Seminars in Pediatric Surgery 24 (2015) 278–282

Contents lists available at ScienceDirect

Seminars in Pediatric Surgery

journal homepage: www.elsevier.com/locate/sempedsurg

The Swiss cheese model of adverse event occurrence—Closing the holes

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ARTICLE INFO

Keywords:
Human factors
Medical error
Crew resource management
Patient safety
Pediatric surgery

ABSTRACT

Traditional surgical attitude regarding error and complications has focused on individual failings. Human factors research has brought new and significant insights into the occurrence of error in healthcare, helping us identify systemic problems that injure patients while enhancing individual accountability and teamwork. This article introduces human factors science and its applicability to teamwork, surgical culture, medical error, and individual accountability.

Introduction

A young Asian male is seen in a busy clinic with his Mandarin-speaking parents. While examining the frightened child, a right inguinal hernia is identified and documented in the history and physical (H and P). A telephone translator communicates with the parents. The H and P is completed at the end of the day by the overworked surgeon, while the office staff submits paperwork to the OR scheduler, booking a *left* inguinal hernia repair for the child. On the day of surgery, the frightened and uncooperative child arrives and is given versed and sleeps through a verification exam that cannot reveal a hernia without valsalva. The H and P from the clinic is not reviewed. A band is placed on the child's wrist rather than a marker being used to document the side of the hernia to avoid tattooing the skin. The Dad, who speaks some English, is not present. Again, using a phone translator the mother agrees to surgery. The patient is taken to the OR and undergoes a negative left groin exploration. In spite of numerous checks—nurse verifications, surgeon verifications, anesthesia verification—a wrong-site surgery occurs.

Medical errors have multi-factorial causes. Unpacking this difficult set of problems can be simplified by human factors analysis. These tools have been pioneered in other industries with dramatic reductions in error and harm. This article addresses one well-known taxonomy of error analysis and applies it to the practice of surgery.

The Swiss cheese model—slices and holes

The late British psychologist, James Reason, worked extensively on issues of human error, first in aviation and later in healthcare. The Swiss cheese model (SCM)[1] explains the failure of numerous system barriers or safeguards to block errors, each represented by a slice of cheese. The defects in these processes are signified by holes in cheese slices that allow errors to pass through and harm to reach the patient. By examining patient harm or near misses in this manner, we can better understand why errors occur, why the holes are present, and identify methods to plug the holes and protect the patient. Following is a description of 5 "slices" that are usually used to increase patient safety.

Slice #1 is *training*-years of repetition, didactic exercises, and practical exposure to safe patient care modeled by mentors, as well as ongoing training, and simulation. A culture that supports continuing learning and training is a system safeguard that can prevent errors.

Using healthcare *technology* and electronic medical records to prevent error would be Slice #2 in the SCM. Electronic pop-ups confirm or warn about physician choices or identify allergies or drug interactions that could be unsafe. An unexpected consequence of best-practice pop-ups or alerts is alert fatigue. Because of the frequency of these notifications, clinicians may begin to consider them as "white noise" and ignore them, allowing injury to reach the patient through a "hole" in the cheese.

Gawande[2] has written about the value of *checklists*, which provide another layer of protection as Slice #3. In the complex system that has evolved in healthcare, standardized communication, confirmation of critical patient information, structured surgical briefings, de-briefings and hand-offs are common examples of checklists, and are cultural barriers to error. *The culturally*

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http://dx.doi.org/10.1053/j.sempedsurg.2015.08.003
1055-8586/

expected scripted or standardized communication between provider and patient, often associated with checklist verification between providers, are communication tools that assure accuracy of patient identification, planning and information. Standardized site marking removes assumptions and failures in verbal communication and prevents wrong-site surgery.

Slice #4 is institutional policies and procedures that are system-level agreements designed to commit practitioners to safe, standardized and consistent care, and to avoid unwanted variations. These procedures may by universally accepted in the profession, or be organizationally specific. Examples of procedures that help prevent human errors include the standard nursing practice of double checking high-risk medications, the use of bar code medication administration, infusion pumps with high and low dose limits built into the software library of medications to prevent dosing error. Each of these barriers to error, like Swiss cheese, unfortunately has holes.

Holes reflect process defects—errors that can be a variable component in the patient's care. Unfortunately, they are often not visible as the holes in a slice of Swiss cheese. Performance and quality improvement efforts catch and "plug" holes that can be found or identified through standardizing processes. For example, x-ray policies for inconsistent counts of radio-opaque gauze, and radio-frequency sponge indicators have significantly decreased the likelihood of retained sponges following an operation. Where technology cannot assist, we often focus on eliminating the adverse events through additional education, policies, checklist items, etc.

In the case of the young patient we started with, there were numerous safeguard failures. Allowing arm banding rather than marking, not having in-person translation services, batching "H and P's" at the end of the day, and not confirming correlation of consent and physical exam in the history and physical all created opportunities for harm to reach the patient (Appendix A). Although policies are present regarding site verification, procedure booking, in-person translation, checklist verification of agreement between history and physical with consent, errors can still occur. Policies, checklists, and education can eliminate some holes, but not all. As the Institute of Medicine authors pointed out in "To Err is Human,"[3] ultimately humans must apply the barriers. To close "people-related" holes we need to understand and impact human behavior. A large body of work addresses behavioral change through human factors engineering. For example, "*Workarounds*" are often used to overcome obstacles or slowdowns in ones' workflow and provide an opportunity for human error. Nurses may pre-print patient labels to avoid delays. Physicians may dictate their clinic notes once the day is complete to avoid prolonging patient wait times. Non-clinical staff may submit case requests for OR booking. One approach to closing such holes is to put in place "forcing functions." For instance, a forcing function prevents batching label printing until the blood draw order time is reached. In the second example, the clinic patient cannot be discharged until a note is completed. Forcing functions may remove variation in care, but often don't get to the root of the problem, which must be addressed for the intervention to be successful. Finding the root cause, comes from continuing to ask "why" until the true nature of the problem is identified (eg, a scribe can be used to facilitate that clinical note being written, thus speeding the visit and avoiding "batching" of clinic notes at the end of the day). If we can improve workflow inefficiencies, nurses and doctors will not seek "workarounds" or alternative unsafe solutions. In the case of delayed clinic dictation, is the problem not enough time with the patient, not enough ancillary or allied staff, or an inefficient EMR? If we can address the root cause, the physicians will be successful at real-time documentation and accuracy will improve. Once in place, these process improvements reduce the need for workarounds. In order to put appropriate process improvements in place, we need to understand human behaviors and truly get an understanding of choices healthcare workers make.

Understanding "Holes"—schematic and attentional behaviors

To understand how to avoid errors related to human factors we must first understand 2 types of human behaviors; *schematic* and *attentional behaviors*. Schematic behaviors are routine or reflexive, and can be assisted through the use of checklists to quickly bring generalized attention and agreement to key safety issues. Attentional behaviors are related to problem solving, are more difficult to control and require supervision, professionalism and, as mentioned above, situational awareness. In addition to traditional approaches to impacting these behaviors such as mentoring and case reviews, using simulation and providing professionalism training can change culture and begin to plug the holes in the Swiss cheese model. Understanding the 2 kinds of failures (active and latent) that can result from attentional behaviors can help determine the appropriate interventions.[4] *Active* failures are those that result from an individual's inappropriate behavior. Defying a safety policy, not following up on a patient in a timely manner, missing a diagnosis, failing to escalate care, not following protocol, over-working tired providers rather that replacing them are all examples of "active" bad decisions. These behaviors require re-education, re-assessment, and ongoing monitoring. They often fall into the category of *unsafe acts* in Reason's human factor classification system.[1] This classification goes on to define a spectrum of latent failures. *Latent,* or hidden, failures are often due to poor policies, or environmental factors that set people up to fail. These might include the ability to order a medication in a toxic form, stocking expired products, and poor protocols around equipment maintenance. As expected, latent failures create the holes in the Swiss cheese that are more difficult to find and identify.

Reason further stratifies types of latent failures, using the following examples from healthcare. *Preconditions for unsafe acts* is exemplified by poor compliance around work hours, resulting in fatigue and decreased capacity for high attention activities. *Unsafe supervision* is the failure of placing individual with limited training (medical students) in situations requiring more senior-level decision making, (trauma evaluations in the emergency department). Lastly, *organizational level* failures result from inadequate peer reviews, incomplete assessment of credentials, lack of interdisciplinary teams reviewing adverse events, or failure to proactively assess a high-risk process of care to look for likelihood of failure. Failure mode error analysis (FMEA) is one approach used to pre-empt an error by identifying failure points prior to an event occurring.

Numerous risk factors for failure can also be understood as "holes" in the cheese. *Poor Communication* is the most common cause of both active and latent adverse events.[5] If the poor communication is the result of an individual's behavior, the failure is an active failure. If it is result of an organizational culture that does not promote openness or healthy interrelationships, then this represents a latent failure. Another example is poor *equipment* design and maintenance, as well as availability of standardized and functional equipment. We can look to barcode medication administration system that works poorly as a case in point. In pediatric hospitals, small vials provide little area for placement of the barcode and may produce inconsistent readings causing a nurse to resort to shortcuts or workarounds such as keeping a barcode of the med at the bedside to scan when needed. Often this occurs as a most critical juncture when a medication is needed frequently or urgently. The potential for error is obvious. In this case, the