HEALTH INFORMATION TECHNOLOGIES: FROM HAZARDOUS TO THE DARK SIDE

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ABSTRACT

This paper explores the effects of Health Information Technologies (HIT) in Operating Rooms (ORs). When functioning well, Health IT are a boon to mankind. However, Health IT in the OR also create hazards for patients for a number of interrelated reasons. We introduce five interrelated components of hazard situations for medical teams operating in the OR: complexity, overload/underload, inadequate individual training, inadequate training of medical teams, overconfidence of surgeons. These components of hazard situations in the OR may negatively impact patient safety. We discuss implications, especially in terms of individuals and medical teams in the OR, as well as work substitution as a broader aspect of the potential dark side of Health IT.

Keywords: Health Information Technology, Patient Safety, Work Substitution, Overload, Underload
INTRODUCTION

Over the past decades, surgery has changed dramatically from an eyes and hands-on environment to an environment supported by highly interdependent technology such as cameras, robots and sensors that allow surgeons to 'operate-by-wire’. Such technology is increasingly offering benefits in the Operating Room (OR). The modern hospital OR is equipped with innovative and costly technologies that are designed to improve surgical performance and reduce patient trauma. In its 2012 report, the Institute of Medicine (IOM) noted: “It is widely believed that health IT [Information Technologies], when designed, implemented and used appropriately, can be a positive enabler to transform the way care is delivered” (ECRI, 2013, p. 3). However it adds the caveat: “Designed and applied inappropriately, health IT can add an additional layer of complexity to the already complex delivery of health care, which can lead to unintended adverse consequences” (idem). By Health IT (HIT) we mean “principles and techniques providing tools for extending the physician’s powers of observation and making more effective his role as therapist” (Andersen and Newman 1973, p. 100). In this article we discuss reasons that we are seeing more hazards in OR due to HIT and propose strategies for reducing them.

Innovative technologies such as minimally invasive robotic surgery systems have literally killed patients in hospital in recent years (Sharkey and Sharkey, 2013). This was the case with a 49-year old Chicago man who died in 2007 when his spleen was punctured by a surgeon who performed the operation using a $1.8 million “hands-on” surgical robot for the first time on a living person. This surgical robot is a master-slave system with multiple arms that surgeons manipulate remotely from a console to operate on a patient. At the end of mechanical arms are high-precision instruments with seven degrees of freedom which
improve surgeon dexterity and give the surgeons the illusion that the tips are their own hands. The robotic system also has an endoscopic camera which offers more depth-perception cues because of its enhanced 3-D image of the surgical site. At the center of the system is software to control and operate the various components based upon the input that it receives from its human operator and other parts of the system.

One estimate places the cost of U.S. medical errors at $3.5 billion annually (Aron, Dutta, Janakiraman and Pathak, 2011). Annually 234.2 million major surgical procedures are undertaken worldwide (Weiser, et al., 2008). A substantial part of all adverse events in healthcare (51.7%) are related to surgery; These adverse events sometime lead to disability (5.5%) or even death (6.2%); Many are preventable (36.5%) (Baines et al., 2013). The problem may be even greater than these percentages suggest because of inadequate IT–related health safety data. There currently is no systematic process for collecting, analyzing, and acting on information related to safety when using this technology. Contractual barriers (e.g., nondisclosure, confidentiality clauses) (IOM, 2012) and a culture which expects physicians to function without error (Leape, 1994) also impede users from sharing information about IT–related adverse health events.

Equipment design in aviation recognizes that perceptual and control errors are inevitable and seeks to minimize these errors (Leape, 1994). For example, safety systems have been developed to reduce operator fatigue and boredom, provide redundant safeguards, and enhance training opportunities. In contrast, healthcare equipment is predisposed to control and perceptual errors, poor maintenance, and inadequate safety engineering (Catchpole, 2013). Like flight teams, the OR is a type of High Reliability Organization (HRO) that is reliant on individuals, the team and the technology performing well. Vogus and Sutcliffe (2007) defined HROs as “organizations that operate hazardous technologies in a
nearly error-free manner under trying conditions rife with complexity, interdependence, and time pressure” (p. 2).

The OR’s highly interdependent components create hazards, or potential sources of danger, for patients for a number of interrelated reasons. Five major HIT hazards to patient safety in an HRO environment are complexity of HIT, overloaded and underloaded OR health professionals, inadequate individual training of healthcare professionals, inadequate training of healthcare teams, and surgeon overconfidence about their ability to use HIT.

**Complexity**

HIT add hazardous complexity to the already challenging HRO environment. IT complexity has increased not only because of the intimidating variety of functions, applications, jargon, technical capabilities and knowledge barriers, but also because of the mental effort and learning curve required to use it (Ayyagari, Grover and Purvis, 2011; Tarafdar, Tu, Ragu-Nathan and Ragu-Nathan, 2007). Further, HIT often are not well-designed for the medical environments in which they are employed (WHO, 2012), making their use even more taxing.

**Overload and Underload**

Medical team members may become overloaded because they are not able to cognitively process the mental load created by HIT in the OR. Their mental load may be increased for a number of reasons. The number one health hazard in 2013 and 2014 was projected to be alarm hazard (ECRI, 2013, 2014). OR team members may be overwhelmed by the many alarms during surgery. Paying attention and responding to these alarms increases their mental load (Tollner, Riley, Matthews, and Shockley, 2005), as do equipment complexity and new medical procedures (Ayyagari et al., 2011; Tarafdar et al., 2007). In addition to performing complex surgical movements under time pressure, surgeons must not only avoid distractions, but also remember the proper sequence of steps for a given procedure
while conversing with the teams about instruments and the patient’s status (Tollner et al., 2005). Not surprisingly, surgeons may be overloaded when allocating their attention properly (Zheng et al., 2010). Consequently they may make mistakes, shed tasks, or otherwise adapt to make their load more manageable considering their limited attentional resources or expertise (e.g., Bettman, Johnson and Payne, 1990; Jones, Ravid and Rafieli, 2004; Shiv and Fedorikhin, 1999; Hallowell, 2005). They may also feel stressed, frustrated, distracted or impatient (e.g. Wickens, 1992; Scholtz, Hellhammer, Schulz and Stone, 2004, Malasch and Jackson, 1981).

On the other hand, others on the medical team, in particular, Medical Doctor Anaesthesiologists (MDAs), may be perceived as “underloaded” (Slagle and Weinger, 2009). Underload occurs in when there is little or no perceived mental load, and the individuals become so bored that they look for distractions. This is the case when their assigned tasks become so automated that the individuals can process information quickly or when there is too little information to process (Schultz and Vandenbosch, 1998). In underload situations, individuals seek more exhilarating mental challenges.

**Individual Training**

Patient safety has been negatively impacted when health professionals are inadequately trained to use the complex technology or perform the new procedures with long learning curves (WHO, 2010). The IOM reported in 2006 that 1.5 million patients were harmed by incorrect technology usage at an alarming annual cost of $3.5 billion (Aron, Dutta, Janakiraman, and Pathak, 2011). New operating technologies require substantial individual training related to psychomotor skills (Moorthy, Munz, Adams, Pandey and Darzi, 2005). Repeated practice is needed to gain tool mastery to the extent that the procedures become automatic, and overload in the OR is reduced. Lack of training and adequate practice clearly was the case of the surgeon who operated on the Chicago man mentioned above who died.
when undergoing robotic surgery. The man’s family won a $7.5 million malpractice lawsuit. Other lawsuits have been won because the surgeons were inadequately trained to use robots (Sharkey and Sharkey, 2013). Robotic surgery complications due to insufficient training was listed as the eight greatest health hazard in 2014 (ECRI, 2014). Unfortunately, only 4.4% of 411 U.S. surgeons performed robotic colorectal surgery in high enough volumes to become proficient in the task (Keller, Hashemi, Lu and Delaney, 2013) and some surgeons have performed advanced laparoscopic procedure without specific training (Giannotti, et al., 2014). The Dutch Health Care Inspectorate (Inspectie GezondheidsZorg, 2007) expressed “great concern” (p.3) to the Dutch Minister of Health about the safety of minimally invasive surgery and, relatedly, insufficient training facilities and programs. Problems with inadequate training are also evident in the even more complex robotic surgery. Since a surgeon must perform 150 to 250 procedures to become adept (Barbash and Glied, 2010), the low volume impedes mastery of necessary psychomotor skills for the robotic surgery. Surgeons with low volumes are linked to significantly more overall complications, post-operative bleeding, longer length of stay and higher costs than those who had performed with higher volumes. But it is not just individual training that is inadequate.

**Team Training**

Training at the team, as well as the individual, level may be insufficient in healthcare organizations introducing complex HIT into the OR. Neily et al. (2010) reported the results of a study a decrease of 18% in the mortality one year after 74 HROs facilities enrolled in the medical team training program. Medical teams can benefit from training programs such as the crew resource management programs that are in widespread use in the military and aviation industries (e.g., Undre, et al., 2007; Yule, Flin, Paterson-Brown and Maran, 2006). These team-based training programs have been developed to ensure that HRO team members are able to work together in their defined roles. They are based on simulation, training technical
and non-technical skills such as communication and teamwork skills (see Flin, O’Connor and Mearns, 2002). These are important for improving OR patient safety (Baldwin, Paysley, Patterson-Brown, 1999). For example, communication problems are credited with causing 43% of errors made in surgery (Gawande, Zinner, Studdert, and Brennan, 2003).

**Overconfident Surgeons**

Finally, the personalities within team roles may lead to dysfunctional behaviour. Typically, surgeons are curious and innovative (Borges and Savickas, 2002) and tend to embrace technological medical innovations. However, they can become overconfident and fail to recognize that they both need more training and suffer from stress when using such complex technology in rich HRO environments (Berguer, Smith, and Chung, 2001; Yule et al., 2006). In one test, 82% of surgeons denied the effects of personal stress on their performance while only 53% of the anaesthesiologists did so (Sexton, Thomas and Helmreich, 2000). Adding new HIT when cognitive and emotional resources are lacking may create stress conditions that seriously impinge on performance and patient safety.

In summary, in a challenging HRO environment such as the OR, the components are interrelated and must work well together as a high-functioning team to save lives and eliminate unnecessary accidents. In today’s OR, HIT is not a separate component, but is actually part of a complex, dynamic system in which all components are highly interdependent on each other. To successfully use the technology and avoid the hazards, training programs incorporating technology must be encouraged for OR teams, as well as for the individual members. Further, steps must be taken to avoid hazards created from excessive overload or underload (boredom). If the hazards go unchecked, HIT may potentially expand to the dark side

**HOLDING HIT HAZARDS IN CHECK**
Holding HIT hazards in check involves changes in training, certification and ensuring adequate levels of mental load. The use of new OR technologies should simply be banned without proper training and certification. We recommend systematic training in two steps: at the individual level to improve motor skill performance and at the team level to improve coordination and communication. The crew training which rotates roles allows each participant to “live through” each other roles. However, the training must designed so as not to reinforce incorrect existing preconceptions about the roles. In particular, trained observers of OR teams noted that surgeons believe that teamwork and communications are good, whereas anaesthesiologists do not hold the same opinion (Sexton et al, 2000). Furthermore, at the individual level, recognition of stressor effects and the tendency of surgeons to deny them may reduce errors and increase the use of effective threat and error management strategies (Sexton et al, 2000). Thus, training at the team level needs to make participants aware of differences in perceptions which commonly exist. Even more difficult is to keep the training at the individual level current. The technology is changing at such a fast pace that it is hard to stay abreast of the most current practices and procedures in preparing training programs and certifying skills.

In conjunction with training we suggest detailed credentialing or certification of skills that have been mastered. Unfortunately, certification of complex technological psychomotor skills in healthcare is not yet systematically performed (Giannotti et al., 2014). Standards of performance need to be developed, promulgated and verified through certification. In the meantime, hospitals can verify that staff have the necessary procedure-specific skills needed (ECRI, 2014)

Training may be designed to get the skills of team members to where they are proficient enough that their mental loads are decreased and overload is not a problem. Care must be taken to reduce boredom from underload. MDAs may be particularly susceptible to
boredom. A recent study found that anaesthesia providers read in 35% of the observed cases (Slagle and Weinger, 2009). Although they need to carefully monitor the technology and avoid distractions during a procedure, MDAs in some ORs are often remote from the action and called into action only in certain exception cases. Typically they are present at patient induction, often outside the OR; After applying the anaesthesia, they exit the room, leaving patient monitoring to an assistant while they apply anaesthesia to a patient in another room. They are normally called into the OR only in the event of a complication, or when it is time to wake up the patient. Thus, the surgeon is frequently the only knowledge-based medical doctor physically present in the OR during the entire surgery, a situation which can increase his or her experience of overload.

Adding more connectivity to the outside world in the OR increases distraction for the entire surgical team, but especially for bored MDAs. In discussing the top ten HIT hazards, the ECRI Institute (2012) notes “… with Internet access or communication channels just a click or tap away --- clinicians can easily succumb to the temptation to conduct personal business during patient care.” Smith, Darling and Searles (2011) found in their survey of medical professionals that 15% acknowledge accessing the Internet and 3% visited social networking sites during cardio-pulmonary surgery. MDAs who perceive themselves as underloaded may use technology (the Internet) to the detriment of patients. At the same time, surgeons who are overloaded may downplay the effects of stress and fatigue ---- also to the detriment of patients. Thus, steps need to be taken to avoid both underload and overload in the OR.

A BROADER VIEW OF HIT’S DARKSIDE

Substitution by technology

New HIT may lead to changes in the composition of OR teams due to substitutions by technology. Physicians and hospital administrators alike see opportunities for improving
patient care and safety using such sophisticated technologies. However, a dark side of HIT is emerging as the healthcare industry is starting to substitute high-knowledge healthcare professionals with cheaper providers or better technologies. Substitution, either human or technical, requires combining a skill-mix of teams and technologies. The success of the changing workforce skill-mix is controversial in the medical literature (Sibbald, Shen and Bride, 2004 for a review).

A vivid example of professional substitution by HIT is the case of MDAs. Once healthcare costs started to spiral, the business model of anaesthesiology became exposed to disruptive market forces (Shapiro, 1997). Other physicians, hospital administrators, managed care administrators and insurers began perceiving MDAs as too expensive and have to make anesthesia delivery more affordable (Longnecker, 1997) and expand their task repertoire (Hug, 2000). Their situation was worsened with claims of poor performance. A study estimated that 80% of anaesthetic-related errors could be prevented and 75% of these were attributable to human error (Aggarwal et al., 2004). Lack of vigilance and failure to adequately monitor were the most frequently reported reasons for the anaesthetic-related errors ----- areas where automation easily could be implemented to improve performance. Consequently, MDA’s are being replaced by better scanning and monitoring technology, as well as lower-knowledge anaesthesiologists in the OR.

Could the same thing happen to surgeons? Maybe substitution of surgeons with HIT is not so far-fetched. With improvements in robotic surgery technology surgeons may be in less demand. Conceivably, fully-automated robots could do their jobs. We expect that situation to occur faster than surgeons would like to admit for six main reasons. First, with robotic surgery the surgeon assistant who used to navigate the laparoscope (camera) has already been replaced entirely with one of the arms of the robot stabilizing the laparoscope. In the future it is not inconceivable that many physical aspects of the surgeon’s job may also be
automated. Second, many of the deaths and other errors in using trendy technologies have been attributed to surgeons (Sharkey and Sharkey, 2013). Some of these could be attributed to surgeons who were unwilling to take the time and effort to train properly on new HIT. Patients may grow increasingly concerned about the avoidable errors surgeons make and look for more reliable alternatives. Third, surgeons are reported to be similar to MDAs in terms of their imagination, curiosity, and innovativeness (Borges and Savickas, 2002). They eagerly embrace new HIT to support patient care. Their own attitudes may actually induce them to adopt new technological innovations which ultimately may lead to their demise. Fourth, improvements in the ability of computers to process and analyze vast amounts of medical data have led to HIT (e.g., computer programs) successfully performing cognitive tasks such as making diagnoses and treatment recommendations that once fell solely in the domain of physicians (Cohn, 2014). Fifth, many surgeons are not willing to take the time and effort to train properly on the new HIT. Last, advances in other technologies (like improved drugs and radiation therapy) reduce the need for surgery (c.f., Harrison, 2015). For example, technology is now available for more consistent radiation treatment delivery. Thus, it is not just the automation of the existing surgical tools that puts the surgeon out of business, but also the automation/emergence of new technologies that can achieve the same goal without the need to cut. For these six reasons, new technologies may eventually serve as substitutes for surgeons. When robots controlled by computer programs are able to operate alone (much like driverless cars), errors in the OR may be reduced. The idiom “err is human”, could led us to believe the skills of programmed robots are superior to those of stressed surgeons.

In the near future, it may not be difficult to convince people that high-paid jobs that have been proven to be dangerous or underloaded offer little added value in our high tech world. Nobel Prize winner Paul Krugman recently published a column entitled “Sympathy for the Luddites” in The New York Times (Krugman, 2013). He stated that “Today, however,
a much darker picture of the effects of technology on labor is emerging. In this picture, highly educated workers are as likely as less educated workers to find themselves displaced and devalued, and pushing for more education may create as many problems as it solves.”

Capital, in the form of technology, is increasingly substituting for labor (The Economist, 2014). A recent study estimated that jobs are at a high risk of being automated in 47% of the occupational categories, many of which are classified as white collar (Frey and Osborne, 2013). As technology evolves in the future we may find the medical profession in a desperate battle with the software economy. Will society line up on the side of robots or human? What about you?

**Conclusion**

HIT offers humanity wonderful potential for increasing patient well-being. The dark side of HIT does not need to become a reality. As IT researchers we need to limit the dark side of HIT by studying its negative unintended consequences and providing technological and systematic recommendations for its design and implementation.

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