Ergonomic aspects of Clinical and Surgical Procedures Symposia Proposal
56th Annual Meeting of the Human Factors and Ergonomics Society
October 22-26, 2012
Westin Boston Waterfront Hotel
Boston, Massachusetts, USA

Objectives: This session aims to identify common ergonomic issues and solutions that affect both outcomes and workers who perform various clinical and surgical procedures. This session will frame and answer questions regarding both the current and future practices of clinical and surgical procedures. Presentations by veteran researchers on a diverse range of surgical and clinical procedures will provide a framework for this discussion. The panel moderators will collect and organize questions from the speakers and audience to guide the panel discussion and to engage all of the speakers in the discussion to achieve the symposium aims.

Moderators:

Thomas J. Armstrong, Ph.D., CIH, CPE, Professor of Industrial and Operations Engineering; Professor of Biomedical Engineering; and Director of Center for Ergonomics, University of Michigan

David Rempel, MD, CPE, Professor of Medicine (UCSF); Professor in Bioengineering (UCB); School of Medicine, Division of Occupational and Environmental Medicine, University of California

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Titles of papers and authors of individual presentations: The following papers and speakers have been confirmed. A couple of the speakers have proposed two papers. Depending on how much time is available, we can limit everyone to one paper each. We also will welcome recommendations for additional papers from the program organizers. The program could fit into one of your two-hour slots by limiting the speakers to 5 minutes each. It is preferable to have one 180-minute block in which we can give each speaker 10 minutes and still have 60 minutes for a panel discussion. Alternatively, the session can be divided into two 90 minute sessions.

1. Disparities between industrial and surgical ergonomics. J. Seagull, University of Michigan

2. Standardization of surgical procedures for identifying best practices and
training. Thomas Armstrong, Stephen Kasten, Denny Hu, Adam Frischknecht, Rebecca Minter, Pamela Andreatta, University of Michigan


4. Ergonomic considerations in natural orifice transluminal endoscopic surgery. Caroline G.L. Cao and Cristina Rivera, Department of Mechanical Engineering, Tufts University

5. Ergonomics risk assessment of nasogastric tube placement and implications for design and training. O. Anderson, Imperial College London, England, Peter Buckle, University of Surrey

6. Ergonomics of novices and experts during simulated endotrachial intubation. Michelle Hallbeck, A. de Laveaga, M. Wadman, University of Nebraska

Optional presentations for expanded or second symposia:


2. Ergonomic considerations in robot assisted surgery. Caroline G.L. Cao and Cristina Rivera, Department of Mechanical Engineering, Tufts University

Abstracts:

Proposed Symposia: Ergonomic aspects of Clinical and Surgical Procedures and Training. Moderators: Thomas Armstrong, University of Michigan; David Rempel, University of California at San Francisco

This symposium aims to identify ergonomic issues that affect both the performance and well being of persons who perform clinical and surgical procedures. The series of presentations will examine these issues for various procedures, e.g., laparoscopic surgery, microvascular surgery, colonoscopies, robot assisted surgery, transluminal surgery, placement of nasogastric tubes and training. The presenters will then discuss common problems, solutions and research needs.

Disparities between industrial and surgical ergonomics. J. Seagull, Department of Medical Education, University of Michigan.

A surgeon’s work environment and working conditions are often harsher than those of an industrial worker. Accepted principles and regulations of ergonomics in manufacturing are largely ignored or absent in the medical/surgical domain. Examples include poor surgical tool handle design, awkward and stressful surgical postures, prolonged standing without breaks and without a foot mat. In these and other areas, there are documented "best practices" for industrial hygiene and ergonomics that are not yet widely accepted for surgery. There is support in the literature for innovations in surgical ergonomics, yet adoption is not widespread. In the absence of these ergonomic principles, surgical repetitive strain injuries in minimally invasive surgery are reaching epidemic levels. As ergonomists, it falls upon us to understand why current solutions have not been widely adopted within this domain, and to derive solutions to the unique challenges of surgery.


Standardized work helps to prevent errors of omission or admission. It also provides benchmarks by which process or material variations can be identified and corrected, for communicating procedures from one person to another so that they can be replicated. Traditional “see one – do one” training results in significant method variations among surgeons and clinics. Methods for describing manual work described by Gilbreth in the early 20th century are still widely used for industrial applications, but are not well suited for complex medical procedures. We have video recorded 55 microvascular anastomoses through video cameras mounted in the dissecting microscope used by the surgeons. A hierarchical task analysis was used to decompose the observed procedures into
successive levels of detail. Focus groups were then conducted with experienced microvascular surgeons to help define steps and step attributes necessary to describe a procedure so that other surgeons can perform the procedure exactly the same way. Coincidently, it was found that because the surgeons’ attention is confined to a very small field of view in which they can see only the veins and arteries and the ends of their instruments, they often have difficulty communicating with others in the operating room. The proposed Taxonomy facilitates communication among clinicians and for developing standard methods that result in the best outcomes for teaching. Standardized methods that provide the best outcomes should be developed for all clinical and surgical procedures.

**Distal Upper Extremity Musculoskeletal Risk Factors Associated with Colonoscopy.** David Rempel, David Lee, Amandeep Shergill, University of California at San Francisco and University of California at Berkeley.

**Background:** Physicians who perform endoscopies are at increased risk for developing recurrent thumb, hand, and elbow pain. We evaluated forearm muscle loads and wrist postures during routine colonoscopy to understand the distal upper extremity musculoskeletal risk factors associated with the different subtasks of colonoscopy.

**Methods:** Twelve gastroenterologists were studied while each performed 2 to 5 colonoscopies. Data were collected for the four subtasks of colonoscopy. Bilateral forearm extensor carpi radialis (ECR) and flexor digitorum superficialis (FDS) surface electromyography and bilateral wrist postures were recorded continuously (Noraxon USA Inc, Scottsdale, AZ).

**Results:** The mean duration (SD) of colonoscopy was 24.2 (±12.1) minutes and was dominated by the withdrawal subtask [13.7 (± 8.8) min] followed by right colon insertion [5.8 (± 4.8) min], left colon insertion [3.5 (± 3.1) min], and retroflexion [1.2 (± 2.1) min]. Median (APDF50) and peak (APDF90) left forearm muscle activity was significantly greater than right forearm muscle activity across all subtasks. Median and peak ECR muscle activity was significantly greater during the left and right colon insertion subtasks compared to retroflexion. Both the right and left wrists were predominantly in wrist extension during all phases of colonoscopy. The left wrist was predominantly in radially deviation while the right wrist was predominantly in ulnar deviation. In all cases the left hand manipulated the colonoscope head while the right hand manipulated the insertion tube.

**Conclusion:** During colonoscopy the left forearm muscle activity was higher than right forearm activity due to differences in hand activity, grip force, and increased wrist radial deviation. The risk factors for the left hand may be reduced with alternative designs and support mechanisms for the colonoscope head.

**Neck and upper back pain among surgeons during robotic surgery.**

Over 23% of robotic surgical cases result in significant neck and upper back pain
in the surgeon. This is may be due to the sustained thoracic and neck flexion required to see the computer monitor. In the da Vinci Si robotic system, the surgeon’s line of sight to the center of the monitor is adjustable between 40 to 60 degrees below the horizon. This low line of sight was designed so that it intersected with the location of the surgeon’s hands even though the hands are obscured by the computer monitor. In order to measure thoracic, neck and head posture video recordings of the surgeon from the side was processed using an automated computer-vision based algorithm. The neck flexion angle, moment around the C7 vertebrae due to head posture, and the flexion/abduction angle and moment of the arm about the shoulder joint were measured and calculated. The head, thoracic and upper arm postures will be presented based on surgical procedure and sub-tasks. The findings challenge the limited range of adjustability of the robotic monitor tilt angles and question whether the visual line of sight should intersect with the location of the hands even if the hands are not visible. The study results may be used to recommend alternative design configurations for robotic surgery workstations.

**Ergonomic considerations in natural orifice transluminal endoscopic surgery.** Caroline G.L. Cao & Cristina Rivera, Department of Mechanical Engineering, Tufts University.

From a technological perspective, there is a natural progression in surgical technique, evolving from traditional open surgery to minimally invasive surgery (MIS), to non-invasive surgery (i.e., natural orifice transluminal endoscopic surgery (NOTES)). The last is the most recent, and most challenging, for the surgeon. In NOTES, surgical sites are accessed through a single incision made either transgastrically or transrectally, or transvaginally (for the female patient population). Visualisation is limited and manipulation of target tissue is constrained. A hierarchical task analysis of NOTES appendectomy and NOTES cholecystectomy procedures was conducted, along with a cognitive task analysis performed with expert NOTES surgeons. Analyses revealed increased complexities of the NOTES technique compared with the laparoscopic technique, resulting in significantly longer procedure times (at least twice as long depending on the procedure). Results also showed that the human factors and ergonomics issues normally encountered in MIS (such as spatial disorientation and limited degrees of freedom in tool manipulation) are more pronounced in NOTES. Additional ergonomic issues as a result of the increased complexity of the surgical technique are also noted. For example, handling of target tissue is limited to one aspect of the surgical site, as defined by the flexible endoscope’s approach. A second tool is sometimes needed to lift or anchor the target tissue from the opposing aspect, requiring an additional port to be introduced – thereby negating the cosmetic advantage of “no scars” from the NOTES procedure. These additional difficulties are partly due to the fact that the surgical tools and instrumentation used for NOTES are borrowed from the MIS tool box, which have not been developed to meet the increased task demands. This presentation will
present the results of this study, with specific design recommendations for NOTES instrumentation.


The placement of nasogastric tubes is known to be prone to error and may lead to serious issues for patient safety and wellbeing. In some instances these have been catastrophic and resulted in the death of the patient. This study sought to explore the potential risks associated with this procedure through the use of systematic prospective risk assessment. The research team used the Prospective Hazard Analysis (PHA) toolkit developed by Ward et al (2010). The study has shown a wide number of risks that cover equipment design, work organization, and training issues. The link between equipment design and training provides an important example of the need for a systematic approach to reducing errors and improving resilience in this aspect of healthcare.

**Ergonomics of novices and experts during simulated endotrachial intubation.** M. Hallbeck, A. de Laveaga, M. Wadman, University of Nebraska.

Endotracheal Intubation, ETI, is an airway procedure commonly used to secure the airway for a variety of medical conditions. Proficiency in ETI procedures requires significant clinical experience and insufficient data currently exists describing the optimal physical ergonomics of successful direct laryngoscopy. The research objectives of this study were to examine how ETI time, error and practitioner biomechanics varied among clinical experience levels and hospital bed heights. Twenty novice and expert participants -- 15 third and fourth-year medical students and 5 experts with more than 5 years of experience in emergency airway management performed simulated ETI procedures using a supine Difficult Airway Trainer at the 96 cm and 62 cm height on an adjustable-height hospital bed. Task completion time and ETI errors did not vary with hospital bed height. Experts exhibited greater wrist extension and less ulnar deviation during task trials. Posture measurements using dual-axis goniometer and torsiometer showed that experienced practitioners grasped the laryngoscope in-line with their forearm and across their palm, rather than gripping the handle normal (perpendicular in orientation) to the forearm and as a result they can complete ETI procedures with less movement or awkward postures of the hand and wrist. EMG measurements of the flexor and extensor carpi radialis muscles showed that clinicians exert 5% - 30% of the maximum effort to perform the simulated task regardless of experience. This work demonstrates how ergonomic studies can be performed to guide ETI procedure training and for improving the design of laryngoscope handles.

Laparoscopic endoscopic single-site surgery (LESS), the next advance in minimally invasive surgery (MIS), is a feasible surgical technique performed using a single, small incision typically within the patient’s navel. Since all of the instrumentation is inserted through a single incision, the surgeon must contend with instrument collisions, transposed instrument viewing (i.e., the surgeon’s right instrument operates on the left side), and an in-line view of the instruments. To examine quantitative and qualitative ergonomic differences between conventional laparoscopy and LESS a study was conducted in which 12 male and 12 female subjects performed a Fundamentals of Laparoscopic Surgery (FLS) peg transfer task using a Fundamentals of Laparoscopic Surgery, FLS, manual skills trainer and two standard length non-locking 5-mm. This novel surgical simulator was adapted from the FLS manual skills trainer for LESS to include a 15-mm synthetic skin interface. For conventional laparoscopy, two standard 12-mm working ports were inserted through a 1.5-cm initial incision approximately 18-cm apart in the synthetic skin. Task completion time, error rates (i.e. number of dropped pegs) and a questionnaire were used to compare the ports. Completion times or error rates were similar for both treatments; however, LESS was qualitatively rated as more difficult and lower overall compared to conventional laparoscopy. Although LESS is feasible, instrumentation challenges increase the complexity and duration of surgeries. In order for LESS to become a viable alternative to conventional laparoscopy, LESS-specific instrumentation needs to be developed that allows for comparable retraction and triangulation.