Society for Technology in Anesthesia

2011 STA Annual Meeting

January 12-15, 2011

Venetian Hotel
Las Vegas, Nevada

Society for Technology in Anesthesia
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Society for Technology in Anesthesia

Society for Technology in Anesthesia Annual Meeting

Dear STA Annual Meeting Attendee,

On behalf of the program committee and Board of Directors, welcome to this year's STA Annual Meeting. I would personally like to thank Dr. Ravindra Prasad and Dr. Maxime Cannesson for organizing this event and securing the outstanding faculty, who have generously given their time to prepare and present their lectures and demonstrations.

The STA Annual Meeting affords an opportunity for clinicians, technicians, engineers and industry specialists at all levels to meet and exchange ideas on the future of anesthesia and healthcare related technologies. We hope that you all take advantage of this unique venue and take time to meet with your fellow attendees during the meeting.

With the increasing fiscal and political challenges that face healthcare and industry, the Society for Technology in Anesthesia and it's Annual Meeting become more essential in understanding and shaping our future. As a Society, we look for continued growth and new input moving forward.

Thank you for joining us. We look forward to a successful meeting.

D. John Doyle, MD. PhD
STA President

Society for Technology in Anesthesia

Mission Statement

The Society's mission is to improve the quality of patient care by improving technology and its application. The Society promotes education, research, collaborates with location, national and international organizations, sponsors meetings, exhibitions, awards grants, and recognizes achievement.

Meeting Objectives

1. Examine and identify problems and solutions in the anesthesia workspace with a special emphasis on exploring new developments in drug delivery, information management and patient monitoring.
2. Explore human factors and ergonomic approaches to improving anesthetic medication delivery systems and patient monitoring systems
3. Investigate safety technologies in domains such as aerospace engineering to see how they may relate to the improvement of clinical care
4. Explore opportunities to advance and enhance environmentally responsible practices within anesthesia care.

CME Accreditation Statement

This activity has been planned and implemented with the Essential Areas of the Accreditation Council for Continuing Medical Education (ACCME) through the joint sponsorship of the Society for Technology in Anesthesia (STA) and the International Anesthesia Research Society (IARS.) The IARS is an accredited by the ACCME to provide continuing medical education for physicians. The IARS designates this continuing medical educational meeting for a maximum 15.25 AMA PRA Category 1 Credit(s)TM. Physicians should claim only those hours of credit that he/she actually spent in the educational activity.

Speaker and Presenter Disclosure Statement

The International Anesthesia Research Society (IARS) adheres to ACCME standards regarding industry support of continuing education. Disclosure of faculty and commercial relationships, if any will be made known at the activity. Speakers are also expected to openly disclose inclusion or discussion pf any off-label, experimental, or investigational use of drugs or devices in their presentations.

Society for Technology in Anesthesia

STA 2011 Annual Meeting Speakers

Jim Bagian, MD, PE is an engineer and was a NASA scientific astronaut. He received a Bachelor of Science degree in mechanical engineering from Drexel University and a doctorate in medicine from Thomas Jefferson University. Dr. Bagian became a NASA astronaut in July 1980. He took part in both the planning and provision of emergency medical and rescue support for the first six shuttle flights. He served as the Astronaut Office coordinator for Space Shuttle payload software and crew equipment, as well as supporting the development of a variety of payloads and participating in the verification of Space Shuttle flight software. He was responsible for the development program and implementation of the pressure suit used for crew escape and other crew survival equipment that was used on future Shuttle missions. Dr. Bagian was in charge of Shuttle search and rescue planning and implementation for the Astronaut Office. Dr. Bagian has authored numerous scientific papers in the fields of human factors, environmental and aerospace medicine. A veteran of two space flights (STS-29 in 1989 and STS-40 in 1991), and has logged over 337 hours in space. He left NASA in 1995. Dr. Bagain was elected to membership in the National Academy of Engineering and the Institute of Medicine. Dr. Bagian is currently the Veterans Health Administration (VHA) Chief Patient Safety Officer, and Director of the VA National Center for Patient Safety and is also a member of the Detroit Science Center's Board of Trustees.
**No Disclosure*

Charlotte Bell, MD is the Chair of the American Society of Anesthesiologists Committee on Equipments and Facilities. Dr. Bell attended the University of Kansas School of Medicine and completed her residency at the University of California-San Francisco. She is former Professor and Director of Pediatric Anesthesia at New York University. Currently, she is employed by Milford Anesthesia Associates in Milford, Connecticut. Dr. Bell is a Past President of the Society for Technology in Anesthesia.
**No Disclosure*

James Berry, MD is currently the Professor of Anesthesiology and Chief of the Division of Multispecialty Anesthesia. Dr. Berry attended the University of Texas Medical School in Houston and went to complete a transitional internship at St. Joseph's Hospital in Houston, Texas. In addition, he completed a research fellowship with the Department of Biophysics at the University of Houston and completed his residency in anesthesiology at the University of Texas. Dr. Berry's research specialty focuses on the environmental effects of inhaled anesthetics.
**No Disclosure*

George Blike, MD is the Medical Director of Patient Safety and Training Center at Dartmouth-Hitchcock Medical Center. Dr. Blike attended medical school at the University of Cincinnati College of Medicine. He went on to complete his internship at the Hartford Hospital in Hartford Connecticut and his Anesthesiology residency at the Yale-New Haven Hospital. Dr. Blike joined the Dartmouth-Hitchcock Medical Center in 1992.
**No Disclosure*

Frank Block Jr., MD is a Professor of Anesthesiology at the University of Arkansas College of Medicine in Little Rock, Arkansas. Dr. Block received his M.D. from the University of Virginia, where he would also go on to complete his residency. Dr. Block would complete a fellowship in Anesthesiology at the University of North Carolina.
***Consultant Mind-Ray North America*

STA 2011 Annual Meeting Speakers (cont.)

Jesse Ehrenfeld, MD, MPH is an Assistant Professor at Vanderbilt Medical School in the Department of Anesthesiology where he serves as Director of the Center for Evidence Based Anesthesia and Director of the Perioperative Data Systems Research Group. He received his M.D. from the University of Chicago Pritzker School of Medicine and his master's degree from the Harvard School of Public Health. Dr. Ehrenfeld's research interests include bioinformatics and the application of information technology to increase patient safety in the operating room environment. Dr. Ehrenfeld's work has led to the presentation of over 40 abstracts at national/international meetings and the publication of over a dozen manuscripts in high impact journals. He has co-authored three textbooks and is co-editing three more. His work around improving physiologic monitoring now includes five other major academic centers – where he is now determining how decision support tools can best impact perioperative care. In addition to his burgeoning research career, Dr. Ehrenfeld has received numerous teaching awards and serves on several distinguished national committees including the ASA Standards & Practice Parameters Committee, the New England Journal of Medicine Publications Committee, and the AMA Public Health Committee.
**No Disclosure*

Richard Epstein, MD is a Professor of Anesthesiology and the Director of Anesthesia Information Systems at tJefferson Medical College in Philadelphia Pennsylvania. Dr. Epstein received his M.D. from the University of Pennsylvania School of Medicine. Dr. Epstein's expertise and research interests include; Anesthesia Information Management Systems, Perioperative Decision Support, Drug Diversion Detection and Medical Informatics.
**No Disclosure*

Scott Kelley, MD received his M.D. from the University of California San Francisco. Prior to attending medical school Dr. Kelley received his Master's Degree in Biological Sciences from Stanford University. Currently, Dr. Kelley is the Vice President of Medical Affairs for Covidien.
** Disclosure: Covidien*

Martin London, MD is a Professor of Clinical Anesthesia at the University of California San Francisco. His research interests are in the field of cardiovascular anesthesia, theepidemiology of perioperative cardiovascular morbidity/mortality and health services research in this area. Clinically, he provides anesthesia for adult cardiac, major vascular and thoracic surgery. Dr. London is an active ember in the Society of Cardiovascular Anesthesiologists.
*** Received Material & Educational Support Aspect Medical Systems. Consultant for Almaden IBM Research Laboratory*

Paul Mannheimer, PhD has more than 25 years of hands-on experience in corporate technology research and product design of: patient monitors; reusable and single patient-use non-invasive sensors, optoelectronic devices, optical fibers and fiber optics components. He was a key contributor in creating, developing and testing new products for use in clinical settings with extensive practical experience in the regulatory, international standards and patent prosecution process. He is the published author of numerous peer-reviewed research papers, abstracts and white-papers. He has more than 70 issued patents with additional U.S. and foreign patents pending. He received his PhD in Biomedical Engineering from the University of Lubeck, Germany.
***Disclosure: Consultant for Covidien/Nellcor*

Timothy Morey, MD currently serves as Professor of Anesthesiology at the University of Florida. His research efforts revolve around medical applications of nanotechnology. Dr. Morey graduated from the University of Florida with a M.D. and completed his residency at Shands Hospital at the University of Florida in Gainesville, FL.

STA 2011 Annual Meeting Speakers (cont.)

John Pawlowski, MD, PhD is the Co- Director of the Shapire Simulation and Skills Center at Beth Israel Deaconess Medical Center in Boston. He is also the Director of Thoracic Anesthesia and an Assistant Professor of Anesthesiology at Harvard Medical School. Dr. Pawlowski completed medical school at UMass Memorial Medical Center. He completed his Residency in Anesthesiology and Fellowship in Cardiac Anesthesia at Massachusetts General Hospital .
**No Disclosure*

Michael Pilla, MD is an Associate Professor of Clinical Anesthesiology and Assistant Director, Residency Program in Anesthesiology at Vanderbilt University School of Medicine. He earned his MD from the University of Pennsylvania School of Medicine, and completed his anesthesiology residency at the Massachusetts General Hospital/Harvard Medical School. He received advanced training in acupuncture from the UCLA/Helms Medical Institute and is a certified acupuncturist. Following residency, Dr. Pilla practiced anesthesiology in the private sector before joining Vanderbilt in 2004 as an Assistant Professor of Anesthesiology. His clinical interests include liver transplantation and vascular anesthesia, while his academic interests include resident and student education, controlled substance diversion protection, and provider and patient safety. He is the Director of Advanced Clinical Training, and co-directs one of the four Vanderbilt Medical School Advisory Colleges, and as such is directly responsible for the career counseling and wellness programs for one fourth of the students in the School of Medicine.
**No Disclosure*

Mohamed Rehman, MD is an Anesthesiologist in the Department of Anesthesiology and Critical Care Medicine, where he is the Director of Health Information Management and the Director of Liver Transplants at the Children's Hospital of Philadelphia. Dr. Rehman attended Mysore Medical College in Mysore, India. He completed his residency at the University of Miami. Dr. Rehman is a Past President of the Society for Technology in Anesthesia.
**No Disclosure*

Brian Rothman, MD is an Assistant Professor of Anesthesiology and Medical Director of Perioperative Informatics at Vanderbilt University Medical Center. Dr. Rothman received his medical degree from the University of Cincinnati and completed his residency training at The Johns Hopkins Hospital in Baltimore, MD. He currently serves on the Committee for Electronic Media and Information Technology for the American Society of Anesthesiologists (ASA) and is a member of the Board of Directors for the American Association of Clinical Directors (AACD). Dr. Rothman has presented at numerous national meetings, and his research in mobile perioperative information management systems recently received both the Innovation and Clinical Application of Technology Awards at the 2010 annual meeting of the Society for Technology in Anesthesia
**No Disclosure*

Susan Ryan, MD, PhD is a Professor in the Department of Anesthesia and Perioperative Care at the University of California San Francisco. Dr. Ryan attended Stanford University and completed fellowships at the University of California- San Francisco in Anesthesia and Critical Care.
**No Disclosure*

STA 2011 Annual Meeting Speakers (cont.)

Noah Syroid, PhD has held positions as a Research Computer Scientist, Biomedical Engineer, and is the current technical director for the University of Utah Center for Patient Simulation Department of Anesthesiology. He is an expert in the area of pharmacokinetic and dynamic modeling and has published extensively in the area. He received his undergraduate computer engineering degree and has over 8 years of experience in software engineering. He also has a M.S. and 6 years experience in biomedical engineering in medical monitoring, pharmacologic modeling, bioinstrumentation and scientific/information visualization.
***Shareholder Medvis*

Michael Vigoda, MD is a pediatric anesthesiologist at the University of Miami Miller School of Medicine. Since 2003, he has been the Director of the Center for Informatics and Perioperative Management in the Department of Anesthesiology at the University of Miami. He was recently appointed co-Medical Director, Clinical Informatics for the University of Miami Health System.
**No Disclosure*

STA Annual Meeting Moderator Disclosures

Jim Blum, MD
**No Disclosure*

Jeffery Feldman, MD
**No Disclosure*

Julian Goldman, MD
**No Disclosure*

Robert Loeb, MD
**No Disclosure*

Kirk Shelley, MD, PhD
**No Disclosure*

Dwayne Westenskow, MD
***Equity Position: Anecare, Medvis, Korr Medical & Axon Medical*
***Salary Support from Axon Medical*
***Research Grant from Philips, Draeger & Anecare*

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STA Annual Meeting 2011: Daily Program Schedule

Wednesday, January 12, 2011

18:00 – 19:30	Rooms: 3303- 3306	**Opening Reception with Vendors & Registration**

Thursday, January 13, 2011

07:00 – 08:00	Rooms: 3303 - 3306	**Registration & Continental Breakfast**
08:00 – 09:30	Rooms: 3501-3520	**Session 1: Patient Safety**
08:00 – 08:15		**Opening Remarks** *D. John Doyle, MD, PhD*
08:15 – 09:30		**Keynote Address: Patient Safety: It's Not Rocket Science** *Jim Bagian, MD, PE*
09:30 – 10:00		**Break with Exhibits and Posters**
10:00 – 12:00	Rooms: 3501-3520	**Session 2: Greening the OR: Improving the Anesthetic Eco-Footprint** *Susan Ryan, MD, PhD– Moderator*
10:00 – 10:15		**Introduction to Sustainable Healthcare**
10:15 - 10:45		**Environmentally Responsible Anesthesia Equipment Choices: Reuse? Dispose? Reprocess?** *Charlotte Bell, MD*
10:45 - 11:15		**Inhaled Anesthetics: Greenhouse Gases in Our Practices** *Susan Ryan, MD, PhD*
11:15 – 11:45		**Anesthetic Gas Capturing Systems** *James Berry, MD*
11:45 – 12:00		**Panel Discussion**
12:00 – 13:15	Rooms: 3503-3505	**Lunch**

Thursday, January 13, 2011 (continued)

13:15 – 15:00	Rooms: 3501-3502	**Session 3: Drug Delivery & Monitoring Technology** *John Pawlowski, MD, PhD- Moderator*
13:15 – 13:45		**Newer, Safer Anesthesia Drug Development** *John Pawlowski, MD, PhD*
13:45 – 14:15		**Safe Technology in Drug Delivery** *George Blike, MD*
14:15 – 14:45		**Drug Effect & Safety Monitors Using Processed EEG Technology** *Scott Kelley, MD*
14:45 – 15:00		**Panel Discussion**
15:00 15:15	Rooms 3303-3306	**Break with Exhibits and Posters**
15:15 – 17:00	Rooms 3501-3502	**Session 4: Research Awards & Presentation** *Kirk Shelley, MD, PhD – Moderator*
15:15 - 16:15		**Research Awards & Presentation**
16:15 – 17:00		**Guided Poster Viewing with Q&A**

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Friday, January 14, 2011

07:00 – 08:15	Rooms: 3303 – 3306	**Registration & Continental Breakfast**

STA Special Session

From Detection to Decision:

The Art, Science and Future of Non-Invasive Monitoring

Non-Invasive monitoring offers the possibility of obtaining meaningful physiological measurements without subjecting the patient to any risk. There have been significant advances in non-invasive monitoring methods over the years and the future holds even greater promise. Sensors and signal processing algorithms continue to improve. Ultimately, monitors can enhance patient care by enabling physicians to make better decisions but the information must be transferred to the clinician by way of displays and alarms.

08:15 – 10:00	Rooms: 3501-3502	**Session 5: Sensors** Dwayne Westenskow, PhD – *Moderator*
08:15 – 08:45		**Light Through Tissue** *Paul Mannheimer, PhD*
08:45 – 09:15		**Gas Analysis** *Timothy Morey, MD*
09:15 – 09:45		**Ultrasound** *Martin London, MD*
09:45-1000		**Panel Discussion**
1000– 1030	Rooms: 3303 – 3306	**Break with Exhibitors**
10:30 – 12:15	Rooms: 3501-3502	**Session 6: Displays & Decision Making** *Jeffery Feldman, MD– Moderator*
10:30 – 11:00		**Alarm Technology- Pitfalls & Promises** *Frank Block, MD*
11:00 – 11:30		**Integrated & Smart Displays** *Noah Syroid, MD*
11:30 – 12:00		**Bringing Data to the Provider: Remote Monitoring** *George Blike, MD*
12:00 – 12:15		**Panel Discussion**

Friday, January 14, 2011 (Continued)

12:15 – 13:30		**STA Business Luncheon & Awards** *D. John Doyle, MD, PhD* *President*
13:30 – 15:30		**Session 7: Concurrent Workshops**
	Room: 3101	**Researchers Workshop** *Kirk Shelley, MD, PhD*
	Room: 3102	**Computers in Anesthesia (CIA) Show & Tell Contest** *Butch Loeb, MD*
	Room: 3103	**MPOG Workshop** *Jim Blum, MD*
15:30 – 17:00		**Session 8: Concurrent Workshops**
	Room: 3105	**Interoperability Workshop** *Julian Goldman, MD*
	Room: 3106	**ASA Advisory Group**
18:00 – 21:00		**Dinner at LAVO** (Included with the Attendee Registration Fee)

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*Located in the Palazzo Wing of the Venetian Hotel.
This is a private event for STA- You MUST have your ticket and name badge to enter. NO EXCEPTIONS.

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Saturday, January 15, 2011

07:15 – 08:00	Outside 3501-3502	Registration & Continental Breakfast
08:00 –09:45	Room 3501-3502	**Session 9: Data Driven Safety: Are We Ready?** *Mohamed Rehman, MD- Moderator*
08:00 – 08:30		Mohamed Rehamn, MD
08:30 – 09:00		Richard Epstein, MD
09:00 – 09:30		Jesse Ehrenfeld, MD
09:30 – 09:45		Panel Discussion
09:45 –10:30	Room 3501-3502	**Gravenstein Award Presentation** *Lecture Presented By: David Gaba, MD*
10:30 – 12:15	Room 3501-3502	**Session 10: Future of Monitoring- Best Practices** *Brian Rothman, MD - Moderator*
10:30 – 11:00		**What Can We Learn About Monitoring From Other Industries** *Michael Vigoda, MD, MBA*
11:00 – 11:30		**Outsmarting the Diverter: PharmaSmart** *Michael Pilla, MD*
11:30 – 12:00		**Mobile Computing Platforms for Monitoring- Forms, Functions & ROI** *Brian Rothman, MD*
12:00 – 12:15		**Panel Discussion**
12:15		**STA Meeting Adjourns**

ALL Annual Meeting Presentations will post on the STA Website by February 15, 2011

Please visit www.stahq.org

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Corporate Membership Profiles

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Advanced Anesthesia is a highly technology-enabled billing service that utilizes our eXtract™ middle-ware software application to connect the industry's premier Anesthesia Information Systems (AIMS) to our billing engine (or your own in-house system!). Our technology and solutions result in improved billing efficiency that dramatically reduces costs, maximizes revenues and provides significant ROI for the acquisition of AIMS technologies.

Codonics

Codonics, incorporated in 1982, is a privately held corporation headquartered in Cleveland, Ohio, and is a leading manufacturer of specialty printing solutions and archival systems for medical applications. Codonics has regional offices in the U.S., Europe, Japan and China, and a strong commitment to continued development of innovative medical products compatible with existing technologies.

Covidien

Covidien is a leading global healthcare products company that creates innovative medical solutions for better patient outcomes and delivers value through clinical leadership and excellence. Covidien manufactures, distributes and services a diverse range of industry-leading product lines in three segments: Medical Devices, Pharmaceuticals and Medical Supplies. With 2010 revenue of $10.4 billion, Covidien has approximately 42,000 employees worldwide in more than 60 countries, and its products are sold in over 140 countries. Please visit www.covidien.com to learn more about our business. CovidienRespiratory and Monitoring Solutions, 6135 Gunbarrel Ave. Boulder, CO 80301, 800-635-5267

Dräger Medical

Dräger Medical is one of the world's leading manufactures of medical equipment. The company offers products, services and integrated CareArea™ solutions throughout the patient care process; emergency care, preioperative care, critical care, prenatal care and home care. Dräger Medical employs nearly 6,000 people worldwide.

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Edwards Lifesciences

Edwards Lifesciences strives to provide you with the valuable hemodynamic information you need, how you need it, when you need it most. From the first Swan-Ganz pulmonary artery catheter, to the latest FloTrac sensor and PreSep continuous oximetry catheter – our goal remains: to provide you with the clarity you need, the moment you need it, in order to advance the care of the critically ill. For educational resources and more information visit www.Edwards.com/CriticalCare. Or download our free eLearning iPhone "App" at www.Edwards.com/ccApp.

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GE Healthcare is dedicated to helping transform healthcare delivery by driving critical breakthroughs in biology and technology. Our expertise in medical imaging and information technologies is enables healthcare professionals around the world to deliver new ways to predict, diagnose and treat disease earlier

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iMDsoft

iMDsoft is a leading provider of clinical information systems dedicated to automating the critical care and perioperative continuum. The Meta Vision™ suite is fully integrated, customizable solution for data collection and presentation, order management, clinical analysis and decision support. Major medical centers across the United States and Europe and Asia use iMDsoft technology to improve quality care, promote patient safety, enhance financial performance, support research and compliance while achieving sustainable market leadership.

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Masimo

Masimo is a global medical technology company that develops and manufactures innovative noninvasive patient monitoring technologies, including medical devices and a wide array of sensors. A key medical technology innovator, Masimo is responsible for the invention of award-winning noninvasive technologies that are revolutionizing patient monitoring, including Masimo SET® pulse oximetry, Masimo Rainbow SET® noninvasive and continuous hemoglobin (SpHb®), acoustic respiration rate (RRa™), and Masimo Patient SafetyNet™.

Mindray North America

Mindray is a global medical device business with three established business segments: Patient Monitoring and Life Support Products, In-Vitro Diagnostic Products, and Medical Imaging Systems. With more than 4,500 employees and with R&D centers on three continents, Mindray offers the medical community a range of innovative solutions designed to contain costs while ensuring the highest quality of patient care. Mindray measures our success by our customer's satisfaction. Our clinical education specialists provide the hospital staff with comprehensive, on-site training and in-service on demand 24-hours a day, 7-days a week. Our dedicated field service and in-house technical support organization are one of the largest direct service teams in the industry. Individually and collectively they are committed to enhancing patient care while protecting your investment.

Oridion Capnography, Inc.

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Philips Healthcare is a worldwide provider of Diagnostic Imaging Products, Cardiac and Physiological Monitoring Systems and Information Management applications. Philips Healthcare currently offers point of care clinical information systems that automatically record, store and provide reports for a given care setting. Today Philips offers Medical IT solutions for the perioperative environment (CompuRecord), the OB environment (OB TraceVue) and the critical care environment (Intellivue Clinical information Portfolio Critical Care or ICIP, CC)

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SIS provides surgery management and anesthesia solutions that improve efficiency and quality for surgical services through the use of technology. SIS' fully integrated anesthesia solution enables anesthesiologists to electronically record/capture all necessary anesthesia record information, increasing productivity and reducing costs by optimizing workflow and minimizing time spent on administrative tasks.

CONTINUOUS AND NONINVASIVE HEMOGLOBIN MONITORING DURING COMPLEX SPINE SURGERY

Lauren Berkow, MD; Stephanie Rotolo; Erin Mirski
Johns Hopkins School of Medicine, Department of Anesthesiology and Critical Care Medicine, Baltimore, Maryland

Background: The ability to measure hemoglobin continuously and noninvasively during surgery may allow for a more rapid assessment of a patient's condition and more appropriate blood management. This study evaluates the accuracy of noninvasive hemoglobin measurement via Pulse CO-Oximetry (SpHb) during complex spine surgeries compared to values obtained from laboratory CO-Oximetry (tHb).

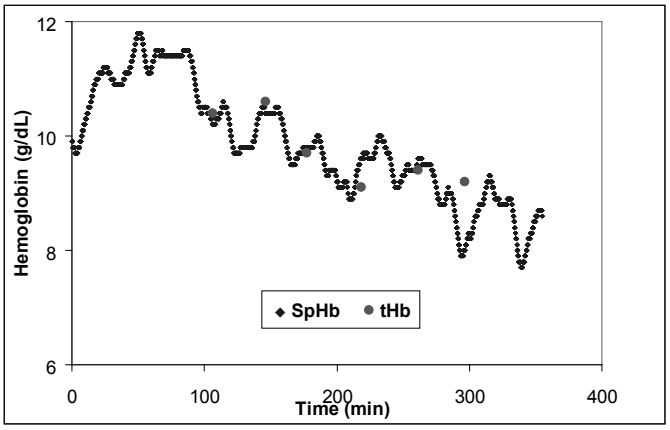
Methods: After IRB approval and informed consent, 28 complex spine surgery patients wore a Rainbow Adult resposable sensor (rev E) connected to a Radical-7 Pulse CO-Oximeter (Masimo, Irvine CA) for the continuous measurement of SpHb, SpO_2, pulse rate, and perfusion index. Patients were monitored with ASA standard monitors and an arterial and/or central venous line as part of their standard care., Blood samples were obtained hourly during the surgery and analyzed by the central laboratory with a Radiometer ABL800 CO-Oximeter (Radiometer America). The resulting tHb measurements were compared to SpHb values obtained at the time of the blood draw by calculating the bias, precision, and accuracy root mean square (ARMS) for the data pairs (Table 1). A representative case of SpHb measurements and tHb over time is presented in Figure 1.

Results:

Table 1

N = 168 data pairs	
tHb Range	6.9 – 13.9 g/dL
SpHb Range	6.9 – 14.5 g/dL
Mean Bias	-0.3 g/dL
Precision	1.0 g/dL
A_{RMS}	1.1 g/dL

Figure 1



Conclusion: Continuous, noninvasive hemoglobin monitoring with the Radical-7 Pulse CO-Oximeter demonstrated clinically acceptable accuracy of hemoglobin status during spine surgery when compared to a standard laboratory reference device. Continuous noninvasive SpHb monitoring may lead to earlier intervention and improved patient safety and care in the OR setting.

UTILIZATION AND CHARACTERISTICS OF A NEW VEIN FINDING DEVICE

Franklin B Chiao, MD, MSc[1]; Thomas Mulroy, MD[1]; Franco Resta-Flarer, MD[1]; Vaclav Hrdlicka, MD[1]; Henry Bennett, PhD[1]
St Lukes Roosevelt Hospital Center, New York, New York

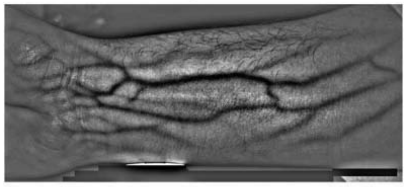
Introduction: Securing venous access can be technically challenging and may require significant time. A vein finding device (VF) that is minimally invasive and portable would allow for improved patient care. We studied a VF (VueTek Scientific) that uses digitized infrared imaging on a head mounted display. It is designed to improve visualization of superficial veins.

Methods: We designed a randomized prospective study to determine if there was a significant difference in the number of veins visible using the VF and conventional eyesight method (CM). Ten operators viewed a minimum of ten independent volunteers with both VF and CM. Order was randomized between VF and CM. A power analysis for moderate effect size, beta=0.9 required 97 samples.

Results: 106 completed samples (212 observations) ranged in age from a few weeks to 72 years of age. Average age of patients was 35 (sd =22). BMI of patients averaged 25 (sd= 6). The VF took a mean time of 12 seconds (sd= 6) to place on the head and position comfortably. On average, 2.5 more veins were found with VF than CM (sd = 1.5, $p<0.01$). Age was a significant variable in the number of veins found. Gender, weight and skin color did not impact vein finding significantly.

Age (years)	CM	VF	Difference
<2	$1.77_{(0.97)}$	$3.44_{(1.42)}$	$1.67_{(1.12)}$
2-17	$4.80_{(2.76)}$	$6.90_{(3.29)}$	$2.10_{(1.25)}$
18-64	$5.04_{(1.68)}$	$7.62_{(3.03)}$	$2.58_{(0.12)}$
65+	$6.00_{(3.02)}$	$9.38_{(2.45)}$	$3.38_{(0.74)}$
Total	$4.79_{(2.99)}$	$7.26_{(3.53)}$	$2.47_{(1.54)}$


Natural light of the arm


Fully enhanced near infrared image of the same arm using DVV technology

Discussion: There were significantly more veins visible with VF than CM. Skin color (dark/light), weight (normal/obese) and gender (M/F) did not affect the VF advantage. Increasing age categories were associated with greater numbers of veins identified with VF.

Conclusion: Our study showed that the VF increased the number of veins visible by 2.5 veins ($p<0.01$). Advanced age was a significant predictor for number of additional veins found. The VF increases the number of veins visible for attempted cannulation and is worthy of further study.

AUTOMATED PHASE OF ANESTHESIA DETECTION FOR PROVIDING CONTEXT APPROPRIATE ALERTS

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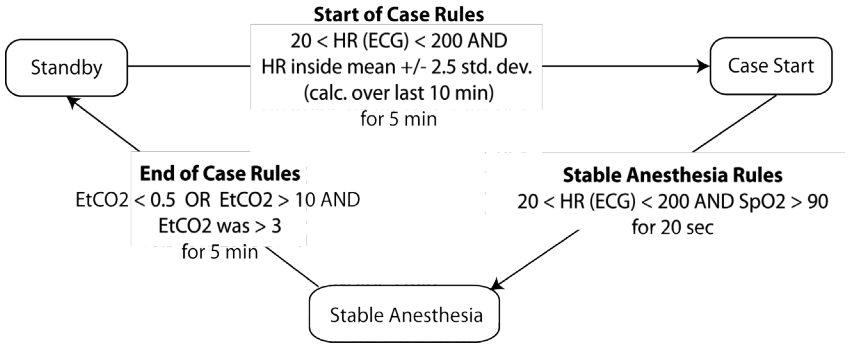
Introduction: The increasing number of parameters being monitored in the operating room has consequently increased the number of alarms. With the introduction of intelligent clinical decision support systems such as *iAssist* [1], false alarms are even more likely. The knowledge rules within *iAssist* were designed for use in the stable phase of anesthesia, but the system lacked this context and fired rules throughout a case. In addition, clinicians have multiple tasks to perform at the start and end of a clinical case and do not have time to initiate the system between cases. To facilitate the automated detection of the phases of anesthesia we have developed a set of phase rules, which deactivate or activate the knowledge rules as appropriate.

Method: The rules for triggering the onset of each of three anesthesia phases: Start of Case, Stable Anesthesia, and End of Case, were selected by referencing real cases and expert clinician opinion. The expert system is initialized with the selected knowledge rule set and the details of the first case. The system runs in standby mode until the start of case is detected, when graphs and trends are displayed and data recording is initiated. Upon detection of stable anesthesia, a popup window requests confirmation to initialize the expert system.



Confirmation is required from the clinician when the end of case is detected for the system to enter standby mode. For each subsequent start of case the clinician is prompted to enter new case details. A 5 minute delay in further detection is introduced if the clinician cancels a phase change. Phases can be changed manually. The tuning of the phase rules have been iteratively improved. Twenty case recordings were examined with and without phase detection to determine the number of unnecessary alerts avoided. All cases were of at least an hour duration and half of the cases ran with phase detection in real time and half were run with phase detection offline.

Results: Phase detection eliminated a median (SD) of 6 (5.56) alerts per case during the induction of anesthesia. The difference in the number of outcomes was significant (Wilcoxon matched-pairs signed-rank test $p < 0.001$). Of the 10 cases originally run without phase detection, 3 included clinician comments marking outcomes as occurring out of context during induction of anesthesia. An additional benefit of the detection of Start of Case and End of Case is that record fusion is avoided (fusion of cases had occurred in 3 of the 10 pre-phase cases).

Discussion: The use of automatic phase detection has provided the intelligent monitoring system an awareness of the context in which support is provided. Phase detection has the potential to improve clinician performance by preventing unnecessary false alerts that degrade the response to clinical alerts. Future research will be directed towards demonstrating an improved response to true adverse events.

DEVELOPMENT AND IMPLEMENTATION OF A PROCEDURE-SPECIFIC INSTITUTIONAL PROTOCOL FOR SURGICAL PROPHYLACTIC ANTIBIOTICS

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Introduction: While the selection and timing of prophylactic antibiotics for surgery moves toward a system-based approach[1,2], most institutions and Operating Room Information Systems (ORIS) rely on individual health care provider preferences. We describe the development and implementation of a procedure-based institutional protocol for the administration of prophylactic antibiotics at Wake Forest University Baptist Medical Center (WFUBMC).

Methods: The change to an institutional protocol was initiated by the WFUBMC Center for Antibiotic Utilization, Stewardship, & Epidemiology (CAUSE)--a multiple disciplinary group from our infectious disease, pharmacy, and quality departments. Antibiotic assignments where made by CAUSE and incorporated into our ORIS's relational database (John Galt Systems, Winston Salem, NC). A new ORIS application (John Galt ProAnti) was developed as a dynamic link library (DLL). Completion of its guided user interface (GUI) was required in our Holding area, Regional area, Anesthesia, and PACU work flow. MSRA colonization status (Healthquest, McKesson Corporation, San Francisco CA) and allergy status (Centricity EMR, GE Healthcare,UK) were displayed via HL7 interfaces. Weight and age appropriate antibiotic dose was automatically populated, simultaneous documentation of a unique incision time was tied to antibiotic administration, and appropriate check boxes were included for documentation of variances. The application was set to 'pop up' initially upon starting the patient care record and then repeatedly for scheduled re-doses.

Results: Editing and review of the entire database for 2136 procedures took CAUSE 8 months during which time the new GUI and database were live. Upon completion of edits in 12/2010, no measured parameter for antibiotic administration showed a lower level of compliance than apparent in 2/2010 when the project began. Overall compliance was higher and incomplete documentation lower to a statistically significant degree:

Table 1:Antibiotic Non-Compliance by Month (%)

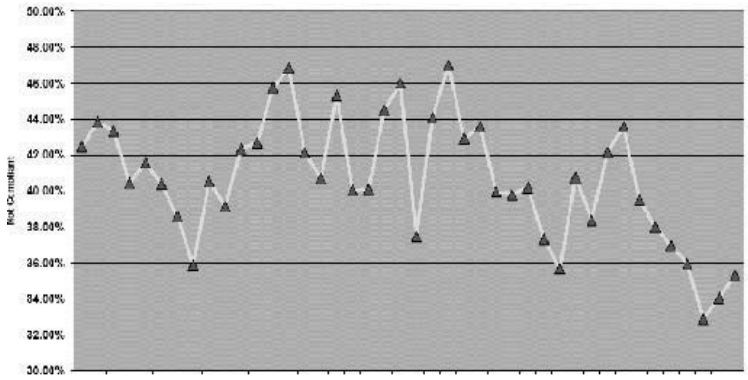

Table 2: Antibiotic Non-Compliance by Type

	2/2010	12/2010	95% CI
Given when none recommended	20%	17%	-1 to 7
None given when recommended	9%	6%	-1 to 5
Given when different recommended	10%	11%	-4 to 2
Incomplete documentation	**3%**	**1%**	0 to 3
Overall non-compliance	**42%**	**35%**	1 to 11
On-time delivery of antibiotic	98%	99%	-3 to 0
Number of patients/week	590	659	

Conclusion: Conversion from traditional provider preferences to procedure-specific institutional protocol was achieved with a statistically significant improvement in overall compliance. Although more complicated and obtrusive information was supplied to anesthesia providers, on-time administration remained high. At the time of this presentation, the future of this protocol is unclear as the institution considers lease of a commercial ORIS which supports only provider-specific preferences. A true systems-based approach might be better achieved by software supporting procedure-specific institutional protocols.

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1. Bratzler DW, Houck PM. Antimicrobial prophylaxis for surgery: an advisory statement from the National Surgical Infection Prevention Project. Am J Surg 2005;189:395-404.
2. *CMS/TJC Specifications Manual for National Hospital Inpatient Quality Measures, Version 3.2 (2010)*. http://www.jointcommission.org/PerformanceMeasurement/PerformanceMeasurement/Current+NHQM+Manual.htm

WHAT IS A "VALID" BREATH? – METHODOLOGICAL ISSUES

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Introduction: There is generally a lack of agreement about what constitutes a valid breath. A clear definition is particularly important to developers of computer based algorithms which estimate clinically important measures such as a respiratory rate, tidal volume and end-tidal gas measurements that are considered critical in the management of patients in clinical environments ranging from pre-hospital to the OR and ICU.

Discussion: The output of computer based algorithms is dependent upon the proper detection and clear definition of respiratory events such as the start of breath (SOB), end of breath (EOB), and the transition between inspiratory and expiratory phases. These boundaries can be inferred in a number of ways – using a constituent component of the breath (e.g. CO2) or through more indirect measurements such as chest wall movement, or acoustic measurements. The definitions of SOB, EOB and what constitutes sufficient volume to be considered a breath are dependent upon clinical environment, context and technology. The criteria for what constitutes a patient effort or breath vary widely between the pre-hospital and hospital environments. Also what constitutes a useful gold standard needs further clarification. It is suggested that the criteria for breath detection and measurement should be optimized for the environment of use, clinical expectations and therapeutic procedure (e.g. procedural sedation, CPR, general anesthesia, and invasive and non-invasive ventilation). The relevant clinical and physiological questions asked in determining what is a breath also vary in a similar manner (e.g. is the breath "effective", does it clear the deadspace, and does the breath represent a patient effort?). The issue is readily apparent with some algorithms where the reported breath rate can vary widely in presence of artifacts and small patient efforts. A recent study (1) using a large OR and ICU dataset found that the fraction of breaths for which the tidal volume was too small to clear the serial dead volume can be significant, and that algorithms which do not indicate the presence of very small breaths may fail to indicate hypoventilation.

Conclusion: The criteria for what constitutes a valid breath need to clearly defined, context specific and clinically relevant. Algorithms need to better disclose their breath detection criteria and to be judged against relevant bench and clinical standards.

Reference:

1. Orr JA, Brewer LM, Jaffe MB. Evaluation of Adequacy of Tidal Volumes Using a Volumetric Capnography Reference Data Set. AARC 2010

HEMOSTATIC RESUSCITATION IN ELECTIVE SURGERY CAUSING MASSIVE BLEEDING AND EMERGENCY SURGERY AFTER MASSIVE BLEEDING: A COMPUTER SIMULATION

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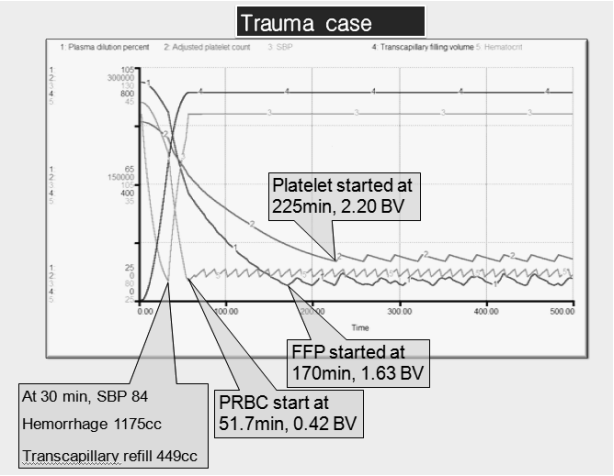
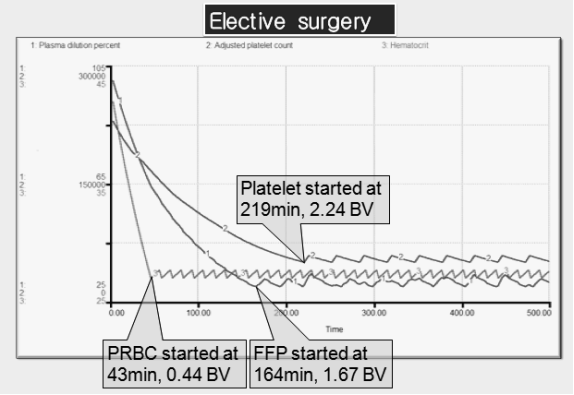
Background: Appropriate blood component therapy might be different between patients who receive elective surgery causing massive bleeding and patients who receive emergency surgery after traumatic massive bleeding, because trauma patients bleed undiluted blood initially and replacement typically lags behind blood loss. We compared them using computer simulation in assumption that coagulopathy begins in less bleeding volume.

Method: We modified multi-compartment dynamic model developed by Hirshberg, and implemented it using STELLA 9.0. In this model, blood pressure changes as blood volume fluctuate, and bleeding rate and transcapillary refill rate are controlled by blood pressure. Using this simulation, we compared elective surgery senario and trauma case senario. In both scenario, patients started to bleed at the rate of 50 ml/min. In elective surgery scenario, fluid was administered to maintain blood volume. But In trauma case senario, no fluid was supplied up to 30 minutes and no blood was supplied up to 50 minutes. Each unit of PRBC was given when hematocrit decrease to27%, FFP was transfused when plasma was diluted to 30% , and PC was transfused when platelet count became 50,000 /cc.

Results: Transfusion of FFP and PC was required at less bleeding volume in trauma case senario. In both senario, appropriate PRBC: FFP ratio was 1: 0.47 until PC infusion was started, and PRBC: FFP: Platelet ratio was 1: 0.35 : 0.39 after PC infusion was started.

Conclusion: Coagulopathy begins in less bleeding volume when fluids are not administered, but it does not alter blood compartment ratio.





A PILOT EVALUATION OF A NOVEL SCREENING TOOL FOR SLEEP RELATED BREATHING DISORDERS

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Oridion Capnography, Inc, Jerusalem, Israel

Introduction: Polysomnography (PSG) is the standard procedure for the diagnosis of sleep related breathing disorders (SRBD) and patients are typically referred for overnight studies when they are identified as being at risk by a clinician. Various tools are in use today to identify patients at risk for SRBD and refer them subsequently for studies. The ASA (American Society of Anesthesiologists) and other professional bodies have published guidelines calling for the recognition of patients suffering from SRBD during perioperative care.

The Capnostream20p capnograph/pulse oximeter with SSDx algorithm is used in many hospital type environments whenever patient monitoring is required. The monitor provides an Apnea Index (AI), based on summation of the no-breath events per hour recognized by the capnograph, and an Oxygen Desaturation Index (ODI), using pulse oximetry. The information is presented in a simple summary report.

The purpose of our evaluation was to assess the level of agreement between the indices generated by the device and overnight polysomnograph studies.

Methods: During routine overnight sleep studies 39 adult patients were monitored with the device. The sleep study was interpreted by a trained clinician who was blinded to the device. The AI and ODI values generated by the device were compared to the sleep study outcomes.

Results: A statistically significant model using the maximal AI and ODI values to predict OSA was defined. At a cut-off point of 19 – (ODI max+AI max) >19., sensitivity equals 0.87 and specificity 0.82. The PPV with actual prevalence of 0.68 (per the clinical data gathered) equals 0.91 and NPV = 0.75.

Conclusion: The results indicated that the device showed high sensitivity and specificity, and hence can be used as a tool for screening and assisting in the diagnosis of adult patients with medium and severe Obstructive Sleep Apnea in the hospital environment.

PROPOFOL AND REMIFENTANIL SPARING EFFECT OF NITROUS OXIDE USING CLOSED-LOOP ANESTHESIA CONTROLLER

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Background: We have developed a proportional-integral-derivative controller allowing closed-loop propofol and remifentanil administration guided by the Bispectral (BIS) monitor[1]. Nitrous oxide (N_2O) has a hypnotic and analgesic effect. We investigated whether the coadministration of N_2O would reduce the amount of propofol and remifentanil required during closed-loop anesthesia maintenance. Drug consumption in all patients, in both men and women was analyzed.

Methods: Patients (ASA I-IV) who were scheduled for minor or major surgery lasting more than 1 hour were randomized in this multicenter trial (11 centers and 34 investigators, NCT00547209). After induction patients were allocated to receive 60 % nitrous oxide-40 % oxygen (N_2O group) or 60 % air – 40 % oxygen (Air Group). In both groups the Dual-loop controller was used to provide induction and maintenance. Anesthesia depth was evaluated by the percentage of time in which the BIS was in the range 40-60 (BIS_{40-60}). Data is presented as mean±SD. Statistical analysis was performed using student-t or Chi-squared tests; $p<0.05$ was considered significant.

Results: 302 patients were included in the N_2O Group, 299 in the Air group. The Dual-loop controller was able to provide anesthesia induction and maintenance for all patients. N_2O and Air groups were similar regarding age (56 ± 16 vs 57 ± 17 yr), weight (74 ± 15 vs 74 ± 16 kg), height (169 ± 9 vs 168 ± 8 cm), maintenance duration (154 ± 106 vs 156 ± 105 min), sex ratio Male/Female (157/145 vs 154/145), use of neuromuscular blocking agent (43 vs 49 % of patients). At similar BIS_{40-60} (76 ± 15 vs 74 ± 13 %), N_2O decreases propofol (4.8 ± 1.7 vs 5.1 ± 1.6 $mg.kg^{-1}.h^{-1}$, p=0.032) and not remifentanil (0.19 ± 0.09 vs 0.20 ± 0.10 $\mu g.kg^{-1}.min^{-1}$, NS) consumption, in the N_20 vs Air group respectively. The subgroups of men, N_2O_{men}(n=157) and Air_{rmen}(n=154) were well balanced with respect to demography, morphometry and surgical procedure. At similar BIS_{40-60} (79 ± 14 vs 78 ± 13%), propofol (4.5 ± 1.8 vs 4.5 ± 1.2 $mg.kg^{-1}.h^{-1}$) and remifentanil (0.19 ± 0.09 vs 0.18 ± 0.07 $\mu g.kg^{-1}.min^{-1}$) consumptions were similar (N_2O_{men} vs Air_{men} group respectively). The subgroups of women, N_2O_{women}(n=145) and Air_{women}(n=145) were well balanced with respect to demography, morphometry or surgical procedure. At similar BIS_{40-60} (73 ± 14 vs 71 ± 13), propofol (5.0 ± 1.7 vs 5.6 ± 1.8 $mg.kg^{-1}.h^{-1}$, p=0.004) and remifentanil (0.18 ± 0.09 vs 0.21 ± 0.10 $\mu g.kg^{-1}.min^{-1}$, p=0.029) consumptions decreased with the coadministration of N_2O (N_2O_{women} vs Air_{women} group respectively). No cases of awareness with recall were recorded.

Conclusions: The Dual-loop controller allowed an unbiased administration of propofol and remifentanil. These results demonstrated that the sparing effect of N_2O on propofol and remifentanil consumption is related to gender. N_2O coadministration allowed significant decrease of propofol and remifentanil consumption in women but the impact is not clinically relevant.

References:

1. Liu et Al. Anesth&Analg in Press.

END TIDAL CARBON DIOXIDE LEVELS PREDICT CARDIAC ARREST

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Introduction: End tidal carbon dioxide (CO2) correlates with cardiac output during cardiopulmonary resuscitation in cardiac arrest patients. Increasing CO2 during CPR can also indicate the return of spontaneous circulation.

Hypothesis: CO2 will decrease prior to a cardiac arrest in patients that are intubated in an intensive care setting.

Methods: CO2 was continuously monitored and recorded every hour in forty-three patients who were intubated and on vasopressor medication.

Results: There were four cardiac arrest events, six patients who were acutely withdrawn from care, and six patients who had hypotensive events (systolic blood pressure<90) while on vasopressors. CO2 measurements were evaluated in patients with an adverse event (acute withdrawal of care, cardiac arrest, and hypotension) at time periods of 1, 2, 3, 4, and 5 hours prior to the adverse event. Normal patients were categorized as those patients enrolled who did not have an adverse event. Mean CO2 values were significantly higher in normal patients when compared to those in patients who had a cardiac arrest (30.18 ± 4.93 vs. 17.45 ± 4.76; $p<0.001$). CO2 levels were significantly lower in cardiac arrest patients when compared to hypotensive patients 1, 2, 3, and 4 hours prior to a cardiac arrest (see Table). CO2 levels were significantly lower in cardiac arrest patients when compared to patients who were acutely withdrawn from care 1,2,3, and 4 hours prior to event (see Table). CO2 levels 5 hours prior to hypotension or acute withdrawal of care were not significantly different than cardiac arrest (see Table).

Conclusion: CO2 levels are lower overall in cardiac arrest patients in comparison to normal patients. CO2 values are lower in the four hours prior to cardiac arrest patients in comparison to the four hours prior to a hypotensive event. A patient who is withdrawn from care does not have a decrease in CO2. Increased numbers are needed to see if this relationship holds true on a large scale.

Hour(s) prior to event	**Cardiac Arrest**	**Hypotension (SBP<90)**	**P value**
1	16.50	20.67	P=0.013
2	16.25	21.83	P=0.013
3	16.50	22.67	P=0.002
4	16.75	21.33	P=0.024
5	21.25	21.33	P=0.99
Hour(s) prior to event	**Cardiac Arrest**	**Acute Withdrawal of Care**	**P value**
1	16.50	23.29	P=0.016
2	16.25	24.43	P=0.001
3	16.50	25.29	P<0.001
4	16.75	26	P<0.001
5	21.25	24.86	P=0.43

USE OF CAPSULE TECHNOLOGY'S NEURON® TO INTERFACE WIRELESSLY TO THE EPIC™ INTRAOPERATIVE ANESTHESIA MODULE

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University of Iowa Hospitals & Clinics, Iowa City, Iowa

The Department of Anesthesia at the University of Iowa Hospitals went live with the Epic intraoperative anesthesia module on November 8, 2010. For the interface between the anesthesia physiologic monitor and the anesthesia machine and Epic, we chose the Neuron, a relatively new product from Capsule. After extensive testing, for the fixed locations, we hard wired the Neuron into our Ethernet backbone. Having many satellite locations where hard wiring was impractical or impossible, we used the wireless feature of the Neuron to provide connectivity. After verifying that the wireless strength (WiFi) in all of the satellite locations was satisfactory, we installed the Neuron on 4 roaming anesthesia machines. For our Epic workstations, we use a Dell Latitude laptop as the CPU with a slaved touch-screen monitor and slide-pad keyboard mounted on an articulated arm on the right-hand side of the machine. In the satellite locations, the Dell also operates wirelessly. The Neuron uses a digital interface module to identify the device it is connected to. All the electrical mains connections-machine, laptop, anesthesia machine, Neuron, and touch screen come to a common power strip. On arrival at a new location, the provider plugs the power strip into an electrical outlet and then turns on the Neuron and the laptop. While both are booting, the provider establishes the gas connections and checks out the machine. To initiate electronic record keeping, the provider opens the Epic application, selects the patient, launches the intraoperative module and starts data collection. The provider enters drugs and events as necessary

In more detail, we use the General Electric S/5 monitor and ADU anesthesia machine. The output of these is RS-232. The Neuron translates these data streams into TCP/IP and sends them over the hospital Ethernet backbone to the Capsule server. This server then translates the data streams to HL-7 and sends them through the Cloverleaf data switch to Epic. To ensure accuracy in patient data flow, Epic contains a look-up table that links the ID of the laptop with the ID of the Neuron. Since going live, this wireless system has performed flawlessly.

This demonstrates the successful use of modern devices with wireless capability in optimal patient care and clinical documentation.

DOWNTIME SITUATIONS AND AUTOVALIDATION OF CACHED DEVICE DATA IN AN MODERN ELECTRONIC ANESTHESIA RECORD

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University of Iowa Hospitals & Clinics, Iowa City, Iowa

At the University of Iowa Hospitals, we use Epic as our hospital information system. On November 8, 2010, we brought up the intraoperative module that allowed us to dispense with the paper record for the majority of our anesthetizing locations. A primary consideration in data integrity was what to do when the flow of data from the patient monitor and the anesthesia machine was interrupted. Our data flow starts with the RS-232 stream from the monitor and machine and is converted to TCP-IP by a Capsule Neuron® that then sends the data over our Ethernet backbone to the Capsule server. This server translates the data to HL-7 and sends it to Epic via a Cloverleaf® server. The Neuron and the Capsule and Cloverleaf servers are capable of caching data indefinitely if there is a failure further down the data stream.

Perioperative data collection needs to be quick, efficient and reliable with minimal impact on the provider's clinical work. Hence, data from devices and monitors flows directly into the record without the provider having to manually validate each data set, a process known as Autovalidation of Data. In downtime situations, as long as data flows into Neuron or further, when connectivity is restored, the cached data flows automatically into the record and populates the appropriate cells with the correct data for the duration of the downtime. The feature is very useful but has drawbacks. During downtime, if there is a change of patient in the OR, autovalidation could result in wrong data going into the wrong patient. In the situation where Epic itself was down, the provider would be unable to stop data collection for the first patient who no longer is in the OR. When connectivity is restored, all the cached data from the devices so far will flow into the record of the first patient. This problem, data going into the wrong patient's record, was identified during downtime testing of each step in data flow in our simulation laboratory.

This prompted us and Epic to develop a fix that would stop autovalidation after a defined period of downtime. In deciding the duration of this period, we wanted to make sure it was not too short, so that, for every brief downtime either planned or unplanned, autovalidation would not be stopped. Similarly if it were too long, there would be a possibility of a turnover happening during downtime and a new patient coming to the OR with wrong data into the previous patient's record. Therefore, based on all these factors and historical turnover time of our ambulatory surgery operating rooms, we elected to set the duration of stop autovalidation at 10 minutes. For longer periods of downtime, we can do a manual validation of the data if the same patient is in the operating room.

This is an important consideration for all institutions planning to implement electronic anesthesia records with modern devices, which have the ability to cache device data and autovalidate.

COMPARISON OF ALPHABETICAL VERSUS CATEGORICAL ARRANGEMENT OF MEDICATIONS FOR ORDER ENTRY IN AN ELECTRONIC ANESTHESIA RECORD SYSTEM

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University of Iowa Hospitals & Clinics, Iowa City, Iowa

Introduction: Anesthesia records are different from other medical records because many data are recorded in a brief period by an individual who is engaged in vital tasks other than data entry. An especially demanding task is the recording of administered intravenous medications. The electronic anesthesia record should be designed and configured to facilitate the accurate and prompt recording of 6-10 drugs administered coincidentally. To help us choose between options implementable in EPIC, we performed multiple systematic searches for experimental and observational studies of impact of display format for medication entry rate and found none. We therefore did a Quality Improvement project within our department. Clinicians completed a task of selecting medications form a simulated environment similar to EPIC's Anesthesia Intraop module.

Methods: Two display formats were modeled on screens proposed for use with EPIC. Anesthesiologists and CRNAs were directed to select and enter a list 25 different medications into mock records in 2 minutes. We evaluated which format/layout resulted in the most rapid completion of the data-entry task with the fewest errors. One layout had medications arranged in an alphabetical arrangement. The other had medications arranged in a categorical arrangement. From the results of this Departmental QI project we designed the EPIC Intraoperative Anesthesia Record.

To gather the information to assess speed and accuracy, we developed a web-based application utilizing ASP.net, jQuery and SQL Server to conduct an experiment. Subjects were divided into 3 groups; 1) <1 yr clinical experience 2) 1-3 yrs clinical experience 3) 4 or more years of clinical experience. 60 providers participated in the experiment, 20 in each group. Subjects were handed an Apple iPad with the application preloaded. Once they clicked the Start Trial button, they had 120 seconds to find and tap drugs. Each subject completed three trials using each of the two templates. Each trial contained the same drugs but in a different sequence. After completing three trials, the subjects were given another interactive demonstration but with the other template. They then completed an additional three trials but using the other template. The drugs displayed in the same order for corresponding trials between the different templates. The number of drugs they could select in each trial and the number of errors was electronically stored in a database with no provider identifiers. The total time commitment for each subject was one session of approximately 20 minutes.

Results: For assessment to guide EPIC implementation, the overall difference in numbers of drugs entered was compared between alphabetical and categorical groups during the 3rd trial. Analysis was by Student's paired t-test. During the first trial, alphabetical provided an average of 3.1 more drugs entered (95% CI 1.8 to 4.4, $P < 0.0001$). This result was expected since categories need to be learned. By the third trial, categorical had mean 5.6 more drugs entered (95% confidence interval 4.5 to 6.8, $P < 0.0001$). Numbers of drugs entered was more for categorical when analyzed by years of clinical experience: 0 years mean 6.1 more ($N = 20$, $P < 0.0001$), 1-3 years mean 5.8 ($N = 20$, $P < 0.0001$), and 4+ yr mean 5.0 ($P < 0.0001$). There was no difference in error rates between groups at either the first ($P = 0.54$) or third trials ($P = 0.53$). The 5^{th} and 95^{th} percentiles of pairwise differences in error rates were -2 and +2 (i.e., symmetric, suggesting that not only on average but outlier providers there are no difference in error rates).

Conclusion: Based on these findings, categorical was used for implementation. As results were extreme, we expect that they would apply to other organizations.

SUCCESSFUL USE OF A TEST SYSTEM (EPIC POC) FOR ACHIEVING TRAINING AND COMPETENCE OF END USERS BEFORE GOING LIVE WITH ELECTRONIC ANESTHESIA RECORDS

Anil Marian, MD, FRCA; Michael Todd, MD; Frank Scamman, MD; Mike Anderson, CRNA; Anita Gillet; Kathy McGowan

University of Iowa Hospitals & Clinics, Iowa City, Iowa

The University of Iowa went live with electronic anesthesia records on November 8th 2010. We are a major university hospital with more than 180 clinical providers including trainees and multiple anesthetizing locations. Transitioning from paper anesthesia records to electronic anesthesia records required adequate preparation and thorough training of all clinical providers. Classroom training is valuable in the early stages, but it has limitations. These limitations include

- Inability to cover all the required information in a limited time.
- Poor acceptance from clinicians for IT training
- Clinicians often tired and hence uninterested or unable to grasp all information
- Class room situation very different from real-time OR situation
- Often forget what was presented in training by the time of go-live
- Limited time for hands on experience

Due to all these factors we explored the possibility of the anesthesia providers using the electronic record in parallel with the paper record for several weeks before going live. Use of actual record, EPIC PROD for this would result in inaccurate or incomplete data entry into actual patients' medical records. EPIC POC (Proof of Concept) is a program that was designed for testing the system as well as to provide an arena to trial new changes. With the help of the hospital HCIS team, EPIC POC was transformed into a trial environment for clinicians to practice and ultimately achieve competence prior to initiating EPIC PROD.

Each clinician took part in a 2-hour classroom training session where they were given an introduction to the system. After this EPIC POC was made available for the clinicians in every OR. During the course of the day, they were instructed to make use of this system and encouraged to use the practice environment as though it was live, using factitious patients. They had the ability to start an anesthesia record, see how the data is collected, and work through various events, staffing, attestations etc as they had time. After initial hesitation, the providers started using the system everyday. With this hands-on experience they became acclimated to the system and learned more than could have been possible in a classroom environment. This training period also provided the clinicians with the ability to provide feedback, which helped us tweak the system and make it even better. At the end of the 4-week period, all of our clinicians were proficient with the system. The result of this was an unbelievably smooth go-live. Even though extensive floor support was planned and provided, most providers required little if any help to make the overnight transition from paper to the electronic record. Even though 2 weeks of floor support was planned, the Ambulatory Surgical Center was support free by the third day and the main OR did not require any extra support by the end of the first week. This allowed us to successfully go-live with satellite locations the following week.

We believe this novel technique, which was hugely successful in our institution for training clinicians in electronic anesthesia records, could be used by other major institutions with similar facilities as well.

STANDARDIZATION OF SOFTWARE LEVELS, DATEX RECORD INTERFACE LEVELS AND OUTPUTS INTERFACE LEVELS OF DATEX-OHMEDA S/5Ä MONITORS FOR IMPLEMENTING ELECTRONIC ANESTHESIA RECORDS AND ITS COST IMPLICATIONS

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The University of Iowa recently went live with electronic anesthesia records by EPIC systems. At our hospital we have different generations of GE/Datex-Ohmeda anesthesia machines, with different generations of Datex-Ohmeda S/5ä monitors attached to them. The output of these is RS-232. The Capsule device, Neuronâ, translates these data streams into TCP/IP and sends them over the hospital Ethernet backbone to the Capsule server. This server then translates the data streams to HL-7 and sends them through the Cloverleaf data switch to Epic. During the process of testing the integration of data from these machines and monitors to EPIC electronic anesthesia records, it was identified that these different generations of monitors had various versions of software, firmware and output levels. This could cause issues not only in the initial data validation and for downtime situations, but also would need more resources assigned for future updates and maintenance. Both the Department of Anesthesia and the Hospital Information Systems department were concerned about this. One example of problems with data flow was, older versions of S/5 monitor will not transmit entropy and NMT data into EPIC even though we could do real time monitoring, unless it was a certain level of Datex Record Interface level.

We found that for our S5 monitors there were 4 different software versions (ANE 03,05,06,07), 3 different Datex Record Interface (DRI) levels (2001,2003,2005) and 4 different Serial Output Interface levels. The estimated total cost of upgrading all these machines and monitors to the latest Software, DRI and Output levels came to around 150,000 USD. Extensive research and consultation with the GE engineers in Helsinki identified that the data output from the S/5 monitors was decided primarily by the DRI and the Output interface levels, as long as the software version was to a certain level. Apart from 4 very old monitors, all the other monitors with various software levels could be either dialed up or down to achieve a standard DRI (2003) and Output levels (8/9) by the local GE team. This meant that we had to upgrade the software levels of just 4 machines to the latest software (ANE07) version and then could standardize the Output and DRI levels of all monitors by dialing them up or down. This dropped our cost of this upgrade from the initial estimate of 150,000 USD to around 10,000 USD. This included the cost of upgrading our central server that the department of anesthesia uses to see waveform fields from different monitors in real-time, so that it is compatible with the new DRI levels.

Since data from our Anesthesia Machines (ADU/Aespire/Aestiva) were either minimal or not digital, we did not upgrade or change any of the software or firmware versions of these Anesthesia Machines.

Any department that is in the process of transitioning from paper to electronic should consider these factors as well and should provide adequate time and resources to make sure that these kind of issues are taken care of before go-live

USE OF A TABLET COMPUTER DEVICE, THE APPLE IPAD, IN THE DESIGNING OF ORDER ENTRY SCREEN FOR MEDICATION FOR AN ELECTRONIC ANESTHESIA RECORD

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Electronic Medical Records are becoming the standard across the country. Many physicians would be using tablet computers for accessing electronic records for the purpose of data entry and for reviewing clinical records in the near future. University of Iowa Hospitals recently went live with EPIC Electronic Anesthesia records. During the process of designing and testing the interface for Intraop Record, we decided to do a Quality Improvement study to compare comparing 2 different simulated layouts for medications order entry in electronic anesthesia record. One layout had medications arranged in an alphabetical arrangement and the other had medications arranged in a categorical arrangement. From the results of this Departmental QI project we designed the EPIC Intraoperative Anesthesia Record.

In this project we wanted to measure speed and accuracy using either design. To gather this information we developed a web-based application utilizing ASP.net, jQuery and SQL Server to conduct an experiment. The experiment was given to clinical anesthesia providers when they were not involved in patient care. We got a total of 60 providers participating in the study.

To run the web application for the trial, we decided to use the power, speed, portability, wireless connectivity and versatility of a new tablet computer- the Apple iPad. Subjects where handed an Apple iPad with the application preloaded. The product had just come to the market and it satisfied all requirements of an easily portable mobile device that we could use for the study. We needed to carry the device around to various locations so that we can get a provider to do the trial. It needed wireless connectivity to access the web application from anywhere in the hospital. For this we used the hospital secure "staffnet" WiFi, which is accessible only by staff working within the hospital. The iPad had a touch screen interface, which was similar to the touch screens we were planning to install in all anesthetizing location for data entry into EPIC record. That meant that the data entry method for the study was similar to actual operating room scenario. It had reliable battery power which helped us make sure we were able to complete each trial without loss of power at different locations. With the help of this tablet device, we were able to reliably complete the study in a short time and were able to implement the results in our intraoperative record before go-live.

In short, we describe the novel and successful use of a new tablet computer device, the Apple iPad, for Quality Improvement study in a medical setup which helped us design the interface of our electronic anesthesia record better.

USE OF A HUMAN PATIENT SIMULATION CENTER TO DESIGN AND TEST AN ELECTRONIC ANESTHESIA RECORD BEFORE IMPLEMENTATION

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Human Patient Simulation Labs are designed to train clinicians by using simulated clinical scenarios and to improve psychomotor skills. We describe a novel use of the patient simulation laboratory to design, validate data and test downtime situations of a new electronic anesthesia record system that the Department of Anesthesia was implementing.

The University of Iowa Hospitals recently adopted EPIC electronic anesthesia records after a long preparation. During this time, we used our patient simulation lab for the purpose of designing and testing this interface. We have a fully equipped, state of the art, patient simulation lab that is configured primarily as an operating room. with an anesthesia machine- GE ADU and a Datex-Ohmeda S/5 monitor attached. The Department of Anesthesia Simulation Center is comprised of approximately 400 square feet of simulation space. One arm is focused on psychomotor skills; the second arm of the curriculum is focused on clinical knowledge and the third arm of the curriculum is focused on team training and human factors.

The primary adult mannequin in the Center is a METI Human Patient Simulator (HPS). The HPS is capable of a modeling a wide range of physiologic responses to the administration of drugs and other stimuli. Additionally, the facility has one infant mannequin, a METI Emergency Care Simulator (ECS) and a Laerdal Advanced Life Support (ALS) trainer. The METI HPS has the capability to model and display uptake and distribution of volatile anesthetic agents. The Andros module that creates and updates those models was only briefly used during development of the Anesthesia Record. Instead, fresh gas flows, along with the dial setting on an empty vaporizer, was recorded and ported over to EPIC. All physiological data were simulated including advanced cardiac monitoring like PAP, CO, etc. The only data that would not come out of the mannequin were Entropy and NMT.

To do the design and testing, Capsule Neuronâ was set up in the Simlab, which sends the data from the ADU/S5 to Capsule Server and then to EPIC over the Ethernet. A test system, EPIC POC (Proof of Concept), was used for the purpose of validation and testing. All the data that came out of the S5 and the ADU were viewed from the doc flow sheets of EPIC as well as the anesthesia record.

In coordination with the Clinical Application wing and the Server team of the Hospital Information Sytems Department and EPIC developers, we were able to use the Simlab for the following purposes.

A. Data validation
1. See whether all physiological data was getting populated
2. Validate the values of those data getting displayed
3. Validate the appropriate units of those data

B. Layout and Design

C. Testing of the System
1. Testing all down time situations by breaking the connections at the different points of the network.
2. Autovalidation of data and cached data after downtime situations.
3. Testing various generations of Datex-Ohmeda S5 monitors with different software versions and interface levels.

D. Training
1. Training our clinical superusers
2. Additional training for clinical providers after the initial class room training

Future plans for the patient simulation center includes using it as a site future testing and development and training of new members of the department. Additionally we are planning to develop the HPS Lab as a site, which other institutions, planning to implement similar anesthesia records, can also utilize to get their "superuser" staff trained and experienced with the system.

HYPER-ALGESIA: A LITTLE KNOWN CONDITION IN PAIN ASSESSMENT AND PAIN CONTROL

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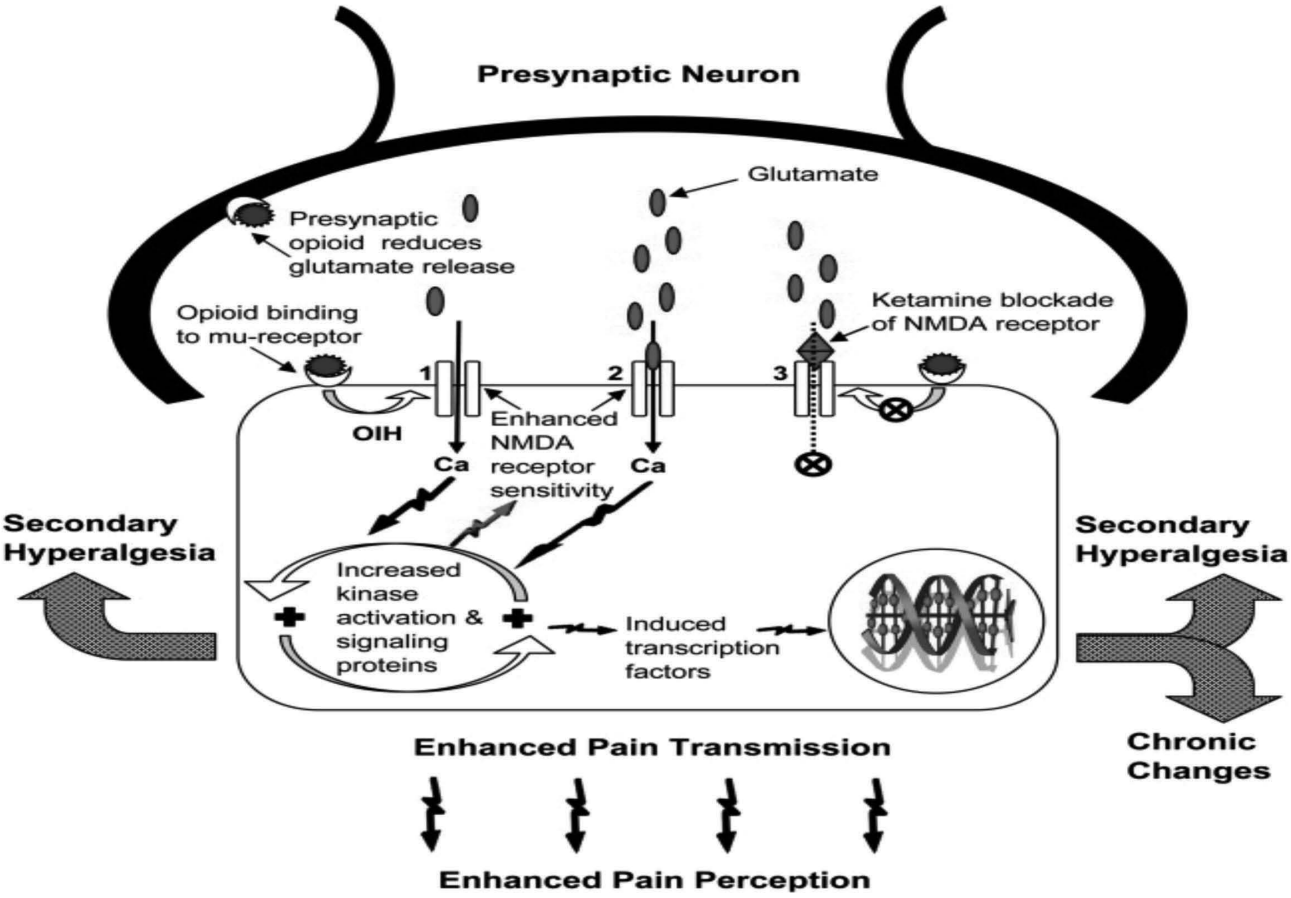
HYPER-ALGESIA is a perception of pain out of the proportion to a given stimulus. This is a poorly understood condition that may impact outcomes of patient care and long term pain-control. A stimulus of pain that activates a cascade in the pre-synaptic neurons at NMDAR causes repeated messages via the dorsal horn of the spinal column.

HYPER-ALGESIA PATHWAY:

- Calcium enters the cell by way of the NMDA channel activation.
- Intracellular signals take paths to cause increase pain transmission.
- Neural signal repeats pain pathway.



Calcium entry into the cell via NMDA channel activation leads to the activation of intracellular signaling pathways causing increased sensitivity, increased transmission, and changes in neural signaling in the spinal cord.

1. Working via intracellular signaling pathways, opioids can cause activation of NMDA receptors allowing calcium passage through the channel, even without strong glutamate activity. This causes opioid-induced hyperalgesia (OIH).
2. Glutamate binding activates NMDA receptors allowing calcium passage through the channel. In both 1 & 2, increased intracellular calcium leads to increased NMDA receptor sensitivity and the development of OIH or secondary hyperalgesia.
3. Ketamine blocks the NMDA receptor channel. This prevents direct glutamate and indirect opioid activation of the NMDA channel from causing calcium entry into the cell thereby reducing hyperalgesia.

The novel wireless telemetry system detected

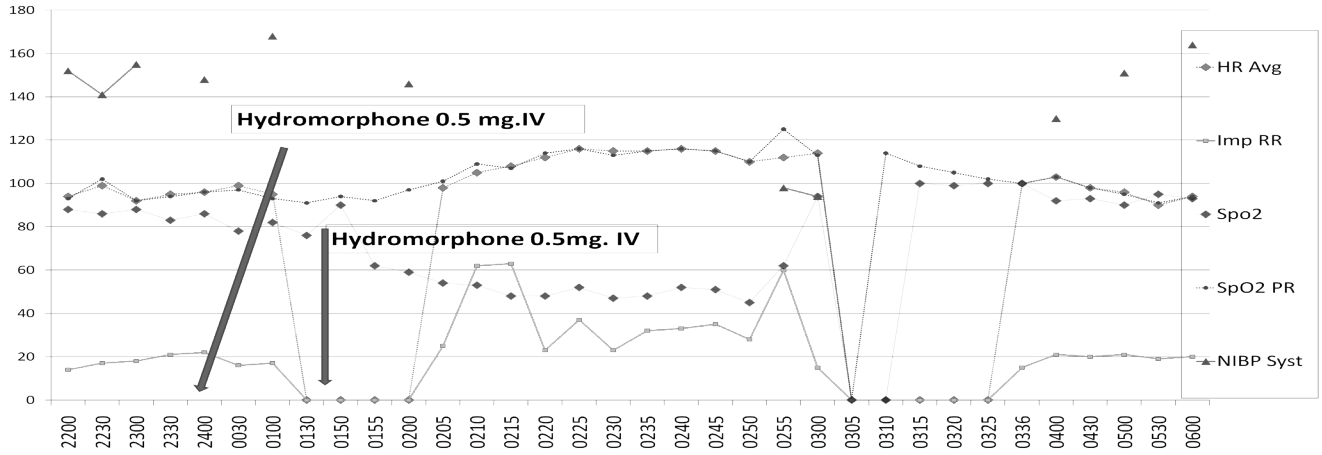
V/S of patient condition relating to HA. Study participant consented to wear device for 24 hours. Recorded vital signs of B/P, EKG, lead ll tracing with respiration, HR and SpO2 data from the non- invasive monitor.

Study FNTX 0549 (C)Participant HX: 51years of age signed consent preoperatively. Surgery admission for LTKR.

Allergic- Codiene (pruritis), HTN, Asthma, with bronchitis reported 1X each yr. Non-compliant with OSA TX of CPAP. Renal insufficiency, Type II diabetes, V/S -SpO295%, B/P 104/69, HR 83, Ht.159cm., Wt.113Kg.

IV meds given perioperatively; **Fentanyl, Midazolam**,Propofol, **Hydromorphom**e.

Medications administered while on study that manifested as HA and led to Rapid response call; **Hydromorphone 4mg.,Oxycodone** SR 20 mg., **Oxycodone 1**0mg.p.o., Phenergan 12.5mg. Trazadone100mg.



Conclusion: With the innovation of a wireless defensive monitoring-device, technology offers safer surveillance of vital signs during postoperative stays. Patients requiring drug intervention for pain can receive safer care by a real time notification system and avoid the potential crisis of over sedation.

A COMPUTER-ASSISTED PERSONALIZED SEDATION SYSTEM

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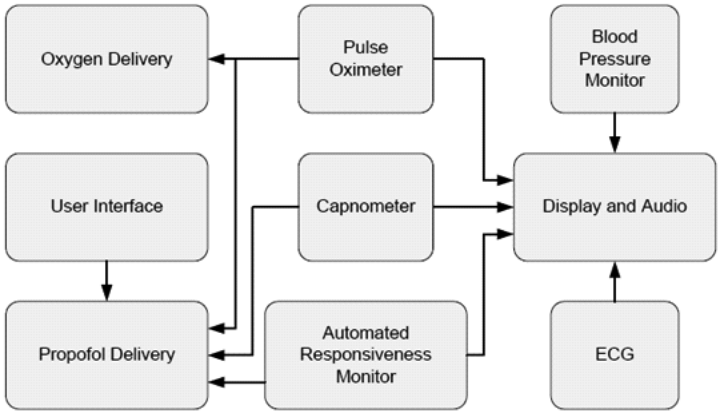
Introduction: The SEDASYS® System is an investigational computer-assisted personalized sedation system that is designed to facilitate the administration of minimal-to-moderate sedation with propofol. The system was designed using the ASA Practice Guidelines for Sedation and the FDA approved propofol labeling. The system provides many safety elements proposed by the anesthesia medical community based on decades of study and experience.

Implementation: The monitors included in the system are a pulse oximeter, a capnometer, electrocardiogram, non-invasive blood pressure, and a novel Automated Responsiveness Monitor (ARM). The ARM assesses the patient's response time to mild verbal and tactile stimulus. The drug delivery algorithms in the system were designed to: 1) achieve the desired clinical effect without overshoot, 2) adhere to dosing recommendations for sedation with propofol, and 3) enable precise titration of minimal-to-moderate sedation. Monitoring is integrated with drug delivery by employing rate limits and reductions based on the ARM. Propofol delivery will stop in response to decreased oxygen saturation or apnea. Oxygen is delivered at a rate that is depended on the patient's arterial saturation.



Schematic of a Computer Assisted Personalized Sedation (CAPS) System

Discussion: The system presented integrates ASA recommended monitoring with drug infusion algorithms that are consistent with the propofol label. The system continuously monitors and responds to the patient's physiological status. The integration of controlled infusion and monitoring provides a safe and effective means to deliver propofol.

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CLOSED-LOOP MANAGEMENT OF FLUID ADMINISTRATION USING DYNAMIC PREDICTORS OF FLUID RESPONSIVENESS

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Introduction: Closed-loop management has been successfully demonstrated for many clinical applications but has been limited in fluid resuscitation due to the absence of reliable predictors of fluid responsiveness. We present simulation data for a novel closed-loop fluid-management algorithm using pulse pressure variation (PPV) as the input variable.

Methods: Using a software simulator which includes an idealized PPV output, three groups of simulations were run using a random set of baseline variables for each run. These baseline variables included weight, height, and hemodynamic parameters. The groups were massive hemorrhage (2,000 ml of blood loss over 20 minutes), steady hemorrhage (1,500 ml over 1.5 hours), and small hemorrhage (500 ml over 1.5 hours). For each group two sets of simulations were performed: twenty were run without the closed-loop, and twenty with the closed-loop algorithm managing fluid resuscitation. Both groups received a 120ml/hour baseline infusion of lactated ringers.

Results: Conditions across all groups were similar at baseline. In the massive and steady hemorrhage groups, there was a significant difference between the control and the closed-loop managed sets in heart rate, mean arterial pressure, and cardiac output throughout the case and at the end of the simulation (Table 1). There was no significant difference between sets in the small hemorrhage group. The closed-loop usually administered fluid before clinical evidence of hemorrhage was apparent.

Discussion: The data from this study demonstrate that our novel algorithm functions well in an idealized testing environment. Future studies will focus on comparison of the algorithm to human management and then animal studies.

Table 1: Final hemodynamic parameters in simulated hemorrhage groups between the no intervention set and the Closed-loop managed set.

	No Intervention (n=20)	Closed-Loop Management (n=20)	p-Value*
Massive Hemorrhage			
Fluid Given (ml)	300 ± 0	1869 ± 50	
HR (bpm)	141 ± 29	72 ± 9	< 0.001
MAP (mmHg)	59 ± 26	91 ± 6	<0.001
CO (l/min)	3.2 ± 1.8	6.7 ± 0.9	<0.001
Moderate Hemorrhage			
Fluid Given (ml)	300 ± 0	1543 ± 54	
HR (bpm)	119 ± 32	73 ± 9	< 0.001
MAP (mmHg)	76 ± 10	88 ± 7	<0.005
CO (l/min)	5.0 ± 1.1	6.9 ± 0.8	<0.001
Slow Hemorrhage			
Fluid Given (ml)	300 ± 0	653 ± 44	
HR (bpm)	77 ± 10	72 ± 9	0.08
MAP (mmHg)	85 ± 7	87 ± 8.8	0.30
CO (l/min)	6.6 ± 1.0	6.5 ± 1.0	0.73

Data are presented as mean ± SD. HR = heart rate, MAP = mean arterial pressure, CO = cardiac output.

EFFECT OF OPERATION END TIME ON THE CIRCADIAN PATTERN OF SELF-ADMINISTRATION OF ANALGESICS

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Background: Our question was whether the diurnal pattern of postoperative pain is influenced by time of the operation completed. We evaluated the changes of circadian pattern of pain using patient-controlled analgesia (PCA).

Methods: Under the IRB approval, we collected the data from the patients who received orthognatic two-jaw surgery. Total 91 adult patients satisfied the inclusion criteria and were divided into two groups (Group1: operation ended between 12:00PM and 4:00PM, Group2: operation ended between 6:00PM and 8:00PM). The combination of 700 μg fentanil and 150 mg ketolorac was diluted to 120 ml normal saline and connected to the PCA device. Basal infusion rate was set to 1.0 ml/h, with bolus dose set to 1 ml, and lock-out time set to 15min. After 3 day infusion, we compared the frequency of pressing the buttons of PCA device as an hour basis among two groups.

Results: The number of patients who pressed the buttons in an hour basis decreased according to time and the most frequent time was from 2:00 to 3:00PM in Group1 (n=45) and from 8:00 to 9:00PM in group2 (n=46) ($P < 0.05$). However, one day after surgery, the frequency of pressing the buttons and the percentage of patients using the buttons were not different to each group ($P > 0.05$). Tendency of pressing the buttons was highest between 9:00AM to 10:00AM in both groups.

Conclusions: One day after surgery, the tendency of requiring the analgesics showed the uniform diurnal pattern in both groups who had different operational schedules.

THE VALUE OF INTEGRATED PULMONARY INDEX (IPI) MONITORING DURING ENDOSCOPIES IN CHILDREN

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The IPI is a software tool that constitutes a representation of 4 parameters: End tidal CO2 (EtCO2), respiratory rate (RR), Oxygen saturation (SpO2) and pulse rate (PR), already displayed on a monitor, in the form of a single index value ranging from 1 to 10 with trend information. The IPI index has been validated for adults and for children older than 1 year of age.

In this study we aimed to study the value of IPI monitoring using Capnostream20® during pediatric endoscopic procedures under general anesthesia (GA) and conscious sedation (CS). We specifically aimed to assess whether 1) IPI monitoring improves patient safety in the pediatric GI suite by reducing hypoxemia and respiratory depression events compared to regular monitoring with oxygen saturation and 2) to assess the safety net of different sedative medications as to adverse respiratory events and patient recovery.

The IPI signal was monitored and analysed in order to detect IPI changes due to various parameters changes such as drug dosage per weight, drug type, and the presence of an anaesthetist.

Results: Our data consisted of 124 measurements of 109 patients undergoing different procedures (upper endoscopy 84 patients, colonoscopy 6 patients, both 9 patients). The data was divided into 3 groups based on the drug type used:Propofol only- 5 patients (group 1) Propofol & midazolam-89 patients (group 2), Propofol, midazolam & Fentanyl-15 patients (group 3). patients in group 2 and 3, had significantly higher IPI levels than group 1. A significantly lower IPI values were found between ages 4-6y compared to 7-12y years old. High midazolam dose was associated with lower IPI levels during the procedure. No significant differences were found for propofol doses. Patients who had an anaesthesist present had lower IPI levels during the procedure compared to those who did not. No differences were noted between the different procedures. IPI values were never higher than 4, a value indicating that the patient requires attention, in all cases of clinically significant respiratory events. IPI alerted all apnea episodes (58 events, IPI=1) and hypoxia (26 events, IPI<=3) episodes, whereas, pulse oximetry captured only the hypoxia episodes (IPI sensitivity=1, specificity 0.98, positive predictive value 0.95).

Conclusions: Younger patient age, use of propofol alone, higher midazolam doses and presence of anesthetist are all associated with lower IPI levels. IPI monitoring adds to patient safety during endoscopic procedures.

HEMODYNAMIC CHANGES INDUCED BY PNEUMOPERITONEUM AND POSITION CHANGE MEASURED WITH ECOM

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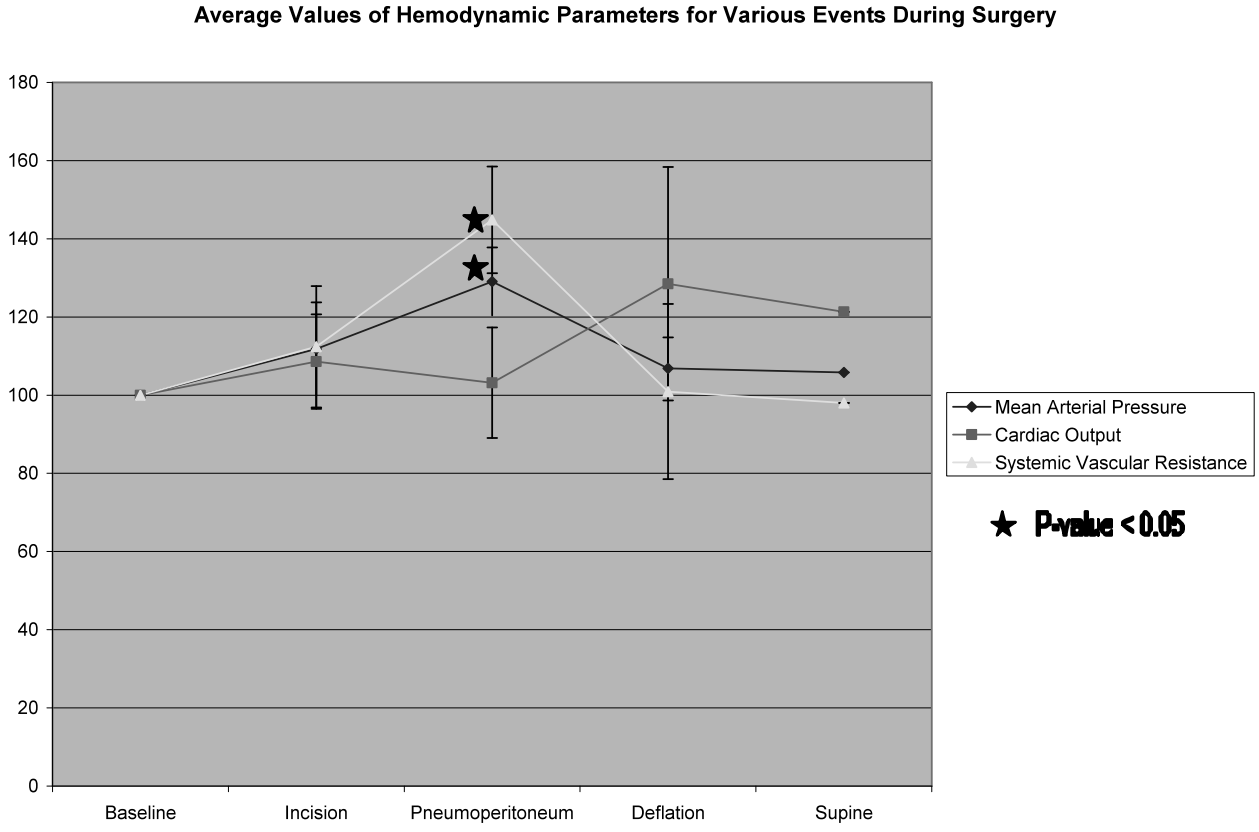
Princeton University, Princeton, New Jersey

Introduction: Laparoscopic surgery presents unique hemodynamic challenges for the anesthetic management of patients. Hemodynamic changes induced by pneumoperitoneum were measured using a new noninvasive device, the Endotracheal Cardiac Output Monitor (ECOM) (ConMed Corp, Utica, NY). This monitor provides measurements – including cardiac output (CO), systemic vascular resistance (SVR), and stroke volume variation (SVV) – that were previously unavailable noninvasively. A better understanding of the applicability and reliability of this new technology in the clinical setting is important for patient safety.

Methods: Hemodynamic parameters were measured using ECOM during laparoscopic surgery with the patients undergoing general anesthesia. ECOM requires an invasive arterial line for measuring blood pressure (BP), and a noninvasive endotracheal tube to measure bioimpedance of the blood flow through the ascending aorta. Cardiac output is calculated from these measurements. Data for cardiac output, systemic vascular resistance, and other hemodynamic parameters were collected with ECOM in seven patients. Measurements were recorded throughout the operation and insufflation and pneumoperitoneum release were noted. The data were analyzed using the paired two-sided T test using Microsoft Excel to find any significant changes from baseline in mean arterial pressure, cardiac output or systemic vascular resistance. The average increase from the baseline, the standard deviation, and the p-values were calculated. p-values <0.05 were considered statistically significant.



Results: On average, pneumoperitoneum caused a 29.1% increase in blood pressure, a 3.2% increase in cardiac output, and a 44.9% increase in systemic vascular resistance ($p<0.05$). As shown in Figure, surgical incision induced an increase in the three monitored indices (MAP, CO and SVR), but this increase was not significant. In contrast, the induction of pneumoperitoneum resulted in a significant increase in MAP and SVR, and a concomitant decrease in CO. These changes in MAP and SVR reverted to baseline upon release of pneumoperitoneum (Figure).

Conclusion: These findings of significant increase in MAP and SVR are consistent with those found in literature (1-4) in cases where the parameters were measured invasively via pulmonary artery catheters. Based on these preliminary data, it appears that ECOM-derived hemodynamic changes reflect those obtained invasively. Therefore, ECOM's noninvasive method to measure CO may be preferable in those patients in whom invasive monitoring is difficult or contraindicated.

Although this study focused on the hemodynamic effects of pneumoperitoneum for laparoscopic surgery, there are other factors – such as respiratory and positional changes – that could affect the hemodynamic parameters. For future research, a more controlled study is planned.

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SURVEY OF ALARM LIMIT SETTINGS FOR ADULT CAPNOGRAPHY USERS

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Introduction: Capnography or end-tidal carbon dioxide ($etCO_2$) is used to monitor ventilation, provide respiratory rate and measure adequacy of ventilation through the measurement of exhaled carbon dioxide. In addition, waveforms provide continuous and real-time feedback on airflow (i.e., apnea) and visual analysis of waveform shape is an indicator of airway obstruction/hypopneas, abnormal ventilatory patterns (hypo/hyperventilation), and as a diagnostic indicator for diseases with airway constriction.[1] Usage has become the standard of care for monitoring ventilation in anesthetized patients in the Operating Room (OR) and is commonplace in the Intensive Care Unit (ICU) for intubated patients. Since the commercialization of sidestream capnography technology and non-invasive exhaled CO_2 oral/nasal sampling interfaces, the use of non-intubated capnography has expanded outside of the OR and ICU into environments of the hospital where caregivers may be less familiar with these monitors (e.g., Procedural Sedation, Patient Controlled Analgesia, Emergency Department, and General Floor).

The alarm settings on these monitors are important and have the potential to prevent untoward events and even deaths by alerting caregivers to dangerous situations such as apnea and significant changes in CO_2 levels. However, excessive alarms including clinically-irrelevant alarms ('nuisance alarms' or false-positive alarms created by artifact) have been shown to desensitize caregivers to clinically-significant alarms and become a threat to patient safety.[2,3,4] In addition, they are a source of aggravation to patients and family members, potentially reducing compliance with monitoring. Recently, algorithms have been developed which have been shown to significantly reduce such clinically insignificant alarms.[5,6]

Additionally, frequent non-clinical alarms may be created by inappropriately setting alarm limits at levels too close to normal ranges. Literature on how best to set alarm limits currently used is lacking. Our goal was to survey experienced users of capnography to determine the ranges of capnography alarm settings commonly used. Such information may be useful to new users in developing their own alarm limit protocols or defaults.

Methods: To conduct our survey, an invitation to participate in a survey of alarm limits was sent to a list of experienced users. Recipients were provided with a link to a web portal (SurveyMonkey.com) for completion of the survey. Those that responded were asked to enter their institutions current alarm defaults based upon the population being served (adult, pediatric, or neonatal with results of the latter two being described elsewhere). Data was compiled and analyzed (Microsoft Excel) for mean, median, mode, and the range of values for each of these populations.

Results: Twenty one experienced users responded for adult applications of capnography. Potential entry errors due to use of different measurement units (i.e., kPa versus mmHg) were confirmed with the participants and omitted if unable to confirm.

	EtCO2 High	EtCO2 Low	FiCO2 High	RR High	RR Low	No Breath (Apnea)
Mean	53.8	20.2	7.3	30.3	7.1	18.3
Median	52.5	22.5	8	29	8	20
Mode	60	30	8	30	8	20
Low	40	8	2	18	3	3
High	60	30	15	50	12	30

Conclusions: Capnography use is has expanded outside traditional use environments creating many new clinical users that may be less familiar with capnography. Having access to alarms limits from experienced users may assist new users in developing their own alarm limits settings. Each institution and ordering physician should recognize that alarm limits should be adjusted based on the population being served and specific patient needs.

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INTEGRATION OF AN INTERACTIVE STEPWISE PRESURGICAL CHECKLIST INTO AN ELECTRONIC PERIOPERATIVE DOCUMENTATION SUITE

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Introduction: Team use of checklists prior to complex or critical procedures improves safety be ensuring that all key factors have been considered prior to beginning. In the operating room, a presurgical time out or safety checklist has been recommended. However, ensuring compliance with this protocol has been problematic. In order to improve compliance with a standardized process, we developed and implemented a stepwise "time out" checklist as an interactive component of an existing perioperative documentation system.

Methods: A static individualized electronic patient safety whiteboard had been in place for several years in all of operating room locations at the Vanderbilt University Medical Center. The safety whiteboard is displayed on a 40" LCD panel in all operating rooms. It is visible to the entire team and referenced during the presurgical time out. The whiteboard software was modified to include a "pre time-out" mode which listed the required time out steps in red.(Fig 1) During the presurgical time out, as each item was announced, the circulator nurse checked a box for each item in the nursing documentation application.(Fig 2) As a result of each check mark, the items in the list turned green.(Fig3) At the end of the checklist, the whiteboard noted "time out complete" and reverted to its static state.(Fig 4)

Figure 1

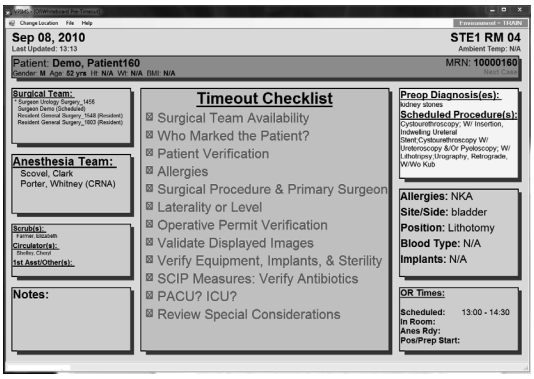


Figure 2

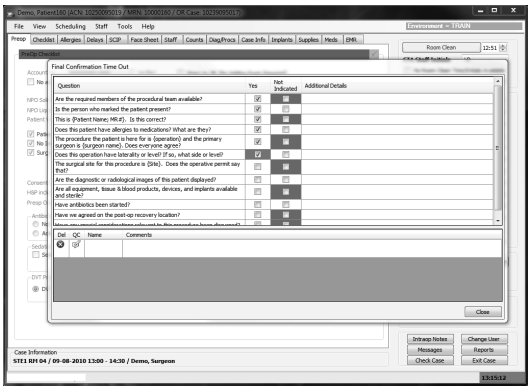


Figure 3

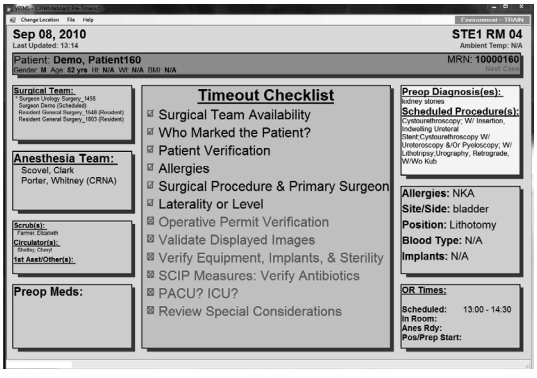
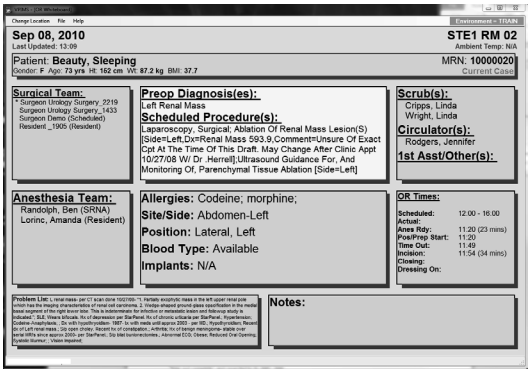


Figure 4



Results: Observations of the time out process were recorded prior to and after the implementation of the new software. Eleven items related to time out completeness and quality were scored by observers. In 10 items, the stepwise timeout significantly improved the rate of compliance. In the 11th, presence of time out prior to procedure, no statistical difference was found.

Conclusion: Software modifications to an existing whiteboard can enhance team compliance with a standardized process by engaging the team in stepwise documentation of each component of a complex sequence. Additional observations will be needed to assess longevity of the improvement.

APPLICATION OF AIMS DATA TO THE DEVELOPMENT OF AN OPTIMAL CARE SCORE FOR ANESTHESIOLOGISTS

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Introduction: Evaluation of care provided by physicians is an important part of pay for performance (P4P) and ongoing professional practice evaluation (OPPE). An optimal care score is an "all or none" summary score which combines several recommended treatment components. Optimal care scores are calculated at the level of the individual patient or patient encounter and then summarized at the physician, service or hospital level. Optimal care protocols have been developed for diseases such as diabetes and heart failure management. We report the development of an optimal care score anesthesia related care delivered to surgical patients.

Methods: A computerized query was developed to assess five anesthesiology related treatments of surgical patients.(Table 1) Data was obtained from an existing AIMS database. Optimal care was deemed to have been delivered if all five items were either successfully achieved or not applicable. An example of not applicable would be antibiotics N/A for patients on continuous abx or for those where . Anesthesiology attending physicians were then ranked on the percentage of their patients who received optimal care based on these criteria.

Results: Utilizing a custom developed computer query, it was possible to combine the four indicators of anesthesiology care into a unified optimal care score (Fig 1). We were further able to rank our providers in percentage of patients who received optimal care. The report was developed with hyperlinks to the relevant clinical documentation.(Fig 2) Physicians can use these links for validation and examination of cases which did not meet optimal care.

Table 1: Criteria selected for optimal care

Criteria
Prophylactic antibiotic administration
CDC central line compliance bundle
Severe vomiting
Pain control (postoperative)
Core body temperature management

Figure 1: Provider listing showing each anesthesiologist and their % of cases achieving optimal care

Anesthetic Care Score Summary (11/1/2010 - 11/15/2010)

Provider Name	Percent of Cases Meeting Criteria
[redacted]	81.3
[redacted]	70.2
[redacted]	86.7
[redacted]	76.9
[redacted]	60.7
[redacted]	76.5
[redacted]	88.5
[redacted]	63.6

Figure 2: Individual practitioner report showing hyperlinks to documentation for each surgical case along with individual component scoring for each of the optimal care score parameters.

Anesthesia Quality Details for [redacted] (11/1/2010 - 11/15/2010)

AnesCaseNumber	Preop	ACR	Postop	Antibiotic	Central Line	Severe Vomiting	Pain Control	Temperature
[redacted]	Preop	ACR	Postop	+	N/A	+	+	+
[redacted]	Preop	ACR	Postop	+	N/A	N/A	N/A	N/A
[redacted]	Preop	ACR	Postop	+	N/A	+	+	N/A
[redacted]	Preop	ACR	Postop	+	N/A	+	+	+
[redacted]	Preop	ACR	Postop	+	N/A	+	+	N/A
[redacted]	Preop	ACR	Postop	+	N/A	+	+	+
[redacted]	Preop	ACR	Postop	+	N/A	+	N/A	-

Conclusion: An optimal care score for anesthesiologists represents a novel methodology for assessing performance. Further work will examine if provision of the optimal care score incentivizes physicians to examine and improve their practice performance on these key indicators.

INFLUENCE OF POSITION ON VENTILATION IN THE AFRICAN BLACK RHINOCEROS (DICEROS BICORNIS) UNDERGOING ANESTHESIA IN THE WILD

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[1]Namibia Ministry of Environment and Tourism
[2]Medical College of Georgia, Augusta, Georgia
[3]Cornell University, Ithaca, New York
[4]Frankfurt Zoological Society, Frankfurt, Germany
[5]Oridion Capnography, Inc.
[6]Zoological Society of the Palm Beaches, West Palm Beach, Florida

Background: The black rhinoceros *(Diceros bicornis)* is critically endangered with just over 4,000 animals surviving in southern Africa. Conservation efforts utilize potent opioids as a foundation for chemical restraint, resulting in respiratory depression, hypoventilation, hypoxemia, and hypercarbia. Preliminary data on the influence of posture on respiratory function was reported here (STA, 2009) but the debate over optimal positioning of rhinos during anesthesia continues. The purpose of this study was to expand on earlier findings and characterize the effects of posture on respiration during field anesthesia of free-ranging black rhinoceros.

Methods: Twenty-four black rhinoceros were anesthetized by remote injection of etorphine and azaperone; 15 rhinos (11 male, 4 female; age 2.5 - 30 yr) had complete sets of data and were included in the analysis. Initial posture was systematically alternated between lateral (LAT) (n=9) and sternal (STE) (n=6) postures. Following initial data collection in one posture the animals were moved into the alternate posture and data collection repeated. Expired gas was collected and measured (Wright's respirometer), while simultaneous arterial blood gas samples were analyzed for $PaCO_2$ (iSTAT). End-tidal CO_2 ($P_{ET}CO_2$) and mean exhaled CO_2 (P_ECO2) were measured with a side stream capnograph (Microcap plus or Capnostream 20). Ventilatory data was indexed for size by dividing values by spine length (m). Data were analyzed with descriptive, inferential (t-test or Mann-Whitney U Test), and general multivariable linear analysis methods using commercially available software (SAS Ver. 9.2)

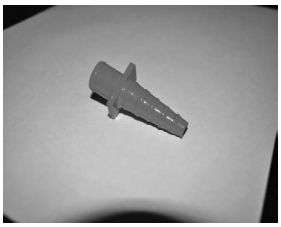
Results: The average time from darting to data collection for posture 1 was 27.6 ± 4.7 min (mean ± SD) and 45.8 ± 6.6 min for posture 2. Nine rhinos were placed in LAT and 6 in STE during posture 1. Average spine length was 2.28 ± 0.17 m. Minute ventilation (VE) averaged 86.8 ± 22.8 L/min, VE/spine averaged 38.0 ± 9.8 L/min/m, tidal volume (VT) averaged 13.7 ± 4.4 L, VT/spine averaged 6.0 ± 1.8 L/m, dead space (VD) averaged 2.5 ± 2.6 L, VD/spine averaged 1.1 ± 1.1 L/m, and VD/VT averaged 18.6 ± 18.5%. $PaCO_2$ averaged 48.5 ± 9.2 mmHg. There were no postural or time differences noted in the above values. $P_{ET}CO_2$ averaged 43.3 ± 5.3 mmHg and was greater in STE (46.7 ± 4.0 mmHg) than in LAT (40.0 ± 4.2 mmHg) $P< 0.001$. $P(A\text{-}a)O_2$ averaged 19.3 ± 11.2 mmHg and was larger in LAT (26.1 ± 5.9 mmHg) than in STE (12.6 ± 11.3 mmHg) ($P = 0.001$). No time differences were noted in $P_{ET}CO_2$ or $P(A\text{-}a)O_2$ values.

Conclusions: In African Black Rhinoceros undergoing anesthesia in the wild, neither posture nor time affected ventilatory parameters (VE, VT, RR, VD). $P_{ET}CO_2$ was smaller and $P(A\text{-}a)O_2$ larger in LAT position when compared to STE irrespective of time. Although these changes in $P_{ET}CO_2$ and $P(A\text{-}a)O_2$ are consistent with changes in ventilation/perfusion (with greater deadspace ventilation in LAT position), we could not measure a postural difference in VD. Possible explanations for this inconsistency include postural effects on cardiovascular function or physiologic shunt, as well as difficulties in collection and measurement of exhaled gases and/or arterial blood.

A UNIVERSAL AIRWAY CIRCUIT CAP CONNECTOR (TIBBLECAP™)

Adam Tibble, MD; Alvin Lee, MD; William Mazzei, MD; Jon Benumof, MD
Department of Anesthesiology, University of California San Diego

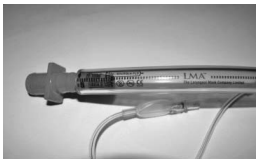
Background: General anesthesia includes initial drug injections that induce unconsciousness and paralysis, causing a patient to stop breathing on their own. The ensuing moments are critical, as a failure to provide oxygen will result in cardiac arrest, brain damage, and ultimately, brain death. Anesthesiologists utilize a multitude of tubes, connectors, and adapters to provide oxygen to the patient during these critical times and throughout the duration of anesthesia. This abstract describes a novel universal airway connector (The TibbleCap™ - ActMD Inc., San Diego, CA) that ensures continuous delivery of life-sustaining oxygen.



The Design: Surprisingly, no other connector like it exists. With its "Christmas tree-like" design, the proximal end fits the standard 15mm airway circuit on all breathing systems. Then, the torso of the connector has ridges to ensure a tight seal and tapers down to a terminal end with an internal diameter of 6mm. This terminal diameter ensures adequate ventilation and negates air trapping[1]; and, it only imparts an air-flow resistance similar to that of a size 7.0 to 7.5mm endotracheal tube[2].

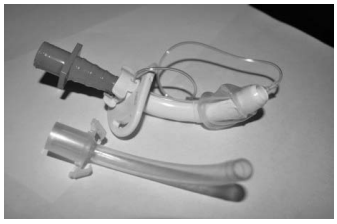
A Few of its Multiple Uses:

Intubating through a "classic" style laryngeal mask à Just cut the LMA!



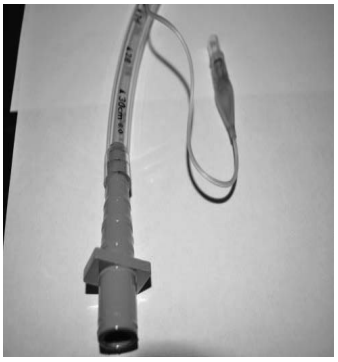
"Classic" style laryngeal masks are used in approximately 8 million surgeries per year in the United States alone. In the event of a "difficult airway" or other scenario, the practitioner can use scissors to cut the LMA at a significantly shorter length, then, place the connector firmly into the laryngeal mask tube. The cutting of the LMA solves the problem of the LMA being too long, and the universal connector allows ventilation to resume while a fiberoptic bronchoscope is summoned. The connector's existence is what allows the practitioner to cut the LMA shorter and converts these LMAs into viable intubating conduits. The TibbleCap™ clearly enhances the utility of these laryngeal masks 1) in difficult airways; 2) in the pre-hospital ambulance or emergency department setting; 3) in elective C-spine cases requiring asleep fiberoptic intubation; and 4) as conversion to a secure airway for any patient with a previously placed "classic" LMA.

Life-saving oxygenation through the outer cannula of a patient's tracheostomy



Many tracheostomy designs have an outer cannula that does not connect directly to a 15mm airway circuit (ex. Shiley™). If a tracheostomy's inner cannula becomes occluded (mucous plugging, etc) as often occurs, the TibbleCap™ can seat firmly within the patient's outer cannula and provide vital oxygen.

Replacing a lost endotracheal tube cap



The endotracheal tube's associated 15mm airway circuit connector cap is often misplaced during fiber-optic intubation. As any anesthesiologist can tell you, it happens frequently. Instead of wasting a separate endotracheal tube solely for the use of its cap, the universal connector can be seated firmly into the endotracheal tube, allowing for ventilation.

Transtracheal Jet Ventilation (through a trans-cricothyroid membrane catheter)

Jet ventilation can take place through a traditional anesthesia machine's oxygen flush valve, but it requires an elaborate contraption of putting an endotracheal tube into a 5ml syringe and inflating the balloon to form a seal. The TibbleCap™ can be seated directly into the syringe (3cc, 5cc, or 10cc), and eliminates the need for an endotracheal tube. Jet ventilation can then be performed through the traditional anesthesia machine, using the oxygen flush valve, TibbleCap™ , syringe, and tracheal catheter.

Summary: This universal circuit cap connector is incredibly functional with many of the tubes, connectors, and airways that are used in medicine. In an emergent scenario, it is integral in obtaining a "secure" airway, a crucial step in providing oxygen to a patient, saving his or her life, and preserving brain function. Additionally, the cap has tremendous utility in c-spine patients, tracheostomy patients, and can function as a replacement tube cap. No other "universal" connector exists that can connect different sized lumens to the standard 15mm airway circuit, and it should be present in all hospitals, operating rooms, emergency departments, and code bags.

References:

1. Dworkin R, Benumof JL, Benumof R, Karagianes TG. The effective tracheal diameter that causes air trapping during jet ventilation. J Cardiothorac Anesth. 1990 Dec;4(6):731-6.
2. Tibble A, Lee A, Mazzei W, Manecke G, Benumof J. The Air Flow Resistance Profile of the Universal Airway Circuit Cap Connector (TibbleCap™) Compared to Various Endotracheal Tube Sizes. Abstract Submission. Society for Technology in Anesthesia – Anesthesia & Analgesia. January 2011.

THE AIR FLOW RESISTANCE PROFILE OF THE UNIVERSAL AIRWAY CIRCUIT CAP CONNECTOR (TIBBLECAP™) COMPARED TO VARIOUS ENDOTRACHEAL TUBE SIZES

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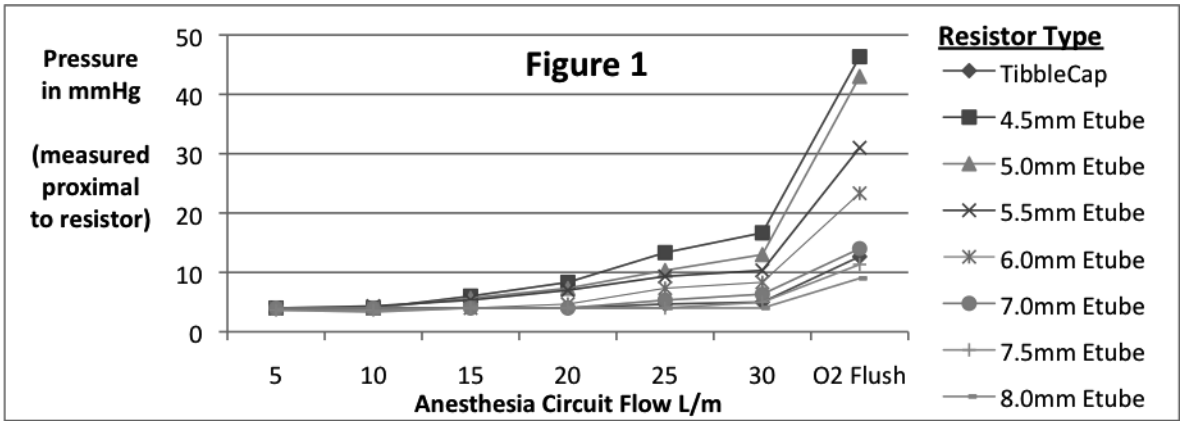
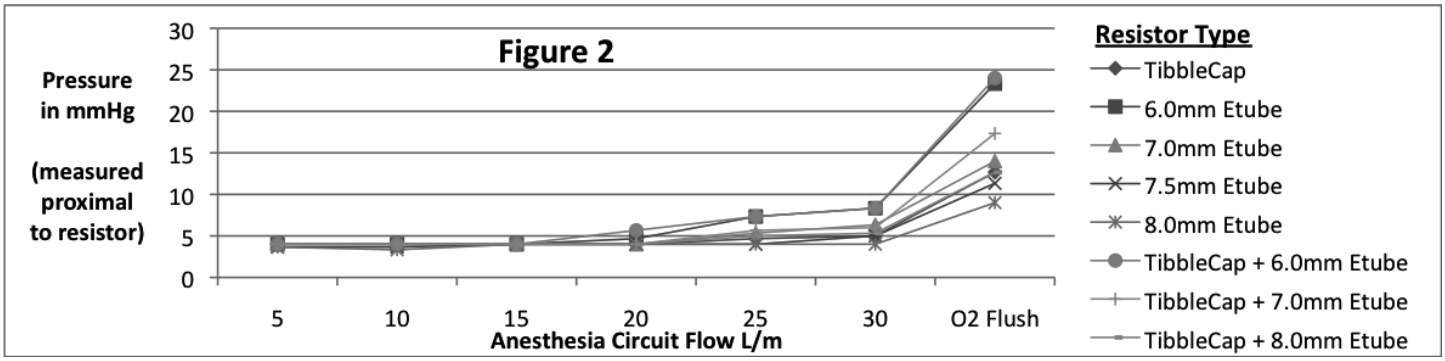
Department of Anesthesiology, University of California San Diego, San Diego, California

Background: The TibbleCap™ (ActMD Inc., San Diego, CA) is a novel universal airway circuit cap connector that allows "classic" style laryngeal masks to function as intubating conduits, provides life-saving oxygen through the outer cannula of a tracheostomy, doubles as a replacement endotracheal tube cap, and finally, simplifies transtracheal jet ventilation[1]. Upon first examination of its structure, the practitioner often voices legitimate concerns regarding the air flow resistance imparted by the TibbleCap™ . In this study, the resistance profile of the TibbleCap™ is compared to various endotracheal tube sizes. Using Ohm's law that resistance is directly related to the change in pressure divided by flow ($R=\Delta P/Flow$)[2], a proximal pressure created by each resistor was measured at identical air flow rates to obtain resistance profiles for each tube or cap.

Materials and Methods: After passing a machine check-out, a Datex-Ohmeda™ Aestiva (model 17002-EX) anesthesia machine was attached to a standard circle system and set to hand ventilation mode. The pop-off valve was closed and the bag port was occluded, thus negating the compliance of the breathing bag, and keeping all air flow within the competent circuit. An arterial line pressure transducer was connected to the Y piece at the CO2 connection port. Identical airflows determined by flowmeters (5, 10, 15, 20, 25, 30 Liters/min) and the O2 flush valve (oxygen direct to breathing circuit from central oxygen supply after passing first stage regulator) were run through the TibbleCap™ and assorted Mallinckrodt™ endotracheal tube sizes. The proximal ends of the resistors were connected to the anesthesia circuit at a secured location just above the transducer. The distal ends were left open to air/atmospheric pressure. Each flow rate was maintained for 30 seconds and the proximal pressures transduced by the arterial line were recorded and verified by two authors and two independent observers. Three trials were taken at each flow rate and averaged.

Results: The novel universal airway circuit cap connector (TibbleCap™) demonstrates a resistance profile between that of a 7.0mm endotracheal tube and a 7.5mm endotracheal tube (Figure 1). Additional data (Figure 2) showed that a TibbleCap attached to a 6.0mm tube creates pressures similar to a plain 6.0mm endotracheal tube. The TibbleCap attached to a 7.0mm tube mirrored the pressures between a 6.0mm and 7.0mm tube. Finally, the TibbleCap attached to an 8.0mm tube shows a resistance profile nearly identical to the TibbleCap alone (between a 7.0mm tube and a 7.5mm tube).





Discussion: Previously well-founded principles such as Bernoulli's effect and turbulent air-flow characteristics are demonstrated in this study. Increased pressure/potential energy is seen proximal to each resistor (Bernoulli); and pressure increases exponentially rather than linearly with increased flow, indicating that flow through the resistor is turbulent (turbulent flow: $\Delta P \propto Flow^2$).

References:

1. Tibble A, Lee A, Mazzei W, Benumof J. A Universal Airway Circuit Cap Connector (TibbleCap). Abstract Submission. Society for Technology in Anesthesia – Anesthesia & Analgesia. January 2011.
2. Schwartzstein R. Respiratory Physiology: a clinical approach. Lipincott Williams & Wilkins. 2006. Pg 62.

FUZZY SAMPLE ENTROPY DETECTS POST-SEDATION IMPAIRMENT OF POSTURAL STEADINESS

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Introduction: Anesthetics impair postural steadiness leading to increased risk of falls. The residual effects of these drugs restrict outpatient throughput due to safe discharge considerations. A practical method to predict the fitness for ambulation and hence a safe discharge time could decrease the risk of postprocedure falls.

Methods: 103 patients (42 males, 61 females, 23-83 years, 150-193 cm, 51-135 kg) stood quietly on a Nintendo® Wii Fit balance board for 60 s before and 60 s after colonoscopy or endoscopy. The patients were sedated with Midazolam (21-132 μg/kg) and Fentanyl (0-3.3 μg/kg). Fuzzy Sample Entropy (FSE)1 was used to quantify the regularity of the sway signal. The separation between the 'before' and 'after' conditions was determined using the area under the receiver operating characteristic curve (AUC) and a Wilcoxon signed rank test.

Results: FSE decreased in 92/103 patients, from 0.22±0.04 to 0.16±0.04 (AUC=0.85, $p<0.001$).

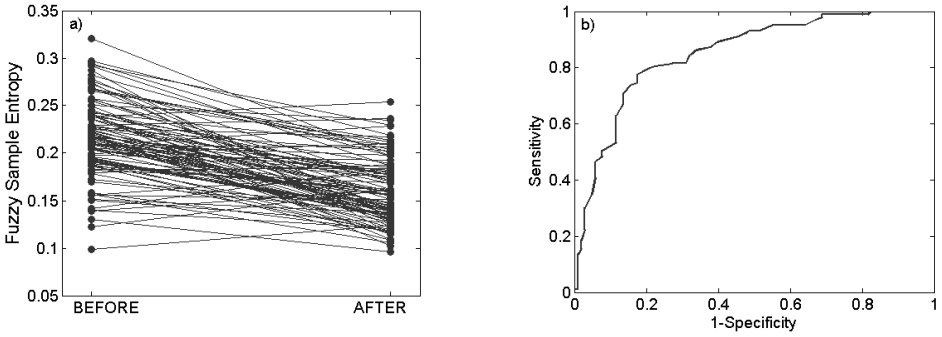

Figure 1: a) Fuzzy Sample Entropy before and after the sedation.
b) Receiver operating characteristic curve with AUC=0.85.

Discussion: FSE detects the impairment of postural steadiness in most patients, and could therefore be used to test their fitness for ambulation. More powerful sway measures could help further separate the 'before' and 'after' conditions by providing larger AUC.

References:

1. Xiong GL et al. Appl Phys Eng 2010;11:270-79.

ANALYSIS OF THE EFFICACY OF WAVEFORM CAPNOGRAPHY MONITORING USING BAG-VALVE-MASK VENTILATION

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Shore Health Systems, University of Maryland, Easton, Maryland

Introduction: Microstream® capnography is applied to spontaneously breathing, assisted breathing and fully supported breathing during resuscitation. It has also been used effectively with noninvasive mask ventilation and CPAP. This analysis examines capnographic monitoring at two sites during simulated resuscitation with a bag-valve-mask (BVM) apparatus in normal subjects.

Methods: Following IRB approval and informed consent, 15 normal subjects between the ages of 20 and 57 were simultaneously monitored with two Oridion Capnostream™ 20 devices. One utilizing the Microstream® Smart Capnoline Plus™ Uni-junction™ Filterline® applied to the face per manufacturers instructions and the other connected inline with the BVM system (typical). The parameters monitored were P_EtCO_2, RR, SpO_2%, F_iCO_2, HR, and Integrated Pulmonary Index (IPI™) as well as the graphic CO_2 waveform. Subjects were monitored during nose breathing at: 3-minute baseline, mouth breathing 3-minute baseline and assisted breathing for 6-minutes with BVM during nose breathing and in the sniffing position mouth breathing with readings taken every minute.

Results: The two monitors showed P_EtCO_2 was within ±2 torr during simultaneous monitoring with BVM supported breathing throughout both nose and mouth breathing. RR was within 1 breath for all BVM monitoring sessions. F_iCO_2 greater than 0 was seen only with the Uni-junction™ appliance. There were no significant changes in P_EtCO_2 using the Uni-junction™ between nose breathing baseline, BVM nose breathing, mouth breathing baseline, or BVM mouth breathing.

Discussion: Effective and accurate measurement of ventilation is critical while monitoring patients during resuscitation. Capnographic measurement of effective ventilation and return of spontaneous circulation is paramount during CPR or while supporting ventilation. Limitations of the typical inline monitoring are that P_EtCO_2 monitoring is lost when the mask is removed after the patient returns to spontaneous breathing and F_iCO_2, indicating deadspace ventilation (rebreathing of CO_2 in mask) is not seen with the typical inline monitoring. Flexibility and continuous monitoring of capnography is enhanced using the Uni-junction™ during mask ventilation and during periods of spontaneous breathing.

Conclusion: There were no significant differences in monitoring the subjects when comparing the Uni-junction™ Filterline® to the typical inline monitoring with the BVM. The Uni-junction™ Filterline® provides continuous monitoring of patient's breathing when the BVM is removed whereas the typical inline system does not provide measurement because the system has been removed from the patient.

CAPNOGRAPHY IMPROVES DETECTION OF RESPIRATORY EVENTS DURING PROCEDURAL SEDATION: A META-ANALYSIS

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[2]School of Public Health – Department of Health Behavior; University of Alabama at Birmingham, Birmingham, Alabama
[3]School of Medicine – Department of Anesthesiology; University of Alabama at Birmingham, Birmingham, Alabama

Introduction: The use of procedural sedation and analgesia (PSA) has increased in frequency and scope, including emergent settings inside and outside of the hospital. Although end-tidal CO_2 ($EtCO_2$) monitoring is routinely used during general anesthesia to monitor ventilatory status, this is not the case for PSA. Pulse oximetry and visual inspection, both with inherent limitations; represent the current standards of care for monitoring ventilatory status during PSA. $EtCO_2$ monitoring may be a preferable method for detecting alveolar hypoventilation and preventing hypoxemia during PSA but is not widely used in this setting. Our study objective was to determine if capnography in addition to standard monitoring improved detection of respiratory events compared to standard monitoring alone.

Materials and Methods: A literature search was conducted using the electronic databases PubMed, CINAHL, and Cochrane Library (Cochrane Reviews, CENTRAL) for studies published between 1995-2009 reporting adverse respiratory events during procedural sedation and analgesia with clearly defined $EtCO_2$ threshold, clear study design, p-value calculation, similar outcome and predictor variable definitions, and binary independent and dependent variable raw data. To limit threats from variations in practice, only reports of adults in the USA were included. Five such studies were evaluated independently. A meta-analysis of these studies was performed.

Results: During PSA, cases of respiratory depression were 17.6 times more likely to be detected if monitored by capnography, vs. cases not monitored by capnography (95% CI, 2.5-122.1; $p<0.004$).

Conclusion: This analysis quantitatively supports the presumption of clinicians administering PSA that EtCO2 monitoring is more effective than traditional monitoring modalities for detecting respiratory depression.

CAPTURING VITAL SIGNS FOR RESEARCH IN A MULTI-BED MONITORING ENVIRONMENT

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[2]Department of Anesthesiology, Pharmacology & Therapeutics, University of British Columbia, Vancouver, British Columbia, Canada

Background: Capturing vital signs for research activities, such as measuring heart rate variability [1], obtaining data to design, or testing novel medical displays [2] or alarm algorithms [3] is traditionally done by directly connecting a data capture device to the patient monitor. A novel method and device that allow researchers to retrospectively analyze data for all patients admitted to an intensive care unit (ICU) is presented.

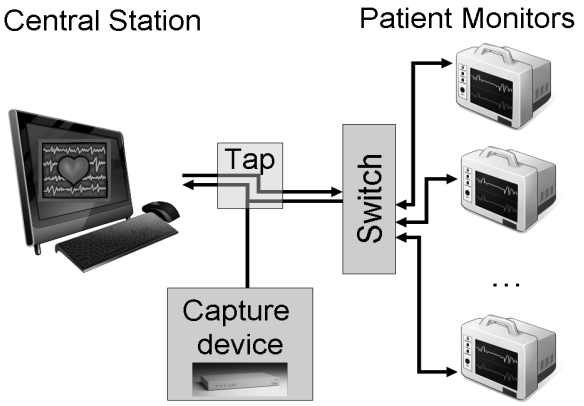

Figure 1: Overview of the patient monitoring network with the data tap and capture device.

Method: A passive tap was installed between the central monitoring station and the switch connecting patient monitors. The tap allowed unobtrusive capture of the entire data stream sent to the central station [4]. A dedicated embedded platform (net5501, Soekris Engineering Inc, Santa Cruz, CA) running a minimal OpenBSD operating system was permanently connected to the data tap. This reduced the risk of connecting and removing a device from the network, interfering with data collected by the central station. The device captured the raw data transmitted to the central station in a compressed packet capture (PCAP) format, partitioned into 1 hr segments, and stored it on an internal hard disk. Arbitrary segments of the recorded data could be extracted to a flash drive at any time from the live system. This data extraction was automatically driven by a spreadsheet table containing a batch list of monitor IDs, start times/dates and durations. To prevent unauthorized extraction of protected health information, the capture box transferred data only to authenticated drives and provided an audit trail by logging all data transfer requests. The researcher used a universal parser to convert the extracted data segments into numeric trends and waveforms in CSV format for further investigation. The parser could decode data from Phillips Intellivue and GE Datex-Ohmeda central networks, although support for other Ethernet-based monitor networks can be added. This will potentially provide a single interoperable patient data access point for incompatible vendor implementations.

Discussion: A simple and safe method of allowing researchers access to previously captured vital sign information in an ICU is presented. Advantages of this solution are 1) low cost and low maintenance, 2) access to comprehensive past data, which allows analysis of rare events, 3) secure access to captured data without the need to connect research equipment to the live monitoring network, 4) modification of the offline parser is possible due to raw data storage e.g. parameters not originally requested by the researcher can be added, 5) the capture box works with any Ethernet based monitor network, and 6) boxes can be chained for simultaneous and redundant storage of data from multiple locations, such as the ICU and operating rooms. Disadvantages of the method are: 1) a special parser is needed to extract information from the captured network packages, 2) using a flash drive is a cumbersome method to extract large chunks of data due to limited transfer speed, and 3) data extraction to the flash drive is delayed from the real-time feed by up to one hour due to the internal data partitioning. Real-time access to the data is possible from a secondary network interface on the capture box, but requires real-time parsing.

Conclusion: The described capture device provides an easy method to access vital sign information for ICU patients. It requires minimal training for the user and reduces the workload for the research group that is providing the device. Finally, it can easily be expanded to operating rooms and wards with telemetry monitoring.

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THE FLUIDOMETER™: A NEW INTRA-OPERATIVE FLUID MANAGEMENT AID

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Introduction: Intra-operative fluid management requires the anesthesiologist to spend time in calculations in order to give the patient the exact volume of fluids according to a vast number of variables, such as patients' anthropometric data, type of surgery, duration of procedure, blood loss, etc, in a fine balance between inputs and outputs. We designed a novel system (Fluidometer™) , as an aid for intraoperative fluid management.

Methods: One hundred patients undergoing either urologic or orthopedic surgery are enrolled and pair-randomized (type of surgery) in two groups of equal size each in order to receive either "standard" fluid management (Control group) or "Fluidometer™-guided" fluid management. All patients received TIVA automatically delivered by an automated anesthesia delivery system (McSleepy™, 1). Arterial blood gases were obtained every 30 minutes. The Fluidometer™, (Figure), is an algorithm which takes into account patient's anthropometric data, the type of surgery, blood loss and gives a real-time visual indication of the patient's hydration status throughout surgery comparing the "target volume" (fluid volume that the patient should have received up to that moment) with the "given volume". The given volume is manually updated by the anesthesiologist every time 500ml of crystalloid or colloid are given, by clicking a special button on a touch screen interface. The Hydration status is shown by the Fluidometer™ as "very dry", "dry", "fair", "wet" or "very wet" if the given volume is respectively -75%, -50%, within ±25%, +50% or +75% than the "target volume" calculated by the Fluidometer™. Patient Data as well as the amount of fluid administered, changes in hemoglobin and hematocrit were analyzed with Student's t-test or chi-square test ($p<0.05$) and are presented as mean (SD).

Results: (Preliminary results of 22 patients) Patients' demographic data and length of procedure were similar in the two groups of 11 patients each. Mean age and weight was 58 (18) yrs and 79 (15) kg in the Fluidometer™-group (7 men, 4 women) vs 60 (16) yrs and 80 (16) kg in the Control group (8 men, 3 women). Mean anesthesia duration was 175 (66) min (Fluidometer™ group) vs 199 (54) min (Control group). The administered fluid volume was significantly less at 1900ml (710) in the Fluidometer™-guided group, vs 2900ml (1300) in the standard fluid management group. The relative hemoglobin and hematocrit decrease were significantly lower in the Fluidometer™ -group than in the standard fluid group (Table 2).

Conclusion: The Fluidometer™ is a novel instrument used to automatically calculate the intra-operative fluid target; it can be used as an aid for intraoperative fluid management. Preliminary results show that in comparison to our present standard fluid administration, it reduces the crystalloid volume given, thus reducing hemoglobin or hematocrit decrease. More patients are needed to confirm the potential of this new monitor.

Reference:

1. CAS meeting 2010, Montreal, Abstract ID: 803213

Figure: User interface

Groups	Fluidometer™	Control	P
Fluid during surgery (ml)	**1864 ± 710**	**2909 ± 1281**	**0.028***
Absolute Hb decrease (g/dL)	1.2 ± 0.6	1.8 ± 1.0	0.067
Absolute Hct decrease (%)	3.8 ± 2.0	5.9 ± 3.1	0.073
Relative Hb decrease (%)	**9.6 ± 4.3**	**16.8 ± 8.7**	**0.023***
Relative Hct decrease (%)	**9.7 ± 4.4**	**16.8 ± 8.8**	**0.025***
Initial Hb (g/dL)	11.8 ± 1.6	10.7 ± 2.1	0.153
Minimum Hb (g/dL)	**10.7 ± 1.3**	**9.1 ± 1.8**	**0.028***
Initial Hct (%)	38.2 ± 5.3	34.5 ± 6.6	0.160
Minimum Hct (%)	**34.5 ± 4.2**	**29.5 ± 5.6**	**0.029***

Table: Fluid and hemoglobin/-crit changes

'*HSS*' – A NOVEL HYBRID SYSTEM FOR CONSCIOUS SEDATION

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Introduction: The aim of this project was to determine the performance of an hybrid closed loop sedation system ('*HSS*') which integrates a decision support system (DSS) for controlled sedation of patients undergoing knee or hip arthroplasty with spinal anesthesia and conscious sedation.

Methods: After Ethics approval and written consent, 120 patients undergoing knee or hip arthroplasty with spinal anesthesia and propofol sedation were randomized to receive either automatic sedation ('*HSS*'-group, Fig 1) or manually administered propofol (Control-group). Bispectral index monitoring (BIS) was used to guide sedation in all patients with a target of 65. The clinical performance of the sedation was defined as "Excellent", "Good", "Poor" or "Inadequate", when the BIS was within 10%, between 10 and 20%, between 20 and 30% or outside 30% of a target BIS of 65, respectively. In addition, a Decision Support System (DSS) which indicated critical events of respiration and hemodynamics via audio-visual alarms and offered decisional aid was evaluated (Fig 2). Critical respiratory events were defined as SpO2 <92% and respiratory rate < 8/min. Critical hemodynamic event was defined as MAP < 60 mmHg and heart rate <40 bpm. The incidence of critical events detected by the DSS system was compared with the incidence of events in the control group as well as the time needed to detect those events and patients' awake time during surgery. Data were analyzed using XLstat 2010 software (data presented as mean, ±SD, $p<0.05$).

Results: Demographic data and surgery duration were similar in both groups. HSS-group: age, 63 (14) years; weight, 81 (16) kg; male/female, 27/33; anesthesia duration, 117 (42) min. Control group: age, 70 (12) years; weight, 80 (16) kg; male/female 23/37; anesthesia duration, 125 (37) min. The number of modifications of propofol doses per hour was significantly higher in the '*HSS*'-group at 22 (5) than in the Control group at 5 (2), with no significant difference of propofol dose at 82 (39) $\mu g\ kg^{-1}\ min^{-1}$ in '*HSS*'- group versus 69 (27) $\mu g\ kg^{-1}\ min^{-1}$ in the Control group. The control of the sedation was better in the *'HSS'*-group (Fig 3). In the HSS-group, the patients' awake time during surgery was significantly shorter, 5min (8) than in the Control group at 14min (14) (Fig 4). All the respiratory and hemodynamic critical events were detected in the *'HSS'*-group, while in the control group 26% of them were not detected. The delay for the detection of the critical events was significantly shorter in the '*HSS*'-group at 8sec (4) than in the control group, at 29sec (21). There were no significant differences in physiological parameters in the two groups during surgery.

Discussion: '*HSS'*, a hybrid closed loop sedation system can control sedation better than manually delivered propofol sedation and detects all respiratory and hemodynamic critical events and in a shorter time frame.

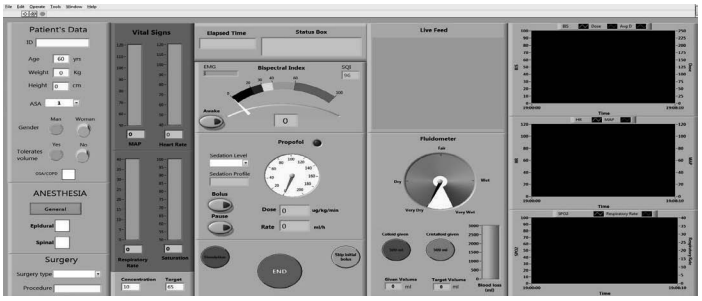

Figure 1: HSS interface

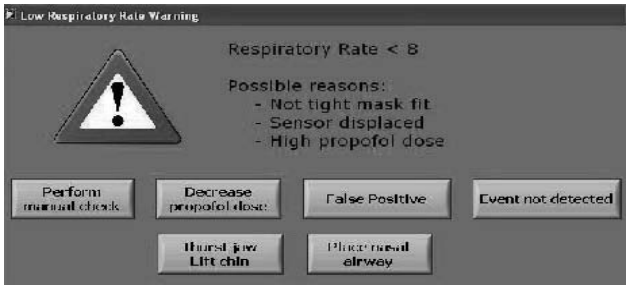

Figure 2: Pop-up menu for Critical events

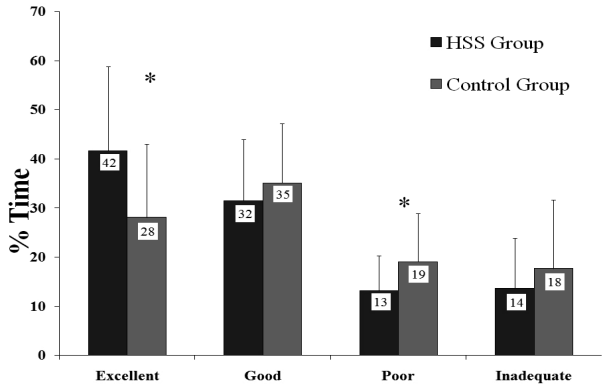

Figure 3: Clinical performance

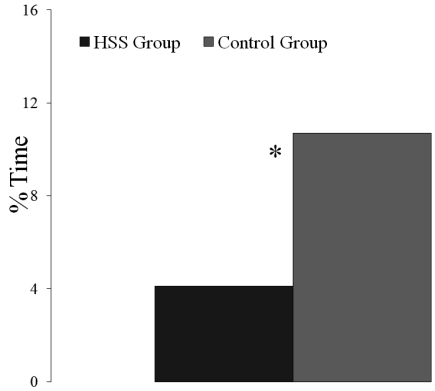

Figure 4: Awake time throughout surgery

DECREASE OF CEREBRAL OXYGEN SATURATION MEASURED BY ABSOLUTE OXIMETRY IN PATIENTS UNDERGOING SPINE SURGERY IN PRONE POSITION

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Introduction: Prone position in patients undergoing spine surgery causes important cardiovascular and pulmonary disturbances. The aim of the present study was to determine incidence and magnitude of the decrease in cerebral oxygen saturation ($SctO_2$) in patients undergoing spine surgery in prone position.

Methods: Fifty consecutive patients undergoing spine surgery were enrolled. The FORESIGHT™ (CASMED, USA) absolute cerebral oximeter was used to measure left, right and average absolute $SctO_2$ and data were automatically recorded every 2 seconds from the awake state to extubation. Standard clinical parameters, bispectral index were continuously recorded. Blood gas analysis was performed every 30 min throughout surgery. Data are shown as mean (SD), and were analyzed using Spearman's correlation test, $p<0.05$.

Results: Patients [aged 59yrs (17), M/F 28/22, ASA I/II/III 15/18/17] showed an absolute baseline $SctO_2$ of 76% (6) during the awake state; 68% of the patients showed a $SctO_2$ value below 65% during prone position, while 26% of them showed a decrease below 60% (Table 1). Exposure time to $SctO_2 < 65\%$ was 34% (33) of prone position total time. Exposure time to $SctO_2 < 60\%$ was 18% (24) of prone position total time (Figure 1). During prone position, a significant number of patients had a decrease of $SctO_2$ of more than 15%. (Figure 2). The decrease in $SctO_2$ was correlated to patient's age, duration of prone position and the relative decrease of hemoglobin and hematocrit. No other correlations with standard clinical parameters were found. The $SctO_2$ decrease disappeared within 10 min in all patients after establishment of supine position.

Conclusions: Prone position during spine surgery is associated with a decrease of $SctO_2$ in a significant % of patients. These desaturations are related to the prone position itself and to blood loss.

Table 1: Exposure under SctO2 thresholds of 65% and 65%.

$SctO_2$ (%)	N (%)	Exposure time (min)	Exposure time (% of prone position)	Duration of prone position (min)
$SctO_2 < 65\%$	34 (68%)	80 ± 95	34 ± 33	233 ± 88
$SctO_2 < 60\%$	13 (26%)	43 ± 58	18 ± 24	238 ± 82

Figure 1: % of time of SctO2 below 65% and 60%

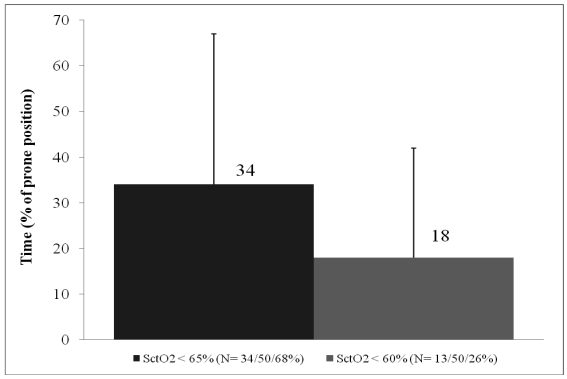

Figure 2: % of pt with SctO2 decrease

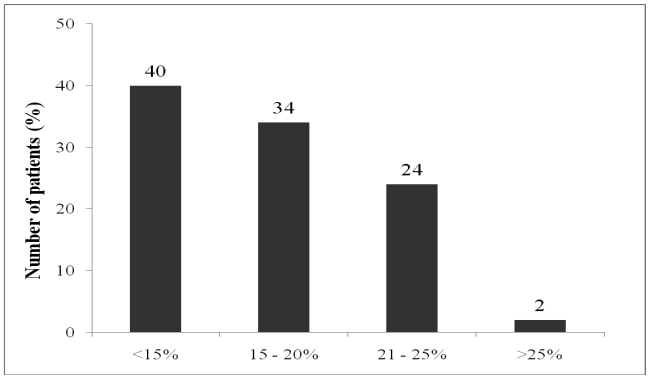

Table 2: Correlation between minimum absolute value of SctO2 and clinical parameters.

Correlation test (Spearman)	R^2	***P-value***
Minimum absolute value of $SctO_2$		
Age	-0.326	0.021*
Duration of surgery	-0.363	0.010*
Duration of prone position	-0.373	0.008*
Relative hemoglobin decrease	-0.429	0.003*
Relative hematocrit decrease	-0.365	0.012*
Relative peripheral saturation decrease	-0.031	0.833
Relative PCO_2 decrease	-0.168	0.254
Relative PO_2 decrease	0.108	0.466
Relative MAP decrease	-0.246	0.092

TRANSCONTINENTAL ANESTHESIA

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Introduction: Tele-medicine has been used in different fields of medicine to overcome the lack of specialist and improve health care. The aim of the study is to determine how anesthesia delivery can be achieved remotely.

Methods: After ethics approval in the remote (Montreal General Hospital, Canada) and local centre (University of Pisa, Italy), 20 patients undergoing thyroid surgery in Pisa were enrolled. The remote and local set-up were composed of a *master*-computer (Montreal – '*anesthesia cockpit*'), a *audio-video*-purpose computer (both sites) and a *slave*-computer (Pisa), respectively. Standard internet connection and remote desktop control software were used in both centres. The AV-computer system was used to collect images from distant monitoring of the patient, video-laryngoscopic intubation guidance, vital signs, ventilator parameters, view of the surgery field throughout the surgery, using HD webcams. [Fig 1]. Pre-operative assessment was performed by anaesthesiologists in both centres using standard protocols. Standard TIVA (propofol, remifentanil, rocuronium) was automatically delivered using a closed-loop system (1) and controlled by the remote centre. The performance of the hypnosis was defined as excellent, good, poor or inadequate, when the BIS was respectively within 10%, between 10 and 20%, between 20 and 30% or outside 30% of the target BIS of 45. Pain was assessed using Analgoscore with a score ranging from -9 to 9, with ±3 representing excellent pain control, -3 to -6 and 3 to 6 good pain control, and -6 to -9 and 6 to 9 inadequate pain control. (2) Data are presented as mean (SD) or value, comparison of the pre-op assessment were done by Cohen's Kappa test, SPSS.

Results: The remotely-controlled closed loop system maintained anesthesia for all patients (4 men, 16 women; age: 44 (13) yrs; weight: 66 (14) kg) throughout surgery without any interruption of the internet connection, providing teleanesthetic drug infusion during 100% of the time. Out of the 8 parameters of comparison of preoperative assessment, 4 showed perfect, 2 good and 2 moderate agreement, respectively [Table 1]. The mean propofol dose was 118 (32) μg/kg/min, the mean remifentanil dose 0.28 (0.07) μg/kg/min, the total rocuronium dose 0.63 (0.11) mg/kg; time to extubation was 9.8 (4.0) min. The system showed 57 (20) modifications of propofol doses/h and 36 (9) modifications of remifentanil doses per hour. The clinical performance was very good and is showed in table 2.

Conclusions: Tele-anesthesia is feasible using remote control of an automated anesthesia delivery system; inadequate control of hypnosis was influenced by electrocautery (marked as artifact) causing unreliable BIS values. Preoperative assessment using AV-communication showed overall good agreement with standard assessment.

References:

1. CAS meeting 2010, Montreal, Abstract ID: 803213
2. Journal of Computers 2009; 4: 311-318.

	Remote Group (N=20)	Local Group (N=20)	Kappa
ASA (1 / 2 / 3)	11 / 8 / 1	12 / 7 / 1	0.77
Allergies (0 / 1 / 2)	17 / 2 / 1	17 / 2 / 1	1.00
Medical History (0 / 1 / 2 / 3)	10 / 8 / 1 / 1	8 / 9 / 2 / 1	0.56
Airway Assessment			
Mouth Opening (1 / 2 / 3)	17 / 3 / 0	18 / 2 / 0	0.61
Mallampati Classification (1 / 2 / 3)	14 / 6 / 0	9 / 9 / 2	0.55
Thyromental Distance (1 / 2)	20 / 0	20 / 0	1.00
Neck Mobility (1 / 2)	20 / 0	20 / 0	1.00
Larynx Mobility (0 / 1)	20 / 0	20 / 0	1.00

Kappa ≤ 0.2: poor agreement; 0.2 < Kappa ≤ 0.4: fair agreement; 0.4 < Kappa ≤ 0.6: moderate agreement; 0.6 < Kappa ≤ 0.8: good agreement; 0.8 < Kappa < 1: very good agreement; Kappa = 1: perfect agreement.

Table 1: Comparison of pre-operative assessment

Figure 1: Video-stream in Montreal from monitoring in Pisa

BIS	Excellent (%)	36.6 ± 15.1	Analgoscore	Excellent (%)	68.0 ± 21.9
	Good (%)	32.8 ± 6.4		Good (%)	24.2 ± 18.4
	Poor (%)	13.3 ± 5.6		Insufficient (%)	5.9 ± 10.5
	Inadequate (%)	12.7 ± 10.3		Artifact (%)	1.8 ± 3.2
	Artifact (%)	4.6 ± 3.6			

Table 2: Clinical Performance

LOCATION INDEPENDENCE IN PATIENT MONITORING

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Introduction: Hospital patients require physiological monitoring throughout their stay. Monitoring requirements depend on the hospital unit (e.g. Admission, OR, ICU, ward). Currently, monitoring devices are stationary and are connected by wires to sensors and patient. This is cumbersome for both patient and health care providers, and sensors must be disconnected when the patient is prepared for transfer between units. Further, sensors located in one unit are often incompatible with those in another. We propose a novel concept that simplifies patient monitoring throughout the hospital.

Method:

Approach: We propose a two level wireless network (Fig. 1). A personal area network (PAN) is private to the patient and is responsible for the control of data communication. The PAN host device connects to all required sensors using a wide range of supported protocols (e.g. serial, USB, WiFi and Bluetooth), and is attached to the patient during the entire hospital stay. The PAN host then wirelessly transmits the standardized data to a local area network (LAN) that records patient health information in a database. This information can be retrieved in real time by either stationary monitoring devices or mobile devices of health care providers throughout the hospital network.

Prototype: The prototype consists of two pulse oximeters (Nonin, USA) connected via Bluetooth and wired connection, respectively, to a computer with a Linux operating system that acts as the host for the PAN. The LAN consists of a server running a web-based sensor actuator network portal called Sense Tecnic[1]. A WiFi enabled mobile device is used as the monitoring display.

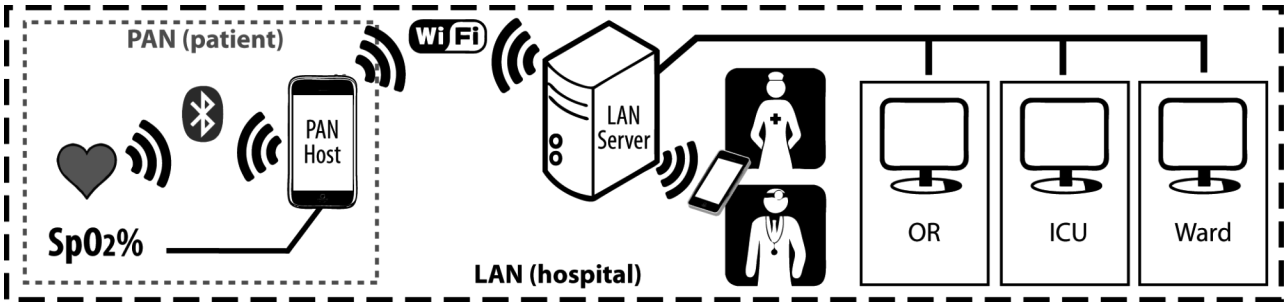

Figure 1: A personal area network (PAN) monitors the patient and transmits the trend data to a local area network (LAN) where health care workers can access the signals in real-time.

Results & Discussion: Blood oxygen saturation and heart rate trend signals are recorded and displayed in real time at a 1 Hz update rate. The web-based data portal allows platform independent, real-time monitoring. The PAN allows for easy connection of sensors to the patient and facilitates monitoring during patient movement and transportation. This approach will facilitate the use of elementary sensors without interruption throughout the hospital. Unit specific sensors can be added to the PAN when required. Future work will include geolocation by indoor triangulation using the WiFi network, and size reduction of the PAN host.

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DESIGN AND IMPLEMENTATION OF AN ANESTHESIA DATA WAREHOUSE USING OPEN SOURCE TOOLS AND SOFTWARE

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Introduction: Large scale data mining and analysis is becoming critical to achieving the next level of safety and quality in anesthesia. For the past four years we have been developing our own single-institution data warehouse, with an emphasis on the use of open source tools and software.

Methods: The current platform is a 3.8Ghz dual processor machine with 6 GB RAM and 1.5 TB disk space, running Ubuntu 10.04 (Linux) and MySQL 5.1. The core of the schema is 18 tables containing case data extracted from our AIMS, normalized loosely by data type. Surrounding this are several dozen lookup/reference tables. Extensive use of views provides an abstraction layer should the structure of the base tables change.

On top of this we have built a suite of tools in Perl, using a variant of the "extract transform load" data warehousing paradigm that we call "load filter transform". There is one program that is responsible for loading data, and another which allows users to query the warehouse. Object oriented design and modularity provides flexibility and extensibility (Table 1).

Results: The warehouse currently contains more than 150GB of data from over 300,000 anesthetics, and growing. The largest table, containing physiologic data, has over 3 billion rows. Intelligent use of partitioning on this table allows for fast inserts and queries. Typical processing time for a complex research question involving calculations on physiologic data is 2.5 seconds per case. Next steps include performance optimization and migration to a larger server supported by hospital IT.

Table 1

Program	Purpose
Case.pm	object that represents a case
crload.pl, CRParser.pm	extract data from AIMS and load into warehouse
extract-physio.pl	main program for querying the warehouse
Filter.pm	logic to filter and clean cases prior to processing
IncludeExclude.pm	transforms inclusion/exclusion criteria into SQL
PhysioCalc.pm	routines to transform physiologic data
Math.pm, Util.pm, Config.pm	common, resusable code

DESIGNING A NEXT GENERATION INTRA-OPERATIVE DECISION SUPPORT SYSTEM

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Introduction: Current generation intra-operative monitoring and decision support technology remains primitive in comparison to other information-intensive fields. We hypothesized that open source tools and platforms could be used to build a next-generation intra-operative monitoring platform with near real-time decision support capability at low cost and with excellent interoperability, extensibility, and performance characteristics.

Methods: Using our institution's anesthesia information management system (AIMS) for data acquisition, we designed a network-based monitoring system that streams intraoperative demographic, drug administration, clinical event, and physiologic data into a central SQL relational database. Server-side heuristic and data analysis algorithms identify events or trends of potentially physiologic importance, and then push notifications to the anesthesia workstation. Institutional Review Board approval was obtained for our decision support system. An opt-out mechanism allows anesthesiologists to not participate in our decision support trials.

Results: Initial implementation of the streaming data collection component took approximately 120 man-hours of work. Primary system components are Ubuntu Linux 10.04, MySQL 5.1 and Perl 5.10. The system monitors 87 anesthetizing locations and updates the database every 30 seconds, with a latency of 1-2 minutes. Average data per case is only 16 - 20 KB at case start and less than 1 KB per subsequent update, so bandwidth is not a limiting factor. Assuming worst case performance of 2 seconds per file, 30 active locations can be handled without significant processing delay.

Conclusions: Building next generation monitoring and decision support systems is both feasible and cost-effective, provided baseline data acquisition and computing infrastructure is already in place. Development of such systems is imperative in order to provide a platform that will support both the next generation of prospective anesthesia outcomes research and continuous quality improvement projects. In the future, real-time quality metrics may become standard of care.

CLOSED LOOP VS. ANESTHESIOLOGIST MANAGEMENT OF SIMULATED MASSIVE HEMORRHAGE

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Background: Dynamic predictors of fluid responsiveness like pulse pressure variation have made automated management of fluid resuscitation feasible. We present simulation data for a novel closed-loop fluid-management algorithm using pulse pressure variation (PPV) as the input variable. The performance of the closed loop was compared to the performance of anesthesiologists in managing a simulated hemorrhage.

Methods: Using a simulator which includes a PPV output, twenty practicing anesthesiology residents and faculty were asked to manage fluids and pressors for a one-hour simulated hemorrhage case of 2L blood loss over 20 minutes (group 1). One week later, they repeated the simulation, but this time fluids were secretly managed by the closed-loop system while practitioner fluid administrations were ignored and only the pressors were entered (group 2). The simulation was also run twenty times with only the closed-loop (group 3) and twenty times with no management (group 4).

Results: Simulated patient weight, height, heart rate (HR), mean arterial pressure (MAP), and cardiac output (CO) were similar at baseline. Once the hemorrhage began, the closed loop groups (2&3) intervened significantly earlier than the practitioners (group 1) and gave more fluid. The mean and final CO was higher in both closed-loop groups than in the practitioners group, and the coefficient of variance was lower. There was no difference in MAP between intervention groups, but all were significantly higher than the unmanaged group.

Conclusion: Our data demonstrate that closed-loop management of fluid resuscitation is feasible using our novel dynamic-parameter based algorithm and that this approach can be used to optimize cardiac output.

Table 1: Fluid Management: Practitioners vs. Closed-Loop

Group	(1) Anesthesiologist Managed	(2) Anesthesiologist Managed Pressors, Closed-loop Fluids	(3) Closed-loop Managed	(4) No Management
First Bolus (minutes)	21.5 ±5.6*	15.6 ±1.1	16.0 ±1.3	-
Total Fluid Given (ml)	1968 ±644*	2875 ±275	2675 ±244	-
Mean Arterial Pressure (mmHg)	76 ±4.2	79 ±2.0	79 ±1.1	61 ±6.9
Mean Cardiac Output During Case (L/min)	5.2 ±0.6*	5.8 ±0.2**	5.9 ±0.2**	3.8 ±0.4
Final Cardiac Output (L/min)	4.8 ±1.5*	5.6 ±0.5**	5.7 ±0.4**	1.7 ±0.9
Cardiac Output During Case, Coefficient of Variation (%)	36.7 ±23*	16.6 ±9**	16.3 ±8**	89 ±29

*Data are reported as mean +/- standard deviation. * p<0.05 vs. groups 2,3, and 4. ** p<0.05 vs. groups 1 & 4.*

PRELIMINARY COMPARISON OF ABSOLUTE AND RELATIVE RULES FOR IDENTIFYING HYPERTENSION IN CHILDREN DURING ANESTHESIA

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Introduction: Blood pressure measurements in children during anesthesia are routinely performed and change alerts typically use absolute threshold values. As intraoperative hypertension is uncommon in children, a literature review yielded no previous publications addressing the event. In adults, however, acute intraoperative increases of blood pressure >20% are considered hypertensive emergencies (1). We recently completed an evaluation of intraoperative hypotension rules for use in children (2). The same cases and method of evaluation were employed to define rules for the automated detection of hypertension.

Method: Following ethics approval, an expert system for anesthesia was evaluated during routine surgery in children (3). Cases were at least one hour in duration and encompassed a variety of surgical procedures. Non-invasive blood pressure (NIBP) measurements cycled every 3 minutes, and were recorded. Real time evaluation of events was completed with absolute threshold values and a limited selection of relative deviation rules. A larger set of relative rules was developed post hoc using a knowledge authoring tool (3). Relative rules were created to detect increases in mean NIBP over a moving historical window, using percent change or standard deviation limits with varying time delays. Retrospectively, one anesthesiologist evaluated the entire NIBP trend for each case and marked episodes of hypertension. The anesthesiologist's opinion was chosen as the gold standard for evaluation of each rule. The same cases were automatically evaluated with the assistance of a MATLAB program comparing this gold standard and the developed absolute and relative rules.

Results: Nineteen surgical procedures including 6 orthopaedic, 5 general, 4 urological, 3 dental, and 1 ENT (mean duration of 171.3 min) performed in children 1.0 to 17.7 years of age (mean 9.2 years) were evaluated. During real time evaluation, a cumulative total of 22 incidences of hypertension were marked, 13 of which were marked as clinically significant. Retrospective analysis by the anesthesiologist revealed 32 (gold standard) incidences of hypertension. A performance summary for both relative and absolute rules in the retrospective analysis is shown in Table 1.

Table 1: Retrospective performance summary of relative and absolute hypertension rules

RULE			RESULTS					
Deviation Above Mean NIBP	Time Frame (min)	Delay (min)	Detected Events*	Missed Events	False Events	Sensitivity (%)	PPV (%)	Ratio of False/ Missed Events
15%	10	2	19	13	6	59.38	76.00	0.46
15%	10	3	16	16	4	50.00	80.00	0.25
15%	20	0	23	9	20	71.88	53.49	2.22
15%	20	2	23	9	13	71.88	63.89	1.44
15%	20	3	22	10	8	68.75	73.33	0.80
15%	30	0	25	7	21	78.13	54.35	3.00
15%	30	2	24	8	12	75.00	66.67	1.50
15%	30	3	20	12	7	62.50	74.07	0.58
20%	30	2	19	13	5	59.38	79.17	0.38
20%	30	3	17	15	2	53.13	89.47	0.13
2 SD	10	0	31	1	104	96.88	22.96	104.00
2 SD	10	2	4	28	0	12.50	100.00	0.00
3 SD	30	0	21	11	29	65.63	42.00	2.64
3 SD	30	2	6	26	7	18.75	46.15	0.27
ABSOLUTE THRESHOLD RULES								
Systolic NIBP ≥160.0 and ≤250 (Adult, 17.0 ≤ age (yr) ≥ 200.0)			0	3	0	0	---	0
Systolic NIBP ≥140.0 and ≤250 (Child, 1.0 ≤ age (yr) ≥ 16.9)			2	27	4	6.90	33.33	0.15

** Total events of clinically marked hypertension = 32; SD = standard deviations; PPV = positive predictive value*

Discussion: Approximately 60% of alerts in real time evaluation of the initial combined absolute and relative rules were considered to be clinically useful. In the retrospective analysis, absolute rules were inadequate in the detection of hypertension in children during anesthesia, as was previously found in the detection of hypotension (2). The following general trends were seen in the data: sensitivity of a relative rule was increased with smaller deviations (15% vs 20% and 2 SD vs 3 SD), whereas PPV of a rule was increased with a longer historical window (30 vs 10 min) and baseline delay (2 vs 0 min). Relative rules provide a more robust detection; however, it was found that there are significantly more false alerts. Hypertension in children may be less clinically important than hypotension, which would allow a wider limit with longer delay to reduce nuisance alerts. Relative rules, specifically percentage change rules, detect hypertension in children during anesthesia better than absolute rules.

FAILURE OF NONINVASIVE BLOOD PRESSURE TO AUTOMATICALLY CYCLE AFTER SOFTWARE UPGRADE

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While upgrading and standardizing the software on all of our institution's Philips monitors, the wrong configuration was used to clone the anesthesia monitors. Over the course of a few days, 19 of our monitors were reprogrammed to default the NIBP to manual instead of automatic cycling q3min. Most providers recognized a problem and simply adjusted their monitor settings. Twenty-seven cases (of 303 at risk) went for periods of greater than five minutes (up to 27 minutes) without BP cuff recycling or an alternative method of blood pressure monitoring. Nine days passed before an anesthesia provider reported the errant monitor behavior. Retrospective chart review showed that no patient had an adverse outcome related to the monitor failure.

The system wide upgrade was carried out without sufficient communication with the clinical engineers or anesthesiologists familiar with our monitor configuration. Expectations of monitor behavior within our providers exposed the latent programming flaw allowing it to become a patient care flaw. We propose that careful oversight of upgrades by providers familiar with their working environment is necessary to avoid this type of problem. Improved monitor capabilities such as changing display color, dropping the display, or triggering an alarm as data ages may help to alert providers of monitor failure. The presence of monitor capture parameters on anesthesia information systems may provide an additional backup alert. Maintaining a culture that is supportive and responsive to feedback from users may minimize exposure to these types of errors.

SONOGRAM OF THE INTERNAL JUGULAR VEIN: A FEASIBLE NON-INVASIVE TOOL FOR VOLUME ASSESSMENT OF PATIENTS UNDERGOING CARDIAC SURGERY?

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Background: Intraoperative volume status assessment is important for guiding fluid therapy and optimizing hemodynamic management. Traditional accepted methods of volume assessment include measurements of left ventricular end-diastolic volume (LVEDV), central venous pressure (CVP), and pulmonary artery diastolic pressure (PAD). However, these methods are invasive, expensive, and can potentially subject the patient to complications and therefore, are not applicable in all surgical populations. Instead, less invasive and more reliable methods of evaluating a patient's volume status are being sought. A recent pilot study reports the successful utilization of ultrasonography of the internal jugular vein (IJV) as a noninvasive tool to predict CVP in spontaneously breathing critical care patients (1). No study to date has performed ultrasound assessment of the IJV as a possible tool in the operating room to assess volume status and guide fluid management in the surgical patient under general anesthesia. This study aims to compare correlations of sonographic measurements of the IJV, CVP, and PAD to LVEDV in this population subset. Additionally, current literature suggests positive correlations between pulse pressure variation percent (PPV%) and left ventricular end-diastolic area as a reliable measure of fluid responsiveness (2). Thus, as a secondary endpoint, we will also evaluate the correlation between PPV% and LVEDV.

Methods: After IRB approval, 18 patients scheduled for cardiac surgery were consented for this prospective observational study. Routine anesthetic management for these patients included invasive hemodynamic monitoring (arterial line, CVP, PA catheter) and transesophageal echocardiography. Echocardiographic and hemodynamic data were collected at two time points: baseline and immediately prior to initiation of cardiopulmonary bypass. We considered LVEDV the gold standard for volume status assessment, against which all other measurements were compared (IJV diameters, IJV cross sectional area (CSA), PPV%, CVP, and PAD).

The IJV was measured by placing a linear-phased array transducer on the patient's left neck, avoiding compression of the vessel during image acquisition. The LVEDV was calculated using Simpson's formula with measurements of the left ventricle obtained in the mid-esophageal four chamber and two chamber views. All measurements of IJV and LVEDV were performed under general anesthesia with the patient supine and the ventilator off. Hemodynamic data were collected and stored via electronic medical record. The derived PPV% was calculated as the pulse pressure modulation at the respiratory frequency divided by mean pulse pressure. All echocardiographic, sonographic, and PPV% data were interpreted offline by a blinded investigator.

Statistical analysis was performed as described by Bland and Altman in which the correlation coefficient between different variables was calculated after removing differences between subjects and looking at changes within individual subjects (3). $P < 0.05$ was considered significant.

Results: Of 18 consented patients, only ten were included in the study analysis of IJV diameters/CSA, and only five subjects were included in PPV% analysis. Patients were excluded from the study due to the development of hemodynamically unstable arrhythmias, presence of IJV clot, ventricular aneurysm, or severe aortic insufficiency. Average intravenous fluid administration and blood loss between the two time points was 950 ml and 400 ml, respectively. The average decrease in LVEDV between the two time points was 27%. The relative variation of the other parameters as compared to LVEDV is shown in the Table. The best correlation was shown between LVEDV:IJVCSA and LVEDV:IJVAP ($p = 0.01$), while the lowest correlation was between PPV% and LVEDV.

Table 1

Correlation Coefficient between LVEDV and Measured Variables						
	IJV AP	IJV Lat	IJV CSA	CVP	PAD	PPV%
LVEDV	R=0.72 (p=0.01)	R=0.51 (p=0.12)	R= 0.76 (p=0.01)	R=0.72 (p=0.02)	R=0.42 (p=0.19)	R= 0.01 (p=0.98)

To test the reliability of IJV image acquisitions we used the intra-class correlation coefficient (ICC) as a measure of intra-rater reliability. This test was performed on a separate study group of 10 healthy volunteers in whom the IJV was imaged and measured 3 consecutive times. The interclass correlation coefficient between the investigator's images was 0.94 (95%CI: 0.84 to 0.98).

Discussion: The data confirm our hypothesis that the sonographic measurement of the IJV correlates with the gold standard for volume assessment, LVEDV, as well as other parameters such as CVP. This preliminary study offers insight into the possibility of using ultrasound as a non-invasive, inexpensive, and user-friendly tool to reliably identify changes in the volume status of surgical patients. It appears to be as accurate, if not more accurate, than some other more invasive measures of volume status (CVP, PAD). In contrast the PPV% had the least correlation with LVEDV and was prone to much artifact from arrhythmias, which are frequently seen in the cardiac surgical population. In conclusion, these preliminary results show that IJV CSA and AP diameter can be reliably used to track changes in volume status in patients undergoing general anesthesia.

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APOLLO VS. FABIUS COMPARISON IN LUNG MODELS SHOWS A DIFFERENCE

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Introduction: Anesthetic ventilators are vital to the safe administration of inhalational anesthetics. There are different models of ventilators with unique features which may be important for optimizing mechanical ventilation in pediatric and adult surgical patients with obstructive or restrictive lung disease while preventing hypoxemia, hypercarbia, and/or barotrauma. This study contrasts two types of anesthesia machine ventilators: The Apollo and Fabius GS. The relative position of the anesthesia bag in the circle system of the Apollo lowers the airway resistance compared with the Fabius (1). Two lung models were used with each machine for comparison. The first lung model (A), an anesthesia bag, represented an ordinary lung. The second lung model (R), an anesthesia bag with resistance, represented an obstructed and/or restrictive lung pattern.

Methods: The two lung models were contrasted using Pressure Limited Volume Control (VC) mode, and Pressure Control (PC) mode using graduated independent variable titration and measurement of dependent variables for both the Apollo and Fabius anesthesia machines. Slope analysis (least squares method) was performed on the linear portion of the ventilation curves. Dynamic compliance Cd = (TV)/(Ppeak) was measured.

Results: In volume mode, lung model A is more compliant than lung model R. The Apollo has more compliance than the Fabius, especially in lung model R. In pressure mode, the Apollo A (TV = 1109.8 mL) and Fabius A (TV = 910.6 mL) demonstrated a 199.2 difference between the means of the two independent samples. This represents a 5.0 difference in dynamic compliance (27.8 vs. 22.8). In volume mode, the Apollo R (Peak = 29 cm H2O, TV = 433.2 mL) and Fabius R (Peak = 32 cm H2O), TV = 404 mL) demonstrated a 29.2 difference between the means of two independent samples at set tidal volume = 500 mL. This represents a 2.3 difference in dynamic compliance (14.9 vs. 12.6).

Average Dynamic Compliance		
Mean ± SEM	Pressure Mode	Volume Mode
Apollo	20.9 ± 0.80	17.1 ± 0.32
Fabius	17.9 ± 0.81	15.9 ± 0.52

In pressure mode, lung model A has more compliance than lung model R. The Apollo has more compliance than the Fabius, especially in lung model A. Apollo has more dynamic compliance than the Fabius across all pressures and volumes in both lung models.

Summary: Our data suggests that there is reduced mean airway pressure and improved dynamic compliance with the Apollo compared to the Fabius. This may be due to the increased resistance from the Fabius machine. Pressure mode seems to have increased dynamic compliance compared with the volume mode. Our results suggest that patients with ARDS may benefit from the features of the Apollo over the Fabius based on the fact that the arrangement of the circuit requires higher mean airway pressures in the Fabius.

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PROTOTYPING A MOBILE APPLICATION FOR ANESTHESIA ASSISTANTS

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Background: At BC Children's Hospital, anesthesia assistants (AAs) help the attending anesthesiologist to keep the patient safe by ensuring that equipment and tools are maintained and readily available, and by providing an "extra pair of hands" when needed. However, requesting their presence using a phone-based paging system is cumbersome and hard to perform from the anesthesia workstation. Therefore, an integrated mobile application facilitating information exchange and communication tasks (such as paging) is proposed.

Method: Participatory user-centered design[1] with three AAs (comprised of shadowing an AA for two shifts, semi-structured interviews, and rapid-prototyping display elements) was used to develop a mobile application prototype. Cognitive Work Analysis[2,3] was used to develop hierarchical models, which were used to guide the design.

Results: An overview of a preliminary Work Domain Analysis (Fig. 1) highlights the balances, general and physical functions, and sensors required to complete the frequent tasks. The highlighted "aid with intubation" task demonstrates the different ways a task can be initiated: For example, a) a request (page) sent by the anesthesiologist, b) a reminder based on the anesthetic phase, or c) by the AAs themselves looking at the room overview page.

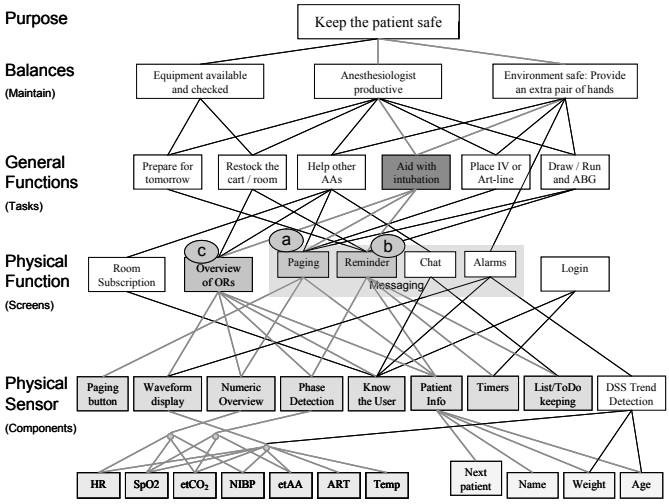

Figure 1: Work Domain Analysis for anesthesia assistants with the "aid with intubation" task highlighted

An example of a potential overview screen, consisting of the room number, anesthetic phase and three vital signs (HR, SpO_2 and $etCO_2$) is seen in Fig. 2a. An example of an urgent request page, with location information as well as captured vital signs, can be seen in Fig. 2b.

Figure 2: Overview and paging screen examples of mobile anesthesia assistant display prototype

Discussion: Work Domain Analysis was found to be a useful technique to structure information obtained in a user-centered design process. It allowed identification of the minimally needed information, interaction between display components, and support for the most commonly performed tasks. Three AAs involved in this project see high potential for the application to improve their workflow and communication with other providers in the OR.

Conclusion: The described mobile application provides an easy method of information exchange and communication of, for example, vital signs, paging and chat messages. It has potential to improve situational awareness[4] of AAs, thereby improving patient safety. Future work will include refinement of the prototype, implementation of the interface on an iPod touch (Apple, Cupertino, CA), followed by an evaluation in normal clinical practice.

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MEASUREMENT OF RAPIDLY CHANGING FLOW RATES AND ASSOCIATED PRESSURES DURING CARDIOPULMONARY BYPASS (CPB)

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Introduction: Our initial work, with Automating Data collection from a CPB system, captured pump outlet pressure through use of a conventional pressure transducer connected to our physiologic monitoring system (Intellivue – Philips). This technique permitted direct export of the pump outlet pressure into our AIMS database. Additional flow rate and temperature data from the pump were then obtained by an RS-232 Communication Module (CM) obtained from our Terumo-Sarns rep. Our AIMS cannot interface directly with an RS-232 port and an Asus Eee PC 901 captured the CM output. As we continued our data collection we noted that some bypass cases had frequent, very large excursions, of brief duration, in the pump outlet pressure and arterial flow rate. A review of the literature revealed the potential of these excursions to alter the cognitive outcomes of patients requiring bypass.[1] [2] [3] Thus we decided to investigate (both in vivo and ex vivo) the measurement of the pressure drop across the CPB Oxygenator (OX) as a means of monitoring the aforementioned flow variations.

Methods: IntelliVue pressure transducers were connected to pressure ports upstream and downstream of the OX. These two pressure signals were directly entered into our AIMS every 15 sec. In addition, these pressure waveforms were also recorded by our IntelliVue Information Center (IIC) which can capture and store four waveforms during a case. Typically, EKG, A-line, CO2, and Pulse Oximeter waveforms are selected for capture and storage. These stored waveforms may be viewed at typical EKG scanning rates (6.25, 12.5, 25 and 50 mm/sec. Data were still recorded from the Pump via the RS-232 CM port and the Asus Eee PC. The Pump flows and temperatures are only updated every 66 sec at the CM port. Calibration data were recorded during the time prior to initiating bypass. During this time the CPB circuit contains only Plasmalyte. Changes in Pump flow rate can be made either slowly and deliberately or very abruptly. For calibration purposes we would hold a given flow at a constant value until the CM module reported two or more consecutive, equal values for a flow rate. The upstream and down-stream OX pressures were then averaged over the time interval(s) where consecutive flow values were constant. Rapid (abrupt) changes in flow rate were plotted for all three of the data sampling rates: 66 sec (CM), 15 sec (AIMS), 10 milliseconds (IIC).

Results: Transient flows are shown below with both actual patient bypass in process and during off-line calibration runs. It is clear that the transient waveforms are not adequately represented by 15 sec samples and 66 sec samples may completely miss a pressure excursion (transient) of short duration. (See Figures Below.) The Plasmalyte, off-line calibration curves showed a strongly non-linear relationship between the Arterial pump flow and the pressure drop across the OX.

Summary: We have been able to collect all pressure transient and calibration data from the three systems noted above. Modification of the sampling rates of both the CM and AIMS systems would be required to obtain clinically useful information regarding the effect of pressure excursions on patient cognitive outcomes.

In the Figures shown below Ao refers to the pressure measured just upstream of the OX, ART is the pressure just downstream of the OX. ABP is patient radial artery pressure. These names were required by the IIC so that our pump pressures would have a high priority ranking, and could then be accepted as one of the four waves stored by the IIC. The Pressure transient shown in the first figure below was taken during the calibration tests. The second graph below was recorded near the end of a bypass run. The third figure is the start of a bypass session. The y axis on the right is [Flow – L/min] and left y axis is mmHg.

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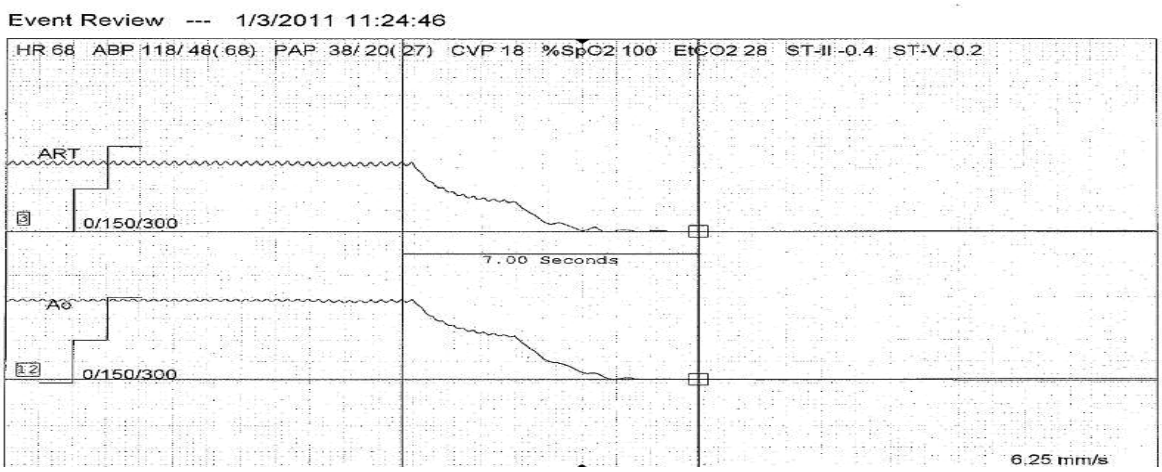
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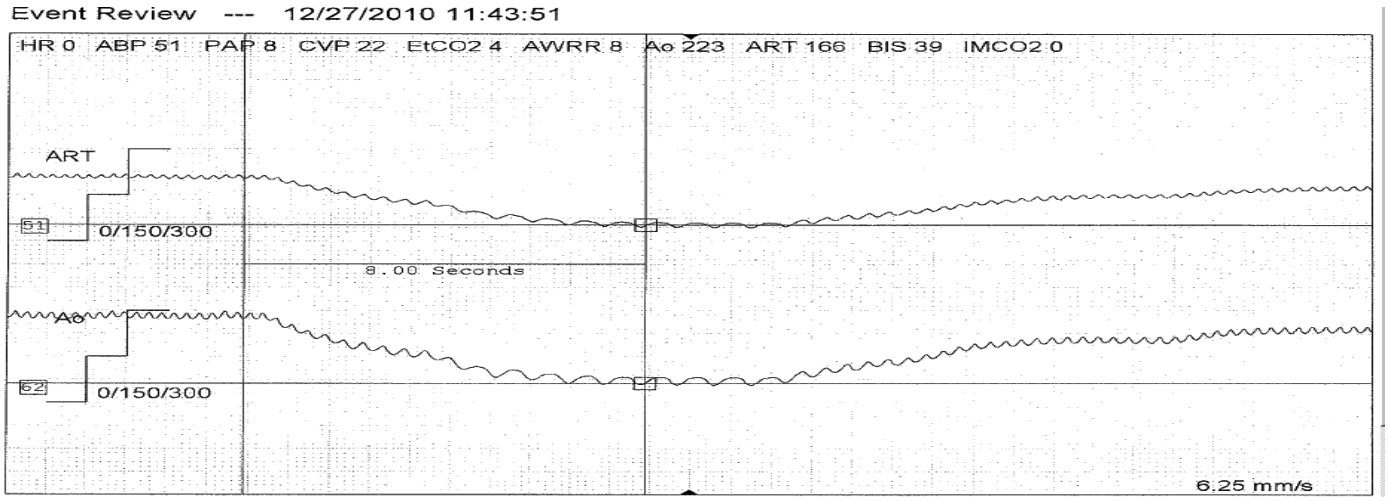
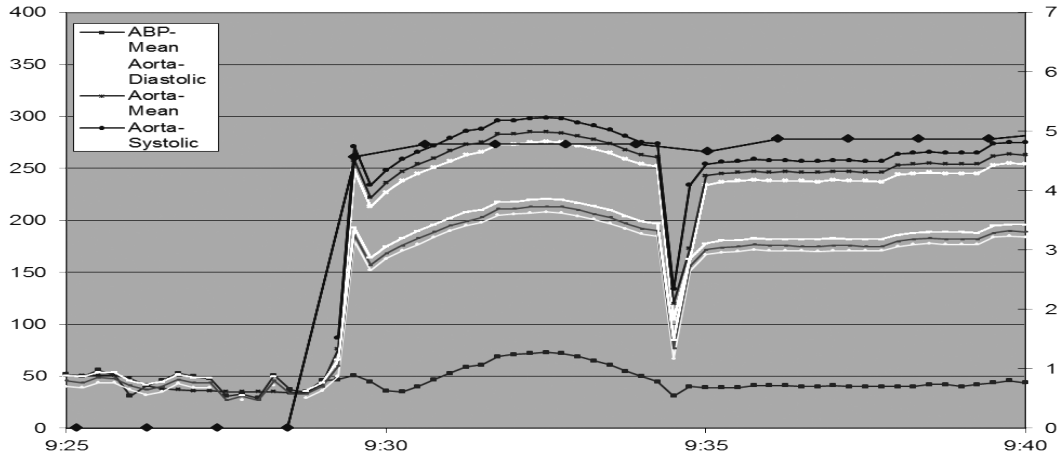
HR 68 ABP 118/ 48(68) PAP 38/ 20(27) CVP 18 %SpO2 100 EtCO2 28 ST-II -0.4 ST-V -0.2
ART
3
0/150/300
7.00 Seconds
Ao
12
0/150/300
6.25 mm/s


Event Review --- 12/27/2010 11:43:51
HR 0 ABP 51 PAP 8 CVP 22 EtCO2 4 AWRR 8 Ao 223 ART 166 BIS 39 IMCO2 0
ART
51
0/150/300
8.00 Seconds
Ao
62
0/150/300
6.25 mm/s


ABP-Mean
Aorta-Diastolic
Aorta-Mean
Aorta-Systolic
400
350
300
250
200
150
100
50
0
7
6
5
4
3
2
1
0
9:25
9:30
9:35
9:40

REAL TIME QI SYSTEM BASED ON AUTOMATED COMPURECORD RESEARCH MODULE

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Introduction: Previous reports have detailed our use of Windows API Calls to automate data extraction from our AIMS server via the CompuRecord Research Module(RM). This report details extensive trials of a QI system based on this automated, "real time" data extraction and analysis of anesthesia case data from all of our anesthetizing locations.

Methods: When the "Exit OR" event is selected by the Anesthesia Team (AT) the entire case data is made available in the AIMS WSave Folder Using the RM we monitor the WSave Folder and quickly extract all the case data, including all the Vital Signs, into an Access 2003 database, that resides in a temporary folder, and is separate from the VBA Access Db which controls the RM. VBA code modules, queries and reference tables are then transferred into this separate Db by the Controlling Db. Preparation of QI reports, printing of these reports and/or emailing them to the AT members is completed during the time the patient is being transported from the OR to the PACU. Once the QI reports and emails have been completed, the Db with the RM extracted data and the snapshot images of the QI reports are transferred to the G: drive for archival storage. The controlling Db must also restore the RM to its prior status so that monitoring of the WSave folder can be resumed. When the AT reopens the case to complete the PACU summary tasks the case data is removed from the WSave Folder. The case data reappears when the AT closes the case with the Anesthesia End event. The aforementioned data extraction, report preparation and emailing procedures are all repeated a second time. This permits comparison of the case information in the AIMS at the Exit OR and Anesthesia End times – this provides a way to measure the charting capabilities of AT members and assess the effectiveness of the QI reporting process.

Results: Our system has been tested extensively by processing all cases that transiently pass thru the WSave file. Beside the current, ongoing OR cases, WSave also will hold cases whenever completed cases are reviewed for clinical, teaching or billing purposes. These other cases are mixed in with the current OR cases, so it is not uncommon to have the RM extracting multiple cases during the hospital's day shift. Table 1 gives the distribution of new cases appearing in the WSave Folder during a typical weekday. The actual time for RM data extraction is only 5 to 10 sec per case. Most of the cycle time that occurs when data are extracted is related to working with the RM. After 3 to 4 days of continuous operation, the controlling Db will expand in size from about 20 megabytes to more than 2 gigabytes due to accumulation of temporary files. Once the 2 gigabyte limit is exceeded the system crashes. To avoid this problem the controlling Db must be 'compacted and repaired".

Table 1

Count New Cases	0	1	2	3	4	5	6	7
Count Of Count	2638	159	53	31	12	2	3	1

A NOVEL RETROFITTABLE ANESTHESIA AGENT ALARM MONITOR

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Recall of intra-operative events occurs in approximately 0.1% of all general anesthetics[1]. Many of these patients experience devastating psychological consequences such as post traumatic stress disorder, and despite awareness monitors, malpractice claims citing recall have remained relatively constant[2]. One frequent and avoidable cause of anesthetic recall is an undetected empty vaporizer. It has been recognized in the anesthesia safety literature that the lack of an "empty" alarm on non-powered vaporizers is a glaring deficiency[3]. We now present the first such alarm, which is completely self contained, rechargeable, safe, effective and completely retrofittable.

In an effort to addrwf the sight glass. The An-Alarm™ is manufactured from the highest quality inert materials and is designed to the highest tolerances. The An-Alarm™ uses a proprietary infrared detection system designed to be completely harmless to the naked eye, efficient in its power consumption, yet accurate and timely in its function. The An-Alarm™ features a visual and auditory alarm set to trigger when the liquid agent level in the sight glass indicates ten percent of reservoir capacity. The following figures illustrate the form and function of this novel device.

Figure 1: The An-Alarm™

Figure 2: The An-Alarm™ as installed

Figure 3: Close up of the An-Alarm™ display and control system. Scan with barcode reader.

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IMPACT OF CENTRAL HYPOVOLEMIA ON PHOTOPLETHYSMOGRAPHIC WAVEFORM PARAMETERS IN HEALTHY VOLUNTEERS. PART 1: TIME DOMAIN ANALYSIS

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Introduction: Lower body negative pressure (LBNP) is an excellent model for hypovolemic circulatory stress[1], since it rapidly decreases central blood volume by sequestering blood in the lower extremities through application of negative pressure around the legs and abdomen. We hypothesize that during a hypovolemic challenge such as Lower body negative pressure (LBNP), a preservation of ear PPG characteristics and a decrease in finger PPG characteristics will be seen. Our study sought to explore changes in PPG waveform parameters; height, peak area, width 50, maximum and minimum slope (figure 1) and to determine which components of the PPG waveform could serve as early indicators of reduction in central blood volume during LBNP in spontaneously breathing volunteers. Previous work has demonstrated a differential vasoconstrictive response in the finger vs. ear during cold pressor testing[2] , the decreased height of the finger was attributable to greater adrenergic activity in this region.

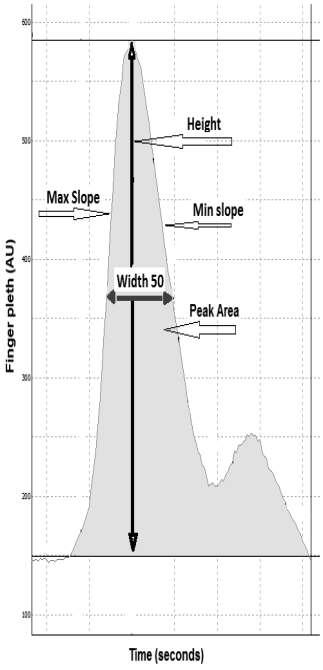

Figure 1

Methodology: With IRB approval, eleven healthy volunteers age 24-37 underwent a lower body negative pressure (LBNP) protocol consisting of a 3 min baseline and successive 3 min intervals at baseline, 30, 75 and 90 mm Hg (or until the subject became symptomatic). Subjects were monitored with finger and ear pulse oximeter probes, ECG, and finger arterial blood pressure monitor. Data recorded and analyzed with commercially available software (Chart, ADInstruments). Data are presented as median and inter-quartile range (IQR). Friedman ANOVA and Wilcoxon test were used to identify changes in hemodynamic and plethysmographic variables, $P < 0.017$ was considered statistically.

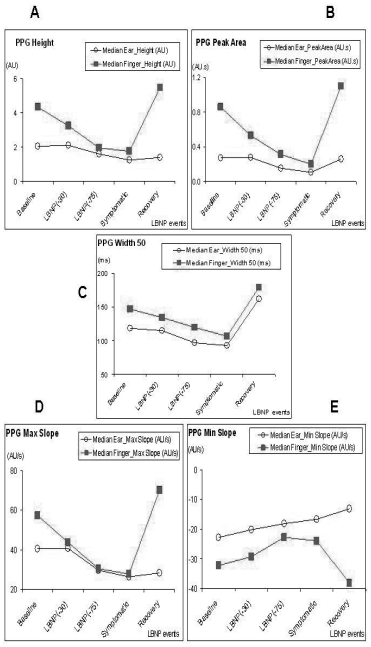

Figure 2

Finger Plethysmography					
Parameters	**Baseline**	**LBNP 30**	**LBNP 75**	**Symptomatic**	**Recovery**
Height (AU)	4.33(2.87)	3.23(2.23)*	1.97(1.53)*	1.76(2.2)*	5.78(2.5)
% change from baseline		*-25.6%*	*-54.5%*	*-59.4%*	*26.1%*
Peak area (AU.s)	0.86(0.52)	0.53(0.36)*	0.31(0.22)*	0.198(0.28)*	1.1(0.58)
% change from baseline		*-38.4%*	*-63.9%*	*-76.9%*	*28.1%*
Width 50 (ms)	146.8(17.8)	134.2(7.4)*	120.1(12.1)*	106.6(15.4)*	179.3(18.2)**
% change from baseline		*-8.6%*	*-18.2%*	*-27.4%*	*22.1%*
Max slope (AU/s)	57.25(38.03)	43.81(26.4)*	30.61(21.2)*	27.72(30.04)*	70.04(27.6)
% change from baseline		*-23.5%*	*-46.5%*	*-51.6%*	*22.3%*
Min slope(AU/s)	-32.26(23.9)	-29.34(16.5)	-22.79(18.8)	-23.96(26.8)	-38.24(15.5)
% change from baseline		*-9.1%*	*-29.4%*	*-25.7%*	*18.5%*
Ear Plethysmography					
Parameters	**Baseline**	**LBNP 30**	**LBNP 75**	**Symptomatic**	**Recovery**
Height (AU)	2.05(0.77)	2.11(0.64)	1.59(0.53)*	1.24(0.74)*	1.4(0.63)**
% change from baseline		*3.1%*	*-22.2%*	*-39.3%*	*-31.4%*
Peak area (AU.s)	0.27(0.1)	0.28(0.13)	0.15(0.7)*	0.10(0.11)*	0.26(0.13)
% change from baseline		*3.3%*	*-44.2%*	*-61.0%*	*-4.2%*
Width 50 (ms)	118.2(16.2)	115.1(13.2)	96.7(12.9)*	92.9(20.9)*	162.1(70.35)
% change from baseline		*-2.6%*	*-18.2%*	*-21.4%*	*37.1%*
Max slope (AU/s)	40.38(14.2)	40.67(9.2)	29.78(12.3)*	26.33(8.1)*	28.19(8.8)
% change from baseline		*0.7%*	*-26.2%*	*-34.9%*	*-30.2%*
Min slope (AU/s)	-22.76(11.6)	-20.15(9.4)	-18.06(6.7)	-16.72(3.5)	-13.22(4.7)
% change from baseline		*-11.4%*	*-20.6%*	*-26.8%*	*-41.9%*

Table 1

Results: There were no significant changes in the blood pressure variables at 30 mmHg, but at and beyond 75 mmHg, the decreases in systolic, mean and pulse pressure were significant as the increase in diastolic pressure. Heart rate increased significantly by 30 mmHg, reaching a maximum of 75.4% above baseline at symptomatic phase. Finger PPG height, peak area, width 50 and maximum slope decreased significantly at LBNP 30 mmHg and reached declines of 59.4%, 76.9%, 27.4% and 51.6%, respectively, during the symptomatic phase (table 1). Ear PPG height, peak area, width 50 and maximum slope did not change significantly at LBNP 30 mmHg, but declined significantly at 75 mmHg. During the symptomatic phase, the respective declines reached 39.3%, 61.0%, 21.4% and 34.9% (figure 2).

Discussion: Systolic, diastolic and mean finger arterial blood pressures together with pulse pressure were well preserved. While finger plethysmographic waveforms characteristics showed significant reduction ($p < 0.017$); peak area (38.4%), height (25.6%) max slope (23.5%) and width 50 (8.6%). On the other hand, ear plethysmographic waveform characteristics were not significantly changed. This suggests that finger plethysmographic waveform parameters (height, peak area, width 50, maximum and minimum slope) might be used as a monitor of sympathetic tone. On the other hand, the ear plethysmographic waveform, because of its location, appears to be more reflective of central hemodynamic changes.

Conclusion: PPG waveform parameters may prove to be sensitive and specific as early indicators of blood loss. These PPG changes were observed before profound decreases in arterial blood pressure. The relative sparing of central cutaneous blood flow is likely parasympathetic in nature when compared to a peripheral site where there is high sympathetic tone and vasoconstriction

References:

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IMPACT OF CENTRAL HYPOVOLEMIA ON PHOTOPLETHYSMOGRAPHIC WAVEFORM PARAMETERS IN HEALTHY VOLUNTEERS. PART 2: FREQUENCY DOMAIN ANALYSIS

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Background: The photoplethysmographic (PPG) waveforms are modulated by respiratory, cardiac and autonomic nervous systems. PPG had two components; the AC component reflects arterial pulse volume variation while the DC component reflects the constant absorption and scattering of light by bone and non-pulsatile venous blood. Lower body negative pressure (LBNP) has been used as an experimental tool to simulate loss of central blood volume (e.g., hemorrhage) in humans. Heart rate variability has been reported to reflect autonomic (sympathetic and vagal) activities. The efferent vagal activity is a major contributor to the HF component (0.15-0.4 Hz), while the LF component (0.04-0.15 Hz), which is considered as a parameter that includes both sympathetic and vagal influences. It has been shown that the standard deviation of the R-R interval (RRISD) can be used as an index of cardiac vagal tone.The aim of our research is to understanding the physiology of progressive central hypovolemia that leads to cardiovascular decompensation and try to develop effective indicators that predict the magnitude and/or rate of progressive hemorrhage before the onset of hemorrhagic shock.

Methodology: With IRB approval, 11 volunteers underwent a LBNP protocol at baseline, 30, 75, and 90 mm Hg (or until the subject became symptomatic). Subjects were monitored with finger and ear pulse oximeter probes, ECG, and finger arterial blood pressure monitor. Amplitude density of low frequency (0.05-0.11 Hz), intermediate frequency (0.12-0.18 Hz), respiratory (0.19-0.3 Hz) and cardiac (0.75-2.5 Hz) components were computed during different phases of lower body negative pressure protocol. Heart rate variability (HRV) was analyzed to the following RMSSD (square root of the mean of the squared differences between adjacent NN intervals), high frequency (0.12-0.18 Hz) to eliminate the influence of respiration and low frequency (0.05-0.11 Hz). Data are presented as median and inter-quartile range. Friedman ANOVA and Wilcoxon test were used to identify changes in hemodynamic and plethysmographic variables, $P < 0.017$ was considered statistically significant.

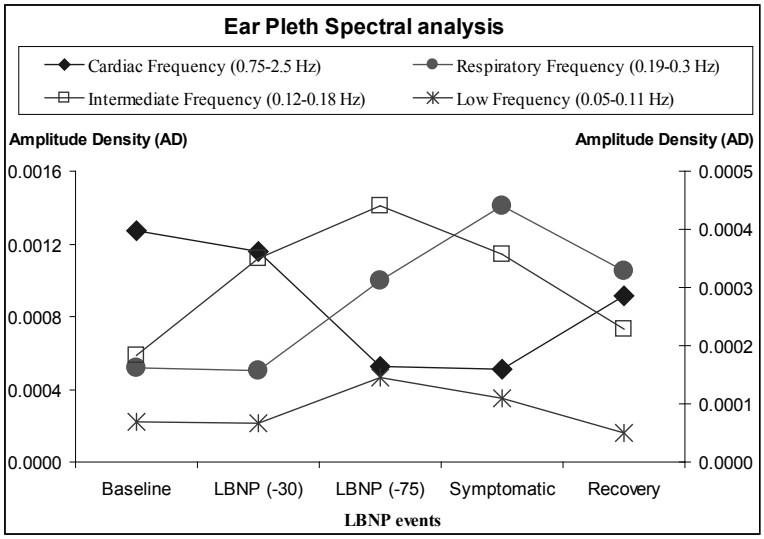

Figure 1: Autonomic, respiratory and cardiac modulation of the ear plethysmographic waveforms during LBNP phases

Results:

- With the progressive increased in LBNP, heart rate increased significantly while systolic, mean and pulse pressure finger arterial blood pressures declined slowly.
- There were significant reduction in RMSSD, high frequency (0.12-0.18 Hz) and low frequency (0.05-0.11 Hz) power of heart rate variability at LBNP 75 mmHg.
- There was significant reduction in the cardiac modulation of finger PPG spectral analysis which is consistent with the reduction in the pulse pressure of the finger arterial blood pressure.
- Ear plethysmographic waveforms spectral analysis had different scenario:
  - shift in the amplitude density from the cardiac component to the respiratory component is evidence of progressive hypovolemia with reduction in pulse pressure and increase in the respiratory induced variations (Figure 1).
  - At LBNP of 75 mmHg, there were a significant increase (>140% increase from the baseline) in intermediate frequency (0.12-0.18 Hz) and significant reduction (>58%) in cardiac modulation amplitude density. At the meantime and during the same LBNP phase, the high frequency amplitude density of HRV which has same frequency, (0.12-0.18 Hz), showed significant reduction (> 80%) from the baseline.

- At the symptomatic phase; there was a shift in ear plethysmographic modulation from the intermediate frequency to respiratory frequency with an increase in the respiratory modulation to ≥ 175% from the baseline.
- The cardiac modulation of ear plethysmographic waveform at the symptomatic phase continued to decrease till it reached > 59% of the baseline value.

Conclusions: The pulse oximeter waveform contains a complex mixture of the influences of arterial, venous, autonomic, and respiratory systems on the central and peripheral circulation. The occurrence of autonomic modulation needs to be taken into account when studying signals that have their origins from central sites (e.g. ear and forehead). The occurrence of autonomic modulation needs to be considered when studying signals that have their origins from central sites (ear). The use of the photoplethysmogram to monitor autonomic balance is intriguing and needs further investigation.

COMPARING CAPNOGRAPHY ALARM LIMITS USED IN DIFFERING CARE ENVIRONMENTS

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Introduction: Alarm settings on capnography monitors are important and have the potential to prevent untoward events and even deaths by alerting caregivers to dangerous situations such as apnea and significant changes in CO_2 levels. However, excessive alarms including clinically-irrelevant alarms ('nuisance alarms' or false-positive alarms created by artifact) have been shown to desensitize caregivers to clinically-significant alarms and become a threat to patient safety.[1,2,3] In addition, they are a source of aggravation to patients and family members, potentially reducing compliance with monitoring. Recently, algorithms have been developed which have been shown to significantly reduce such clinically insignificant alarms.[4,5]

Our goal was a secondary analysis of data from an alarm survey of experienced users of capnography to compare capnography alarm settings commonly used between multiple care environments. Due to differing monitoring needs in each environment, alarm settings used may differ and such information may be useful to new users in developing their own alarm limit protocols or defaults for each care environment.

Methods: A survey of experienced capnography users was conducted using a web portal (SurveyMonkey.com). Results for the entire group across all care environments are described in a separate paper. In this secondary analysis, data was reviewed and averages analyzed (Microsoft Excel) by individual care environments.

Results: Twenty one experienced users responded for adult applications of capnography. Responses were received from five different care environments. Average values for responses from each environment are presented below.

Table 1 – Average Capnography Alarm Limits Used by Care Environment

Environment	Respondents	$etCO_2$ High	$etCO_2$ Low	F_iCO_2 High	RR High	RR Low	No Breath Delay
Procedural Sedation	6	52.5	23.0	6.3	24.0	6.6	17.1
Emergency Depart.	6	50.8	24.5	11.5	28.3	8.3	13.2
General Floor	4	60.0	8.5	6.8	45.0	4.5	27.5
OR-PACU	3	56.7	19.3	3.0	24.0	8.0	19.3
Intensive Care Unit	2	50.0	25.0	NA	32.0	9.0	15.0
All	21	53.8	20.2	7.3	30.3	7.1	18.3

Conclusions: Capnography use has expanded to multiple care environments across the hospital. Alarm limit requirements may vary significantly from one environment to the next based on patient needs. Clinical users in these environments may be less familiar with capnography and having access to alarms limits from experienced users may assist new users in developing their own alarm limits settings. Each institution and ordering physician should recognize that alarm limits should be adjusted based on the population being served and specific patient needs.

References:

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ELECTRONIC TRACKING AND REPORTING OF ANESTHESIOLOGY POSTOPERATIVE VISITS USING AN IPAD APPLICATION

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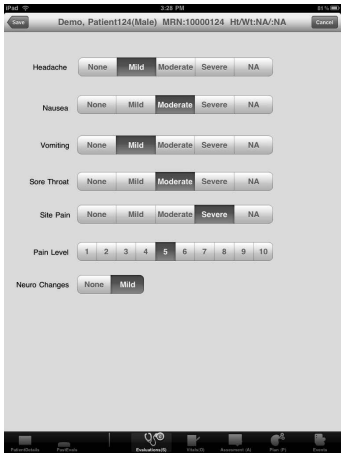
Introduction: Regulations and guidelines from entities such as CMS and the ASA toward ensuring compliant and complete postoperative anesthesiology assessments necessitate improved methods of recording and tracking these visits. We expanded an existing perioperative documentation suite to include an integrated postoperative component. We then created an iPad application to facilitate data entry while visiting the patient postoperatively at the bedside.

Methods: An AIMS (GasChart) was modified to generate a list of pending post-operative evaluations by comparing a one day old surgical schedule to a current hospital inpatient list. Pending evaluations were presented in a list fashion accessed from the main screen of the iPad application. Each individual postop was recorded on separate screens built into the AIMS system. Fields were included to allow for follow up visits, and critical event reporting. When each encounter is completed and documented, an electronic PDF of the encounter is automatically sent by the system to the EMR. A second de-identified copy of the PDF is sent to the primary anesthesiologist who cared for the patient via secure email.

Conclusion: Information technology can be used to successfully create an auditable and traceable post-anesthesia evaluation note. Integrating the post-anesthesia note into a frequently used AIMS documentation system enables users to leverage existing systems knowledge such as patient admission status and patient location to facilitate use of postoperative rounding time. By utilizing a portable iPad application to enter data into the AIMS, efficiency is optimized. We plan to deploy this system at our institution in the near future.



ACCURACY OF PATIENT IDENTIFICATION IN BLOOD PRODUCT ADMINISTRATION: THE ROLE OF BARCODES

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Introduction: Ensuring that a patient always receives the correct blood product is known to be very difficult and reducing transfusion error is a national patient safety goal. In recent years, the standard mechanism has used the Typenex system where a wrist band with identification code is placed on the patient and peel-off labels with the same code are placed on the blood-sample tube and the blood-product requisition. The blood bank then sends the blood product to the operating room along with the code. Prior to transfusion, 2 people verify that the code on the patient's wrist matches the codes on the bag and chart copy. This system is known to be unreliable as the 2-person check is subject to lapses and bypassing without the ability to audit the check. We have instituted a comprehensive computerized barcode scanning system to decrease the probability of misadministration of a blood product.

Methods: Software was written for our in-house-developed healthcare information system for proper identification matching for transfusion samples, blood products and patients. This program has 8 functions: 1) printing barcode labels that contain the patient's name, hospital number and its barcode, date of birth and date and time of printing. Barcode printers are located in each OR. The patient's wristband ID is a barcode label; 2) scanning at the time of blood draw to verify that the barcodes on the patient's wrist band, blood tube and requisition are identical; 3) verifying tube and requisition match – and recording to a database- when the sample arrives in the blood bank; 4) matching the release requisition, patient ID and blood product ID when blood products are dispensed from the blood bank – and recording to a database; 5) verifying by scanning at the time of administration that the patient's wrist band barcode matches the patient ID and blood-product-ID barcodes on the bag (from step 4); 6) establishing a proxy function so that a secondary barcode label within the OR may be scanned if the patient's wrist is not available; 7) scanning units returned to the blood bank; and 8) creating a history and reconciliation function so that any discrepancies between units dispensed, administered and returned can be detected and investigated.

Results: In the 6 years that the system has been functional, the history function has recorded over 700,000 scans. During this time, we have documented only 1 misadministration of a blood product and that occurred as the system was being rolled out on a unit where it was being used for the first time. There have been no misadministration events detected since then. Potential mismatches between patient and product have been detected (and misadministration prevented) at a rate of 1.3 events per month.

Comments: Prior to implementing the system, our interval of misadministration was about 1.25 years. If one considers the rate at which mismatches are prevented and the rate of failure to scan (about 1%), we estimate that the average interval between misadministration events is now about 9 years. Besides the enhancement of safety, another valuable aspect is that the 2-person check is no longer needed. In practice, a unit can be verified every 8 seconds with a positive verification giving a green background for 4 seconds and a negative giving a red background requiring operator input to clear. The system has provided a powerful new way to comprehensively track and analyze errors in the transfusion process. We hope to integrate the system with our new hospital information system (Epic) in the near future.

Society for Technology in Anesthesia Upcoming Events

IARS 2011 Annual Meeting – STA Problem Based Learning Discussion
"Airway Imaging, Gadgets, Algorithms and Physics – Exploring the Clinical Technologies Behind Modern Airway Management"
Saturday, May 21, 2011
7:00am-8:00am
Westin Bayshore Hotel
Vancouver British Columbia Canada

IARS 2011 Annual Meeting – STA Breakfast Panel
"Imagining Future Developments in Anesthesia Technology"
Saturday, May 21, 2011
4:15pm-5:45pm
Westin Bayshore Hotel
Vancouver British Columbia Canada

American Society of Anesthesiologist Annual Meeting Events

STA Ty Smith Dinner
Sunday, October 16, 2011
Chicago, Illinois

STA Breakfast Panel
"Communication Technology in the Operating Room: Today & Tomorrow"
Monday, October 17, 2011
7:00am-8:15am
Chicago, Illinois

STA 2012 Annual Meeting
January, 11-14, 2012
Miami, Florida

STA 2013 Annual Meeting
January, 9-12, 2013
Scottsdale, Arizona

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