AHRQ Issue Brief

Health Care Simulation To Advance Safety:

Responding to Ebola and Other Threats

While this Issue Brief was written to advocate for the use of simulation to improve patient and healthcare worker safety during the Ebola outbreak a decade ago, threats to patient and healthcare worker safety are ongoing and this Issue Brief articulates important principles.

Foreword

Simulation has long been recognized for the integral role it plays in high-risk industries. Our aerospace, transportation, and power-generation industries have become steadily safer over the years with the aid of simulation. As the Ebola virus disease is amply demonstrating, health care is a high-risk industry. Yet providers and health care workers should not have to put their own lives at risk when caring for the sickest patients.

Several simulation centers are already initiating simulation-based preparations to optimize their own readiness for Ebola patients and more rigorously address essential training, protocol development, personal protective equipment, and facilities issues. This issue brief underscores the helpful role simulation can serve in response to the Ebola virus disease, other emergent epidemic challenges, provider and patient safety, and quality of care in general. In addition to tested and verified protocols, health care professionals need practice implementing them through simulation.

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This brief also addresses simulation's essential features and benefits, approaches and uses, the concept of mastery learning, the Agency for Healthcare Research and Quality's (AHRQ's) programmatic focus on simulation, and some selected lessons learned that still represent a challenge.

While all the lessons learned are yet to be recorded and digested, the relevance of simulation extends not only to the immediate Ebola response, but beyond Ebola to other serious viral outbreaks and influenza threats. Although the numbers of patients with Ebola virus disease to be admitted to U.S. hospitals is expected to be very low, there will almost certainly be similar outbreaks in the future.

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A Global Challenge

The deadly 2014–15 West African Ebola virus disease has taken more lives than all earlier epidemics combined and promises to be "a long hard fight" according to the director of the Centers for Disease Control and Prevention (CDC), Dr. Tom Frieden.[1] More than 99 percent of the infected cases originated in Liberia, Guinea, and Sierra Leone. Even amid some stabilization in Liberia, much work remains. Key to the strategy of curtailing the Ebola threat in the United States is defeating it at its source in West Africa. In support of the whole-of-government effort to accomplish the strategy, employees in agencies across the U.S. Department of Health and Human Services (HHS) are actively engaged both domestically in preparedness and research efforts and on the front lines internationally, providing guidance and training to health care workers and infection control teams as well as caring for health care workers with Ebola.

Nevertheless, detecting and responding to emergent outbreaks before they become pandemics is a complex undertaking. Virulent disease does not respect national borders. Thousands and thousands of registered contacts of infected patients need to be monitored if the Ebola epidemic is to be contained. Deep-rooted cultural norms such as personal handling of the bodies of deceased relatives clash with recommended protocols for post-mortem care. Even the best and safest protocols may need to be revised, tested, and reissued as emergent conditions and new information become available.

The Role of Simulation in Preparedness

By providing practice, simulation can serve a useful role in helping to detect breaches in safety protocols as they evolve and in establishing high levels of individual and team performance. Simulation's value was recently demonstrated by a team at Northwestern University Feinberg School of Medicine that was featured in AHRQ's *WebM&M*.[2] The Northwestern team was able to identify serious gaps in Ebola safety protocols by using simulation to detect breaches in sterile technique when providers were fully donned in personal protective equipment, transporting suspected Ebola patients, drawing blood from a peripheral intravenous catheter, and in placing a central venous access line.

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>
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The simulation took place in a hospital that considered itself "ready" for Ebola patients as a result of earlier developed guidelines and training in donning and doffing personal protective equipment. "At Northwestern Memorial Hospital, we have learned that preparing detailed guidance is not enough," noted Jeffrey H. Barsuk, M.D., M.S., associate professor of medicine at Northwestern University Feinberg School of Medicine. "We must conduct realistic drills and offer clinicians and administrators both practice and honest feedback on their performance." The learning that occurred as a result of the simulation reveals opportunities for organizations to address gaps and improve aspects of their preparedness efforts to respond successfully to real patients.

Information about AHRQ Issue Briefs

AHRQ Issue Briefs examine important national health care issues consistent with the Agency's mission to produce evidence to make health care safer, higher quality, more accessible, equitable, and affordable, and to work within the U.S. Department of Health and Human Services and with other partners to make sure that the evidence is understood and used. Each brief describes the scope of a particular problem, ways AHRQ and its partners approached solutions to the problem, and emerging trends and policy implications. These briefs are intended for health care providers and administrators, policymakers, and researchers.

Simulation in health care has grown remarkably during the past 15 years and schools of medicine and nursing have been quick to acquire their own simulation centers. But are they being used to their full potential, could they be used as a test bed to identify breaches in protocols in Ebola preparedness, and could they be used for further staff preparedness and training once the vulnerabilities have been pinpointed? In many teaching hospitals, the director of the emergency department might not be fully aware there is a simulation center in another building that could play a key role in assessing emergency department preparedness when patients are transported from point of entry to the designated Ebola treatment area. Other hospitals may lack simulation expertise and relationships that provide access to simulation centers—assets that could contribute significantly to the safety and quality of care that is being delivered. In brief, simulation has a definite role to play when tasks are infrequent and complex, relatively new and evolving, and when consequences of sub-standard performance can be life-threatening.

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Essential Features and Benefits

The same essential features and benefits of simulation that other high-risk industries have realized for decades apply to health care as well. In health care these include safety of patients and providers, creation of optimal learning conditions, focused and near real-time feedback, integrating multiple skill components,[3] and using simulation as a test bed to identify gaps in technologies, procedures, and protocols.

Putting safety first

With respect to safety, simulation enables the training of tomorrow's practitioners without putting today's patients at risk. When practice on the job is not acceptable because of safety concerns, simulation provides the opportunity to reach proficiency on difficult and critical skills that are needed for safe and reliable system performance. In high-risk environments such as aviation and military operations, operators are not allowed to take the controls unless they have reached a pre-established level of performance competency in a simulated setting. In health care, the simulated setting allows participants to make mistakes safely, and to learn from these mistakes while avoiding patient harms that might otherwise occur. Levels of performance competency for critical tasks in most specialty areas of medicine are yet to be established, but surely need to be addressed.

Optimizing learning conditions

Simulations have the advantage of creating conditions that optimize the learning process. Much of learning in the actual clinical environment occurs sporadically. What is learned during a typical rotation is highly dependent on the particular mix of patient conditions to which residents are exposed. The next wave of residents will encounter a different mix of patient conditions. The creation of optimal conditions for learning refers to the purposeful manipulation and programming of patient conditions, equipment anomalies, and organizational variables that are combined to expose providers to appropriate levels of clinical challenge.

By adopting a crawl-walk-run approach to learning, the limited performance repertoires of less experienced providers can be efficiently expanded. More experienced providers typically test out at higher levels of simulated clinical challenge, thus enabling optimal learning for them and efficient use of simulation resources as well. A further feature is that difficult elements of a procedure or protocol can be selectively practiced again and again until they are mastered—something near impossible to achieve in the actual clinical setting.

Providing valuable feedback

The receipt of feedback and learning about the consequences of one's decisions and actions is the feature that gives simulation its compelling and engaging quality. It makes believers out of original skeptics. Feedback is what allows participants to recalibrate their performance. Much of the feedback occurs in real or near-real time with the participant "in the loop" as an active component, but not the only component, as the simulation unfolds. More focused forms of feedback with the guidance of an instructor are likely to occur during a debrief session in order to underscore and reinforce salient lessons to be learned from the simulated experience. Not all simulations share the goal of running in real time, however. For disease conditions that are difficult to diagnose because they evolve slowly over time, the pattern of subtle cues and manifestations can be more salient and learner-centered if they are compressed to run faster than real time. In doing so, a fuller range and progression of the patient's unfolding conditions across time can be sampled for the purpose of learning.

Integrating multiple skills

Simulation also plays a key role in promoting the integration of multiple skill components. Health care providers are educated and trained in separate disciplines, but many are lacking when they find themselves working in teams. Teamwork is a condition of work for which an otherwise superb clinical education might not provide very good preparation. It is to medicine's credit, and anesthesiology's in particular, that it pioneered the adoption of crew resource management techniques from aviation for improving communication, crew coordination, and failures of leadership.[4,5] Through the creation of realistic and challenging scenarios, simulation provides a venue for enabling the integration of diverse multiple skills that need to flow together for effective team performance. Likewise, procedural skills that are found in surgery or in placing a central line require a unique combination of perceptual, psychomotor, cognitive, and affective components that need to be exercised together and integrated into a fluid sequence of purposeful action.

Simulation in health care serves multiple purposes. The most frequently used purpose thus far is as a training technique. It exposes individuals and teams to realistic clinical challenges through the use of task trainers, mannequins, virtual reality, standardized patients, in-situ approaches, and other hybrid forms. However, of greatest relevance to the global Ebola response and other rapid-response situations is the use of simulation as a test bed to identify failure modes and other weaknesses in new procedures, protocols, and technologies that might otherwise

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be unanticipated. With Ebola unfortunately, the unintended consequences of breaches in protocols can be further contamination. The relevance of using simulation to identify gaps in hospital-derived Ebola protocols is illustrated in the Northwestern work. Clearly there is enough work to do across the entire spectrum of preparedness—from testing pre-hospital transport plans to management of the deceased.

Approaches and Uses of Simulation

The simulation community has witnessed tremendous growth and energy in the past 15 years, occurring in parallel with improvements in patient safety outcomes during the same period. A greater variety of simulation equipment, approaches, and uses is especially evident. One or more of these approaches may be employed, depending upon the clinical domain of interest and the difficulty of the tasks and procedures to be performed.

Part-task trainers: For many highly specific procedural skills, what is needed for training basic skills is an anatomically correct reproduction with landmarks of a portion of the patient. For example, a lifelike airway management trainer would include the upper torso and head to simulate real-world challenges when performing intubation, ventilation, and suction tasks. Part-task trainers exist for vascular access, paracentesis, cardiac assessment, lumbar puncture, and gynecologic examination, among many other applications.

Full-body mannequins: Fuller scale simulations that involve full-body mannequins expand a simulation center's training capacity by incorporating changing physiology.

The physiology of the mannequin is active and programmable with respect to vital signs, blood gas exchange, and heart sounds. Mannequins also have vocal capability (e.g., "my stomach hurts") and enable intravenous access. In addition to teaching physical examination skills, full-body mannequins are used for rapid response to failing patient conditions.

Team training and simulation: Much of health care delivery is a team activity, and there is considerable evidence of the patient harms that occur when clinical teams function poorly. Team training approaches combined with simulation typically focus on non-procedural skills—clear communication, coordination of roles and responsibilities, briefing others on intent and plans, and speaking up when needed—that are essential in many acute care environments, including emergency departments, operating rooms, and obstetric units. Key underlying principles of

teamwork in relation to patient safety can be found in TeamSTEPPS®, a comprehensive training system developed by AHRQ and the Department of Defense. It also contains a guide for using simulation in team training.[6]

Virtual reality: As a rapidly growing technology, virtual reality refers to an immersive computer-generated environment that simulates physical presence in real-world spaces (or imagined spaces), which, in turn, is influenced by the decisions and actions of the person experiencing it. In health care, learners might be immersed in an emergency department, operating room, or intensive care unit, assigned roles to play via avatars, and interact with the presented environment which, in turn, will change or lead to different branches as a consequence of the learner's actions.

Standardized patients: Standardized patients refer to lay people who are trained to portray medical patients with particular medical histories and physical findings, as well as patients with missing or incomplete information. In response to clinicians' inquiries, they may evoke a wide range of emotional and behavioral characteristics that occur in real practice. With the aid of an objective assessment tool, standardized patients have been used to evaluate and provide feedback on learners' specific skills and behaviors in response to challenging clinical situations. Such a situation could involve skill in error disclosure, for example, informing a loved one (portrayed by standardized actor) of a serious patient harm or preventable death of the patient.

In situ simulation: Literally meaning "in the situation," in situ simulation moves the simulation from a separate simulation center or locale into the actual clinical environment where the newly acquired knowledge and skills will be used. Given the time pressures, interruptions, and noise levels of many clinical environments, the aim is to provide a more realistic testing ground for the simulation and thereby enhance the learning experience. In situ simulations also help to identify latent threats and broader system issues that compromise patient safety.

Simulation as a test bed: Simulation is seeing greater use as a way to test, detect gaps, and improve clinical protocols, technologies, and equipment before their introduction on the unit floor. New health care technologies, devices, and equipment come to market with certain improvements and efficiencies, but also introduce new forms of error as unintended consequences. By taking advantage of human factors engineering methods, usability testing, and analytic tools, these unanticipated threats to safety in existing and evolving technologies and protocols can be identified and earmarked for improvement.

Modeling and simulation: Modeling is the process of representing simply but realistically an actual system that is infeasible to manipulate directly for the purpose of forecasting the effect of changes to the actual system under different conditions. Simulation in this context refers to the computerized running of the model, compressing time and space, and enabling one to perceive interactions and projected outcomes that otherwise would not be apparent. Taking into account relevant variables of interest, modeling and simulation can help ascertain the optimal design of a new emergency department or how it might perform under crisis conditions when patient load surges to 50, 75, or 100 percent above normal capacity.

While these simulation approaches serve different aims, they are neither mutually exclusive nor collectively exhaustive. They frequently are used in combination, giving rise to more nuanced and realistic simulation experiences. However, each approach is sufficiently unique to require different subject matter expertise and skill sets. As with any tool, each approach requires learning how to use it, as well as extensive preparation and practice, if it is to be implemented effectively.

The Concept of Mastery Learning

Mastery learning is a rigorous and structured form of competency-based instruction where all learners must demonstrate a high and uniform performance standard as established by panel members with expertise and experience in the particular domain. Various methods for setting performance standards in medical education exist.[7,8] In some military settings, a high performance standard might entail performing a complex procedure without a significant misstep two or three consecutive times in a row. Before moving on to the next unit of instruction or before learners can be considered competent to apply new knowledge and skills in their assigned setting, they need to accomplish the performance standard. In mastery learning, the number of simulation encounters is likely to vary before learners meet the performance standard (e.g., one learner may be able to perform the procedure at the mastery level after five simulation encounters while it takes another learner nine encounters to reach the same level). Training time of individuals may vary, but everyone is required to reach the same performance outcome. When learners leave the simulation environment, training directors know the skills and knowledge learners possess, because they have demonstrated it successfully. By way of contrast, in traditional apprenticeship learning environments, the time spent in the environment is fixed (e.g., a 1- or 2-month rotation), but individuals leave the learning environment with variable and often unknown knowledge and skill levels. When asked to perform a thoracentesis on a simulator, one study showed graduating internal medicine residents lacked sufficient skills, scoring an average of 52 percent on the skills-based exam when the minimal acceptable score was 80 percent.[9]

Mastery learning and other forms of deliberate practice align well with CDC guidance and assessment efforts already underway for Ebola response preparedness.

Retention of skills over periods of non-use is a well-known training challenge. There can be decay of both cognitive and procedural skills—knowing what to do and how to do it—that occurs with the passage of time without encountering actual patients or without engaging in some form of deliberate practice. Skill decay has been found in traditional procedures training in airway management,[10] advanced cardiovascular life support,[11,12] and advanced trauma life support.[13,14] On the other hand, use of simulation resulted in attenuated amounts of skill decay in the management of shoulder dystocia after 6- and 12-month retention intervals[15] and in central venous catheter insertion skills.[16] Mastery learning represents a different way of thinking about establishing, maintaining, and sustaining critical skills throughout the health care provider workforce when high stakes are involved. There is reason to believe that mastery learning and other forms of deliberate practice align well with CDC guidance already underway as part of the response to Ebola.

AHRQ's Programmatic Focus on Simulation

More than 2 decades ago, AHRQ initiated a grant program to advance knowledge of how simulation can improve patient safety across diverse health care disciplines, settings, and populations. Grant awards have been made on a steady basis, year after year, since program launch. Representative of the diversity were awards that focused on central venous catheter insertion, diagnosis of melanoma, obstetric emergency response drills, pediatric airway management, rapid response teams, acute coronary syndrome management in rural settings, patient care hand-offs, virtual reality team training, and disclosure of medical error.[17] In 2008, AHRQ along with other organizations, supported an academic emergency medicine consensus conference that was organized to define a national research agenda for maximizing effective use of simulation across undergraduate, graduate, and continuous medical education.[18] More recently, multi-year demonstration grants expanded into new areas, including cardiac surgery, pathology diagnosis, recognition of sepsis, pediatric resuscitation, leadership and emergency team performance, usability testing of rapid-prototype infusion pump designs, femoral arterial access, and measuring attentional capacity underlying laparoscopic skill.[19]

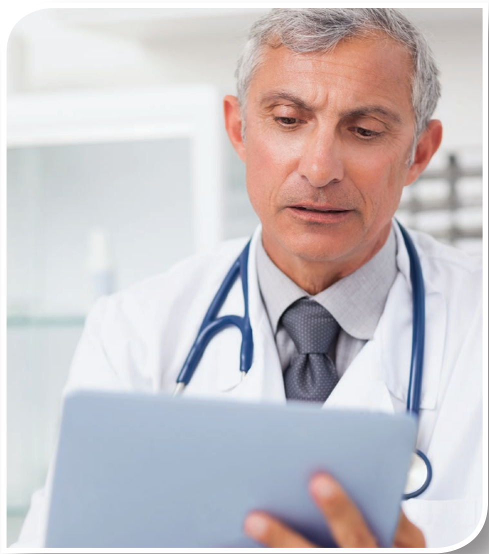
Despite simulation's impressive growth and an expanding evidence base, health care simulation applications are at an early stage of development compared to other high-risk industries. Aviation has been employing simulation for over 80 years and is still learning new things about effective implementation. To make the same advances as other hazardous industries, the programmatic effort needs to continue. The following table lists some of the research challenges that remain. While great progress has been made, there are now more opportunities and greater challenges to tackle.

Table 1. A Sample of Research Challenges in Health Care Simulation

Procedural skills	What are the best simulation methods and metrics to establish highly competent performance for procedures, processes, and protocols? Can criterion levels of performance be established for different levels of proficiency—novice, intermediate, and expert?
Skill decay	Are certain dimensions of skilled performance more subject to skill decay in the absence of practice than others? How much simulation retraining is needed to restore decayed performance to an earlier established level of proficiency?
Team performance	What are the appropriate performance measures for individuals within teams? What are the appropriate team performance measures when the collective team is the unit for measurement and analysis?
Methodological issues	Can agreed-upon nomenclatures, taxonomies, and metrics be established to guide research and aggregate research findings for the tasks, skills, and procedures that make up different provider specialty areas? How should concerns relating to variable patient acuity, complexity of operations, and less frequently occurring crisis-response situations be factored into metrics and research designs?
Training issues	What are the methods and analyses used to identify difficult tasks, clinical areas of vulnerability, and other performance deficiencies for which simulation is appropriate? What type of performance records need to be kept on individuals and teams to track performance levels achieved and for appropriate placement into subsequent simulation sessions?
Accreditation and certification	How can simulation be used reliably for accreditation of special programs and certification of specialists to ensure that knowledge, skills, and standards are maintained at the highest levels of quality and safety? How can simulation be used to ensure that veteran practitioners learning new procedures and technologies are qualified in their use and do not put patients at increased risk?

Lessons Learned From Simulation and Training

Myriad lessons have been learned since the launch of AHRQ's grant program on simulation. Those selected here focus on some of the more persistent lessons that still represent a challenge.



Recognizing simulation is not just for residents and nursing students: The education and training of providers is a life-long process, especially as new technologies, less invasive procedures, and new protocols make their way into clinical practice. Given their senior status and years of successful practice, veteran clinicians might not fully appreciate the perils of climbing the learning curve with respect to patient safety as different skill sets are acquired. The same need for practice applies to procedural skills where complying with full sterile technique is critical. Since attending physicians routinely relegate many of the simpler procedural tasks to residents, they may find, when called upon to step in, they have become deskilled in the same set of tasks.

Starting with a problem analysis (known as requirements analysis in systems engineering): The quality and effectiveness of simulation-based training is enhanced when there is a strong and direct relationship between the training content and the performance demands placed on providers. An essential first step is deciding what needs to be trained. What are the performance deficiencies? A task analysis is employed to establish acceptable performance for a set of tasks. It answers the questions: what tasks, performed in what manner, under what conditions, in response to what cues, to what standards of performance, are critical for highly competent performance. Doing an informative problem analysis is labor intensive; frequently too few resources are devoted to it.

Using a systems approach: Considerable variation and gradations of effectiveness exist in training efforts to design and develop simulation-based materials. A systems approach takes the guesswork out of these efforts. Starting with the problem analysis, the systems approach further encompasses design, development, implementation, and evaluation.[21] Training objectives are established during the design stage. A well stated objective specifies the required outcomes in observable and measureable terms. It identifies what the learner is to do, the conditions under which tasks are to be performed, and the standard of performance that must be achieved. During development,

the selection of simulation approach along with support materials that will best satisfy the training objectives and promote optimal learning takes place. Iterative evaluation occurs with small groups of representative users for the sole purpose of improving the materials. The implementation stage affords the opportunity to evaluate a fuller and integrated complement of simulation approach, support materials, learners, instructors, equipment, and facilities all functioning together. Once the simulation program has been operational for a while, it undergoes an in-depth summative evaluation.

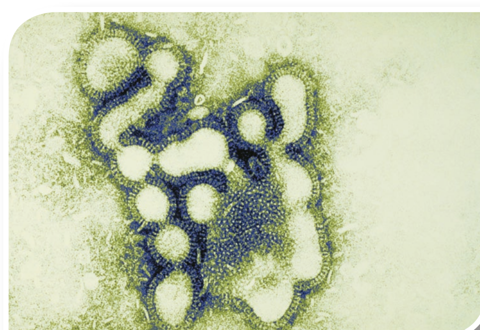
Given that unexpected events will occur, there are lessons to be learned regarding their anticipation and mitigation before these events worsen and cause harm.

Managing the unexpected: The value of a systems approach for training development of tasks embedded in procedures and protocols is well understood. However, there are many clinical situations where a traditional task analytic approach will be limited and will need to be supplemented by cognitive engineering insights as to how the more dynamic aspects of clinical work actually gets done. Because of the uncertainty, complexity, and rapidly emerging conditions that occur in many health care settings, it is not possible to develop step-by-step procedures for every possible emergent event. As the role of the provider shifts from one who executes procedures to that of a problem solver in uncertain circumstances, the case is made for resiliency in managing the unexpected. Resiliency is one of the hallmarks of high-reliability organizations.[22] Given that unexpected events will occur, there are lessons to be learned regarding their anticipation and mitigation before these events worsen and cause harm. Simulation provides a needed platform for operationalizing and testing resiliency concepts.

Ensuring effectiveness of simulations: As with many tools, AHRQ's funded simulation investigators are learning it takes practice to maximize the effectiveness of their simulations. Some investigators have expressed unease in attempting to test the effectiveness of their simulations before they have sufficient time to maximize fully their effectiveness. The amount of time and effort it takes to develop scenarios and support materials and effectively implement the simulation may be unappreciated at the time of grant writing. Just as it takes considerable practice for learners to acquire new skills and reach a high standard of performance, it also takes practice and considerable trial-by-error development for patient safety investigators to maximize the effectiveness of their simulations.

Future Directions

A recent *Simulation in Healthcare* editorial[23] raised a key question: will the lessons learned from our response to Ebola aid us in a more systematic response to Severe Acute Respiratory Syndrome, Middle East Respiratory Syndrome, other virulent influenza forms, and the more contagious seasonal influenzas? As noted in this brief's foreword, there is near certainty that similar infectious disease outbreaks will occur in the future and other lessons are yet to be learned. As the HHS agency charged with improving health care quality and safety, AHRQ applauds the efforts of the simulation community in demonstrating the relevance of simulation to the Ebola response and in highlighting the continuing, broader worldwide challenge that has been neglected too long. What is learned about Ebola extends beyond Ebola.



To shape a more proactive and safer health care future with the greatest impact, collaboration is needed between many government agencies and professional groups. The point-of-care experience of physicians, nurses, patients, and support personnel needs to be captured. Many voices need to be heard—infectious disease experts, preparedness specialists, simulation researchers and vendors, health care educators, systems and human factors engineers, facility designers, health care technologists, and those who are at the forefront of innovation and new ways of thinking. Given the expertise that is available, a coordinated collective resolve, and plenty of hard work, there is reason to believe that the safe health care encounters we would like to see and deserve can be realized.

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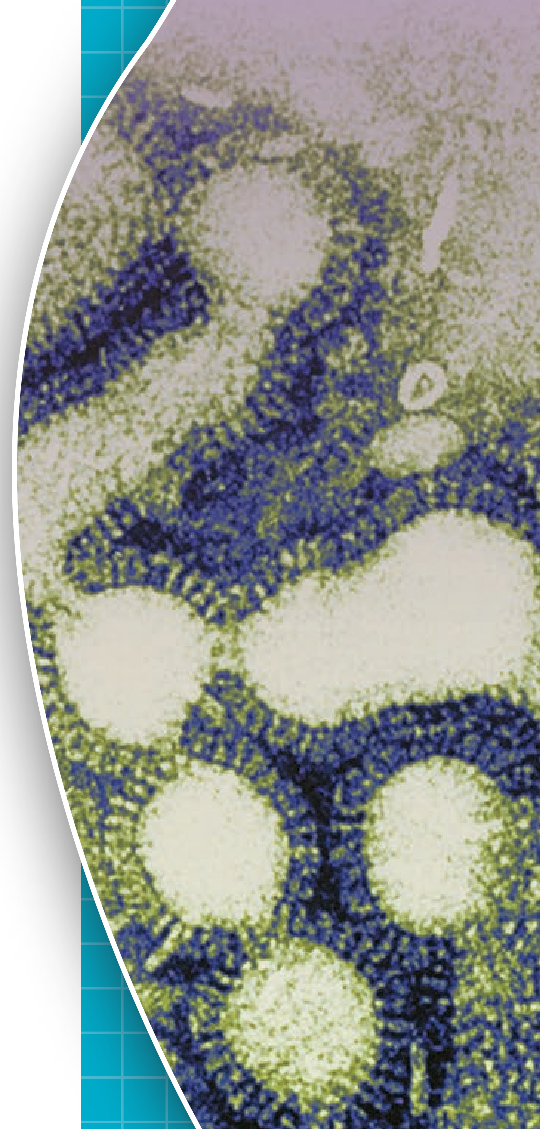

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Cover photo of health care worker in personal protective equipment is courtesy of the Centers for Disease Control and Prevention.

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