Equipment, Environment, and Ergonomics: An Enigma of Infection Risk

James Davis, MSN, RN, CCRN, CIC, HEM
Senior Infection Prevention Analyst
Pennsylvania Patient Safety Authority

ABSTRACT

Equipment design, the environment, and worker interaction with the equipment all factor into the effectiveness of healthcare delivery. It appears that within the medical literature, there exists a bias toward focusing on ergonomics related to the prevention of workplace injury. Literature that makes a direct correlation between healthcare provider ergonomics and patient safety is sparse. As a result of consultation with a facility regarding a cluster of infections, Pennsylvania Patient Safety Authority analysts suspected a link between ergonomic design and the development of those infections. The analysts then queried the Pennsylvania Patient Safety Reporting System for data on the existence of other epidemiologic links, specifically targeting procedural systems, procedural environments, and equipment. Analysts identified two specific clusters of patient exposures to equipment that demonstrated a link between ergonomics and a patient's risk of acquiring an infection. Equipment, environment, and ergonomics can be combined either in a structured or haphazard format. If a structured format is employed, then opportunities to prevent healthcare-associated infections can be identified and addressed. (Pa Patient Saf Advis 2015 Mar;12[1]:37-40.)

INTRODUCTION

One of the most eloquent examples that expresses the merging of equipment and humans is the fifth statement in the United States Marine Corps creed "My Rifle":

> *My rifle is human, even as I, because it is my life. Thus, I will learn it as a brother. I will learn its weaknesses, its strength, its parts, its accessories, its sights and its barrel. I will ever guard it against the ravages of weather and damage as I will ever guard my legs, my arms, my eyes and my heart against damage. I will keep my rifle clean and ready. We will become part of each other. We will . . . ."*[1]

In healthcare, the workers never merge with their equipment in every aspect of its life cycle as a marine does with their rifle. The proceduralist may merge with an endoscope during a procedure, but after the procedure, the endoscope is handed off to another worker who merges with it for another purpose, such as cleaning and disinfection. Never do the workers reach the level of total care for equipment that the marine has with their rifle. It would be impractical for a proceduralist to assume total care of a piece of equipment; however, the healthcare system needs to care for its equipment, like the marine, because lives depend on the equipment functioning properly.

A modern healthcare delivery system is heavily reliant on the workers, the equipment, and the environment, which are components of that system. Worker skill and knowledge about equipment and environment will impact equipment effectiveness. Similarly, equipment and environmental attributes for assessment or treatment will impact the worker's effectiveness. The aforementioned challenges can be magnified when equipment is retrofitted or newly installed into spaces that are suboptimal with respect to size, flow, or access. For example, if the new patient bed will not roll flat through the existing room door because the opening is too small, the patient cannot be transported in the bed. Staff experience increased workload because of the added manual labor required to transfer the patient from bed to litter when transport is necessary.

Equipment may also be inserted into a work system without assessing the direct impact of equipment design on the user. For example, if personal protective equipment is purchased in response to an infectious environmental threat but the equipment is not easily doffed, removal requires extensive assistance, and the available doffing space is suboptimal, the combination of equipment design and the environment increases workload and raises potential exposure risks. These two examples describe situations that may lead to staff dissatisfaction, variation of task performance, delays in treatment, and potential patient or staff harm.

Ergonomics (or human factors) is "the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design in order to optimize human well-being and overall system performance."[2] It appears that within the medical literature on ergonomics, there exists a bias toward focusing on the prevention of worker injury.[3-8] Medical literature that correlates ergonomics with patient safety is sparse, and literature that correlates ergonomics with a patient's infection risk is almost nonexistent.

METHODS

As a result of consultation with a facility regarding a cluster of infections, Pennsylvania Patient Safety Authority analysts suspected a link between ergonomic design and the development of those infections. The analysts then queried the Pennsylvania Patient Safety Reporting System for data on the existence of other epidemiologic links,

Scan this code with your mobile device's QR reader to access the Authority's toolkit on this topic.

specifically targeting procedural systems, procedural environments, and equipment. Analysts identified two specific clusters of patient exposures that warranted further investigation and examined the narratives included in each of the event reports for both epidemiologic clusters.

RESULTS

The first cluster involved patients exposed to a contaminated endoscope. The narratives describe that several endoscopes had been sent out for repair. Loaner endoscopes (i.e., endoscopes loaned by the manufacturer) were placed into the system to temporarily supplement supply until the repaired endoscopes could be returned to service. The loaner endoscopes varied in design from the endoscopes the technicians were used to cleaning, as they contained an additional channel. Because the technicians were unfamiliar with the new equipment, the additional channel was not manually brushed (i.e., debrided) as part of the endoscope cleaning process.

The second cluster involved equipment purchased and retrofitted to an existing procedure room. The room was also used to perform other procedures and housed equipment related to those procedures, which in turn affected available space. The proceduralist had to change their surgical approach due to the room size and position of the equipment. This change in approach resulted in a cluster of ophthalmic infections.

DISCUSSION

The science of ergonomics addresses the parts or qualities of equipment or environmental design that facilitate easy and effective use. With any reusable equipment (such as endoscopes), *use* includes reprocessing. In the first cluster of infections, the design of the endoscopes did not make reprocessing intuitive in regard to the reprocessing staff being made aware of the additional channel. Considering how the reprocessor uses the endoscope, there may be an opportunity for a systems fix if a facility is aware of equipment changes.

For example, a facility could tag the loaned endoscopes with a traditional break lock (commonly used on code/crash carts/medication boxes), which would be placed postprocedure. The assistant or proceduralist could write on the break lock the number of channels the particular scope possessed. The reprocessing staff would then be aware of differences in endoscopes.

This concept may have particular value where there tends to be a lack of a critical control point for loaner equipment entering the system as well as in ambulatory surgical centers, where ancillary departments, such as biomedical engineering, tend to be nonexistent. The addition of the break locks to the endoscope is heavily dependent on individual personnel's knowledge of the process. This process would also be dependent on the facility knowing the loaner endoscopes varied in design from those that had been sent out for repair.

A more permanent, intuitive fix would be for the manufacturers of endoscopes to label the number of channels and any other pertinent reprocessing information on the handle or body of the endoscope. Labeling to guide action has been described in the literature for at least 35 years. A seminal example is the case of a data scope M/D3 defibrillator/monitor, where there was confusion related to switch activation required to deliver a shock to the patient. Following investigation, the manufacturer issued new labels that made the functions and operation of the defibrillator more intuitive for the operator.[9]

MMWR Case Example

In January 2014, an article in the *Morbidity and Mortality Weekly Report* (*MMWR*) highlighted a carbapenem-resistant Enterobacteriaceae outbreak associated with endoscopic retrograde cholangiopancreatography.[10] The article reported that "retrospective review and direct observation of endoscope reprocessing did not identify lapses in protocol."[10] Other studies have identified that the design of these particular endoscopes may make disinfection challenging.[11-13]

In an effort to address the findings related to the case highlighted in *MMWR*, enhanced training of reprocessing staff in terms of brushing, spending extra time cleaning the elevator port, and detergent flushing is emphasized.[12] The intended suggestion does not evade the work but tries to vary the process to circumvent design problems that impede reprocessing; the variation may be effective but will fail if a user forgets the variation. Perhaps labeling could play a role in this case, combined with the additions to suggested reprocessing. The scope could be labeled with a simple phrase to remind the operator about the elevator channel cleaning step—for example, "Warning: Forceps Elevator Channel—refer to instructions for reprocessing."

If the endoscopes from the outbreak case highlighted in *MMWR* were designed with all of the users in mind, they may have had characteristics supportive of effective and safe reprocessing (such as additional labeling). An ergonomics perspective includes consideration of whether the design of the endoscope and its parts and qualities, as well as instructional materials, consider the needs of all users.

The Environment

The second cluster of patient infections—involving equipment purchased and retrofitted to an existing procedure room—demonstrates how the physical environment impacts the proper use of equipment. In this example, the equipment was used in a space with insufficient clearance, and the user had to change how they performed the procedure. Again, it appears variation has been created to

compensate for poor ergonomic design. The equipment may have been designed properly, but the environment where the equipment was used was not optimal for the intended function. Space limitations impact the interaction between the user and equipment, resulting in preventable patient harm.

Design Evaluation

Usability engineering methodology that incorporates ergonomic principles and a user-driven approach can be utilized to optimize equipment selection and environmental characteristics while also considering other crucial operations such as cleaning and disinfection. There are six steps classically associated with the process of usability engineering: user studies, goal-setting, concept development, design detail, specification, and field testing.[14] Usually an institution will have little if any influence over the goals, concept, detail, or specification of the equipment that has been designed, though an institution may be involved in user studies and perhaps specification if there is a relationship with the manufacturer and industry. Considering the examples presented herein, user studies would be of key importance when evaluating equipment for use or purchase.

When evaluating equipment, user studies, particularly interviews following field testing or simulation, have proven beneficial before finalizing equipment design. For example, Wiklund notes, "User interviews and [field] testing revealed that a thumbwheel was the best way to achieve single-handed control of articulation for the illumination catheter of [a particular type] of endoscope."[14] Field testing during the planning and evaluation phase will provide information about how a particular piece of equipment will affect users in a facility.

At the facility level, field testing is easily accomplished through simulation by way of placing a prototype, the real equipment or mock equipment, into a real or simulated environment, which would allow equipment use and its impact on users to be traced during diverse scenarios. Simulation observations and user interviews can be compiled to select equipment that would be the most ergonomic for all users and to select or design environments that address all aspects of clinical use, including cleaning and reprocessing. Furthermore, there needs to be a defined critical control point that is the single way equipment is evaluated and purchased or placed into use in a facility or system. Once a critical control point is established, only then can checklists, simulations, and user interviews become effective at mitigating device-related patient harm.

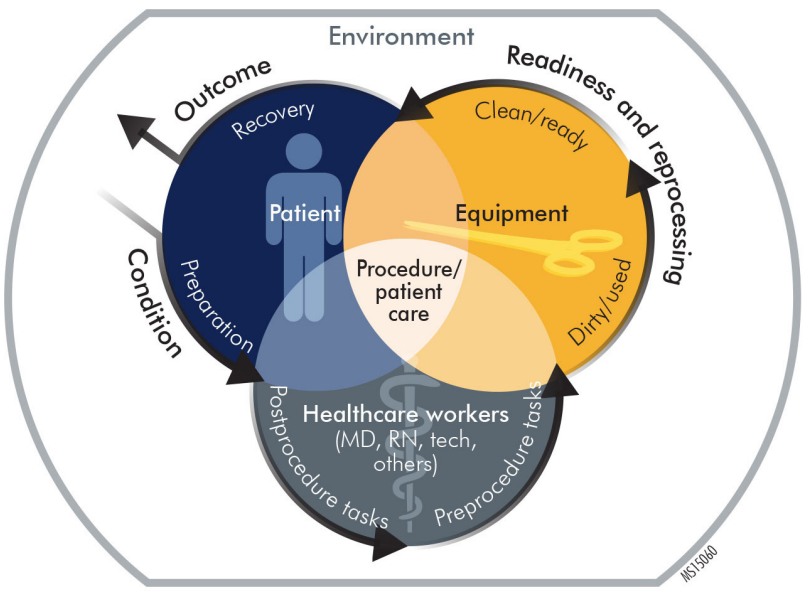
Medical Device Evaluation Tool

In order to provide a structured assessment, the Authority has developed a sample tool that focuses on ergonomic factors and related patient risk. Depending on respondent answers, the Authority tool may point to the National Aeronautics and Space Administration's Task Load Index[15] assessment tool in order to gather further information about a device's impact upon its users in their own environment. The tool accompanying this article is available at http://patientsafetyauthority.org/EducationalTools/PatientSafetyTools/Pages/home.aspx.

CONCLUSION

A structured format that includes consideration of the entire continuum of processes involved in patient care provides opportunities to identify and address ergonomic problems to minimize infection risk and prevent patient harm. The Figure is typical of the continuum of processes institutions face when delivering care to a patient. The environment encircles and flows through the patient, the healthcare workers, and the equipment. All of the elements are interconnected and must be considered individually *and* as part of a larger whole in order to fully comprehend efficiency or inefficiency of design.

Figure. Ergonomic Factors and the Continuum of Care Delivery



To mitigate infection risk, it is essential to consider the ergonomic relationships involving the patient, the care providers, and the equipment reprocessors, as well as the equipment itself and the related work environments. The patient, healthcare staff, equipment, and environments may be combined either in a structured format or haphazardly. If the combination of people, processes, equipment, and environment is left to chance, poor decision making or ill-conceived ergonomics will likely lead to a game of Russian roulette in terms of a patient's infection risk mitigation.

Acknowledgments

Susan C. Wallace, MPH, CPHRM, patient safety analyst, and Edward Finley, BS, data analyst, Pennsylvania Patient Safety Authority, contributed to data acquisition for this article. David Molter, MD, St. Louis Children's Hospital, provided the concept of the rifleman's creed as an example in ergonomics.

NOTES

1. Rupertus WH. My rifle—the creed of a United States Marine [online]. 1942 Mar 14 [cited 2015 Feb 4]. http://www.mcu.usmc.mil/historydivision/pages/frequently_requested/Rifle_Creed.aspx
2. Human Factors and Ergonomics Society. What is human factors/ergonomics? [online]. [cited 2015 Jan 26]. https://www.hfes.org/web/AboutHFES/about.html
3. Occupational Safety and Health Administration. US Department of Labor. Safety and health topics: ergonomics [online]. [cited 2014 Dec 12] https://www.osha.gov/SLTC/ergonomics/index.html
4. Centers for Disease Control and Prevention. Ergonomics and musculoskeletal disorders [online]. Updated 2014 Jul 17 [cited 2014 Dec 12]. http://www.cdc.gov/niosh/topics/ergonomics
5. Poosanthanasarn N, Lohachit C, Fungladda W, et al. An ergonomics intervention program to prevent worker injuries in a metal autoparts factory. *Southeast Asian J Trop Med Public Health* 2005 Mar;36(2):512-22.
6. Chhokar R, Engst C, Miller A, et al. The three-year economic benefits of a ceiling lift intervention aimed to reduce healthcare worker injuries. *Appl Ergon* 2005 Mar;36(2):223-9.
7. Laing AC, Frazer MB, Cole DC, et al. Study of the effectiveness of a participatory ergonomics intervention in reducing worker pain severity through physical exposure pathways. *Ergonomics* 2005 Feb;48(2):150-70.
8. Owen BD. Preventing injuries using an ergonomic approach. *AORN J* 2000 Dec;72(6):1031-6.
9. ECRI Institute. Datascope model M/D3 defibrillator/monitor. *Health Devices* 1980 Apr;9(6):162.
10. Centers for Disease Control and Prevention. Notes from the field: New Delhi metallo-ß-lactamase-producing *Escherichia coli* associated with endoscopic retrograde cholangiopancreatography—Illinois, 2013. *MMWR Morb Mortal Wkly Rep* 2014 Jan 3;62(51-52):1051. Also available at http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6251a4.htm
11. Muscarella LF. Investigation and prevention of infectious outbreaks during endoscopic retrograde cholangiopancreatography. *Endoscopy* 2010 Nov;42(11):957-9.
12. Alrabaa SF, Nguyen P, Sanderson R, et al. Early identification and control of carbapenemase-producing *Klebsiella pneumoniae*, originating from contaminated endoscopic equipment. *Am J Infect Control* 2013 Jun;41(6):562-4.
13. Muscarella LF. Risk of transmission of carbapenem-resistant Enterobacteriaceae and related "superbugs" during gastrointestinal endoscopy. *World J Gastrointest Endosc* 2014 Oct 16;6(10):457-74.
14. Wiklund ME. *Medical device and equipment design: usability engineering and ergonomics*. Buffalo Grove (IL): Interpharm Press, Inc.; 1995:3-20.
15. National Aeronautics and Space Administration. NASA TLX: Task Load Index [online]. [cited 2014 Dec 22]. http://humansystems.arc.nasa.gov/groups/tlx

PENNSYLVANIA PATIENT SAFETY ADVISORY

This publication is disseminated via e-mail. To subscribe, go to http://visitor.constantcontact.com/d.jsp?m=1103390819542&p=oi.

To see other articles or issues of the Advisory, visit our website at http://www.patientsafetyauthority.org. Click on "Patient Safety Advisories" in the left-hand menu bar.

THE PENNSYLVANIA PATIENT SAFETY AUTHORITY AND ITS CONTRACTORS

PATIENT SAFETY AUTHORITY
An Independent Agency of the Commonwealth of Pennsylvania

The Pennsylvania Patient Safety Authority is an independent state agency created by Act 13 of 2002, the Medical Care Availability and Reduction of Error (Mcare) Act. Consistent with Act 13, ECRI Institute, as contractor for the Authority, is issuing this publication to advise medical facilities of immediate changes that can be instituted to reduce Serious Events and Incidents. For more information about the Pennsylvania Patient Safety Authority, see the Authority's website at http://www.patientsafetyauthority.org.

ECRI Institute
The Discipline of Science. The Integrity of Independence.

ECRI Institute, a nonprofit organization, dedicates itself to bringing the discipline of applied scientific research in healthcare to uncover the best approaches to improving patient care. As pioneers in this science for more than 40 years, ECRI Institute marries experience and independence with the objectivity of evidence-based research. More than 5,000 healthcare organizations worldwide rely on ECRI Institute's expertise in patient safety improvement, risk and quality management, and healthcare processes, devices, procedures and drug technology.

ISMP
INSTITUTE FOR SAFE MEDICATION PRACTICES

The Institute for Safe Medication Practices (ISMP) is an independent, nonprofit organization dedicated solely to medication error prevention and safe medication use. ISMP provides recommendations for the safe use of medications to the healthcare community including healthcare professionals, government agencies, accrediting organizations, and consumers. ISMP's efforts are built on a nonpunitive approach and systems-based solutions.

Scan this code with your mobile device's QR reader to subscribe to receive the Advisory *for free.*