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Drawing lessons in safety and efficiency and adopting concepts from other industries to improve workflow and safety systems in Anaesthesiology.

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Introduction

Ever since the first public demonstration of anaesthesia on the 16th October 1846, and the establishment of anaesthesia as a medical specialty, the discipline itself has evolved tremendously, allowing surgeries of growing complexity to be performed, while improving patient outcomes and patient safety[1]. The discipline of anaesthesiology as achieved this through its leadership within the medical field in the adoption of innovations in medical technology, pharmaceutics and the incorporation of concepts from various industries, wherever applicable.

In this era of rapidly evolving technology, shifting policies, evolving structures, ever-growing complexity of clinical practice, physicians are being called upon to step into leadership roles and asked to coordinate teams comprising an assortment of different clinicians, while making managerial decisions on policies and financial management.[2] Medical systems have grown in complexity, necessitating its partitioning into different specialties and sub-systems, inevitably carrying old problems, and creating new ones along the way. Some, but not all of those problems are unique to anaesthesia or healthcare, and this therefore gives us the opportunity, and perhaps also the duty, to seek solutions to similar problems across other industries, and adapt or improve them for use in healthcare.

None of the concepts and systems discussed further are new, and some have already been adapted to be used within the medical field, including anaesthesiology[1]. However, some of the lessons learnt by various industries have come at great cost (in human lives), yet have led to a better understanding of how human factors contribute to errors, how efficiency, cost-effectiveness and safety can be built within systems and how to best create interfaces between those systems to allow seamless operation.

The ultimate goal in learning from other industries is to prevent harm, improve patient safety, improve quality of care, minimise waste and inefficiency, at a time of ever rising cost of healthcare. The above goals are also in line with some of the Batho Pele principles shown below.

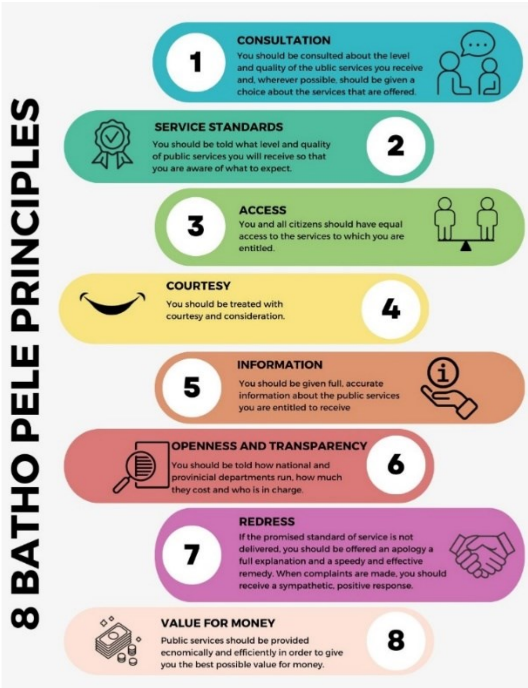

Figure 1: *The 8 Batho Pele Principles*

High reliability organisations

The concept of high reliability organisations (HRO) was introduced by researchers at the University of Berkeley California, to study organisations with the ability to avoid catastrophic operational outcomes, despite the fact that they were managing and operating technologies with exceptionally high levels of risk, which comprised intrinsically hazardous and complex technical systems while sustaining high levels of performance and safety within industries with significant public intolerance to failure[3]. They sought to identify the commonalities between the various HRO's. Their research included United States nuclear aircraft carriers, the Federal Aviation Administration's Air Traffic Control system, and nuclear power operations at Pacific Gas and Electric's Diablo Canyon reactor.[4] The following 5 principles were the product of their work.

Figure 2 - *The 5 HRO Principles[5]*

High Reliability Organizations (HROs) are organizations that achieve safety, quality, and efficiency goals by employing 5 central principles[5]:

1. **Sensitivity to operations**

   The organisation is aware that having a good understanding of the situation at hand, and the relevant, often complex systems and processes, requires close collaboration with frontline workers. Leaders communicate with employees at all levels, with concerns and feedback taken seriously.

2. **Reluctance to simplify**
   The organization acknowledges that that work is complex, with the potential to fail in new and unexpected ways, and some complex solutions necessitate equally complex solutions. The leadership has no aversion to challenging long-held beliefs, while continuously studying the data, benchmarks, and performance metrics to prevent simplification.

3. **Preoccupation with failure**

   Even the simplest of failures cannot be ignored. A small failure has the potential to snowball into a tragedy. Near misses are viewed as opportunities to improve, rather than proof of success.

4. **Deference to expertise**

   The organizational leadership has good knowledge of the expertise possessed by the individual team members, and attaches value to insights from staff with the most pertinent safety knowledge over those with greater seniority. They also encourage team members to become experts and promote the upkeep of acquired skills.

5. **Practicing resilience**

   Anticipating problems and system failures, having pre-planned solutions including staff emergency training, and having the ability to improvise for unexpected problems. Emphasising team work and actively removing barriers that inhibit functional collaboration.

Nuclear power and aviation are classic examples of industries that have applied HRO principles to achieve minimal errors, despite highly hazardous and unpredictable conditions.[5]

Lessons from the aviation industry

Aviation is said to have many similarities with the practice of anaesthesia. While analogies may be drawn, the key to drawing valuable lessons from aviation resides in recognising the common denominator that is human behaviour, and then going through the process of analysing the differences in how safety and reliability are achieved in each, using human behaviour as the main common denominator between the two.

Records of past aviation accidents and near-misses conclusively demonstrate that the single largest single causal factor in accidents is flight crew actions or inactions[6]. The same records further show that human factors also influence safety in other areas, such as maintenance and air traffic control[6].

In the last two decades, the aviation industry has undergone a major overhaul in its way of thinking and dealing with failure. The current concept accepts that error is inevitable and a result of human physical and cognitive limitations. There is also acceptance that human involvement in complex systems is also both necessary and beneficial, due to the human ability to adapt and to be flexible, and also the recognition that other equally relevant factors such as organisational culture, work environment, processes, equipment, among others have a role in accident causation[6].

Counter-intuitively, the stellar aviation safety record achieved today is not the result of the adoption of evidence-based practice. Instead, it focused on bringing a constellation of small changes in procedures, equipment, training and organization that produced the combined effect of very effective practices and an extremely strong safety culture. Those changes were based on sound principles and scientific theories, and experience, and also addressed real-life problems[7]. The same can be said about how anaesthesia safety, which has been the tip of the spear in matters relating to patient safety in healthcare for the last few decades, with a decline in mortality rates exceeding 10-fold.[7] Many systems were borrowed, adapted and implemented not on the basis of their evidence base, but based on the same principles used to improve aviation safety, and by adopting a similar multi-pronged approach to safety.

The Safety Management System

One such approach has been human factors training. However, human factors training, as implemented by the aviation industry, or any other HRO, has been based on a systematic approach to safety, without which, the success of such interventions would most likely be limited. This systematic approach at the organizational level, not dissimilar to the concept of Clinical Governance (CG) in healthcare, is known as the Safety Management System (SMS). The contrasting element between CG and SMS is that SMS requires an organizational manual. The components of an SMS are shown below[6]:

- Safety policy
- Senior management accountable for safety
- Hazard identification and Risk management
- Organisational manual
- Trained and competent personnel
- Reporting system
- Compliance monitoring system

One important means of implementation and expression of the components of the safety system in aviation is the Airline Operations Manual (AOM). This incorporates not only the Standard Operating Procedures (SOP's), but also information and guidance in an up-to-date, accessible, and highly structured format. Checklists for routine and emergency procedures, among other cognitive aids, are also contained within the manual. This centralized source of information is readily available to staff members should the need to retrieve any information arise[6].

Human factors training

Outside of the organizational level, at the crew or individual levels, the two pillars of human factors training are:

- **Human performance and limitations (HPL)**
    - Relevant physiology and psychology
    - Initial training only (didactic)
- **Crew Resource Management (CRM) - Mandatory in aviation since 1992.**
    - Techniques for adapting to limitations
    - Cognitive and team working skills
    - Initial and recurrent training (3 year cycle – facilitative)
    - Six-monthly simulator training, assessed using NOTECHS.
        - NOTECHS assessment is based on observation of behavioural markers.

The NOTECHS assessment is a tool aimed at assessing the operator's non-technical skills through the use of observation. The assessment is carried out during simulator training and is based on the observation of the following behavioral markers:

- Cooperation
- Leadership
- Managerial skills
- Decision-Making
- Situational Awareness

In the field of anaeasthesia in South Africa, fitness for purpose has been defined by a panel of experts, expanding on the existing CanMEDS framework which defined the essential skill set of a specialist anaesthesiologist.

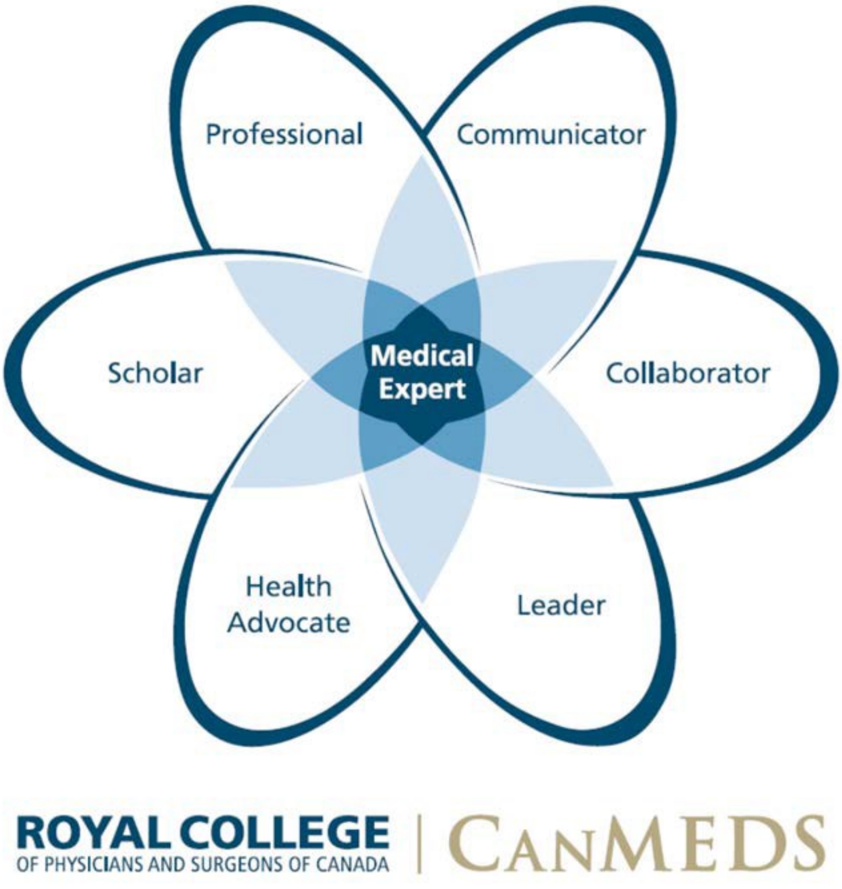

Figure 3 The Canadian Medical Education Directives for Specialists[8]

The CanMEDS framework and its South African adaptation define a full set of non-technical skills required at an anaesthesiology specialist level[8]. Other aspects covered by the NOTECHS assessment also feature in the expanded list of qualities a specialist should possess, such as situational awareness, defined by "the ability to perceive, comprehend the meaning of, and to predict the impact of variables in the work environment"[8]. Contrasting between NOTECHS and the non-technical skills under CanMEDS, we note that although the skills set is well-defined and has a lot in common with NOTECHS, there is no formal training domain within the current anaesthesia specialist training programme that aims to impart or improve on those skills, except for one – the Managing Emergencies in Paediatric Anaesthesia (MEPA) course[9]. Another noteworthy observation is that the scoring system utilised during the NOTECHS assessment has many similarities with the global rating scale utilised in the MEPA course internationally[9, 10].

The incorporation of the new Entrustable Professional Activities (EPA) into the UKZN anaesthesia registrar programme, may possibly bridge that gap. However, if one has to compare the metrics by which competency is graded with EPA's with those of MEPA participants[9, 11], it would appear that both EPA's and simulator-based crisis management training complement each other in the achieving the desired level of competence in both managing day to day routine work and in managing crisis situations.

Anaesthesia Crisis Resource Management

Anaesthesia Crisis Resource Management (ACRM) training began in 1990, and was inspired from the aviation industry's "Crew Resource Management", or "Cockpit Resource management"[12]. The gaps in training of healthcare professionals had been identified based on prior simulated emergency scenarios and a curriculum devised to bridge the technical and behavioural gaps identified. Below is a set of key points on which ACRM training is based. It must also be highlighted that every clinical scenario is followed by a debriefing session, and the clinical scenarios are staged in a high-fidelity environment and hi-fidelity patient simulator.

Points Regarding Decision Making and Cognition	*Points Regarding Teamwork and Resource Management*
Know the environment	Exercise leadership and followership
Anticipate and plan	Call for help early
Use all available information and cross check	Communicate effectively
Prevent or manage fixation errors	Distribute the workload
Use cognitive aids	Mobilize all available resources for optimum management

Figure 4 The key points of anaesthesia crisis resource management[12]

Other concepts from aviation

A few other concepts that have found their way into day to day anaesthetic practice is the use of cognitive aids like mnemonics and checklists for equipment checks, as well as the use of standardised protocols, for example standardised anaesthesia monitoring, post-operative analgesia, ERAS protocols among many others[6].

Other concepts that may help improve focus and avoid errors at critical periods are the principle of 'sterile cockpit' and the concept of 'shared mental model'. The former calls for only essential communication pertaining to the flight during critical periods of the flight (take-off and landing), while the latter calls for every action or change in the flight configuration to be called out so that both pilots have a shared mental image of their flight status and aircraft configuration. All communications within the cockpit are also closed-loop, while actions and flight data are often cross-checked by both the captain and the first officer and confirmed verbally. Similar to those stages of flight, anaesthesia also has critical periods that calls for heightened situational awareness and focus. In anaesthesia, like in aviation, the anaesthesiologist and the surgical team have to constantly communicate when faced with a difficult situation so that there is a shared mental image of the pertinent issues at hand and what is being done to address them. Often, there may be more than one anaesthesiologist working on the same patient and maintaining a shared mental image is also crucial in preventing errors or omissions which may adversely affect the patient.

Lessons from the automotive industry

Kaizen

The term Kaizen is a combination of the Japanese words Kai (Change) and Zen (Good) and originates from the Japanese manufacturing industry. Kaizen is a structured, iterative and participatory strategy aimed at making continuous small improvements within an organisation's processes at relatively small cost[13, 14]. Kaizen also uses visual management tools to illustrate their processes, allowing employees to have a shared cognitive picture of the process and the issues at hand[13]. What makes Kaizen unique is that change and innovation are originated at all levels of the organisation, not just from the top-down. It promotes thinking and welcomes ideas from all levels of the organisation. Due to its very nature, it confers immense efficiency, adaptability and systemic resilience to the organisation and encompasses many of the HRO principles discussed earlier, while promoting employee's job satisfaction and well-being.[13]

Lean Six-Sigma

The Lean Six-sigma concept is a combination of "lean systems", pioneered by Toyota and "Six-Sigma" pioneered by Motorola.

Lean systems was introduced by Toyota as part of its Toyota Production System. Its goal was "delivering to customers exactly what they need, when they need it, every time, defect-free, in a safe environment at the lowest cost, without waste"[1]. It also emphasised the role of rapid problem solving and work redesign in order to achieve its goal[1].

The strategy of lean systems was to streamline flow through their processes, while ensuring minimal waste and impeccable quality. Lean systems also seeks to eliminate bottlenecks in their processes, which may have an impact on safety, quality and safety. Lean systems aims to eliminate specific categories of waste[1]:

1. **Defects** – any deviations from the finished product specification.
2. **Overproduction** – the excessive production of items that are not needed in that specific place at that specific time.
3. **Waiting** – by either staff or clients.
4. **Not using talent** – placing the wrong people in the wrong roles.
5. **Transportation** – streamlining the production process by minimising the need for any part of the production that requires transport for the next step of the process.
6. **Inventory** – Overstocking supplies.
7. **Motion** – Items needed are not where they need to be.
8. **Extra processing or rework** – any activity that occurs as a workaround to something else that is dysfunctional within the process.

The Six-Sigma philosophy was adopted in the 1980's by Motorola as a quality improvement strategy that focuses on error reduction by setting aggressive goals[1]. With sigma being defined as one standard deviation from the mean within a normal distribution curve, setting a goal where "product" outcomes mostly fall within 6 standard deviations from the statistical mean also sets a goal that errors or defects should not exceed a frequency of 3.4 errors/defects per 1 million "products"[15].

The Lean Six-Sigma (LSS) method utilises a conceptual framework known as 'DMAIC' to guide projects aimed at improving processes. DMAIC is short for:

1. Define the process and desired outcomes
2. Measure performance
3. Analyse the process to determine deficiencies
4. Improve the process by creating interventions to eliminate problems
5. Control to ensure the interventions are maintained.

The LSS method has been widely adopted in manufacturing industry, but has also been adopted in healthcare within several clinical units, including in the operating room and post-anaesthesia care unit where it has led to improvements in workflow efficiency and quality of care[15, 16]. The LSS method is fairly readily transposed to healthcare, especially in the operating theatre because of easily identified areas of waste[15]. Some hospitals have adopted LSS systems to improve the availability of the right manpower, the right equipment and everything else that may be required for a particular patient, with an emphasis on the coordination and cooperation of the multiple units involved in patient care, to ensure efficient workflow[1].

Formula 1 and ICU handovers

Patient handovers from the operating theatre, with anaesthetic, nursing staff and surgical team accompanying and monitoring the patient is fairly routine. To ensure continuity of care, it is crucial that all the relevant information is communicated from the team that may have had the critically ill patient under their care for several hours, to the new team in the Intensive Care Unit (ICU). A transfer from the operating theatre to the ICU involves disconnecting and reconnecting lines, monitoring equipment and ventilators. Upon arrival at the ICU, crucial information is usually communicated between multidisciplinary teams, while all lines, monitors and ventilators are again disconnected and reconnected. This task is accomplished, often with an element of time pressure as well, thereby further adding to the complexity of this task and making this task highly susceptible to human error, equipment failure, miscommunication and the resulting potential for harm to the patient[17]. The prominent risk factors for ineffective handovers include the lack of standardized procedures, time pressure, interruptions, suboptimal surroundings, multitasking, inadequate feedback between sender and receiver, and the absence of safety culture[17]. Strategies that have been used to mitigate those risks have been the improvement of communication skills, team training, standardising of procedures and communication, and the implementation of cognitive aids[17].

A fairly similar process happens in Formula 1 racing, where the members of a pit crew have to handle a multitude of different and complex tasks flawlessly and perform as a single unit in a high risk environment and under immense time pressure[18]. It is therefore not surprising that the pit-stop process in Formula 1 racing has been used as an example of how a multi-disciplinary team can come together and function as a single unit with the goal of performing complex tasks safely, efficiently.

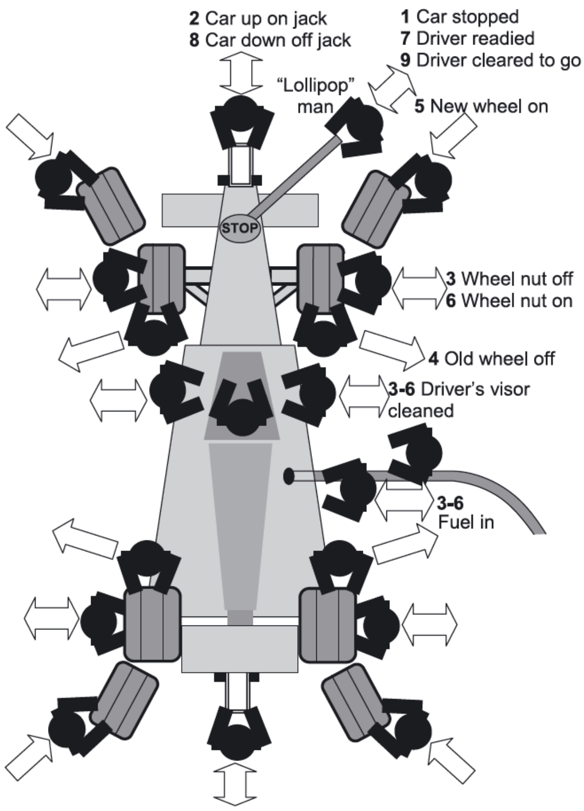

***Figure 5** - Multidisciplinary pit-crew performing multiple tasks simultaneously*[18]

The pit-stop process inspired the anaesthetic department at a children's hospital in the United Kingdom to devise a simple, reliable and easily trainable handover protocol, which showed a significant improvement in handover safety at their hospital[18].

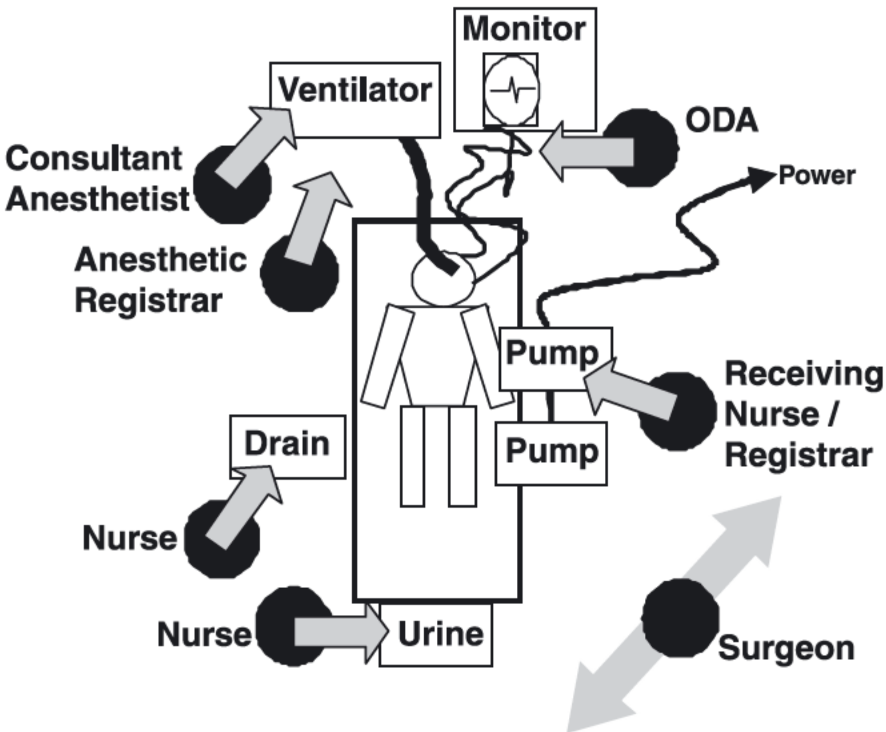

***Figure 6** Example of task allocation for ICU handovers*

The safety themes identified were as follows:

1. **“Leadership**
    a. The lead anaesthesiologist was given the overall responsibility of coordinating the team, which was subsequently transferred to the intensivist at the end of the handover.
2. **Task sequence – 3 phases identified**
    a. Equipment and technology handover
    b. Information handover
    c. Discussion and planning
3. **Task Allocation – each team member was allocated a specific task**
    a. Ventilation – anaesthesiologist
    b. Identification of important information and handover to key receiving team members - anaesthesiologist
    c. Monitoring – Operating department assistant (Anaesthetic-trained nurse)
    d. Drains - Nurses
4. **Predicting and planning – Failure Modes and Effects Analysis (FMEA)**
    a. Modified FMEA conducted and seniors discussed highest areas of risk
    b. Safety checks introduced
    c. Ventilation transfer sheet introduced
5. **Discipline and composure**
    a. Communication limited to essential discussions during equipment handover.
    b. Anaesthesiologist, then surgeon speak uninterrupted, followed by discussion and recovery plan.
6. **Checklists**
    a. New checklist introduced, which also served as admission note.
7. **Involvement**
    a. All team members and all grades encouraged to speak up.
8. **Briefing**
    a. Planning begins with a multidisciplinary team meeting for the relevant cases.
    b. 30 minutes prior to transfer, a patient transfer form is completed by the anaesthesiologist and is sent to the receiving ICU. Bed and ancillaries are prepared according to the specified requirements.
9. **Situational awareness**
    a. Anaesthetic and ICU seniors have the shared responsibility for maintaining situational awareness during the handover process.
10. **Training**
    a. Formal training to ICU nurses as well as laminated training manuals available at every bedside.
11. **Review meetings**
    a. Issues discussed at regularly held clinical governance meetings”.[18]

Discussion

The healthcare sector has, in the past decades, drawn from principles of HRO's in proposing best practice measures and interventions to improve healthcare. The Joint Commission, the accreditation agency for hospitals in the USA went to far as to propose that all healthcare institutions should adopt HRO principles[19].

However, this is easier said than done, and multiple challenges lay ahead of successful implementation of those principles. Some, if not all of the HRO interventions implemented in healthcare have been through staff training. This approach, while it may familiarise those trained in the language of HRO principles, may not translate into deeper understanding of the meaning of those principles, resulting in minimal impact on behavioural change. This lack of depth has been attributed to a broader trend of discounting ideas or solutions developed in other fields, as they were not created within the medical professions as well as a general lack of enthusiasm for new concepts[3].

The Not Invented Here Syndrome

There is also a common misunderstanding within healthcare organisations and leadership that healthcare challenges are unique. This failure to appreciate the value of learnings from other disciplines has held back any paradigm shift towards more progressive and inclusive management styles. The term coined for this type of reluctance to draw lessons from other industries is the "Not invented here syndrome"[2].

While other industries may be called to invite collaboration from people in the organisational and social sciences, human factors and systems engineering, healthcare organisations have often preferred to stick with a scientific-bureaucratic model of safety and reliability, which fall under the control and leadership of clinician administrators[3]. While multidisciplinary approaches may exist within the medical field, they tend to involve other stake holders within the medical and paramedical fields, rather than a more broad-based multi-institutional and multidisciplinary approach and they tend to be centred around specific clinical scenarios rather than gathering perspectives and analysing the different components of the system itself, and deferring to outside expertise where applicable.

Other industries, for example the aviation industry, have long adopted such multi-institutional approaches to safety. The way errors, adverse events and near-misses are handled are also vastly different. It would be hard to conceive, in this day and age, that an aircraft accident would be solely analysed by an in-house team of flight crew members, yet this is commonplace in the medical field[3].

Regarding healthcare's commitment to resilience, yet again we find that the interpretation and implementation of this HRO principle is relatively shallow. The many interventions to build resilience in healthcare are centred on training individuals as the locus of resilience and reliability with the focus on the individual as both the source and the solution of its reliability shortcomings. In contrast, HRO's lay bigger emphasis on a system-centric approach to capacity and resilience building.[3]

Conclusion

The healthcare industry has been relatively slow to adopt new strategies and whenever novel strategies were introduced, the necessary paradigm shift and full commitment to a deeper evolution have not always followed suit. Anaesthesiology, as an exception, emerges ahead of the pack when it comes to its safety record, as well as its willingness to innovate and adopt tried and tested strategies from other fields to improve safety. That being said, there is still a lot more than can be done to further improve safety, workflow management, efficiency and cost-effectiveness within the operating theatre, and drawing inspiration from the strategies outlined above may help us achieve that.

Illustrations sources

Figure 1, Source: https://www.pa.org.za/blog/public-service-month-september-2023.

Figure 2, Source: Veazie S PL, Bourne D. Evidence brief: Implementation of High Reliability Organisation Principles. Program ES, editor. Washington DC: Health Services Research and Development Service; 2019.

Figure 3, Source: https://www.royalcollege.ca/en/canmeds/canmeds-framework.html

Figure 4, Source: Gaba DM, Howard SK, Fish KJ, Smith BE, Sowb YA. Simulation-based training in anesthesia crisis resource management (ACRM): a decade of experience. Simulation & gaming. 2001;32(2):175-93.

Figure 5, Source: Catchpole KR, de Leval MR, McEwan A, Pigott N, Elliott MJ, McQuillan A, et al. Patient handover from surgery to intensive care: using Formula 1 pit-stop and aviation models to improve safety and quality. Paediatr Anaesth. 2007;17(5):470-8.

Figure 6, Source: Catchpole KR, de Leval MR, McEwan A, Pigott N, Elliott MJ, McQuillan A, et al. Patient handover from surgery to intensive care: using Formula 1 pit-stop and aviation models to improve safety and quality. Paediatr Anaesth. 2007;17(5):470-8.

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