Tubing Misconnections – A Systems Failure with Human Factors: Lessons for Nursing Practice

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Since 1972, there have been reports of failures to connect the correct tubing to intravenous, epidural, intracranial, intrathecal, and other high-risk systems (Berwick, 2001; Reason, 2004; Wallace, Payne, & Mack, 1972). In 2006, The Joint Commission published Sentinel Event Alert Number 36: Tubing Misconnections – A Persistent and Potentially Deadly Occurrence. The alert cited misconnections of central intravenous catheters, peripheral intravenous catheters, nasogastric feeding tubes, percutaneous enteric feeding tubes, peritoneal dialysis catheters, tracheostomy inflation cuff tubes, and automatic blood pressure insufflation tubes reported to The Joint Commission as sentinel events. However, the number reported to The Joint Commission may be a very low representation of the actual number of misconnections that occur (Aspden, Corgigan, Wolcott, & Erikson, 2004; The Joint Commission, 2006). Further review of misconnections reported to the United States Pharmacopeia found 300 cases that include connections of epidural lines to intravenous catheters, bladder irrigation solutions connected to primary infusion sets, intravenous infusions misconnected to indwelling (Foley) catheters, and various other misconnections between critically incompatible infusion and drainage sets (Hicks & Becker, 2006). The common element in each misconnection is the luer tip, or small bore connector, the ubiquitous connector used in health care (see Figure 1). For this article, the term luer connector will be used.

The 2004 Institute of Medicine (IOM) report, Keeping Patients Safe: Transforming the Work Environment of Nurses, suggested that a basic knowledge of human factors and ergonomics is necessary to establish safer work processes in the nursing environment (Gosbee, 2002; Page, 2004). Tubing misconnections create one such hazard to patients that can be mitigated by a human factors approach. Learning from the incidence and prevalence of tubing misconnections provides an opportunity to translate recommendations from the IOM to the practice of nursing and to redesign the work environment of nurses to support safe patient care.

Misconnections as a Human Error

Worthy contributions to health and safety of clients is clear in the nursing role. However, IOM reports have repeatedly cited nurses as playing a major role in patient harm from unintended medical errors (Corrigan, Cohen,
Davidson, & IOM, 2000; IOM, 2001; Page, 2004). Nurses are the professionals most likely to be at the patient’s bedside when an error occurs; this has earned the profession the title of “sharp end” of the error and has increased the importance of understanding the role of nurses in error incidence (Cook & Woods, 1994).

One of the most common admonitions to nurses to increase safety is to be vigilant in patient care. Vigilance is explained as the very “essence of nursing;” however, the concept of vigilance is used across disciplines in manners that vary widely in meaning and context (Meyer & Lavin, 2005, p. 38). In nursing, vigilance is used to describe behaviors linked with patient safety, caring, and effectiveness of nursing care. The presence or absence of vigilance may also be used as a measure of culpability for disciplinary action (Benner et al., 2002).

Expert opinion and accepted fact in most industries regard vigilance as a flawed defense mechanism against threats of danger and errors (Corrigan et al., 2000; Perrow, 1999; Shojania, Duncan, McDonald, Wachter, & Markowitz, 2001). Recent literature supports the human factors view of mental and physical inability to maintain a constant vigilant state (Dorian et al., 2008; Scott, Rogers, Hwang, & Zhang, 2006) and describes fatigue as being a threat to safe patient care. Mandated changes in the scheduled hours of medical residents also support the thought that fatigued health care providers are not able to provide safe care (Jagsi, Shapiro, Weissman, Dorer, & Weinstein, 2006).

Humans are known to make errors recurrently and predictably, and human factors science explains how a normally skillful and knowledgeable person can make a serious error of this type. Errors with tubing misconnections may occur as a result of cognitive “slips” in performance when the provider is unaware he or she is connecting the wrong tubing. Cognitive psychologist James Reason describes this state as being in automatic mode, the level of functioning where the error is not detectable by the participant at the time the event occurs. These errors are often discovered by someone else rather than the participant (Beyea, Simmons, & Hicks, 2007; Reason, 1990; Simmons, 2006). These “slips” in performance often occur in common, familiar tasks that are repeated frequently and perfectly without failure (Reason, 1990, 2004). Performing a tubing connection is a routine, familiar, and common task in nursing.

Tubing misconnections as a “slip” occur at the subconscious level and are not under the conscious control of the health care provider. Detection of this error is delayed, which makes vigilance and carefulness ineffective in its prevention. Skillfulness in execution of the task and knowledge of the consequence of making the error are also ineffective preventative because the “slip” occurs at the subconscious level (Reason, 1997).

The implication for design of health care devices is clear. Anticipating human failure creates an imperative to design devices and processes that do not rely on vigilance (Corrigan et al., 2000; IOM, 2001; Page, 2004). This has already been accomplished in medical gas connections in which connectors make misconnections of anesthesia gases impossible (The Joint Commission, 2001). This design is visible in our everyday lives at the gas station – gasoline nozzles make it impossible to pump diesel fuel into a car that requires unleaded gas. Incompatible systems should not be able to connect, and a redesign to prevent connection when an individual loses vigilance creates such a safety net. Understanding human factors is necessary to design safer processes for care delivery (Gosbee, 2002; IOM, 2001).

An initial reaction to a tubing misconnection results in questioning the carefulness, skill, and vigilance of the nurse. However, what explains an experienced practitioner who makes this error? What explains a failure when the nurse has performed this task perfectly and repeatedly over years? The path that leads us to condemn the offender for a lack of carefulness and decreased vigilance does little to help us prevent recurrence. However, an understanding of human factors explains these phenomena and offers a solution in the form of redesign. Nursing must rapidly incorporate this knowledge of human failure into the care environment in order to practice safely.

**Misconnections as a Systems Error**

Early IOM reports suggest that health care is mistakenly designed on the assumption that human performance can be perfect (Corrigan et al., 2000). The report admonished health care to redesign systems at all levels “to make it harder for people to do something wrong and easier for them to do it right” (IOM, 1999), to examine systems contributions to errors, and to move toward systems accountability instead of individual blame. These statements created a new paradigm for health care and health care professionals, with a shared accountability across health care systems.

A systems view of tubing misconnections illuminates levels of health care that fail to capture a known hazard. Regulatory and safety-focused organizations considered the threat of common connectors as early as 1986, when the ECRI published the Medical Device Safety Report describing the connection of enteral feeding tubing to a tracheostomy cuff and asked for a redesign by the industry (ECRI, 1986). In 1996, the Infusion Device Committee of the Association for the Advancement of Medical Instrumentation (AAMI) passed American National Standard ANSI/AAMI ID54:1996 after considering the universally connected properties of feeding sets and adapters, as well as the possibility of harm when these connectors were inadvertently con-
connected to other devices (AAMI, 1996). This standard was reconsidered by the expert committee and pronounced in force in 2005.

The Joint Commission (2006) also recognized the eminent threat of using small bore connectors. A Sentinel Event Alert #36 was issued that acknowledged the severity of tubing misconnections and cited nine cases that were reported to the Sentinel Event Database, noting that these are important and under-reported. The Sentinel Event Alert #36 added that “the basic lesson from these cases is that if it can happen, it will happen. Luer connectors are implicated in or contribute to many of these errors because they enable functionally dissimilar tubes or catheters to be connected.” Furthermore, the alert encouraged manufacturers to implement “designed incompatibility” as appropriate to prevent dangerous misconnections of tubes and catheters (The Joint Commission, 2006). Prevention of tubing misconnections is part of the World Health Organization’s (WHO) Nine Solutions for Patient Safety published in conjunction with The Joint Commission International in 2007, recognizing that tubing misconnections occur in many other countries. However, The Joint Commission has failed to make the resolution of tubing misconnections a national patient safety goal (WHO, 2007).

The U.S. Food and Drug Administration (FDA) has alerted the public to the hazards of luer connectors in several publications and Web casts (Eakle, Gallauresi, & Morrison, 2005; FDA, 2003, 2004, 2007). In January 2007, the FDA met with concerned stakeholders and developed a consensus paper asking for a redesign of connectors (Guenther et al., 2008). The FDA has not enforced the AAMI standard passed in 1996, although publications and cautions from the FDA recognize the threat to patient safety.

The American Nurses Association (ANA) issued a position statement in October 2007 that supported systemic design changes in each discrete tubing system. ANA’s review of the literature identifies many systems issues, such as high patient acuity, inadequate staffing, staff fatigue, and constant interruptions, as contributors to the likelihood of a tubing misconnection error, especially when the connector’s physical design allows one system to be connected to another incompatible system. ANA points out that “awareness and training of nurses, physicians, technicians, medical and nursing students, nursing assistive personnel, patients, and families is essential but limited in accomplishing ultimate patient safety” (ANA, 2007, p. 3). The error will only be eliminated by making a misconnection physically impossible.

Despite multiple attempts to warn of the dangers of tubing misconnections, the problem persists in health care. Tubing misconnection errors carry serious consequences, including sepsis, embolus, and death. Since the redesign of these systems requires extensive resources and time to implement, and the industry has not responded, it is highly probable these errors will continue to occur.

**Case Study: The Inadvertent Connection of a Feeding Tube to an Intravenous Access Port**

An experienced nurse inadvertently connected a feeding tube of expressed breast milk to an intravenous device. The infusion remained undetected until another nurse responded to the completed infusion alarm on the pump. The infant sustained no harm and numerous tests were performed to assess any untoward affects. The infant was placed in an intensive care unit for monitoring.

The nurse caring for the infant was a 15-year expert nurse with extremely high performance evaluations. In interviews of the nurse’s peers, she was repeatedly described as an expert and resource for this high-intensity health care setting. The task of connecting the feeding to the naso-gastric feeding tube was a familiar task with each of her

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**Table 1. Eindhoven Classification: Examples of Contributing Factors Identified**

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<th>Classification Factor</th>
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<td><strong>Technical Factors</strong></td>
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| \(n = 5\)             | • Ubiquitous design of the connectors on the feeding set and intravenous tubing  
                        | • Feeding pump not manufactured for this rate of feeding  
                        | • IV tubing was able to connect to syringe containing breast milk |
| **Organizational Factors** |         |
| \(n = 12\)            | • Policy allowed feedings and intravenous infusions to use same syringe pump  
                        | • One syringe pump was at bedside  
                        | • Risk of connecting incorrect tubing was not recognized as a possible error by the unit staff  
                        | • Expressed breast milk sent to unit in a luer tip syringe  
                        | • Production pressure  
                        | • Labeling of tubing not perceived as a priority in patient care unit |
| **Human Factors**     |         |
| \(n = 7\)             | • Familiar task, increases risk of “slips”  
                        | • Distractions  
                        | • Interruptions  
                        | • Low light environment |
| **Patient Factors**   |         |
| \(n = 6\)             | • High-risk medical condition  
                        | • Patient unable to participate in care  
                        | • Multiple lines in place |
assigned three patients. Patients in this unit were fed and infused with intravenous medications utilizing the same syringe pump needed to deliver low volume feedings. At the time of this event, there were no alternatives to using this syringe device for both feeding and infusions, although recently, manufacturers have responded with feeding pumps that deliver this rate of flow. Contributing factors were categorized according to the Eindhoven Classification Model (see Table 1) (Battles, Kaplan, van der Schaaf, & Shea, 1998).

The health care institution immediately responded to this untoward event. The patient was immediately transferred to a higher level of care and assessed for any untoward reactions. The family was notified, full disclosure made, and frequent contact was maintained until it was ascertained the patient was unharmed from the event.

The nurse involved took a voluntary leave of absence after the event. As is common with “slips,” the nurse did not remember connecting the tubing to the intravenous line and was seriously impacted by this lack of recall. The nurse’s concern for the patient was evident in daily calls to check on the patient’s condition and her great amount of emotional distress. Even after being assured the patient sustained no injury, the nurse remained remorseful and distrustful of her own skill level and needed peer support to return to duty. The nurse remarked she would have not returned to nursing if harm to the infant had occurred.

The health care organization immediately began searching for solutions for this high-risk procedure, but quickly discovered there were few alternatives to low-volume and low-infusion rate feeding in this population. This made the syringe pump the only alternative, contributing to the probability of a recurrence of this event. Only recently have feeding tubes and pumps been redesigned to ensure they cannot connect to luer connectors in this population. Without a standard or enforcement in the industry, the threat of connecting feeding sets to intravenous lines in the neonatal and adult population will persist.

Future Implications

An error made in connecting therapeutic systems resulting in severe injury or death of a patient is a critical event to a health care organization and is a significant event for the nurse. Inadvertent connections of systems that create critical incompatibilities are too easily accomplished within the current health care environment in which the majority of infusion and tubing systems end in a luer connector. The prevalence of luer connectors in health care creates a constant opportunity for errors of misconception.

Creating designs for high-risk systems has been successfully completed in other industries in which human failure rates are considered and recognized. Health care remains resistant to such changes and continues to rely on human vigilance (Reason, 1997). Unfortunately, inadequate response to these well-documented threats to safety continues to cost patient lives and adversely impact nurses.

As nurses—who are humans—perform front-line care of patients in such a high-risk system as health care, considerations of the limits of human performance are essential to understanding and preventing patient harm. Directives from the IOM, the proven experience of other high-risk industries, the science of human factors, and the history of errors, such as tubing misconnections, align with one another and squarely point to required design changes as necessary solutions for increasing safety. “It may seem a strange principle to enunciate as the very first requirement in a hospital that it should do the sick no harm” (Nightingale, 1863, p. iii).

References


