Forum

Strategies for Improving Communication in the Emergency Department: Mediums and Messages in a Noisy Environment

Shari J. Welch, MD, FACEP; Dickson S. Cheung, MD, MBA, MPH; Julie Apker, PhD; Emily S. Patterson, PhD

A large body of research provides strong evidence that hospitals are loud environments with noise levels far exceeding those recommended by the World Health Organization (WHO).[1] WHO guidelines specify 35 decibels (dB) for continuous background noise in patient rooms, with nighttime peaks not to exceed 40 dB.[2] Hospital background noise exceeds those levels, and peaks frequently exceed 90 dB.[3–6] Staff voices and medical equipment typically produce noise at 70–75 dB levels. Other sources of noise include alarms, bedrails, telephones, ice machines, paging systems, and pneumatic tube systems. The noise from portable x-ray machines can exceed 90 dB, analogous to walking next to a highway when a large truck passes.[1(p. 39)]

Noise is good for neither patients nor health care providers. High levels of ambient noise in patient care areas have been associated with increases in blood pressure and heart rate and poor sleep patterns.[7–9] Noise in nurseries has been associated with higher oxygen-support therapy needs.[10] Hagerman et al. reported an increase in readmissions at a coronary care unit following discharge for patients who had poor room acoustics and noisy hospital stays.[11] The emergency department (ED) can be a particularly noisy environment—and noise elevates stress in patients. Weiland et al. found that ED patients listening to a digital audio recording of nature sounds, a soothing beat, or acoustical music demonstrated less anxiety than control subjects listening to a recording of ED noise.[12] The prospects for health care workers in terms of health and hearing loss are just as grim. Work in settings with high levels of ambient noise has been associated with hypertension and coronary artery disease.[13,14] Noise-induced stress has been identified as a predictor of burnout in critical care nurses.[15] In the ED, noise levels have been identified as stressful and interfering with communication and teaching.[16] High noise levels in a hospital setting have been associated with hearing loss.[17,18]

In the last two decades, there has been much interest in improving communication, including a substantial review of research on communication during patient handoffs in hospitals.[19,20] Yet little attention has been given to the potential opportunities and challenges associated with technology-based communication, particularly with respect to its use in environments with high levels of ambient noise, such as the ED.[21] Nevertheless, Lund et al. reported that text messaging was a "practical and feasible tool" in mass casualty events, during which background ambient noise levels are inordinately high.[22(p. 2)]

In this article, we (1) review the effects of noise on patients and providers; (2) analyze the modes, mediums, and affordances of the prevalent communication mechanisms in the ED; and (3) suggest strategies to reduce ambient noise and improve communication in the ED and ways to evaluate the impact of these strategies.

Noise and Communication Breakdowns in the Emergency Department

Dugdale and colleagues have shown in computer simulations in emergency call centers that communication processes and effectiveness are affected by the distance between people, the intensity of speech, the general noise level, the level of mutual awareness, the ability to overhear, the involvement a person has with a task, and the choice of interrupting.[23] The emergency call center is an environment with factors that negatively influence effective communication, and these factors are analogous to those identified in the ED.

The ambient noise level consistently experienced in EDs is particularly high and comparable to that experienced by rock stars who subsequently have demonstrated significant hearing loss.[24–27] High noise levels have been reported to have a negative influence on patient satisfaction in the ED.[28,29] Higher levels of ambient noise impede oral communication by making it difficult to discern auditory cues from background noise.[30]

According to a 2002 Joint Commission *Sentinel Event Alert*, just over half of sentinel event cases of patient death or permanent injuries due to delays in treatment occur in the ED. Analyses of those cases revealed that communication errors were the number one cause of these sentinel events; 84% of

hospitals cited a breakdown in communication as a root cause for a sentinel event.[31] These data are not surprising because work domain analyses of ED work show that clinicians spend about 80% of their time communicating.[32] Noise, then, has the potential to reduce, prevent, and/or distort interactions in settings where communication failures are well documented.

The ED is a site of critical communications delivered at a rapid pace and embedded in a chaotic environment. Eisenberg et al. identified triage, testing, handoffs, and admitting as processes in ED encounters that are particularly vulnerable to communication breakdowns.[33] Communication breakdowns related to noise in the ED may take one of the three forms characterized by Vincent and Wears—omission, ambiguity, and excessive volume[34]:

1. Communication Omission: Physical layout, leaded walls (which interfere with wireless radio signals), interruptions and distractions, and too many work-arounds required to enter data in an electronic system are examples of conditions that can contribute to the omission of communication, such as the failure to record a new allergy, which could result in a medication error.

2. Communication Ambiguity: Communications may be undermined by semantic ambiguity (in which the sender and receiver assign different meanings to a phrase), phonetic or lexical ambiguity[34] (as reflected in the sound-alike medications "amrinone" and "amiodarone" or the diagnoses "aortic stenosis" and "atherosclerosis"), and message ambiguity[35] (a noisy "channel" such as an ED results in a mismatch between the message transmitted and received). Unfortunately, the natural response to noise is to speak louder, thereby further increasing the overall level of ambient noise.

3. Communication Volume: The volume of information may overwhelm short-term memory,[34] "causing some of the information to be lost before processing is completed."[35(p. 642)] Talbot and Bleetman found that only 49%–57% of verbal content from a handoff update from emergency medical services personnel to ED staff was retained after five minutes.[36] These findings were consistent with findings from the operating room setting, where noise levels > 77 dB were associated with anesthetists having lower short-term memory retention and mental efficiency.[37]

Unfortunately, most EDs spend little time planning for and assessing the effectiveness of the communication mediums they employ. ED clinicians and administrators should carefully plan a communication scheme using several communication mediums to fit the situational complexities of ED interactions.

Communication Modes

Each of the two most common modes of communication—verbal and written—has advantages and limitations, particularly in the ED setting. Verbal communication, whether face-to-face or via telephone or another device, is a quick and direct method for efficiently creating a shared understanding about a patient. Pitch and intensity can be varied to convey complex messages with many subtleties. In face-to-face communication, receivers can offer immediate feedback and indicate comprehension through body language and by asking questions. Verbal communication also tends to be less formal and is appropriate for conveying short-term information about what needs to be done in the immediate future. It further allows for an iterative back-and-forth conveyance of patient information and provides an opportunity for questioning between sender and receiver, a feature that has been noted in the communication strategies of high-performance organizations during handoffs.[38]

Written communication is a critical mode in health care because it constitutes the permanent record. In an electronic format, information can be easily accessed by multiple staff members and can be widely disseminated as a broadcast message. When information contains highly technical terms or specific numeric values, written communication is much preferred because it is permanent, can be reviewed, and is less prone to misinterpretation.

A third mode of communication prevalent in the ED is visual signaling. Typically, the signal or cue is an actionable item that uses existing symbols that have been pre-identified to exclusively mean something. In a recent study, for example, a pulsing flashlight was used as a feedback device to guide medical students through cardiopulmonary resuscitation (CPR) in a noisy environment.[39] When guided by the pulsing visual signal, the medical students, who had had no previous experience of using flashlight-guided CPR, performed effectively and were able to constantly maintain the desired rate of chest compressions, despite the high level of artificially generated background noise.

In Table 1 (page 281), these three modes of communication are used to categorize several examples of communication-support technologies, which are also grouped by whether the communication is intended for one or many receivers.

Communication Mediums

Mediums are the means by which information is transmitted (typically between a speaker or writer and a receiver). They can be organized according to whether or not they are based in

Table 1. Communication Modes in the Emergency Department and Examples

	MODES		
	Verbal	**Written**	**Visual Signal**
One-to-One	Face-to-face Pagers Secure cell phones Voice mail Telephone landline Answering service	Text messaging Written orders E-mail communication Fax messages	Passing chart to flow coordinator Passing chart to person
One-to-Many	Overhead paging Walkie-talkie radios	Internet communication Tracking board free text	Light over patient's room Flag on chart Movement of chart Electronic tracking cue Whiteboard cue Cueing with signal on chart

Table 2. Communication Mediums in the Emergency Department Based on Technology

Technology-Independent	**Technology-Driven**
■ Overhead paging	■ Fax machines
■ Face-to-face communication	■ Walkie-talkie radios
■ Cueing on a whiteboard	■ Wireless hands-free communication devices
■ Cueing by physically altering the chart (for example, flags)	■ Pagers
■ Cueing by physically moving the chart	■ Text messaging
■ Cueing by initialing, signing, highlight, checkbox	■ Secure cell phones (short and long range)
■ Turning on a light over a patient's room	■ E-mail communication
■ Funneling orders through a coordinator (for example, charge nurse)	■ Intranet/Internet messaging
	■ Electronic tracking boards
	■ Voice mail
	■ Telephone landline
	■ Answering service

technology (Table 2, above). EDs vary in their technology support, and smaller EDs may have no electronic tracking system, cell telephones, or radios. We have attempted to identify all of the mechanisms available for communication in EDs, whether they have robust technological support or are still whiteboard- and paper-driven. The goal is to get ED staff thinking about the communication mediums available to them with current resources and to encourage them to create a comprehensive scheme for managing communication in the ED. It is also important for ED leaders to anticipate their departmental needs as they continue to gain in census and to consider the resources that might be necessary to optimize communication in the future.

Factors Influencing Medium Selection and Use

A number of factors influence the optimum selection of a communication medium in the ED and influence its effectiveness. We now consider these factors and their implications.

Census and Physical Layout Variations. The ED's physical environment, particularly the size and layout, greatly influences the choice of optimal communication methods. In a 15,000-visit, 10-bed, 2,500-square-foot department, simple traditional modes of communication such as face-to-face, writing on a whiteboard, and flagging the physical chart (a visual signal) may suffice. However, in a 100,000-visit, 50-bed department, a hierarchy for communication is likely required unless the ED is subdivided into smaller units, such as geographic zones that function like small EDs. Face-to-face communication gives way to wireless hands-free communication devices in mid-volume EDs, where direct communication becomes more difficult to carry out.[40] But as volumes go up, such devices become less usable because of ambient noise and interruptions.[41] Therefore, it is not surprising that ultra-high-volume EDs are increasingly using dedicated cellular telephones with speed dialing and text-messaging features.

Certain principles regardless of ED size likely apply.

Table 3. Communication Mediums and Their Affordances

	Affordances				
	Urgency	Privacy	Target	Length	Capacity for Dialogue
Mediums					
Overhead page	High	–	+	Short	–
Face-to-face	High	+	+	Long	+
Phone	Med	+	+	Long	+
Text	Med	+	+	Short	–
Wireless hands-free communication device	Med	–	–	Short	–
Pager	Med	+	+	Short	–
Visual signal*	Low	–	–	Short	–

* See Table 2 for examples of visual signals.

Convenience is a threshold by which providers often decide whether or not to pursue communicating essential messages. Proximity and accessibility support frequent interaction and relational development conducive to collaboration in health teams.[42] Physical layouts that afford clear "lines of sight" and include common workspaces facilitate good communication habits. Studies have shown that face-to-face communication is still the most common means of communicating patient care information in the ED and that the charge nurse is often the pivotal figure receiving the most communications per shift.[43,44]

Stationing ancillary services (such as a radiology unit and laboratory personnel dedicated to the ED) in close proximity to the central work hub appears to promote teamwork and communication, thereby resulting in better performance on time metrics.[45] Departments that are fortunate enough to have a dedicated pharmacist located near the nurses' station are more likely to receive greater medication oversight, partially because of increased informal verbal communication.[46]

Communication Needs of Nurses and Physicians. Nurse communication is mostly local and can occur without divulging protected patient information (for example: "Julie, can you take more Zofran to Room 6 for me?" or "Dr Smith, can Bed 4 have more pain meds?") Yet when nurses hand off a patient, such as when a nurse calls the floor to give a report about a patient, the communication exchange is usually longer; the nurse typically sits down and uses a landline telephone with the paperwork in front of him or her, with appropriate consideration of protected information; faxing reports is a possible alternative.

In contrast, physician calls are frequently made to persons outside the ED and even outside the hospital. Private health information, including the patient's name and health data, is usually exchanged, which is why dedicated cell phones are the preferred route of communication for physicians. While nurses are comfortable with wireless hands-free communication devices, physicians often view them as disruptive to their work flow. When used by the physician, such devices can loudly disrupt the bedside encounter or important phone consultations with other physicians. At ChristianaCare (Wilmington, Delaware), where the ED has 114,000 visits a year, the nurses use these devices, which can also be used to call physicians on their (dedicated cell) phones. While Breslin, Greskovich, and Turisco reported benefits from the use of such wireless communication,[47] Woloshynowych et al. found that the use of such devices in the course of patient care was associated with more interruptions.[44]

Affordances in Communication Mediums

An *affordance*, according to Norman, is an aspect of an object's design that provides strong clues as to how the object should be used. It "refers to the perceived and actual properties of a thing, primarily those functional properties that determine just how the thing could be used."[48(p. 9)] The term is typically applied to new technologies but can be applied to all the mediums available for communication in the ED. In a sentinel publication articulating the elements necessary for effective communication, Clark and Brennan discuss affordances in communication.[49] Characteristics such as cotemporality (whether participants are present at the same time, such as for the phone versus using a visual signal on a whiteboard) and simultaneity (for example, pager messages are received, but responses cannot be sent at the same time using the pager) influence the choice of communication mode selected. The ideal choice of communication mediums will depend on a host of factors. The mediums listed in Table 3 (above) are appropriate for different levels of urgency, with modification by other

Table 4. Measuring Improvement in ED Communication

- Measure decibel noise level.
- Use a pedometer to measure distance that staff members walk.
- Monitor frequency of communication (for example, by provider, by shift).
- Monitor subcycle times (turnaround times).
- Survey staff satisfaction.
- Audit for failed communications.

affordances, including privacy, target, length and complexity, and need for dialogue.

The *urgency* of a message demands that it be communicated quickly. For example, an overhead distress page is still an effective way to obtain an immediate response to a highly urgent or emergent situation. Less urgent communication, such as, "Our lab result is back," may be sent by a visual-signal system (for example, whiteboard, electronic tracking cue, flagging a chart). The *privacy* of a message may require a one-to-one communication; patient privacy and confidentiality in the ED is an important concern. That said, a common misinterpretation of HIPAA[50] is to sacrifice patient safety for privacy by, for example, taking down a tracking system or whiteboard or otherwise hindering communication supported by shared technology.[51]

The need to *target* the delivery of the message to a particular recipient can be met by sending the phone call, text, or voice mail directly to the responsible party. These techniques will be less disruptive to the department at large, while information can still be delivered in a timely fashion. Finally, the *length and complexity* of the message can dictate the method of communication, with two-way communication being best. Sometimes staff members simply need to have a *dialogue* about complex patients, enabling the give-and-take that can enhance sensemaking and problem solving. Longer messages are best handled through a face-to-face conversation or a phone call.

There are subtleties embedded in a communication that may make one communication medium more desirable than another. For example, an order for pain medication in a patient with a kidney stone may require a more urgent communication (via a targeted phone call or text message to the physician), in contrast to a less urgent message regarding routine test results, in which a visual-symbol communication, such as an icon on an electronic tracking system, may suffice.

Measuring Improvements in ED Communication

There are a number of ways to determine whether or not the communication strategies being employed are effective or, with change, are improved (Table 4, above). The actual measurement of decibel levels is seen in the acoustical science literature and in the growing body of design research. Patterson and Wears provided a review of measures of patient handoff communications.[52] Another approach comes from Lean methodology; simply measure the distance each provider must travel to perform his tasks. Much added waste of movement occurs when there are repeated attempts to communicate with another health care provider. Traditionally, movement is measured by an observer's counting the steps taken to care for a given number of patients. A more practical approach is for the provider to wear a pedometer. Another approach is to monitor the frequency of each communication modality (for example, texting, phone calls, flagging) used. A more global measure would be to monitor subcycle times (turnaround times) for ED processes. As communication is optimized, delays embedded in processes due to communication constraints should begin to decrease and performance metrics improve. Hand audits for communication breakdowns or problems could help articulate whether progress is being made. Perhaps the simplest way to measure improvement in communication comes from qualitative research techniques: Measure staff satisfaction. Most survey tools designed to measure the safety culture now include a "teamwork and communication" portion as a key piece of the investigation.[53]

Strategies for Improving Communication in the ED

Strategies for improving communication in the ED, as summarized as reducing ambient noise and designing a communication scheme, often need to involve architects and designers (Table 5, page 284).

Reducing Ambient Noise

Reports of efforts at reducing noise in health care settings have appeared in the literature. At one site, the ICU installed a noise-level monitor. As noise on the unit increased, the staff received a real-time signal.[54] When levels were in range, the monitor showed a green light. When the sound exceeded the recommended levels, it went yellow; and when it was in a danger zone, the monitor showed red. "High-sound" contributors such as the lids on the garbage bins were very noisy, so they were replaced: A less noisy x-ray machine was purchased, and alarms and phones were programmed to a lower decibel level. At an inpatient neuroscience unit, overhead paging was reduced and staff were trained to speak more quietly.[55]

Single-patient rooms have been shown to be quieter than

Table 5. Strategies for Improving Communicaiton in the Emergency Department

Reducing Ambient Noise
- Use a sound meter to identify loud noise.
- Pad trash can lids.
- Pad tube system.
- Limit portable x-ray machine use.
- Replace loud paper towel dispensers.
- Limit overhead paging.
- Limit radio use.
- Provide staff training to decrease speech volume.
- Provide sound-absorbing ceiling tiles.
- Provide sound-absorbing wall paper.
- Decentralize work areas.

Designing and Articulating a Communication Scheme
- Provide whiteboard communication.
- Track system communication.
- Provide text messaging.
- Provide dedicated cell phones.
- Limit overhead paging.
- Limit radio use.

multiple patient rooms, which, along with the lower associated risk regarding health care–associated infections, has led to an increase in their use, even in the nursery.[56] Another important and proven design intervention is to install high-performance sound-absorbing ceiling tiles that reduce echoing and reverberation and sharply diminish sound propagation. A key component of quieting facilities is to eliminate noise sources. Even motion-sensing paper towel dispensers have been shown to increase the decibel level in a clinical unit. Every design change must be considered in terms of its contribution to the noise level.[57] Insulating ice machines and pneumatic tube systems can significantly decrease noise levels in the ED.[1] Noise-reducing panels and wallpaper, strategically placed, significantly reduced noise in an oncology ward at Johns Hopkins Hospital.[58]

Decentralizing workstations on nursing units has also been shown to reduce noise in inpatient settings.[59,60] EDs with large numbers of rooms operating out of a central hub are particularly noisy.

Designing and Articulating a Communication Scheme

By crafting a deliberate scheme with a hierarchy for communications and understanding the affordances of each medium, EDs can improve communication and decrease noise. This can be done in both technology-driven and technology-independent departments alike. In particular, an emphasis on decreasing overhead paging in the department would be a big step on the road to improved communication. High overall noise levels are a detriment to patient and staff well-being and an impediment to effective communication. By carefully selecting and articulating the mediums to be used in the ED, organizations can improve the overall efficacy of communication. Through deliberate methods, the noise level of a department can be decreased and the communication model improved. By deliberately identifying levels of urgency or emergency in communication content, and then implementing an appropriate communication method, a communication scheme can be designed that is appropriate for a particular department.

The potential for information technology to improve communication in the ED is just beginning to be realized. A homegrown consultation management system that automatically sends out consulting pages and tracks responses decreased the length of stay for ED patients at a hospital in South Korea.[61] At the ED at Mt. Sinai School of Medicine (New York City), following implementation of a fully integrated information system that was designed to facilitate clinical work flow with computerized provider order entry, improvements were reported for length of stay, door-to-physician time, and imaging and laboratory turnaround times.[62] These two examples are likely the beginning of a trend in which care processes, information technology, and architectural design combine to bring about improved communication, operational efficiencies, and an improved quality of work environment.

However, technology alone will not improve communication in clinical settings. For example, Quan et al. recently reported that the implementation of a new Web-based communication system increased interruptions of clinical providers by 233%.[63] The authors stated, "failing to account for the sociotechnical aspects of HIT [health information technology] or the interplay of technology with existing clinical workflow, culture, and social interactions may create other unintended consequences."[63(p. 137)] The TeamSTEPPS program[64] and similar initiatives designed to improve teamwork and communication are being applied in various health care settings, including the ED. We suggest that there are environmental and technological aspects to improving communication in clinical settings with high-intensity work, like the ED, and that these need to be managed as well. Clearly, there is room for improvement in the ED beyond the addition of new technologies.[65]

When the University of Kentucky rebuilt its ED, close attention was paid to noise and communication. This ED, which had more than 50 providers, including residents, on duty at a time, had struggled with high levels of ambient noise

and interruptions. The new department, whic was completed in 2011, was designed into smaller pods, which, like decentralized nursing stations, as stated, reduce noise and improve communication. ED staff were told that there would be no overhead paging system and that they had to craft communication strategies using other modalities. The frontline workers devised a tiered communication system that included a mixture of face-to-face communication, wireless hands-free communication devices, status boards, and dedicated cell phones. They heavily relied on their computer system for non-emergency communication. The department installed 240 computers with ID badge smart readers for easy log-on. After several months, they were allowed to use overhead paging for emergencies, but the new system was well established. Staff reported that the stress level decreased with the decibel level, even on busy shifts, providing a more calm environment for patients and families.[66]

Conclusion

It is possible in the future that we will identify the gold standard for communication in EDs, including the best communication schemes and the best communication mediums by volume. The best results will be seen when process improvement, technology, and environmental design come together in this work. The sophisticated ED will use multiple modes of communication purposefully chosen to meet the needs of its unique environment. As the field moves forward, the following understandings relative to ED communication strategies are critical:

- The noise level in most EDs is too high and is bad for patients and staff and has important patient safety implications.
- The respective communication needs of nurses, physicians, and staff may be different.
- There are affordances in each ED communication medium that can be factored into the optimal selection for a particular message.
- The need to limit interruptions and decrease the overall noise level in the ED while improving overall communication strategies should be a prime goal for our specialty.
- A method of assessing the effectiveness of any communications scheme should be employed as improvement efforts are initiated.
- There are design elements involving layout and building materials that can improve the efficacy of communication and reduce noise.
- Improving communication in the ED will require a multidisciplinary effort involving operations and processes, information, and other technology and environmental design. J

Shari J. Welch, MD, FACEP, is Fellow, Intermountain Institute for Health Care Delivery Research, Salt Lake City. **Dickson S. Cheung, MD, MBA, MPH,** is Attending Physician, Department of Emergency Medicine, Sky Ridge Medical Center, CarePoint, PC, Denver. **Julie Apker, PhD,** is Associate Professor, School of Communication, Western Michigan University, Kalamazoo, Michigan. **Emily S. Patterson, PhD,** is Assistant Professor, Division of Health Information Management and Systems, School of Health and Rehabilitation Sciences, College of Medicine, Ohio State University, Columbus; and a member of *The Joint Commission Journal on Quality and Patient Safety*'s Editorial Advisory Board. Please address correspondence to Shari Welch, sharijwelch@gmail.com.

References

1. Ulrich RS, et al. The environment's impact on stress. In Marberry SO, editor: *Improving Healthcare with Better Building Design*. Chicago: Health Administration Press, 2006, 37–63.
2. Berglund B, Lindvall T, Schwela DH, editors. *Guidelines for Community Noise*. Geneva: World Health Organization, 1999.
3. Allaouchiche B, et al. Noise in the postanaesthesia care unit. *Br J Anaesth.* 2002;88(3):369–373.
4. Meyer TJ, et al. Adverse environmental conditions in the respiratory and medical ICU settings. *Chest.* 1994;105(4):1211–1216.
5. Gabor JY, Cooper AB, Hanly PJ. Sleep disruption in the intensive care unit. *Curr Opin Crit Care.* 2001;7(1):21–27.
6. Pai JY. A study in hospital noise—A case from Taiwan. *Int J Occup Saf Ergon.* 2007;13(1):83–90.
7. Blomkvist V, et al. Acoustics and psychosocial environment in intensive coronary care. *Occup Environ Med.* Mar 2005;62(3):e1.
8. Berg S. Impact of reduced reverberation time on sound-induced arousals during sleep. *Sleep.* 2001 May 1;24(3):289–292.
9. Parthasarathy S, Tobin MJ. Sleep in the intensive care unit. *Intensive Care Med.* 2004;30(2):197–206.
10. Slevin M, et al. Altering the NICU and measuring infants' responses. *Acta Paediatr.* 2000;89(5):577–581.
11. Hagerman I, et al. Influence of intensive coronary care acoustics on the quality of care and physiological state of patients. *Int J Cardiol.* 2005 Feb 15;98(2):267–270.
12. Weiland TJ, et al. Original sound compositions reduce anxiety in emergency department patients: A randomised controlled trial. *Med J Aust.* 2011 Dec 19;195(11–12):694–698.
13. Zhao YM, et al. A dose response relation for noise induced hypertension. *Br J Ind Med.* 1991;48(3):179–184.
14. Heinonen-Guzejev M, et al. The association of noise sensitivity with coronary heart and cardiovascular mortality among Finnish adults. *Sci Total Environ.* 2007 Jan 1;372(2–3):406–412.
15. Topf M, Dillon E. Noise-induced stress as a predictor of burnout in critical care nurses. *Heart Lung.* 1988;17(5):567–574.
16. Ratnapalan S, et al. Physicians' perceptions of background noise in a pediatric emergency department. *Pediatr Emerg Care.* 2011;27(9):826–833.
17. Yassi A, et al. The noise hazard in a large health care facility. *J Occup Med.* 1991;33(10):1067–1070.
18. Willett KM. Noise-induced hearing loss in orthopaedic staff. *J Bone Joint Surg Br.* 1991;73(1):113–115.
19. Cohen MD, Hilligoss PB. The published literature on handoffs in hospitals: Deficiencies identified in an extensive review. *Qual Saf Health Care.* 2010;19(6):493–497.
20. Ong MS, Coiera E. A systematic review of failures in handoff communication during intrahospital transfers. *Jt Comm J Qual Patient Saf.* 2011;37(6):274–284.

21. Welch SJ, Cheung D. Quality matters: Enterprise to McCoy: The future of communications in the ED. *Emergency Medicine News.* 2011;33(6):20–21.
22. Lund A, et al. Text messaging as a strategy to address the limits of audio-based communication during mass-gathering events with high ambient noise. *Prehosp Disaster Med.* 2013;28(1):2–7.
23. Dugdale J, Pavard B, Soubie JL. A pragmatic development of a computer simulation of an emergency call centre. In Dieng R, et al., editors. *Designing Cooperative Systems: The Use of Theories and Models*. Burke, VA: IOS Press, 2000, 241–256.
24. Short AE, et al. Noise levels in an Australian emergency department. *Australasian Emergency Nursing Journal.* 2011;14(1):26–31.
25. Orellana D, Busch-Vishniac IJ, West JE. Noise in the adult emergency department of Johns Hopkins Hospital. *J Acoust Soc Am.* 2007;121(4): 1996–1999.
26. Tijunellis MA, Fitzsullivan E, Henderson SO. Noise in the ED. *Am J Emerg Med.* 2005;23(3):332–335.
27. Axelsson A, Eliasson A, Israelsson B. Hearing in pop/rock musicians: A follow-up study. *Ear Hear.* 1995;16(3):245–253.
28. Walsh P, Cortez V, Bhakta H. Patients would prefer ward to emergency department boarding while awaiting an inpatient bed. *J Emerg Med.* 2008;34(2):221–226.
29. Walsh M, Knott JC. Satisfaction with the emergency department environment decreases with length of stay. *Emerg Med J.* 2010;27(11):821–828.
30. Kiukaanniemi H, Sorri M. Speech intelligibility in difficult signal/noise circumstances. *Scand Audiol Suppl.* 1988;30:215–218.
31. The Joint Commission. Delays in Treatment. *Sentinel Event Alert* No. 26. Jun 17, 2002. Accessed May 4, 2013. http://www.jointcommission.org/assets/1/18/SEA_26.pdf.
32. Chisholm CD, et al: Task analysis of emergency physician activities in academic and community settings. *Ann Emerg Med.* 2011;58(2):117–122.
33. Eisenberg EM, et al. Communication in emergency medicine: Implications for patient safety. *Communication Monographs.* 2005;72(4): 390–413
34. Vincent CA, Wears RL. Communication in the emergency department: Separating the signal from the noise. *Med J Aust.* 2002 May 6;176(9): 409–410.
35. Gosbee J. Communication among health professionals. *BMJ.* 1998 Feb 28;316(7132):642.
36. Talbot R, Bleetman A. Retention of information by emergency department staff at ambulance handover: Do standardised approaches work? *Emerg Med J.* 2007;24(8):539–542.
37. Murthy VS, et al. Detrimental effects of noise on anesthetists. *Can J Anaesth.* 1995;42(7):608–611.
38. Patterson ES, et al. Handoff strategies in settings with high consequences for failure: Lessons for health care operations. *Int J Qual Health Care.* 2004;16(2):125–132.
39. You JS, et al. Effects of flashlight guidance on chest compression performance in cardiopulmonary resuscitation in a noisy environment. *Emerg Med J.* Epub 2012 Aug 27.
40. Richards JD, Harris T. Beam me up Scotty! Impact of personal wireless communication devices in the emergency department. *Emerg Med J.* 2011;28(1):29–32.
41. Spencer R, Coiera E, Logan P. Variation in communication loads on clinical staff in the emergency department. *Ann Emerg Med.* 2004;44(3):268–273.
42. Propp KM, et al. Meeting the complex needs of the health care team: Identification of nurse-team communication practices perceived to enhance patient outcomes. *Qual Health Res.* 2010;20(1):15–28.
43. Fairbanks RJ, Bisantz AM, Sunm M. Emergency department communication links and patterns. *Ann Emerg Med.* 2007;50(4):396–406.
44. Woloshynowych M, et al. Communication patterns in a UK emergency department. *Ann Emerg Med.* 2007;50(4):407–413.
45. McGrayne J. The data driven ED: Demographic and performance data. Presented at Good to Great: The Advanced ED Management Course, Las Vegas, Dec 9, 2009.
46. Rothschild JM, et al. Medication errors recovered by emergency department pharmacists. *Ann Emerg Med.* 2010;55(6):513–521.
47. Breslin S, Greskovich W, Turisco F. Wireless technology improves nursing workflow and communications. *Comput Inform Nurs.* 2004;22(5):275–281.
48. Norman DA. *The Psychology of Everyday Things.* New York City: Basic Books, 1988.
49. Clark HH, Brennan SE. Grounding in communication. In Resnick LB, Levine RM, Teasley SD, editors: *Perspectives on Socially Shared Cognition*. Washington, DC: American Psychological Association, 1991, 127–149.
50. US Department of Health & Human Services. Health Information Privacy. Accessed May 4, 2013. http://www.hhs.gov/ocr/privacy/.
51. Welch S, Klauer K, Fontenot SF. *Risk Management for Emergency Departments: Executive Leadership for Protecting Patients and Hospitals*. Chicago: Health Administration Press, 2011.
52. Patterson ES, Wears RL. Patient handoffs: Standardized and reliable measurement tools remain elusive. *Jt Comm J Qual Patient Saf.* 2010;36(2):52–61.
53. Sexton JB, et al. The Safety Attitudes Qusestionnaire: Psychometric properties, benchmarking data, and emerging research. *BMC Health Serv Res.* 2006 Apr 3;6:44.
54. Stephens C, Daffurn K, Middleton S. A CQI approach to the investigation of noise levels within the intensive care unit environment. *Aust Crit Care.* 1995;8(1):20–23, 26.
55. Connor A, Ortiz E. Staff solutions for noise reduction in the workplace. *Perm J.* 2009;13(4):23–27.
56. Stevens DC, et al. Neonatal intensive care nursery staff perceive enhanced workplace quality with the single-family room design. *J Perinatol.* 2010;30(5):352–358.
57. Brandon DH, Ryan DJ, Barnes AH. Effect of environmental changes on noise in the NICU. *Adv Neonatal Care.* 2008;8(5 Suppl):S5–10.
58. MacLeod M, et al. Quieting Weinberg 5C: A case study in hospital noise control. *J Acoust Soc Am.* 2007;121(6):3501–3508.
59. Gurascio-Howard L, Malloch K. Centralized and decentralized nurse station design: An examination of caregiver communication, work activities, and technology. *HERD.* 2007;1(1):44–57.
60. Zborowsky T, et al. Centralized vs. decentralized nursing stations: Effects on nurses' functional use of space and work environment. *HERD.* 2010;3(4): 19–42.
61. Cho SJ, et al. Decreased emergency department length of stay by application of a computerized consultation management system. *Acad Emerg Med.* 2011;18(4):398–402.
62. Baumlin KM, et al. Clinical information system and process redesign improves emergency department efficiency. *Jt Comm J Qual Patient Saf.* 2010;36(4):179–185.
63. Quan SD, et al. It's not about pager replacement: An in-depth look at the interprofessional nature of communication and healthcare. *J Hosp Med.* 2013;8(3):137–143.
64. Turner P. Implementation of TeamSTEPPS in the emergency department. *Crit Care Nurs Q.* 2012;35(3):208–212.
65. Rydenfält C, et al. Compliance with the WHO Surgical Safety Checklist: Deviations and possible improvements. *Int J Qual Health Care.* 2013;25(2): 182–187.
66. Welch SJ. Quality matters: Data drove design of University of Kentucky ED. *Emergency Medicine News*. 2011;33(8):22–23.