al., 2014, Wakeam et al., 2014b, Wakeam et al., 2014a). While recent US data suggest that top performing hospitals were able to reduce surgical mortality significantly over the past decade largely by reducing FTR rates (Fry et al., 2020), the management of acute deterioration remains highly variable.

### **1.3 From failure to rescue to the management of the deteriorating patient**

Failure to rescue, as a concept is focused on poor management of deterioration and its perceived causes. The identification of failure and its causes has been among the standard approaches for improving patient safety alongside the quality improvement (QI) tradition (Wears and Sutcliffe, 2019). Examples of patient safety management practices in healthcare, which were adopted from safety-critical industries, include the development of healthcare incident reporting systems, the assessment of patient safety culture, the extensive use of checklists and – more tentatively – proactive assessment of risk using Healthcare Failure Mode and Effects Analysis and Human Reliability Analysis (Barach and Small, 2000, DeRosier et al., 2002, Sexton et al., 2006, Sujan et al., 2020, Clay-Williams and Colligan, 2015).

However, another way to frame the issue underlying FTR is to focus not as much on why organisations fail to rescue patients, and instead study how the management of the deteriorating patient normally succeeds. This focus on learning from normal work as opposed to finding and fixing instances where work has broken down has its foundation in Resilience Engineering (Hollnagel et al., 2006), which has recently been the topic of special issues in

several leading safety and ergonomics journals, including *Reliability Engineering & System Safety* (Nemeth and Herrera, 2015), *Safety Science* (Hollnagel et al., 2019) and *Applied Ergonomics* (2020). Resilience has been defined as “the intrinsic ability of a system or organization to adjust its functioning prior to, during, or following changes, disturbances, and opportunities so that it can sustain required operations under both expected and unexpected conditions” (Hollnagel et al., 2015). The Resilience Engineering perspective suggests that imperfect conditions are ever-present in complex modern healthcare systems, full of inevitable tensions, contradictions and competing priorities (Suja et al., 2015). Thus, good outcomes come not only from procedures, safeguards and barriers, but also from organisational resilience in the face of variable conditions - the core abilities suggested as contributing to resilience being monitoring, responding, anticipating, and learning (Hollnagel, 2011). Since there is never a perfect protocol, or full staffing, or perfectly designed technology, or fully predictable demands and patient needs, enhancing the ability of the system to adapt and succeed in the face of these factors should be a core goal of safety improvement efforts.

#### **1.4 A Resilience Engineering perspective for studying failure to rescue**

This paper describes the analysis of the management of deteriorating patients in a surgical emergency unit (SEU) in a National Health Service (NHS) hospital from a Resilience Engineering perspective. In order to explore work-as-done (WAD) on the SEU, the Functional Resonance Analysis Method (FRAM) is used (Hollnagel, 2012). FRAM is among the most widely employed Resilience Engineering methods for analysing complex systems, but its use has so far been rare in surgical settings, with one study looking at neurosurgery and a second study looking at preoperative anticoagulation management (Patriarca et al., 2018, Damen et al., 2018).

We aim to demonstrate how FRAM can be used to explore the adaptations and priority decisions (“trade-offs”) clinical staff make in order to manage acute post-operative deterioration in emergency surgery patients, and how this analysis can help identify opportunities for systems-based intervention to strengthen resilience and potentially improve outcomes.

## **2 METHODS**

### **2.1 Setting**

The setting was the surgical emergency unit (SEU) of an NHS foundation trust in England. The SEU has 54 beds, and is divided into an area for triage, two wards, an ultrasound area, and a waiting room. Daytime staffing is: eight healthcare assistants, 15 registered nurses, five

junior doctors, three middle grade doctors, and four consultant surgeons as well as a dedicated peri-operative medicine team (one consultant, one middle-grade doctor, one junior doctor). Night cover is provided by two junior doctors, two middle grade doctors, and one consultant.

## 2.2 The Functional Resonance Analysis Method

The Functional Resonance Analysis Method (FRAM) was used as the primary method. FRAM is a systematic approach for studying complex socio-technical systems (Hollnagel, 2012), which has been used in a range of safety-critical industries (Patriarca et al., 2020). In healthcare, FRAM has been applied, for example, to investigate blood sampling (Pickup et al., 2017), intravenous infusion and medication administration (Furniss et al., 2020, Kaya et al., 2019, Schutijser et al., 2019), handover in emergency care (Sujaan and Felici, 2012) and the application of fluoride varnish in dental settings (Ross et al., 2018). FRAM investigates process variability to better understand and improve everyday work. Work processes are represented as interrelated functions (human, technological and organisational), where a function is described with six characteristics (called aspects), see Figure 1.

The focus of the analysis is on the relationships (couplings) between functions, and how variability in one function can affect others. Coupling of functions in FRAM depends on how they relate to each other via their aspects. The most intuitive coupling is the input-output relationship, where the output of one function serves as input for another. Functions can also be linked in other ways, for example where an output from one function might serve as a precondition or a resource for another function, act as a control upon it, or provide a temporal relationship. When used graphically, functions are drawn as hexagons, and couplings as vectors between them.

Aspect		Description of Aspect	
Input		Something that starts the activity	
Output		The result of the function	
Precondition		A condition that should exist before the function	
Resource		Something that is needed while carrying out the	
Control		Something that monitors or guides the function	
Time		Temporal relationship	

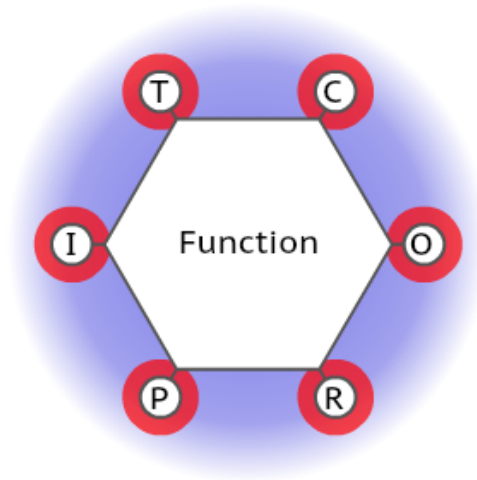


Figure 1: Graphical representation of a function in FRAM (using the FMV software tool)

FRAM distinguishes between model and instantiations. The FRAM model is the tabular representation of all of the functions and their *potential* couplings. An instantiation is the representation of a particular set of *actual* couplings, i.e. it could be regarded as a scenario or use case.

A FRAM analysis is described as consisting of four steps: (1) identification of functions, (2) description of how the output of each function can vary, (3) analysis of potential couplings between functions and their effects, and then (4) strengthening of resilience. The link between the third and fourth step is not currently unambiguously proceduralised, and hence varies in the FRAM literature (Patriarca et al., 2020).

### 2.3 Data Collection and Analysis

In depth semi-structured interviews (n= 31 in total) and two workshops (n= 14 in total) were undertaken following the four steps of the FRAM method (see above), where the interviews focused on steps one and two (identification of functions and description of variability), and the workshops on steps three and four (analysis of couplings and recommendations) (Hollnagel, 2012). A purposive recruitment strategy was used based on staff role and relevant experience, with participants either working on SEU or being involved in the wider system of escalation of care for patients on SEU (see Table 1). Experience was based on participants' staff grade, and participants were not asked specifically for the number of years they had been working in the organisation.

*Table 1: Overview of study participants by job role and data collection method (typical years of experience for doctor grades: Junior doctor – up to 2 years; middle-grade doctor – 3 – 7 years; consultant min. 8 years)*

<b>Participant role</b>	<b>Participant interviews</b>	<b>Participant workshops</b>
Nurse (SEU)	8	4
Junior doctor (SEU)	8	1
Middle-grade doctor (SEU)	4	2
Consultant (SEU)	2	1
Junior doctors' assistant (SEU / pastoral)	1	-
Gastroenterologist	1	1



Interventional radiologist	1	1
General radiologist	1	-
Anaesthetist	2	1
Middle-grade doctor (intensive care)	-	2
Consultant (intensive care)	1	-
Consultant (peri-operative medicine)	-	1
Theatre manager	1	-
Porter	1	-
<b>Total</b>	<b>31</b>	<b>14</b>

Interview data were analysed in a structured manner based on FRAM. First, key functions were identified and represented in a tabular format. Then, descriptions of variability and its causes were identified, and were appended to the corresponding function.

Two half-day FRAM workshops were held. The workshop facilitator provided a brief introduction to FRAM, and then used the graphical FRAM representation to explain the current model of functions relevant to the management of the deteriorating patient. Participants were invited to provide feedback and clarifications. Participants identified functions, which they perceived to have significant variability, and gave their views on the causes of this, and explained the likely impact of the variability on other functions (step three of the FRAM analysis). Finally, participants were invited to suggest and discuss potential strategies for improving the resilience of the process, based on the insights gained during the analysis (step four). No further validation of participant suggestions was undertaken.

## 2.4 Ethics

The research has ethical approval by the Health Research Authority and IRAS approval from Cambridge East REC (IRAS project ID 270881, REC reference 20/EE/0259)

## 3 RESULTS

### 3.1 Functional Representation

23 functions were identified, which have been grouped into five clusters: recognition of deterioration, escalation of care, collaboration across departmental boundaries, documentation and organisational (background) functions (see Table 2). The last cluster comprised generic organisational functions that provide important resources and controls for other (foreground) functions, e.g. suitably qualified staff (via rostering and recruitment), specialist equipment (via maintenance and procurement), standard operating procedures and physical hospital infrastructure. Background functions have not been analysed further.

*Table 2: Functional clusters and functions relevant to the management of deterioration*

<b>Functional Cluster</b>	<b>Functions</b>
Recognition of deterioration	Admit patient to SEU
	Assess likelihood of complications
	Look for signs of deterioration
	Do vital signs observations
	Raise concern
	Assess patient
Escalation of care	Escalate deterioration
	Manage case load
	Determine escalation plan
	Monitor patient closely
	Provide critical care on SEU
Collaboration across departmental boundaries	Provide specialist input
	Arrange porter
	Transfer to ICU
	Care for patient on ICU
	Transfer to theatre
	Operate on patient

Documentation	Record clinical information
Organisational (background) functions	Roster staff
	Maintain work procedures (SOPs)
	Procure / maintain equipment
	Manage beds (ICU)
	Manage theatres

The functions listed include both functions that are prescribed or documented formally in work procedures (e.g. “do vital signs observations” and “escalate deterioration concern”) and others, which are not (e.g. “assess likelihood of complications” and “manage case load”). The graphical representation of an instantiation of the management of deterioration is shown in Figure 2. This instantiation describes the management of deterioration with transfer to intensive care (ICU). Note, that this specific instantiation only includes a subset (18) of the total number of functions (23) identified.

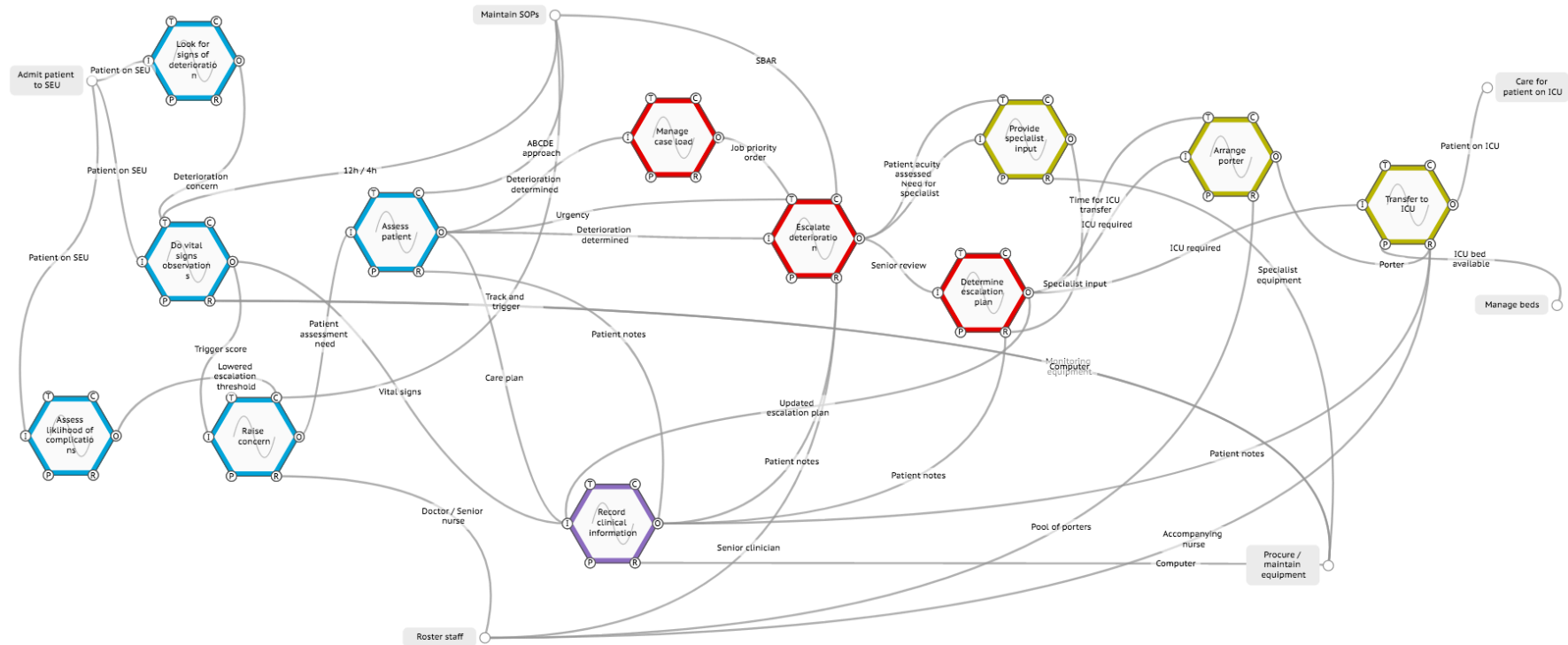


Figure 2: Graphical representation of an instantiation of the management of deterioration with transfer to ICU (using FMV software)

Table 3: Overview of key variability identified

Function(s)	Manifestation of variability: what was described?	Tensions and uncertain performance conditions: what are the reasons for this variability?	Functional coupling: what are the potential consequences of this variability?
Do vital signs observations	Variability with respect to timing.	Nurses trade-off a number of variables to determine the timing for doing vital signs observations, including suggested observation time as per protocol, patient comfort, patient condition and their own workload.	<p>The timeliness of vital signs observations can affect the functions “raise concern” and “determine escalation plan” both positively and negatively. Timely vital signs observations can facilitate prompt escalation, but if concerns based on vital signs observations are raised frequently and unnecessarily this can negatively affect downstream functions by ultimately resulting in diminished responses (“cry wolf syndrome”).</p> <p>Doctors might create an additional function “assess likelihood of complications” to reflect their anticipation of an elevated risk of deterioration. This can change the way vital signs observations are used by (a) increasing the frequency and (b) lowering the escalation threshold for a given trigger score.</p>
Escalate deterioration	Escalation of deterioration concern to senior colleagues varies with respect to timeliness.	Junior doctors and nurses make trade-offs between the perceived risk to the patient and creating excessive workload for senior colleagues, while being mindful of the limitations of their own knowledge and experience. An important consideration for them is the trade-off between the requirement to demonstrate their ability to take decisions and the need for timely notification of senior colleagues.	<p>Variability can have a positive impact on senior clinicians, whose workload is reduced when escalation is avoided (e.g. function “manage case load”). Successful avoidance of escalation can improve junior doctors’ self-confidence and decision-making capacity, but carries a risk of putting the patient at risk through loss of time if it is ultimately unsuccessful.</p> <p>Delegating the response to escalation to a less experienced colleague has a positive impact on the function “manage case load”, but might introduce additional variability in the function “determine escalation plan” due to the potentially more limited understanding of the colleague.</p>

		Senior colleagues make trade-offs between responding to an escalation concern and attending to other priorities, based on their workload, their own perception of urgency and their level of trust in the requesting colleague.	
Provide specialist input	There is high variability in the timing of requests for investigations and imaging, and in the speed of response.	<p>Specialists sometimes alert the surgical team proactively when they find something of concern rather than wait for the requesting doctor to contact them for the results.</p> <p>Radiology and other specialist departments may have high levels of workload and prioritise requests based on perceived urgency. Some specialist equipment, such as CT scanners or mobile imaging equipment, might be in use and not become available for a period of time.</p>	<p>Proactively alerting the team contributes to speeding up the flow of important information, thereby facilitating the function “determine escalation plan”.</p> <p>If specialist input is received late, then the function “determine escalation plan” might be performed without this information and, hence, with greater levels of uncertainty.</p> <p>Senior doctors might engage in personal negotiation with the specialist about prioritisation. Junior doctors might request the senior doctor to have this personal negotiation with the specialist.</p> <p>When SEU doctors expect delays in receiving specialist input, they might make the request earlier than usual to ensure that the information is available when they require it.</p>
Transfer to theatre	Transfer to theatre has high variability in terms of timing.	There is a trade-off between perceived risk to the patient from delay in operating and availability of resources required to perform surgery safely (people, theatre space). Other urgent cases may be prioritised. During night time, there might not be sufficient suitably qualified staff available.	When there is insufficient staffing, the senior doctor might suspend this function until staffing levels are adequate if the risk to the patient is judged to be higher when an operation is attempted than when it is delayed until as there are enough people around. The senior doctor will consider not only the urgency of the patient’s condition in isolation, but also the impact on other patients if, for instance, staff on call from home are called in, precluding them from working the next morning and increasing the risk of cancellation of elective cases.

			Doctors will create an additional function “monitor patient closely” to enable them to re-evaluate the risk picture dynamically.
Transfer to ICU	Transfer to ICU has high variability in terms of timing.	ICU beds are scarce resources, and ICU staff need to prioritise patients. To manage this, they generally develop a group consensus (which may be explicit or implicit) about whether patients merit full ICU care, limited threshold care, or should be declined because of low chance of survival. SEU staff may negotiate to reach agreement on how their patient is categorised, often acting as the patient’s advocate.	<p>Timely request to transfer the patient to ICU allows ICU staff to prepare and, if necessary, to speed up discharge of patients on ICU (this function was considered beyond the scope of analysis) in order to free up resources in ICU.</p> <p>SEU staff might trigger this function early if they expect delays with ICU transfers in order to provide ICU staff with the opportunity to prepare.</p> <p>SEU staff and ICU staff might engage in discussion to determine an acceptable escalation plan involving enhanced care and monitoring on the ward and an agreed threshold for ICU admission.</p>

### 3.2 Performance Variability and Functional Couplings

Every function, and therefore every functional cluster, has a certain degree of variability. Table 3 provides an overview of the adaptations and trade-offs identified by participants as the most important drivers of variation, their explanations for how they controlled and allowed for variability, how this might contribute to resilience, and its potential for “knock on” impact (positive or negative) on other functions. Owing to the time-critical nature of the management of deterioration, the timing aspect was perceived as particularly important by participants even though other forms of variability were also described.

While recognition of deterioration is based on visible cues and many other factors, the regular monitoring of vital signs plays a prominent role. Clear guidelines and protocols determine the timing and frequency of vital signs observations, but in practice variability is considerable. This can serve useful purposes, such as enhancing patient comfort (e.g. delaying observations when patient is asleep) and prioritisation of other tasks (e.g. undertaking care tasks for another, more acutely unwell patient).

In an ideal “work as imagined” situation (Hollnagel, 2015), the escalation of care should follow a clear protocol, driven by elevated early warning scores and clinical evaluation. However, in practice many adaptations and trade-offs were described regarding the decision to escalate and the way in which senior input is sought. When considering escalation, nurses and junior doctors trade-off considerations about the perceived risk to the patient and the urgency of escalation against the workload of senior colleagues, the added pressure that escalation might place on them, and the potential for this to compromise the care of other patients (e.g. interrupting surgery). Junior doctors also feel the need to be seen to be able to trade-off their own uncertainty against the need to take decisions. Senior doctors drawing on their experience often communicate a potential deterioration risk to juniors based on the patient’s medical history, and “keep an eye” on patients they are particularly concerned about. Senior doctors also need to make trade-offs between responding to a deterioration concern immediately and other competing priorities, principally operating in a timely fashion on patients who need it. Senior doctors can inject additional flexibility by delegating tasks to juniors, trading off the perceived risks from a less robust assessment by a junior against speed of initial assessment and the freedom to accomplish other urgent tasks simultaneously by delegating.

Collaboration across departmental boundaries is critical for the successful management of deterioration, (e.g. arranging investigations to allow decisions on treatment) and for the



onward journey of the patient (e.g. arranging transfer to intensive care or theatre). However, such collaboration requires additional coordination and adjustments. Prioritisation decisions are often required, e.g. which radiological requests to process first, or where to send mobile imaging equipment etc. SEU staff often anticipate potential bottlenecks and request specialist input early to allow more time to manage their workload appropriately. For example, anticipation of the likely need for an intensive care bed can alert ICU staff to speed up the discharge of a lower risk patient, freeing up a critical resource. Anticipation also works the other way around – radiologists and laboratory staff will alert SEU staff before reports are written in order to speed up the process of care for urgent cases. A particularly difficult trade-off occurs around the decision whether to undertake emergency surgery during night-shift hours (8pm to 8am), when resources are lowest and most difficult to ramp up, versus the risk of irreversible deterioration if operation is delayed till morning.

Staff tend to make these trade-offs dynamically, i.e. with consideration of the requirements of each specific situation, but base their judgement on heuristics developed through experience and through understanding of local norms. This can instil resilience into the system required for managing deterioration successfully under changing demands and competing priorities, but can also sometimes contribute to deterioration. For example, delaying vital signs observations in favour of other tasks can result in delayed recognition of deterioration; putting off escalation because senior colleagues appear to be busy can cause the patient to deteriorate further, and delegating the initial response to junior colleagues can lead to underlying causes going unnoticed; delaying transfer to intensive care or theatres due to lack of available resources might result in potentially life-saving interventions not being provided in a timely manner.

### **3.3 Linking Variability to Resilience Abilities**

In the final step of the FRAM analysis the findings about performance variability in everyday work were linked explicitly to the four resilience abilities. For example, clinicians might actively look for signs of deterioration based on their expectation that a patient is likely to deteriorate, and share this knowledge with others, thereby contributing to the ability to pick up early, weak signals (i.e. the ability to monitor). Suggested interventions to further strengthen this ability put forward by participants included the explicit design of opportunities for inter-professional communication, such as shared, multi-professional office spaces and multi-professional huddles, or the introduction of machine learning to emulate the experience of senior clinicians in predicting and prioritising patients at risk of deterioration. Table 4 provides a detailed summary of participant views on what makes the management of

deterioration work on SEU in terms of the ability to monitor, to respond, to anticipate and to learn.

Table 4: Summary of learning from everyday work

Resilience Ability	Learning from everyday work (what goes well)	Suggestions for strengthening resilience
Monitoring	Knowing what to look out for and prioritising certain types of patients (e.g. keeping an eye on patients likely to deteriorate)	Encourage sharing of concerns and thoughts about a patient by designing opportunities for inter-professional communication into the workspace (e.g. shared office spaces).
	Knowing experience / limitations of colleagues / roles	Machine learning solution that predicts likelihood of deterioration.
	Having an overview of whole department (e.g. dedicated consultant)	Create and maintain roles with explicit and sustained responsibility for having awareness of patients and patient movements across the department.
	Building an awareness (e.g. patients that are not one's own)	IT solution that provides ubiquitous access to relevant electronic data across devices (e.g. mobile phone).
	Sharing awareness / building shared awareness (e.g. letting nurse in charge know about concerns)	Having a dynamic plan for patients that involves inter-departmental collaboration from the outset.
Responding	Sharing tasks and making decisions collaboratively (e.g. nurse – junior doctor collaboration)	Break down professional and hierarchical barriers.

	<p>Taking responsibility when colleague is busy or does not have sufficient experience / skills (e.g. nurses escalating to senior doctor)</p> <p>Offering help (e.g. nurses supporting junior doctors)</p> <p>Allocating people dynamically (e.g. pulling people in)</p> <p>Preparing resources / people for potential deterioration so that action can be taken quickly if needed (e.g. letting other departments know)</p> <p>Being able to trust colleagues (e.g. when referring patients)</p> <p>Accommodating other people's workloads and being responsive to them</p>	<p>Doctors' assistant role to help build psychological safety and trust.</p> <p>Include roles that are deployable flexibly (e.g. floating staff).</p> <p>Rehearse and formalise which roles and which areas can provide resources during peak demand.</p> <p>Multi-professional simulation training.</p> <p>Support cross-departmental communities of practice.</p> <p>Create opportunities for discussion (e.g. lone junior doctor on night shift having someone to bounce ideas off, discuss uncertainties).</p>
Anticipating	Knowing when peaks are likely to arise in order to support workforce and skill-mix planning	<p>Implement IT systems that collect and aggregate relevant data longer-term.</p> <p>Machine learning to predict busy periods in real-time to facilitate dynamic allocation of staff and resources.</p>
Learning	Appreciating gaps between work-as-imagined and work-as-done (trade-offs)	Implement organisational learning processes that capture everyday work.

Establishing effective multi-disciplinary team and inter-departmental working relationships

Creating and promoting psychological safety

Understanding of roles and their actual and potential responsibilities

Building and maintaining trust

Design resilient procedures and work processes that explicitly consider the need for trade-offs.

Create opportunities for informal and inter-departmental learning.

Cross-departmental review of past cases (successful as well as unsuccessful) and prospective learning opportunities.

## 4 DISCUSSION

The study sought to explore how healthcare workers identify and manage deteriorating patients on a surgical emergency unit by understanding what makes this process work rather than by investigating cases or patterns of failure. The results illustrate the numerous everyday dynamic trade-offs staff make in order to balance competing priorities and mismatches in demand and capacity. Resilient systems for managing deterioration are characterised by dynamic response in adjusting the way functions (such as performing vital signs observations, escalating care, seeking and providing senior input and collaborating across departmental boundaries) are modified in response to a complex matrix of pressures and considerations.

Much is known about the incidence of FTR (Portuondo et al., 2020, Massarweh et al., 2016, Rosero et al., 2020, Chung et al., 2017, Ghaferi et al., 2009b, Sheetz et al., 2013, Ghaferi et al., 2009a), factors affecting its prevalence (Wakeam et al., 2014a, Blegen et al., 2013, Ghaferi et al., 2011, Johnston et al., 2015b, Sheetz et al., 2016), and potential causes and contributory factors (Burke et al., 2020, Johnston et al., 2015a, Johnston et al., 2014). The latter include potential failure of the following: to notice that the patient is unwell, to measure vital signs, to calculate early warning scores correctly, to check notes, to escalate in a timely fashion or to arrange definite care management. Previous studies of FTR have directed attention at reducing such failures, through education (e.g. training in the use EWS), improved documentation (e.g. increased use of electronic systems), communication (e.g. structured communication protocols), standardised work procedures (e.g. clear escalation of care protocols), and organisational factors (e.g. increasing staffing levels and reducing reliance on agency staff) (Burke et al., 2020, Johnston et al., 2015a, Johnston et al., 2015b, Wakeam et al., 2014b). Such interventions flow from structured risk assessments (Johnston et al., 2015a), have face validity and have arguably contributed to reducing FTR, but implementation has proved challenging, and they have not brought about the radical improvements hoped for (Bedoya et al., 2019, Donohue and Endacott, 2010).

The argument put forward in the Resilience Engineering perspective is that the successful management of deterioration is not simply achieved by eliminating failures. Rather, the thinking behind the FRAM analysis is that successful management of deterioration relies to a large extent on the presence and effective use of resilience abilities. Examples of this include: clinicians constantly monitoring the condition of individual patients, and proactively looking out for signs of deterioration (*monitoring*); departments planning built-in flexibility so that they are able to draw upon additional resources (even from other departments) when needed (*responding*); data collection and analysis at departmental and organisational level to enable targeted workforce planning for likely peak demands (*anticipating*); and provision by the organisation of opportunities for building multi-disciplinary team

and inter-departmental working relationships (*learning*). These resilience abilities might be compared conceptually to the characteristics of high-reliability organisations and the principle of mindful organising (Weick and Sutcliffe, 2007, Sutcliffe et al., 2017).

#### **4.1 Towards recommendations**

This view of the complexity of clinical work predicts that narrowly defined interventions aimed at preventing specific failures are unlikely to achieve the anticipated improvements. It is a consequence of functional coupling that no one individual or professional group can easily bring about positive outcomes. Rather, potential improvements will likely need to be multi-faceted and address resilience abilities.

Hollnagel defines four components of resilient performance (Hollnagel, 2018): the ability to respond, to monitor, to anticipate and to learn. The ability to respond might benefit from breaking down professional and hierarchical barriers, and from more flexibility in load and role sharing between staff groups to provide resources during peak demand. Monitoring refers to the ability to pick up early warnings and weak signals (Macrae, 2014). Monitoring might be strengthened by encouraging the sharing of concerns about patients by designing opportunities for inter-professional communication (e.g. informal “huddles” and joint handovers); by emphasising responsibilities for maintaining awareness of patient status and patient movements across the department; and by implementing IT solutions (e.g. electronic whiteboard) that enhance shared awareness of the current situation amongst all members of staff. Anticipation refers to the ability to detect and foresee potential risks and opportunities. The ability to anticipate at the organisational level relies on data and data analysis, as well as on a commitment to utilise such data to inform workforce planning. Anticipation at unit level is also important, but currently relies on the subjective impressions of senior staff who have a “feel” for the status of the unit, and who are therefore able to foresee and prepare for problems.

Organisational learning approaches are usually based on learning from adverse events through incident reporting systems and analysis of failures (Sujan, 2015), and have frequently not yielded meaningful and sustainable improvement (Macrae, 2015, Peerally et al., 2016, Tucker and Edmondson, 2003). A Resilience Engineering perspective calls for a shift in focus towards learning from everyday clinical practice (Sujan et al., 2017), for example in morbidity and mortality meetings (Verhagen et al., 2020). The aim of learning for improvement would then become understanding of the variability in everyday clinical work and the underlying conflicts and trade-offs, and using this understanding to identify ways to strengthen adaptive capacity (Sujan, 2018).

Experienced clinicians will recognise many of the trade-offs described in the analysis. This illustrates its validity, but may call into question what new information it yields. However, much experiential knowledge is implicit, not shared, and creating a shared systematic description of everyday clinical

work, including the dilemmas it raises, allows discussion and honest reflection, which is not centred on potentially threatening adverse event scenarios, and this promotes psychological safety and trust amongst professional groups (Sujan and Spurgeon, 2018). These characteristics have been suggested as underpinning mechanisms of resilient healthcare (Sujan et al., 2019), and are recognised as important within the FTR literature (Smith et al., 2018, Wakeam et al., 2014b). Trust within a heterogeneous group of healthcare professionals might be enhanced by developing and promoting personal and team relationships, and by improving mutual awareness of each other's goals and motivations (De Jong et al., 2016). Psychological safety can be increased by reducing hierarchical authority gaps, actively seeking and valuing staff input, and acknowledging fallibility (Edmondson et al., 2016).

## **4.2 Limitations**

As a single-centre study, this research may be unrepresentative of the response to deterioration in emergency surgery across the UK and internationally, although many of the themes are familiar from other reports. The proposal that improvements based on Resilience Engineering may be more effective and sustainable than those based on error reduction strategies is currently based mainly on theory, and rigorous evaluation of empirical examples is still required. Finally, the questioning for this analysis was focused strictly on the process of response, and relied on the testimony of frontline staff. Issues that are known to affect team performance in this kind of situation, but which the witnesses may have been reluctant to discuss, might therefore have been omitted. More traditional qualitative research approaches, e.g. based on Grounded Theory (Corbin and Strauss, 2015), could potentially complement the functional analysis of FRAM.

## **5 CONCLUSIONS**

Application of FRAM provided a detailed and plausible description of the process of recognising and rescuing deteriorating surgical patients using a different perspective from the conventional problem-seeking approach. Linking variability back to resilience abilities allowed some conclusions to be drawn about potential interventions that might strengthen resilience and thereby patient safety. The impact of such interventions should be evaluated further in clinical situations.

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## **COMPETING INTERESTS**



None declared.

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