Simulation and Human Factors Analysis of the Delivery of Anesthetic Care in Austere Environments

Benjamin H. Lee, MD, MPH1; Michael Rosen, PhD2; John Sampson, MD1; Rahul Koka, MD, MPH3; Megan K Marx, MSN, MPH1; Adaora Chima, MBBS, MPH1; and Eric V. Jackson, Jr, MD, MBA1,3

1Department of Anesthesiology/Critical Care Medicine and the 2Armstrong Institute of Patient Safety and Quality, Johns Hopkins University School of Medicine (JHU/USM), Baltimore, MD.; 3Value Institute, Christiana Care Health System, Newark, DE.

Abstract

Background: Anesthesia-related adverse events likely contribute to high peripartum morbidity and mortality rates in resource-poor environments. In low/middle income countries (LMICs), estimates for peripartum mortality range from 1:150 to 1:3000. Anesthesia care delivery is a complex interaction between anesthesia care providers and equipment; anesthesia delivery systems are the most common source of equipment-related problems. Simulation combined with human factors approaches may help identify optimal conditions for reducing preventable harm while using anesthesia delivery systems in resource-constrained settings.

Objectives: To evaluate the usability of the Universal Anesthesia Machine (UAM), an anesthetic delivery system designed for use in austere environments, among anesthesia providers of varying expertise during systems-based and adverse anesthetic-related events.

Methods: After obtaining IRB approval, anesthesia care providers were enrolled. Simulation scenarios were performed to analyze the subjects' ability to perform machine checks, recognize machine faults, and analyze performance and human/machine factors using scenarios that represented patient-related and environment-related issues associated with the delivery of anesthesia with the UAM. Human factors issues and machine performance were examined using scripted scenarios depicting power outage, disruption of oxygen supply, machine failure, as well as clinical patient-related intraoperative events. The investigators are continuing to enroll providers and are preparing the system and tools used to evaluate participant performance, environmental factors, and human factors methodologies.

Results: Four scenarios were developed to assess machine and human factors issues: UAM machine check, wake/fatal patient, power failure, and patient with intraoperative bronchospasm. UAM use was analyzed using qualitative analytical tools with providers completing questionnaires, NASA task load analysis, and key-task item checklists. Semi-structured interviews were analyzed using thematic synthesis; issues disordered thus far include possible provider fatigue, understanding of when machine converts from flow-over anesthesia to draw-over anesthesia, and the ability to assist ventilation in the anesthetized patient, possible provider fatigue with prolonged use, understanding of when machine converts from flow-over anesthesia to draw-over anesthesia modes of operation, and using UAM machine cues to provide adequate minute ventilation without monitors for respiratory rates and tidal volumes.

Conclusions: Use of human factors methodologies and simulation are useful tools to assist in the efficient and safe use of the UAM, and would likely be useful for introduction of anesthesia delivery systems/equipment for use in resource-challenged environments.

Background

Global surgical volume is estimated to be large with an estimated 234 million surgical procedures annually worldwide; a majority of these procedures are carried out in high-income countries (HICs). A majority of urgent surgical need occurs in low/middle income countries (LMICs) in which human, infrastructure, and financial resources are limited. In 2008, the worldwide burden of surgical disease was estimated to be 1% of the global burden of disease.

Disparities in surgical services in LMICs have existed for quite some time. In HICs, anesthesia-related adverse events are reported to be less than 1 in 200,000. With limited infrastructure for record keeping in LMICs, it is difficult to rely on mortality statistics to ascertain causality; however, it is believed that in LMICs, the anesthesia-related mortality rate is between 1:150 and 1:3000. Much of this preventable harm is due to anesthetic care, care that often lacks the appropriate levels of monitoring and technology and that may lack adequately skilled providers.

Simulation is a powerful tool for evaluating systems-based practice. It affords the opportunity to bring the world into the lab, that is, an opportunity to evaluate complex performance as it happens in clinical practice in a safe and controlled environment. Human factors is a multidisciplinary approach to the design and evaluation of socio-technical work systems that applies the scientific understanding of human abilities and limitations to the design of tasks, tools, technology, work structures, and processes in order to maximize overall system performance.

Objectives

To evaluate the usability of the Universal Anesthesia Machine (UAM) to determine if the UAM will provide an alternative to conventional anesthesia machines that:

a. Is easy to use
b. Requires inducing user error
c. Is satisfying to use
d. Can be operated easily and safely during routine general anesthetic procedures.

To evaluate the usability of the UAM among anesthesia care providers of varying expertise in environments simulating austere environmental conditions and with systems-based and adverse anesthetic-related events.

Methods

After obtaining IRB approval, anesthesia care providers were enrolled. Demographic information on the participants was obtained. Simulation scenarios were performed to test the participant's ability to perform machine checks, recognize machine faults, and analyze performance and human/machine factors using scenarios that represented patient-related and environment-related issues associated with the delivery of anesthesia with the UAM. Human factors issues and machine performance were examined using scripted scenarios depicting power outage, disruption of oxygen supply, machine failure, as well as clinical patient-related intraoperative events. Participants were encouraged to "think aloud" during the scenario. Audiovisual recordings were made and rated using a key-action item checklist, the NASA Task Load Index (TLX), and a semi-structured interview. Use of human factors methodologies and simulation are tools to assist in the efficient and safe use of the UAM, and would likely be valuable for the introduction of anesthesia delivery systems/equipment for use in resource-challenged environments.

Results

Participant enrollment and data analysis are ongoing. Semi-structured interviews were analyzed using thematic synthesis; this is an initial pilot study to present the system and tools used to evaluate participant performance, environmental factors, and human factors methodologies.

Conclusions

Use of human factors methodologies and simulation are tools to assist in the efficient and safe use of the UAM, and would likely be valuable for the introduction of anesthesia delivery systems/equipment in resource-challenged environments. With a wide variety of anesthesia care providers of differing clinical experience and training, the use of simulation and human factors testing can be useful tools to guide instruction/training with unfamiliar equipment, examine human-machine interface issues, and evaluate knowledge and performance in a safe environment with no patient harm.

References


Supported by a research grant from Gradian Health Systems, LLC