

TECHNOLOGY  
ADVANCING  
PERIOPERATIVE  
OUTCOMES

**FAER**

*Foundation for Anesthesia  
Education and Research*

Featuring a Joint Session with  
the Foundation for Anesthesia  
Education and Research



**2017**  
**SYLLABUS**

**STA 2017 Annual Meeting**  
**January 11-14, 2017**  
**Hilton San Diego Bayfront**  
**San Diego, California**

**#STA17SanDiego**

**Society for Technology in Anesthesia**

6737 W. Washington St., Suite 4210 • Milwaukee, WI 53214 • (P) 414-389-8600 • (F) 414-276-7704 • [www.stahq.org](http://www.stahq.org) • [stahq@stahq.org](mailto:stahq@stahq.org)

# WELCOME

Welcome to the 27th Annual Meeting of the Society for Technology in Anesthesia (STA). STA is an exceptional and unique gathering for physicians, engineers and industry representatives. The Annual Meeting of the STA is a wonderful opportunity to stay abreast of new technologies, meet with colleagues and associates, and enjoy a pleasant venue and climate.

I am grateful to this year's Program Chair, Dr. Jonathan Wanderer, MD, MPhil, for organizing the program. He has done an outstanding job selecting the meeting speakers and topics. The perioperative care, Big Data, outcome measurement, entrepreneurship, education, and medical device sessions should all deliver the cutting-edge information we desire.

I also want to thank Abstract Co-Chairs Dr. Lara Brewer, PhD and Dr. Jonathan Tan, MD, MBA, who have expertly selected this year's abstracts. The STA has enjoyed a continual improvement in abstract

quality over our 27 years of Annual Meetings. This year, I expect the trend to continue with the poster sessions demonstrating higher quality, cutting-edge work than in prior years and look forward to discussing them with the presenters.

Finally, I want to especially thank our corporate sponsors for their support, without which STA's meeting would not be possible. I encourage all attendees to visit the exhibits, learn what is available and offer insights to the exhibitors where appropriate.

Sincerely,



**Brian S. Rothman, MD**

President, Society for Technology in Anesthesia

## INVITED FACULTY

**Aymen Alian, MD**  
*Yale University School of Medicine*

**Steven Barker, MD, PhD**  
*University of Arizona College of Medicine*

**Brian Bateman, MD**  
*Harvard Medical School/  
Massachusetts General Hospital*

**Lara Brewer, PhD**  
*University of Utah  
Abstract Co-Chair, STA 2017  
Annual Meeting*

**Maxime Cannesson, MD, PhD**  
*University of California, Irvine*

**Janak Chandrasoma, MD**  
*University of Southern California*

**Larry Chu, MD, MS**  
*Stanford University School of Medicine*

**Alexander Davey, FRCA**  
*Northern Ireland Medical Deanery*

**Jesse Ehrenfeld, MD, MPH**  
*Vanderbilt University Medical Center*

**Richard Epstein, MD**  
*University of Miami, Miller School of Medicine*

**Jessica Feinleib MD, PhD, CHSE**  
*Yale University School of Medicine*

**David Feinstein, MD**  
*Beth Israel Deaconess Medical Center*

**Jenny Freeman, MD**  
*Respiratory Motion, Inc*

**Thomas Hemmerling, MD, MSc, DEAA**  
*McGill University*

**Ira Hofer, MD**  
*Ronald Reagan UCLA Medical Center*

**Timothy Houle, PhD**  
*Massachusetts General Hospital*

**Viji Kurup, MD**  
*Yale University School of Medicine*

**Karim Ladha, MD, MSc, FRCPC**  
*University of Toronto and Toronto General Hospital*

**Christine Lee, MS**  
*University of California, Irvine*

**Jeff Mandel, MD, MS**  
*University of Pennsylvania*

**Michael Mestek, PhD**  
*Medtronic*

**James Moore, MD**  
*University of California, Los Angeles*

**John Pawlowski, MD, PhD**  
*Beth Israel Deaconess Medical Center*

**Christian Petersen, PhD**  
*British Columbia Children's Hospital*

**James Philip, MD**  
*Brigham & Women's Hospital and Harvard Medical*

**Mark Rice, MD**  
*Vanderbilt University School of Medicine*

**Emily Richardson, MD**  
*Encompass Medical*

**Brian Rothman, MD**  
*Vanderbilt University Medical Center  
President, STA*

**Norma Sandrock, MD**  
*Beth Israel Deaconess Medical Center*

**DeLaine Schmitz, MSHL**  
*AQI Executive*

**Kirk Shelley, MD, PhD**  
*Yale University School of Medicine*

**Jonathan Tan, MD, MPH**  
*Children's Hospital of Philadelphia  
Abstract Co-Chair, STA 2017  
Annual Meeting*

**Avery Tung, MD**  
*University of Chicago*

**Jonathan Wanderer, MD, MPhil**  
*Vanderbilt University School of Medicine  
Program Chair,  
STA 2017 Annual Meeting*

# MEETING ACCREDITATION INFORMATION

## Activity Overview

The Society for Technology in Anesthesia (STA) 2017 Annual Meeting will provide a forum for discussion of the future of anesthesiology and innovation in perioperative care through application of bioinformatics and analysis of Big Data within perioperative medicine, advances in outcome measurement and tracking, novel approaches to education and advances in medical devices.

## Target Audience

This live activity is designated for a national and international audience of physicians, engineers and industry members, as well as other practitioners in the field of anesthesia seeking an update on the current and future state of anesthesia technology.

## Educational Objectives

**As a result of participation in this CME activity, learners should be able to:**

- Describe how anesthesiologists can transition between clinical care, entrepreneurial work and medical staff leadership.
- Understand multiple approaches to large scale database research and the statistical challenges within each.
- Review recent findings with obstetric and pain management derived from database analyses.
- Discuss the current state of outcome measurement and tracking in the anesthesia community.
- Describe systematic processes to resolve data definitions at a national clinical registry.
- Explore perioperative technology that is on the horizon and its potential impact on outcomes and finances.
- Describe novel approaches to education within perioperative medicine that leverage information technology.
- Review novel medical devices under development for respiratory monitoring and training in airway management.

## Barriers to change:

- Translating advances with cutting-edge technology and novel insights from scientific evidence into change in routine clinical practice.

## Accreditation Statement

This activity has been planned and implemented in accordance with the accreditation requirements and policies of the Accreditation Council for Continuing Medical Education (ACCME) through the joint providership of Amedco and the Society for Technology in Anesthesia (STA). Amedco is accredited by the ACCME to provide continuing medical education for physicians.

## Credit Designation Statement

Amedco designates this live activity for a maximum of **17.75 AMA PRA Category 1 Credits™**. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

## PRE-CONFERENCE SESSION

### *Challenges and Opportunities in Developing Anesthesia Products (for industry)*

**Wednesday, January 11, 2017 • 0800 - 1200**

Experienced anesthesiologists have developed this course for corporate members who may be new to the anesthesia market as well as those with experience. The course is designed to provide a concise overview of the specialty and an opportunity to discuss the role of technology in a collegial (non-sales) environment. The course is intended to foster one of STA's primary goals, which is to establish relationships between users and developers of technology.

This course will demonstrate the anesthesiologists' interaction with patients and devices through a dynamic, interactive agenda. The day will include expert mini-lectures and group discussions on key aspects of the clinical specialty, including anesthesia 'work', behaviors driving equipment usage, the state of anesthesia-induced unconsciousness and machine function. **OPEN TO INDUSTRY PARTICIPANTS ONLY.**

# SCHEDULE OF EVENTS

## Wednesday, January 11, 2017

0730 – 0800	<b>Challenges and Opportunities Registration &amp; Continental Breakfast</b>
0800 – 1700 <i>Aqua 311A Foyer</i>	<b>Exhibitor Registration &amp; Setup</b>
0800 – 1200 <i>Aqua 311A</i>	<b>Challenges and Opportunities in Developing Anesthesia Products (for industry ONLY)</b> <i>David Feinstein, MD, Norma Sandrock, MD, John Pawlowski, MD, PhD, Jesse Ehrenfeld, MD, MPH</i>
1600 – 1800 <i>Hotel Pool Deck</i>	<b>Resident's Gathering</b>
1800 – 1930 <i>Aqua Salon DE</i>	<b>Registration &amp; Welcome Cocktail Reception</b>

## Thursday, January 12, 2017

0700 – 0800 <i>Aqua Salon DE</i>	<b>Registration &amp; Continental Breakfast</b>
0800 – 0815 <i>Aqua Salon BC</i>	<b>Welcome Address</b> <i>Brian Rothman, MD, Jonathan Wanderer, MD, MPhil</i>
<b>Session 1: Keynote Address</b> <b>Moderator: Jonathan Wanderer, MD, MPhil</b>	
0815 – 0930 <i>Aqua Salon BC</i>	<b>The Importance of Devices in Outcomes: Experiences of an Anesthesiologist and Entrepreneur</b> <i>Mark Rice, MD</i>
0930 – 1000 <i>Aqua Salon DEF</i>	<b>Break with Exhibitors &amp; Posters</b>

### Session 2: Insights from Large Database Research

**Moderator: Brian Bateman, MD**

1000 – 1030 <i>Aqua Salon BC</i>	<b>Big Data in OB and OB Anesthesia Research</b> <i>Brian Bateman, MD</i>
1030 – 1100 <i>Aqua Salon BC</i>	<b>Statistical Issues in Large Database Research</b> <i>Timothy Houle, PhD</i>
1100 – 1130 <i>Aqua Salon BC</i>	<b>Big Data for a Big Pain: The Role of Databases in Perioperative Pain Management</b> <i>Karim Ladha, MD, MSc, FRCPC</i>
1130 – 1200 <i>Aqua Salon BC</i>	<b>Panel Discussion</b>
1200 – 1315 <i>Promenade Plaza (Level 1)</i>	<b>Luncheon</b>

### Session 3: What's in an Outcome: Definitions and Risk Adjustment

**Moderator: Avery Tung, MD**

1315 – 1345 <i>Aqua Salon BC</i>	<b>What Does AQI Think You Should Measure?</b> <i>Emily Richardson, MD</i>
1345 – 1415 <i>Aqua Salon BC</i>	<b>Would it Smell as Sweet? The Link Between Definition and Measurement</b> <i>Avery Tung, MD</i>
1415 – 1445 <i>Aqua Salon BC</i>	<b>Solving Definitional Issues at STS</b> <i>DeLaine Schmitz, MSHL</i>
1445 – 1515 <i>Aqua Salon BC</i>	<b>Panel Discussion</b>
1515 – 1545 <i>Aqua Salon DEF</i>	<b>Break with Exhibits &amp; Posters</b>

### Session 4: Research Awards and Presentations

**Moderator: Thomas Hemmerling, MD, MSc, DEAA**

1545 – 1610 <i>Aqua Salon BC</i>	<b>Excellence in Technology Award Presentation: Concurrent Piezo- and Photo-Plethysmography for Enhanced Signal Context</b> <i>Christian Petersen, PhD</i>
1610 – 1635 <i>Aqua Salon BC</i>	<b>Best Clinical Application Award Presentation: Patient Monitoring Quality Improvement Program: Impact on Respiratory Compromise</b> <i>Michael Mestek, PhD</i>
1635 – 1700 <i>Aqua Salon BC</i>	<b>Best of Show Award Presentation</b> <b>Deep Learning for Predicting In Hospital Mortality</b> <i>Christine Lee, MS</i>

## Friday, January 13, 2017

0700 – 0800 <i>Aqua Salon DE</i>	<b>Registration &amp; Continental Breakfast</b>
<b>Session 5: Technology on the Horizon: Show Us the Evidence on Outcomes and Finances</b> <b>Moderator: Brian Rothman, MD</b>	
0800 – 0830 <i>Aqua Salon BC</i>	<b>Improving Perioperative Care: Death, Disability and Digital Records</b> <i>Alexander Davey, FRCA</i>
0830 – 0900 <i>Aqua Salon BC</i>	<b>MACRA &amp; MIPS: The Intersection of Quality and Payment</b> <i>James Moore, MD</i>
0900 – 0930 <i>Aqua Salon BC</i>	<b>Implementing the Perioperative Surgical Home: Politics, Logistics and Economics</b> <i>Brian Rothman, MD</i>



# SCHEDULE OF EVENTS *CONTINUED*

## Friday, January 13, 2017 *continued*

0930 – 1000 **Panel Discussion**  
*Aqua Salon BC*

1000 – 1030 **Break with Exhibits & Posters**  
*Aqua Salon DE*

### **Session 6: STA & FAER Joint Session: Education, Innovation and Technology**

**Moderator: Larry Chu, MD, MS**



1030 – 1100 **Precision Education: The Role of Learning Analytics in Driving Innovation in Medical Education**  
*Aqua Salon BC*  
Larry Chu, MD, MS

1100 – 1130 **Use of Technology to Enhance Learning: Getting Your Hands Dirty**  
*Aqua Salon BC*  
Janak Chandrasoma, MD

1130 – 1200 **Evidence Based Teaching and Learning: Is It Practical?**  
*Aqua Salon BC*  
Viji Kurup, MD

1200 – 1215 **Panel Discussion**  
*Aqua Salon BC*

1215 – 1330 **STA Business Luncheon and J.S. Gravenstein Award Presentation**  
*Sapphire M*  
James Philip, MD

### **Session 7: Concurrent Workshops**

1330 – 1530 **Young Researchers Workshop**  
*Aqua 305*  
Christine Lee, MS  
Maxime Cannesson, MD, PhD

The objective of this workshop is to bring together a community of young research scientists. In this community, researchers will share their individual research experiences, as well as develop collaborative relationships to further promote the advancement of technology in anesthesia. The focus of this year's workshop will be on the use of predictive analytics in health care. The workshop will include a short course on predictive modeling with Python in collaboration with the UC Irvine Data Science Initiative, as well as a discussion on the current status and future of machine learning in medicine.

1330 – 1530 **Making the Most of Data: Turning the Raw Information into Useful Information**  
*Aqua Salon E*  
Ira Hofer, MD, Emily Richardson, MD

The objective of this workshop will be to explore the opportunities and challenges associated with collecting accurate data on your patients and transforming that data into information that can be used to improve care delivery. The workshop will briefly address the overall goals and challenges with collecting data. Then, tasked with collecting data around a specific endpoint, participants will split into two smaller groups: One will discuss specific challenges and strategies associated with collecting data either from AIMS/EMR and the other will discuss how to attack the same endpoint in a practice setting that lacks these resources. At the end the participants will come together to share what they have learned as well as discuss the challenges associated with combining the data from the various sources.

1530 – 1545 **Break with Posters**  
*Aqua West Foyer*

### **Session 8: Fresenius Research Recipient Presentations**

1545 – 1615 **2015 Fresenius Research Recipient Presentation**  
*Aqua Salon BC*  
Christian Petersen, PhD

1615 – 1700 **2016 Fresenius Research Recipient Presentation**  
*Aqua Salon BC*  
Richard Epstein, MD

1730 – 1930 **STA Closing Cocktail Reception**  
*Sapphire Terrace (Level 4)*

## Saturday, January 14, 2017

0730 – 0830 **Registration**  
*Aqua West Foyer*  
(No breakfast provided)

### **Session 9: STA Engineering Challenge**

**Moderator: Jeff Mandel, MD, MS**

0830 – 1015 **Engineering Challenge**  
*Aqua Salon BC*  
Jeff Mandel, MD, MS

1015 – 1030 **Break**  
*Aqua West Foyer*

### **Session 10: Medical Device Innovation and Integration**

**Moderator: Kirk Shelley, MD, PhD**

1030 – 1100 **Oxygen Reserve Index: A New Pulse Oximetry Measurement**  
*Aqua Salon BC*  
Steven Barker, MD, PhD

1100 – 1130 **Difficult Airway Algorithm and Rescue Cricothyrotomy - The DAARC Serious Video Game**  
*Aqua Salon BC*  
Jessica Feinleib MD, PhD, CHSE

1130 – 1200 **Non-Invasive Respiratory Volume Monitoring**  
*Aqua Salon BC*  
Jenny Freeman, MD

1200 – 1230 **The Role of the Anesthesiologist in Medical Device Development**  
*Aqua Salon BC*  
Aymen Alian MD

1230 – 1300 **Panel Discussion**  
*Aqua Salon BC*

1300 **Adjourn**

# HILTON SAN DIEGO BAYFRONT MAP

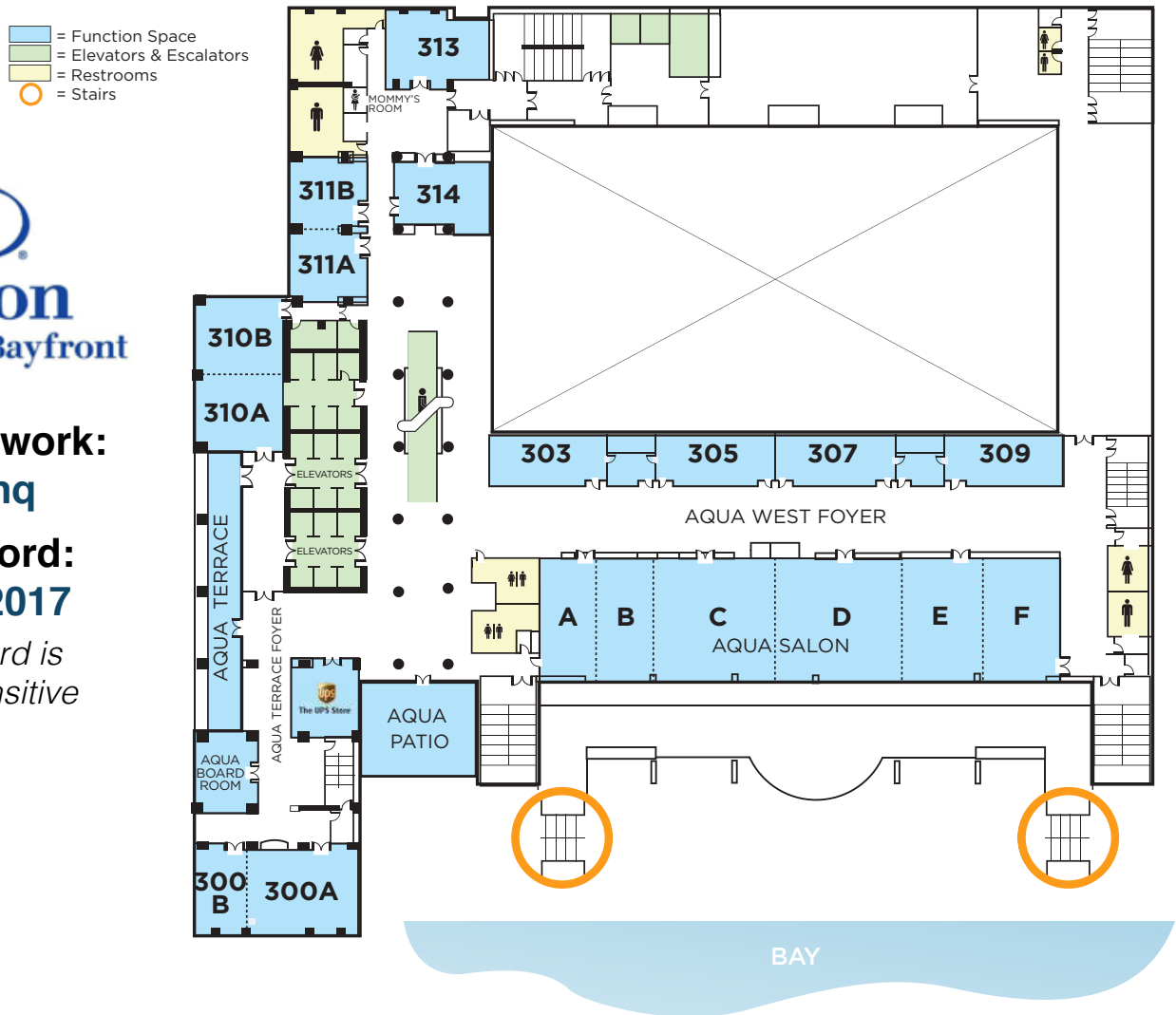
## AQUA LEVEL (Third Floor)



## WIFI Network: STAhq

**Password:**  
**stahq2017**

*Password is  
case sensitive*



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- Monitor Mask
- Respiratory Motion

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Codonics ..... [www.codonics.com](http://www.codonics.com)  
Respiratory Motion ..... [www.respiratorymotion.com](http://www.respiratorymotion.com)

# COMPANY DESCRIPTIONS



### AlertWatch

AlertWatch develops integrated decision support software to help anesthesiologists improve quality across the entire continuum of care. The software integrates device and medical record information to produce real-time alerts focused on improving performance on process measures which are associated with better patient outcomes and improved reimbursement.

Our newest product is AlertWatch:OB, the world's first electronic maternal surveillance system. The software facilitates the early recognition and management of maternal morbidity, including postpartum hemorrhage and severe hypertension. With maternal mortality on the rise in the United States, AlertWatch:OB will become a key part of your labor & delivery unit.



### BD

BD is a global medical technology company that is advancing the world of health by improving medical discovery, diagnostics and the delivery of care. BD leads in patient and health care worker safety and the technologies that enable medical research and clinical laboratories. The company provides innovative solutions that help advance medical research and genomics, enhance the diagnosis of infectious disease and cancer, improve medication management, promote infection prevention, equip surgical and interventional procedures, and support the management of diabetes. The company partners with organizations around the world to address some of the most challenging global health issues. BD has more than 40,000 associates across 50 countries who work in close collaboration with customers and partners to help enhance outcomes, lower health care delivery costs, increase efficiencies, improve health care safety and expand access to health. For more information on BD, please visit [www.bd.com](http://www.bd.com).



### Canary Sound Design, LLC

Canary Sound Design, LLC innovates patient-centric music volume control for the noise polluted operating room. Integration of music with the anesthesia monitor brings advanced sound settings to the head of the bed and allows for automated music volume reductions that simplify workflow and enhance patient care.

# COMPANY DESCRIPTIONS



## **CODAN**

CODAN offers two lines of anesthesia IV administration sets and blood administration sets: The exclusive, customizable Walrus® by CODAN® product line of specialty anesthesia IV sets as well as the high quality, in-stock line of standard CODAN blood administration sets. Our Blood sets feature 170 and 200 micron blood filters. The comprehensive specialty WALRUS® by CODAN® product line consists of high quality infection prevention products, IV administration sets, blood administration sets, extension sets, stopcocks, one-way valves, manifolds, and select accessories. CODAN focuses on the specific needs and wants of each customer through low minimum order requirement and quick turnaround time. Visit [www.codanusa.com](http://www.codanusa.com) for further details.



## **Codonics**

Codonics Safe Label System (SLS) is the standard of care in more than 4,000 ORs in the world's renowned hospitals.

SLS integrates with leading anesthesia dispensing carts (ADCs) to provide unparalleled safety and comprehensive barcode labeling.

For electronic documentation in the OR, SLS integrates with Epic Anesthesia and Plexus Anesthesia Touch, offering a complete solution for barcode medication identification and verification of IV meds at the point of care. An FDA Class II device, the system ensures TJC compliance with best practices and standards to improve patient safety and workflow efficiency while eliminating disparate systems and human error to enhance clinical delivery.



## **Dräger**

For more than a century, Dräger has been providing anesthesia solutions clinicians can count on. Our experience has led to innovations such as the Perseus A500 – the first and only anesthesia machine in the United States to offer Airway Pressure Release Ventilation (APRV). From anesthesia machines to anesthesia monitors to AIMS, no other company is more focused on anesthesia care than Dräger.



## **Edwards Lifesciences**

Edwards is the global leader in heart valves and hemodynamic monitoring. Edwards provides a choice of advanced hemodynamic monitoring solutions for the surgical environment, including the ClearSight, FloTrac and Swan-Ganz systems, which provide continuous, dynamic and flow-based parameters to enable you to make more informed volume administration decisions. Know more visit [Edwards.com/ESRsolutions](http://Edwards.com/ESRsolutions)



## **Foundation for Anesthesia Education and Research**

The Foundation for Anesthesia Education and Research is the charitable arm of the American Society of Anesthesiologists. For over 30 years, FAER has been dedicated to Developing the next generation of physician-scientists in anesthesiology.

Charitable contributions and support to FAER help fuel the future of anesthesiology through innovation. Funding priorities include: Research, Education, and Training. For more information, visit [www.faer.org](http://www.faer.org).



## **GE Healthcare**

GE Healthcare provides transformational medical technologies and services to meet the demand for increased access, enhanced quality and more affordable healthcare around the world. GE (NYSE: GE) works on things that matter - great people and technologies taking on tough challenges. From medical imaging, software & IT, patient monitoring and diagnostics to drug discovery, biopharmaceutical manufacturing technologies and performance improvement solutions, GE Healthcare helps medical professionals deliver great healthcare to their patients.



## **Kronos EZCall**

Kronos EZCall is the leader in automated physician scheduling. Delivered as a Software as a Service (SaaS) solution, EZCall creates flexible, fair, and equitable physician work schedules. Even the most complex rules can be automated using a powerful and sophisticated scheduling algorithm. For over 10 years, EZCall has helped organizations make smarter staffing decisions, in less time, ensuring the right provider, is in the right place, at the right time. Please stop by the EZCall booth or visit us online at [www.ezcall.com](http://www.ezcall.com).



# COMPANY DESCRIPTIONS



## **Masimo**

Masimo is a global medical technology company that develops and manufactures innovative noninvasive monitoring technologies, including medical devices and a wide array of sensors that may enable earlier detection and treatment of potentially life-threatening conditions. 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® noninvasive and continuous hemoglobin (SpHb®), acoustic respiration rate (RRa™), Masimo Patient SafetyNet™, SedLine® (EEG-based) Brain Function Monitors, and PhaseIn™ respiratory monitors.



## **Medtronic**

Medtronic is committed to improving lives through our medical technologies and solutions. By joining together with Covidien, we can accelerate and advance our ability to create meaningful innovations for hospitals, health systems, and healthcare providers so they can deliver the best care possible to patients and their families around the world.



## **Mindray**

Mindray, established in 1991, is a leading international manufacturer of medical equipment with global headquarters in Shenzhen, China, North American headquarters in Mahwah, NJ, and R&D centers on 3 continents. We offer a broad range of medical solutions to clinicians including medical imaging, patient monitoring & life support, and diagnostic products. Anesthesia products include a range of anesthesia delivery systems, patient monitors and POC ultrasound devices for various acuity types.



## **Monitor Mask, Inc.**

The Monitor Mask CapnoVue® face masks were developed by a practicing anesthesiologist to address a void in the market --- the lack of an optimized oxygen face mask capable of sampling the patient's exhaled carbon dioxide. Two families of face masks have been introduced to the market. The M1 masks are for standard sedation cases and are available in adult, pediatric and infant sizes. The Scope masks address trans oral procedures, and are available in adult and pediatric sizes. No other competitive approach matches the versatility of CapnoVue products to provide consistent, reliable carbon dioxide sampling over the full range of oxygen delivery flow rates and a standardized approach for nearly all clinical situations and areas of medical practice. Our products were highlighted in the Anesthesiology News Special Edition as key technologies for anesthesiology in 2016.



## **Respiratory Motion, Inc.**

Respiratory Motion, Inc. is the global leader in innovative, non-invasive Minute (MV) Ventilation monitoring and offers ExSpiron™1Xi, the only MV monitor providing a direct assessment of respiratory status in non-intubated patients.



## **Sentec**

SenTec is a medical device company which develops, manufactures and markets the SenTec Digital Monitoring System (SDMS) for noninvasive ventilation and oxygenation patient monitoring. The digital transcutaneous V-Sign Sensor overcomes the drawbacks of some current hypoventilation monitoring technologies when these procedures involve non-traditional ventilation, such as jet ventilation for EP procedures, and/or for those supported with CPAP, BiPAP or high flow cannula, making SenTec's technology an excellent fit for ventilation monitoring on virtually all patient populations.

# MISSION STATEMENT



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

# ABSTRACT TABLE OF CONTENTS

★ **Best of Show Award**  
★★ **Excellence in Technology Award**

★★★ **Best Clinical Application Award**  
★★★★ **Honorable Mention**

Abstract #	Full Abstract Title	First Name	Last Name	Degree(s)	Institution
1	Mitigating Motion in the Video Photoplethysmogram Using Running Wavelet Archotyping	Paul	Addison	PhD	Medtronic
2	NIRS-Based Gradient Adjustment Technique to Delineate Intact Regions of Autoregulation for the Determination of Target Blood Pressure	Paul	Addison	PhD	Medtronic
3	Miniature Raman Spectroscopy Probe May Differentiate Each Tissue from the Skin to the Spinal Cord During Epidural Needle Placement	Thomas	Anderson	MD, PhD	Massachusetts General Hospital/HMS
4	The Perception of Novel Auditory Alarms in a Simulated Intensive Care Unit Environment	Danielle	Bodzin	MD	University of Miami Miller School of Medicine/Jackson Memorial Hospital
5	Evaluation of Oxygen Delivery Efficiency Using a Prototype Intelligent Oxygen Flowmeter	Kyle	Burk	BS	University of Utah
6	A Novel Bed-Mounted Projection System is as Effective as Pharmacologic Modalities to Treat Pediatric Preoperative Anxiety	Thomas	Caruso	MD, MEd	Lucile Packard Children's Hospital Stanford
Not Posted	Evaluation of Low Cost High Fidelity USB Powered Arterial Line Simulation Device for Ultrasound Guided Vascular Puncture and Cannulation	Gaurav	Chauhan	MD	Henry Ford Health System
8	Visibility of Pulse Pressure Variability in Spontaneously Breathing Patients	Christopher	Choi	MD	Yale-New Haven Hospital
9	3D Printing the Affordable Video Laryngoscope	Joshua	Christiansen	R4 Resident	Virginia Mason Medical Center
10	Comparison of a Low-cost 3D Printed Video Laryngo-Borescope Blade versus Direct Laryngoscope for Simulated Endotracheal Intubations	Theodore	Cohen	MD	University of Illinois Health, University of Illinois at Chicago
11	The Value of the Pulse Oximeter in the Prediction of Beach Chair Position Induced Hypotension During Shoulder Surgery	Anna	Dikstein	BA	SUNY Downstate Medical College
12	Obstetric Anesthesia App: Development of a Mobile Application for Obstetrical Anesthesia Education	Ryan	Durk	MD	Washington University in St. Louis
13	A New Programming Language for Computer Simulation	Thomas	Engel	MD	Loma Linda University
14	Perioperative Temperature Measurement Considerations Relevant to Reporting Requirements for National Quality Programs	Richard	Epstein	MD	University of Miami
15	Methods for Analyzing Clinical Utility of Respiratory Rate Monitors	Sean	Ermer	BS	University of Utah
16	Using Photoplethysmography to Detect Low Respiratory Rates	Sean	Ermer	BS	University of Utah
17	Complications Associated with Mortality in the National Surgical Quality Improvement Program Database	Robert	Freundlich	MD, MS	Vanderbilt University Medical Center
18	Virtual Reality for Proton Therapy - Child-life Guided Interactive Tour for Adolescents	Jorge	Galvez	MD, MBI	The Children's Hospital of Philadelphia
19	Neural Network Classifier for Automatic Detection of Invasive Versus Noninvasive Airway Management Technique Based on Respiratory Monitoring Parameters in a Pediatric Anesthesia	Jorge	Galvez	MD, MBI	The Children's Hospital of Philadelphia
20	The Case for An Oxytocin Infusion Safety-Interlock System For Active Management Of Labor (POSI)	Julian	Goldman	MD	Massachusetts General Hospital/HMS
21	Development and Validation of an Artifact Rejection Method for use in a Cardio-Respiratory Coherence Monitor	Matthias	Görges	PhD	The University of British Columbia
22	Simplifying Anesthesia Supply Management Using a Cloud-Based Service	James	Han	MD	University of Illinois at Chicago
23	Evaluation of a Non-Invasive Respiratory Volume Monitor in Subjects Under Non-Invasive Ventilatory Support	Brian	Harvey	PhD	Respiratory Motion, Inc.
24	Evaluation of a Non-Invasive Respiratory Volume Monitor Without Patient-Specific Calibration	Brian	Harvey	PhD	Respiratory Motion, Inc.
25	Disaster Recall: Optimizing Hospital Surge Capacity	Ali	Hassanpour	MD	Texas Children's Hospital/ Baylor College of Medicine
26	Bispectral Index Guided Propofol Induction Dose in Patients Preloaded with Crystalloids	Anto Abey	Illickal	MBBS, MD	St. John's Medical College
27	Fully Automated Anesthesia, Analgesia and Fluid Management using Physiologic Closed-loop Systems in High Risk Patients: A Pilot Study	Alexandre	Joosten	MD	Erasmus University Hospital
28	Implementation of a Computer-Assisted Intraoperative Goal-Directed Fluid Therapy in Major Abdominal Surgery: A Before - After Study	Alexandre	Joosten	MD	Erasmus University Hospital
29	A Novel Device to Standardize Infection Control in Anesthesiology	Murlikrishna	Kannan	M.D, FRCA	Dept of Anesthesiology, Mount Sinai Medical Center, Miami Beach, FL 33156
30	Filling the Gaps of Current Monitoring to Optimize and Individualize Anesthesia Delivery	Anthony	Kaveh	MD	Brigham and Women's Hospital
31 ★★★★	The Contribution of the Induction Period to Overall Gas and Vapour Consumption	Ross	Kennedy	MD, PhD	Christchurch Hospital
32	Using Differential Pressure to Determine Isoflurane Gas Concentration	Patrick	Kolbay	BS	University of Utah

# ABSTRACT TABLE OF CONTENTS *CONTINUED*

Abstract #	Full Abstract Title	First Name	Last Name	Degree(s)	Institution
33	Reducing Volatile Anesthetic Waste Using Activated Charcoal	Patrick	Kolbay	BS	University of Utah
34	Applying 360-Degree Videos to Interdisciplinary Training and Simulation	Chad	Lee	MD	University of Illinois at Chicago
35 ★	Deep Learning for Predicting In Hospital Mortality	Christine	Lee	MS	University of California, Irvine
36	A Prospective Clinical Study of Tom-Stylet, Its Safety, Efficacy for Intubation, Accuracy in Measuring, Guiding ETT Position	Thomas	Lei	MD	Regional Medical Center of San Jose, CA
37	Blood Pressure Analysis on ICU Patients Receiving Vasopressor Therapy from the Mimic II Database	Michael	Ma	BS	UC Irvine Health
38	A Low-Cost and Novel App for Improving Anesthesia Operating Room Equipment Supply	Clyde	Matava	MD	Hospital for Sick Children, Toronto
39 ★★★	Patient Monitoring Quality Improvement Program: Impact on Respiratory Compromise	Michael	Mestek	PhD	Medtronic
40	Development of a Compact, Versatile and Low Cost Mechanomyography Device for Quantitative Train of Four Assessment	Kelly	Michaelsen	MD, PhD	University of Washington
41	Use of Google Glass for Interactive Live Streaming in Medical Student Education	Shoeb	Mohiuddin	MD	University of Illinois at Chicago
42	Development and Pilot Evaluation of a Real-Time Clinical Decision Support Module Integrated with an Enterprise Anesthesia Information Management System	Bala	Nair	PhD	University of Washington
43	Factors Contributing to Anesthesia Residents' Learner Engagement and Learning Experience in a Mobile App: A Mixed-Method Design Study	Lynn	Ngai	MD	Stanford University
44	Adjunctive Intrathecal Morphine Analgesia For Postoperative Pain In Adult Spinal Surgery	Arif	Pendi	MS	University of Southern California
45	Infection Rates with Use of Adjunctive Intrathecal Morphine in Posterior Instrumented Spinal Fusion Surgery: Preliminary Findings of a Retrospective Study	Arif	Pendi	MS	University of California, Irvine
46	Air-Driven Syringe Pump for Anesthesia in Low-Resource Settings	Christian	Petersen	PhD	University of British Columbia
47 ★★	Concurrent Piezo- and Photo-Plethysmography for Enhanced Signal Context	Christian	Petersen	PhD	University of British Columbia
48	Pharmacy Labeling Can Cause, Rather Than Prevent, Drug Errors: An Unintended Consequence of Poor Design	David	Polaner	MD, FAAP	Children's Hospital Colorado and University of Colorado School of Medicine
Not Posted	Comparison of Hemodynamic Responses and Upper Airway Morbidity Following Orotracheal Intubation in Hypertensive Patients - Macintosh Direct Laryngoscope Versus Glidescope Videolaryngoscope	Vimi	Rewari	MBBS, MD	All India Institute of Medical Sciences
50	Patient Controlled Sedation and Changes of EEG During Dental Treatment	Kwang-Suk	Seo	MD	Seoul National University, School of Dentistry
51	Augmented Index of Finger Pulse Oximeter During Mild Hypovolemia	Tiantian	Shi	MD	Yale School of Medicine
52	Effect of Phenylephrine on PPG Augmented Index and Local Vascular Compliance	Tiantian	Shi	MD	Yale School of Medicine
53	The Effect of Phenylephrine on Peripheral Pressure Volume Loops	Tiantian	Shi	MD	Yale School of Medicine
54	When Technology Hurts Instead of Helps: The Impact of Supraglottic Airway Devices on Neck Masses During Magnetic Resonance Imaging in Children	Allan	Simpao	MD	The Children's Hospital of Philadelphia
55	Building a Natural Language Processing Tool to Identify Acute Chest Syndrome in Children with Sickle Cell Disease	Allan	Simpao	MD	The Children's Hospital of Philadelphia
56	Screening and Monitoring of Postoperative Respiratory Compromise to Reduce Code Blues	Greg	Spratt	BS, RRT, CRFT	Medtronic
57	Usability Evaluation of Panda, a Smartphone Application Designed to Support Pediatric Post-Operative Pain Management at Home	Terri	Sun	MD	University of British Columbia
58	A Novel Mandibular Advancement Bite Block Prevents Hypoxemia During Sedative Endoscopy	Wei-Nung	Teng	MD	Department of Biomedical Engineering, National Yang Ming University; Department of Anesthesiology, Taipei Veterans General Hospital, Taipei, Taiwan
59	The Impact of AlertWatch, A Multifunctional Decision Support System, on Intraoperative Process Measures and Postoperative Outcomes	Kevin	Tremper	PhD, MD	University of Michigan
60	Operating Room Fires: Drapes and Oxygen Contamination of the Surgical Field	Kenisha	Webb	MD	Texas A&M University College of Medicine

## Mitigating Motion in the Video Photoplethysmogram Using Running Wavelet Archotyping

**Presenting Author:** Paul S. Addison, PhD, Technical Fellow. Medtronic, Minimally Invasive Therapies Group, Edinburgh, Scotland, UK.

**Co-Authors:** Dominique Jacquel, PhD, David M.H. Foo, PhD. Medtronic, Minimally Invasive Therapies Group, Edinburgh, Scotland, UK.

**Introduction:** The determination of physiological parameters from video image streams has attracted significant attention in recent years, with a variety of signal processing and hardware approaches being employed to address the problem [1]. However, the acquired signal - the video photoplethysmogram (video-PPG) - is highly susceptible to three main confounders: motion artefact, lighting levels (both low levels and dynamic variations) and skin pigmentation. Here we report on a protocol for head motion and on a novel method to process video-PPG using wavelet transforms [2] to determine the heart rate ( $HR_{vid}$ ).

**Method:** Video was acquired during a sequence of head movements: yaw, pitch and roll (figure 1a). A video-PPG was acquired from a region of interest (ROI) on the forehead. This signal contains significant movement artefact (figure 1b).

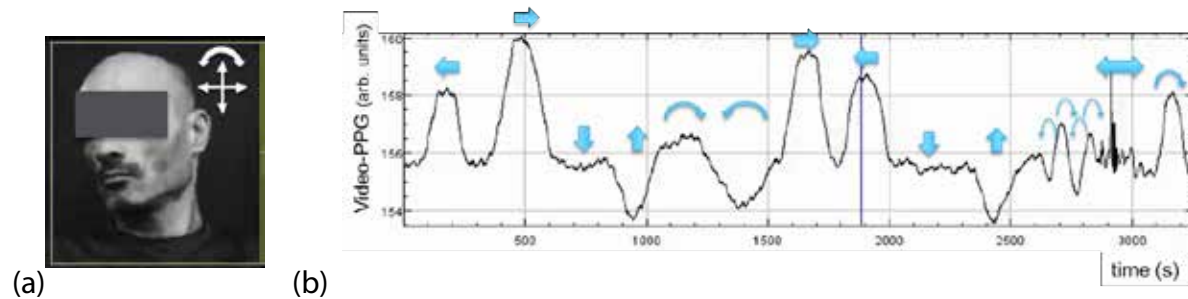


Figure 1: a) Range of Head Movements: Yaw, Pitch, Roll and Resulting Video-PPG; b) acquired video-PPG signal.

A novel running wavelet archetype (RWA) [3] was computed from the wavelet transform of the acquired signal (figure 2). This enables a time-frequency ensemble averaging in the transform domain. A particular feature of the RWA method is that it does not require knowledge of signal fiducial points, unlike temporal ensemble averaging methods. The archetype transform,  $T_{RWA}(a,b)$ , is generated using a weighted averaging scheme as follows:

$$T_{RWA}(a,b)=w.T(a,b) + (1-w).T_{RWA}(a,b-P(a)) \quad [1]$$

where  $w$  is a predefined weight,  $T_{RWA}(a,b-P(a))$  is the previous archetype value separated from the current value by a period  $P(a)$ , and  $T(a,b)$  is the computed wavelet transform. In the method, each time a value of  $T(a,b)$  is computed, it is used with the previous archetype transform value to form an updated value of the archetype transform. As the wavelet transform already separates out the signal information into natural temporal scales according to the periodicity of the wavelet function, we may use the characteristic period of the wavelet at each scale for  $P(a)$ . Thus we see that there is no requirement for the determination of fiducial points in the method, as the wavelet information is naturally 'rolled up' at each scale using  $P(a)$  based on the wavelet function itself. Once  $T_{RWA}$  is calculated, the ridge of the pulse band in wavelet space is tracked to determine the heart rate, (i.e., the instantaneous frequency of the ridge component of the pulse band is converted to beats per minute). A high level flow chart of the algorithm is presented in figure 3.

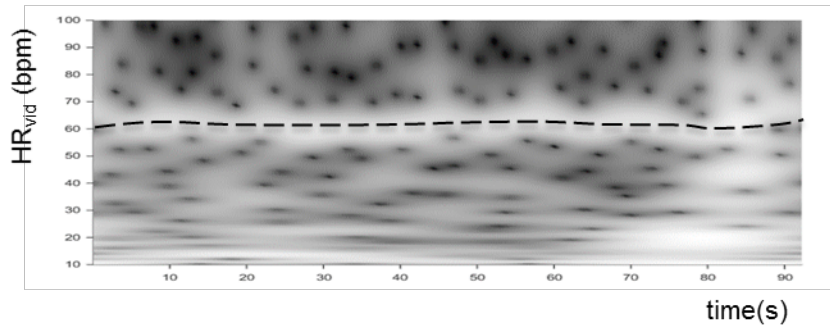


Figure 2: The CWT of a Motion Study Signal

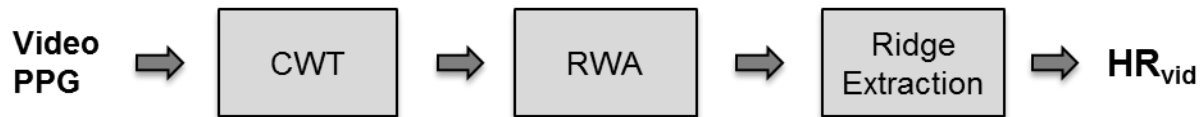


Figure 3: High-level Flowchart of the HR video processing using the Running Wavelet Archotyping Algorithm

### Results:

The root mean square difference (RMSD) between the extracted video heart rate and a reference pulse rate from a Nellcor pulse oximeter (Medtronic, Boulder, CO) attached to a non-moving finger was found to be 1.47 bpm. Whereas, using the original scalogram ridge (i.e. before performing the RWA) for the whole signal resulted in an RMSD of 1.61 bpm (figure 2).



**Conclusions:** Preliminary results have been reported for the determination of heart rate from a video-PPG where the region of interest exhibits a high degree of motion artefact due to large scale movements of the subject's head. A novel protocol involving a series of defined head movements was followed, and a novel RWA algorithm employed to determine a video-based heart rate. Although at an early stage, the method shows promise for more accurately determining video-PPG-based physiological parameters during motion.

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## **NIRS-Based Gradient Adjustment Technique to Delineate Intact Regions of Autoregulation for the Determination of Target Blood Pressure**

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**Co-Authors:** Dean Montgomery. Algorithm Engineer. Medtronic Respiratory & Monitoring Solutions, Edinburgh, Scotland, UK.

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**Introduction:** Cerebral blood flow is regulated over a range of systemic blood pressures through the Cerebral Autoregulation (CA) control mechanism [1]. The near infrared spectroscopy (NIRS)-based COx measure has been proposed as a suitable proxy for blood flow in the analysis of CA [2]. Delineation of intact and impaired regions of autoregulation in COx plots requires setting a minimum threshold above which the COx measure is associated with impaired autoregulation [3]. This assumes that the gradient in the intact region is non-positive, which in practice is not true. The method presented here allows for the enhancement of changes that occur between the intact and impaired regions of autoregulation, allowing a simple, automated algorithm to delineate the lower and upper limits of autoregulation (ULA/LLA).

**Method:** We used data from an in-house porcine study (N=9) that elicited blood pressure transitions below the LLA. This is a different dataset from the one analyzed in [4]. A linear regression between the NIRS-based measure and MAP is calculated and used to subtract the values from the NIRS-based signal. The gradient adjusted measure is calculated as

$$GA(x_i) = NIRS(x_i) - y(x_i) \quad [1]$$

where  $GA(x_i)$  is the gradient-adjusted signal for the sample point  $x_i$ ,  $NIRS(x_i)$  is the original NIRS-based measure for the sample points  $x_i$ , and  $y(x_i)$  is the value of the regression line for the same sample point.

**Results:** Figure 1a shows the gradient adjustment technique applied to one of the animals in the study. It is very noticeable that in the top COx plot there is not a clear-cut intact region, and traditional methods to segment the plot in intact/impaired regions would probably fail. The bottom plot depicts the same dataset after applying the GA method. The transition zone between intact and impaired autoregulation is now obvious. Figure 1b shows box plots that includes the data for all the animals. The boxes for COx above/below the LLA have a large overlap, and there is not a large difference (0.149) between the median COx values in both

regions. In the boxes using the GA method, there is a clear difference (1.334) between the points above and below the LLA

**Conclusions:** The gradient adjustment method was successfully applied to a pig model to automatically evaluate the lower limit of autoregulation. There was a significant improvement in enhancing the transition zone between intact and impaired states. The gradient adjustment method appears to be a promising and simple to apply technique for evaluating the limits of autoregulation.

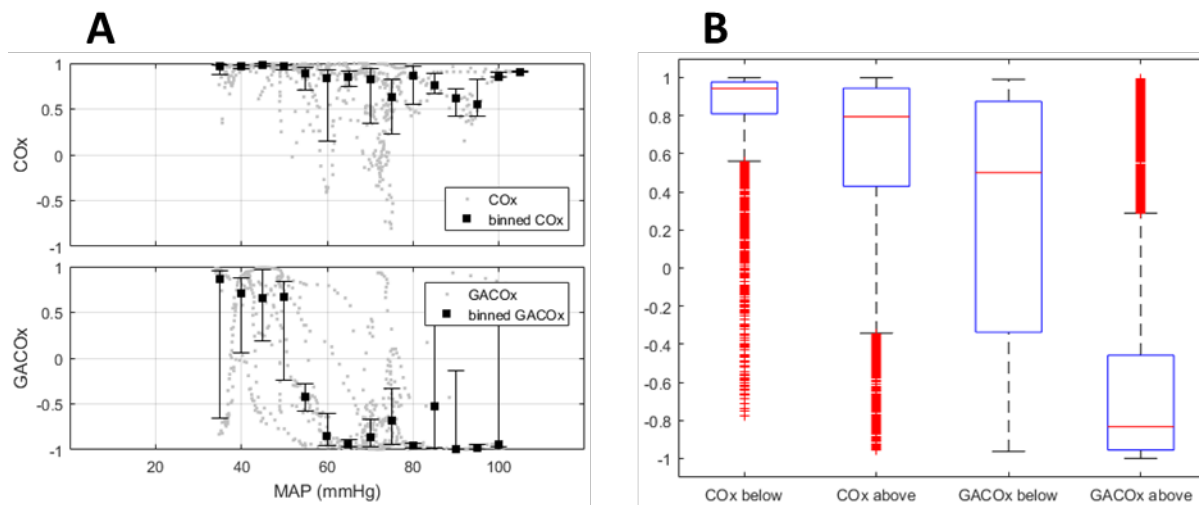


Figure 1. **A:** COx and GA method applied on the COx data for a single data set. **B:** box plots for all the animals for the COx and GA method, separated in regions below the LLA and above the LLA. For the COx data, median below LLA = 0.943, IQ: [0.810 0.9765] and median above LLA = 0.794, IQ: [0.429 0.944]. For the Gradient-adjusted data, median below LLA = 0.501, IQ: [-0.337 0.875] and median above LLA = -0.833, IQ: [-0.955 -0.458].

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## **Miniature Raman Spectroscopy Probe May Differentiate Each Tissue from the Skin to the Spinal Cord During Epidural Needle Placement**

**Presenting Author:** T. Anthony Anderson, PhD, MD<sup>1</sup>

**Co-Authors:** Jeon Woong Kang, PhD<sup>2</sup>, Tatyana Gubin<sup>3</sup>, Ramachandra R. Dasari, PhD<sup>4</sup>, Peter T. C. So, PhD<sup>5</sup>

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**Background:** Neuraxial anesthesia and epidural steroid injection techniques require precise anatomical targeting to ensure successful and safe analgesia. Epidural steroid injections are effective for symptomatic relief of radiculopathy and neuraxial anesthesia decreases labor and delivery as well as perioperative pain. However, the traditional loss of resistance technique has a relatively low sensitivity and specificity for epidural space localization. While ultrasound and fluoroscopy can localize epidural needles relative to bone, they are unable to identify tissues at the needle tip. We previously showed that Raman spectroscopy can differentiate each tissue from the skin to the spinal cord with a high degree of accuracy and precision in an ex vivo animal model. We hypothesized that real-time needle-tip spectroscopy may aid epidural needle placement and tested the ability of a 500um outer diameter Raman spectroscopy probe to identify the same tissues in a live animal model.

**Methods:** We developed a 500 micrometer outer diameter Raman spectroscopy probe compatible with 17-gauge Tuohy epidural needle and low cost Raman spectroscopy system. We sought to validate the probe and system in a live swine model. The miniature probe within an epidural needle was inserted in the spinal column at the midline between spinous processes and lateral to the midline in order to mimic the two commonly used approaches to epidural space localization. Raman spectroscopy (RS) data was recorded continuously during epidural needle insertion. The probe in needle was advanced at 1 mm increments starting at the skin, through the epidural space, and ending at the spinal cord in order to acquire data from all tissue types along each of the two trajectories. Data was recorded during multiple midline and lateral insertion points. Simultaneous x-ray imaging was used to capture needle

tip position along each trajectory. At the completion of the experiment, spine tissue was removed and tissue along each needle trajectory was dissected and underwent H & E staining and identification by a qualified pathologist.

**Results:** While initial results appear to corroborate prior data showing that RS can differentiate each tissue from the skin to the spinal cord, final analysis of the Raman spectrographic data acquired from the 500 um RS probe during insertion in a live animal model is pending. Data analysis will be completed by the annual STA meeting in January 2017.

**Conclusions:** A prior study demonstrates Raman spectroscopy can distinguish the tissues encountered during epidural needle insertion using a two millimeter RS probe in an ex vivo swine model. A miniaturized RS probe, compatible with an epidural needle may prove useful during needle placement by providing evidence of its anatomical localization.

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Anderson TA, Kang JW, Gubin T, Dasari RR, So PT. Raman Spectroscopy Differentiates Each Tissue From the Skin to the Spinal Cord: A Novel Method for Epidural Needle Placement? *Anesthesiology*. 2016 Oct;125(4):793-804.



## **The Perception of Novel Auditory Alarms in a Simulated Intensive Care Unit Environment**

**Presenting Author:** Danielle K. Bodzin, MD, University of Miami Miller School of Medicine  
Department of Anesthesiology

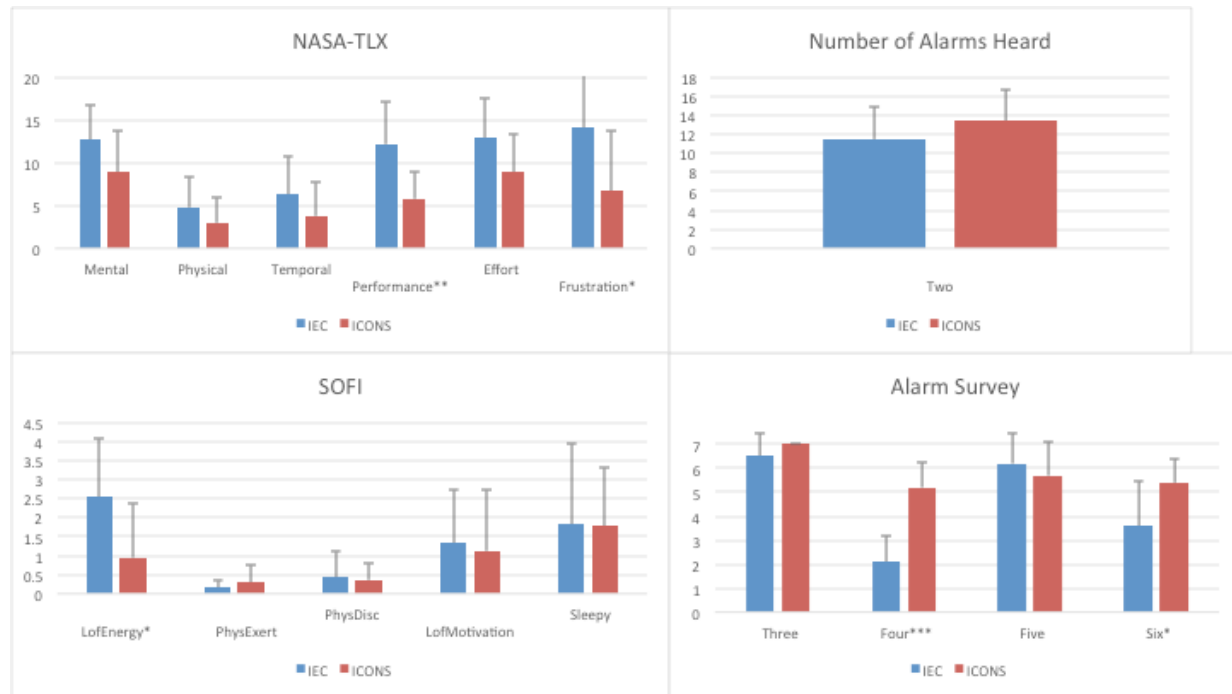
**Co-Authors:** Richard R. McNeer, MD, PhD, University of Miami Miller School of Medicine  
Department of Anesthesiology; Roman Dudaryk, MD, University of Miami Miller School of  
Medicine Department of Anesthesiology; Christopher L. Bennett, PhD, University of Miami  
College of Engineering Department of Biomedical Engineering

**Introduction:** Alarms are frequent, inevitable sounds in any intensive care unit (ICU), and play an important role in patient safety. [1] Unfortunately, the current International Electrotechnical Commission (IEC) alarm sounds [2] have been associated with high rates of alarm fatigue, poor alarm recognition, and inability to determine alarm urgency. [3] Novel auditory “Icon” alarms were created that correspond with IEC categories, but are metaphoric in nature (for example, a whistling kettle corresponds with abnormal temperature). They have been tested on non-anesthesiology participants in a non-simulation, computer-based setting, and demonstrated significant improvement in learnability over IEC alarms. [4] We hypothesize that in a simulated ICU environment, when compared to IEC alarms, anesthesiology residents and physicians will rate Icon alarms as: less frustrating, less energy to identify, easier to distinguish between, more helpful, and will perceive their performance in identifying the alarms as better.

**Methods:** MATLAB was used to create novel Icon alarm sounds. Resident and physician anesthesiologists were randomized to either the control (IEC alarms) or experimental group (Icon alarms). An instructional presentation was reviewed in which participants heard alarms for each category. Subsequently, they gave a break to a “physician” in a simulated ICU, during which time alarms intermittently sounded. Participants chose the reason why the alarm was sounding. They underwent an identical experiment about a week later, after which they were asked to complete psychometric questionnaires (including the National Aeronautics and Space Administration Task Load Index (NASA-TLX) and Swedish Occupational Fatigue Inventory (SOFI)).

**Results:** A total of 20 participants, 17 anesthesiology residents and 3 attending physicians, were separated into 2 groups (10 participants in each). When compared with the IEC alarms, the Icon alarms were rated as less frustrating ( $p < 0.05$ ), less energy consuming ( $p < 0.05$ ), easier to identify ( $p < 0.001$ ) and more helpful ( $p < 0.05$ ). However, IEC participants perceived their performance to be better than those in the Icons group ( $p < 0.01$ ).

**Discussion:** Although IEC alarm sounds have been in use for many years, the need for more intuitive, easily identifiable alarm sounds is apparent. [5] The goals of Icon alarms are to reduce alarm fatigue, improve learnability, and in turn, improve patient safety. This study had several limitations, including but not limited to: a small number of participants, single-center trial, potential for response bias, and lack of blinding. Still, given the improved psychometric perception associated with Icon alarms (less frustration, less energy expenditure, greater ease of identification, and greater helpfulness), further investigations should be conducted to study the potential positive impact of these novel alarm sounds in the ICU setting.



**Figure 1.** NASA-TLX and SOFI questionnaires; Alarms survey: Item 2- Total number of alarms heard, 3- To what extent were you aware of alarms?, 4- How easy was it to figure out what alarms meant?, 5- How easy was it to hear alarms, 6- How helpful did you find the alarms?; \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

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## Evaluation of Oxygen Delivery Efficiency Using a Prototype Intelligent Oxygen Flowmeter

**Authors:** Kyle M. Burk, B.S., Derek J Sakata MD, Joseph A. Orr Ph.D., University of Utah, Departments of Anesthesiology and Bioengineering

**Introduction:** Supplemental oxygen ( $O_2$ ) is routinely delivered during procedural sedation and patient controlled analgesia. Traditionally,  $O_2$  is delivered continuously via nasal cannula regardless of breath phase. An alternative method for delivering supplemental  $O_2$  is to deliver the  $O_2$  on demand. Demand delivery gives a pulse of  $O_2$  at the beginning of inspiration and stops during expiration. Although demand delivery systems are widespread for home use, these systems are currently not used to deliver supplemental  $O_2$  during sedation and monitored anesthesia care.

We have developed a prototype intelligent  $O_2$  flowmeter that is similar to demand delivery systems but specifically intended for patients receiving sedatives and opioids. The prototype determines respiration rate and inspiratory effort by measuring intranasal pressure through a nasal cannula (NC) port. The amount of  $O_2$  flow given by the system varies according to the respiratory rate so that as the respiratory rate slows, due to opioid and sedative drugs, the delivered volume of  $O_2$  is increased. By increasing  $O_2$  delivery as respiratory rate slows, the system maintains a constant alveolar delivery of inhaled oxygen per time regardless of breath rate.

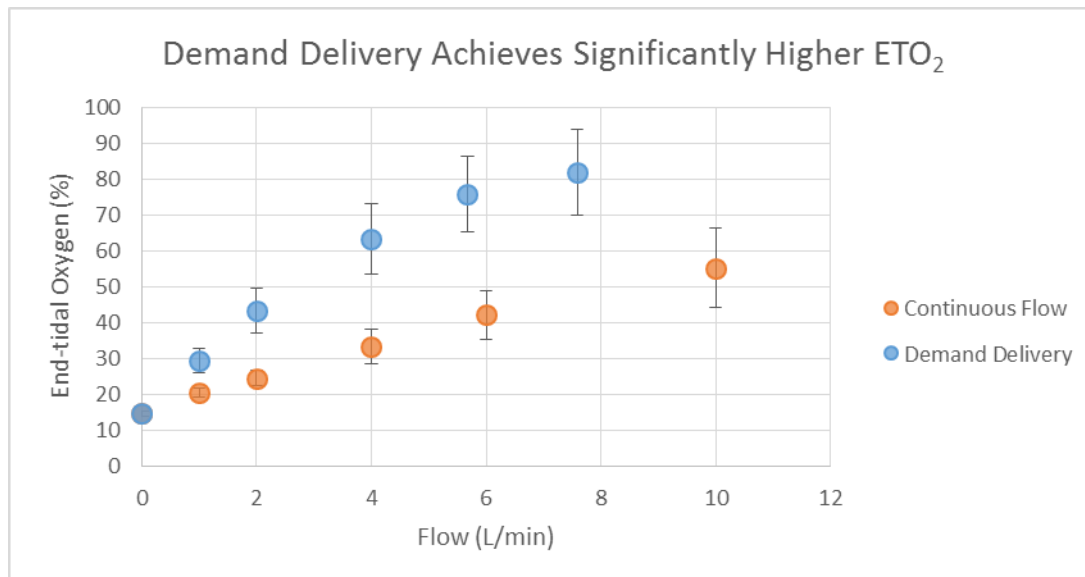
We conducted a volunteer study to determine the amount of pulsed  $O_2$  necessary to provide equivalent end-tidal  $O_2$  ( $ETO_2$ ) levels as continuous flow delivery.

**Methods:** Thirty healthy volunteers (16 Male, 14 Female, average age = 34) were recruited and fitted with a standard nasal cannula and pulse oximeter. The cannula sensing port was connected to the system's pressure sensor and to an oxygen and  $CO_2$  gas analyzer (CapnoMAC, Datex, Helsinki Finland). Volunteers were asked to lie down in a hospital bed. They were then given  $O_2$  through the NC at 5 flow rates (1, 2, 4, 6, 10 L/min) using both modes of delivery for two minutes at each flow and mode combination. At the end of each two-minute period,  $O_2$  flow was turned off and the expired gas was sampled for three breaths.  $ETO_2$  was then measured using a gas analyzer and the  $ETO_2$  prior to turning off the oxygen was estimated using a backward linear extrapolation of the three expired  $ETO_2$  values.

**Results:**  $ETO_2$  values were significantly higher ( $P < 0.05$ ) during demand delivery than during continuous flow (See figure). Higher  $ETO_2$  values indicate that higher concentration of the  $O_2$  in the alveoli ( $F_AO_2$ ) was achieved using demand delivery. Higher  $SpO_2$  values were also observed during demand delivery, indicating that higher  $PaO_2$  values were achieved. For  $O_2$  flows of 1-4 L/min, 100% of the  $O_2$  was delivered during demand delivery. For higher flows during demand delivery, the system was not able to deliver the set  $O_2$  flow because inspiration was either too shallow or too

short as indicated by the measured nasal pressure. On average, 95% of  $O_2$  was delivered during 6 L/min set flow and 76% of  $O_2$  was delivered during 10 L/min set flow. Even though demand delivery gave less  $O_2$  when the flow rate was 6 and 10 L/min, the  $ETO_2$  concentrations and  $SpO_2$  values were still higher than continuous flow at the set flow rate. For flow rates of 1-4 L/min, less than 40% of constant flow  $O_2$  values were needed to obtain equivalent  $ETO_2$  concentrations when using demand  $O_2$  delivery.

**Discussion:** Higher  $ETO_2$  concentrations and  $SpO_2$  values can be achieved using demand  $O_2$  delivery. These findings are consistent with prior evaluation of demand  $O_2$  delivery systems used for long-term  $O_2$  therapy. Even though the prototype system delivers  $O_2$  intermittently,  $ETO_2$  concentrations are higher since all of the oxygen delivered is inhaled. This study has shown that our intelligent  $O_2$  flowmeter can obtain  $ETO_2$  and  $SpO_2$  values equivalent to or higher than continuous flow  $O_2$  delivery while providing the benefits of demand  $O_2$  delivery including  $O_2$  conservation, reduced operating room fire hazard and increased  $ETCO_2$  and respiratory rate monitoring accuracy.



## **A Novel Bed-Mounted Projection System is as Effective as Pharmacologic Modalities to Treat Pediatric Preoperative Anxiety**

**Presenting Author:** Thomas J. Caruso, MD, Med<sup>1</sup>

**Co-Authors:** Samuel Rodriguez, MD<sup>1</sup>, Ellen Wang, MD<sup>1</sup>, Andrew Terajewicz, BS<sup>2</sup>, David Brockington<sup>3</sup>, Christine Cunningham, MBA<sup>4</sup>, Paul J. Sharek, MD, MPH<sup>5</sup>, Juan Marquez, MD

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**Background:** Most children undergoing anesthesia experience preoperative anxiety [1-4], which is associated with increased postoperative pain, emergence agitation, and sleep disturbances [5, 6]. Non-pharmacologic interventions that effectively decrease anxiety include parental presence at induction, tablets/phones, video games, and video glasses. Despite their efficacy, they share limitations of time, cost, and necessary patient cooperation.

We explore an inexpensive, novel, near-immersive Bedside Entertainment Theater (BERT) as an alternative method of preoperative anxiolysis. We propose that near-immersive video projection is the ideal non-pharmacologic intervention because it engages the child's attention while allowing for their passive participation in the preoperative process. The primary objective was to determine if BERT provides anxiolysis equivalent to other modalities without prolonging pre-induction time.

### **Methods:**

#### *Context*

This retrospective cohort study was conducted between February 1, 2016 and October 1, 2016. Exclusion criteria included cardiac anesthesia patients and anesthesia recipients at locations where BERT was not offered.

#### *Intervention*

BERT consists of a battery-powered projector (Asus P3B) enclosed in a custom acrylic case (Infection Prevention-approved), its clamp (Dinkum ActionPod) mounted at the bed's head,



and a 24 x 36" plastic screen mounted via Manfrotto Super Clamp and double ball joint at the bed's foot. Patients have a choice of age-appropriate videos that play from the preoperative area into the OR.

The intervention group included patients exposed to BERT. The control group included patients exposed to alternative methods of anxiolysis (midazolam, ketamine, phone/tablet, and parent present induction).

### *Outcomes*

Demographic data collected included gender, age, and ASA status. Timeliness was determined by comparing three preoperative periods. Efficacy of BERT versus other anxiolytics was determined by analyzing patient cooperation, and anesthesiologist assessment of anxiolytic response (medically sedated, age appropriate, playful, reserved, anxious, distressed, and panicked). Data were collected through chart review of the electronic medical record.

### *Data Analysis*

Chi-square analysis or Fisher's exact test was used, as appropriate, to determine differences between control and intervention groups regarding gender, ASA, and patient response to anxiolytic. Additional post hoc analyses using residuals were undertaken when appropriate. Analyses of differences in ages and time between groups were calculated using Mann Whitney U Test. Results were significant at a p value < 0.05.

**Results:** 686 patients were included. 343 patients were exposed to BERT, and a randomized control group of 343 patients were not. Results are presented as (control mean vs BERT mean, p value).

### *Demographics*

There were no differences between age (8.6 vs 7.7 years,  $p=0.45$ ) and gender (40.2% vs 45.5% female,  $p=0.19$ ). There was a higher proportion of ASA 1+2 patients in the intervention group compared to control (85.1% versus 73.5%  $p=0.002$ ).

### *Timeliness*

There were no significant differences in time of anesthesiologist evaluation of patient preoperatively (26.5 vs 23.1 minutes,  $p=0.16$ ), transport from preoperative area to OR (2.0 vs 1.5 minutes,  $p=0.5$ ), and patient arrival in OR to induction (20.5 vs 17.3 minutes,  $p=0.35$ ).

### *Response to Anxiolytic*

There were no significant differences in patient cooperation after administration of anxiolytic in the preoperative area ( $p=0.49$ ) and cooperation with induction ( $p=0.48$ ).

There was a difference in reaction to anxiolytic in the preoperative area ( $p<0.0001$ ) due to higher proportions of medical sedation in control group and playfulness in BERT group. Similarly, there was also a significant difference in reaction to anxiolytic at induction of anesthesia ( $p<0.0001$ ) due to higher proportions of medical sedation in the control and playfulness in BERT group.

**Conclusion:** These results demonstrate that BERT is not inferior to other modalities of anxiolysis. BERT is effective in augmenting pharmacologic anxiolytics, or as a standalone modality. The use of BERT does not increase time to induction and results in more playful patients.

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## Evaluation of Low Cost High Fidelity USB Powered Arterial Line Simulation Device for Ultrasound Guided Vascular Puncture and Cannulation

**Presenting Author:** Dr. Gaurav Chauhan, MD, Henry Ford Health System, Detroit, MI.

**Co-Authors:** Dr. Jamie Garzon- Serrano, MD, Henry Ford Health System, Detroit, MI.

**Background:** The use of ultrasound imaging before or during vascular cannulation greatly improves first-pass success and reduces complications. Appropriate training is required for ultrasound-guided vascular cannulation and a portion of this training can be accomplished in a simulated environment that allows a trainee to develop the dexterity needed for simultaneous probe manipulation and needle insertion. In this instance, the use of ultrasound simulators (or phantoms) is an attractive component in such training. However, commercial phantoms are expensive and the homemade phantoms require time, skill and suffer from a short shelf life.

**Objective:** To create a low cost, effective, high fidelity arterial line insertion simulator to help train medical professionals to insert radial arterial lines. We developed a fully functional Universal Serial Bus (USB) powered arterial line simulator with a high shelf life.

**Material and methods:** We used low cost materials for the device, which was made based on sizes of an average radial artery. The device is capable of simulating blood flow that can be identified by using the color Doppler mode of Ultrasound and with cannulation of the simulated artery. 18 trainees (medical students and residents) were trained by a staff anesthesiologist on how to perform the US guided arterial line cannulation using the model. The trainees were able to practice both catheter-over-needle and catheter-over-guidewire techniques. The simulator was then evaluated as a training tool using an established assessment questionnaire.

**Results:** So far a total of 18 residents and medical students participated in the anonymous survey out of which 4 were medical students, 7 were CA1, 4 were CA2 and 3 were CA3. All the participants unanimously agreed that they would have preferred to have used this model to practice before placing one on a patient. The survey is still ongoing.

Questionnaire	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Standard Deviation	Responses	Weighted Average
I would recommend this learning tool to others	0 (0%)	0 (0%)	0 (0%)	2 (11%)	16(89%)	6.25	18	4.89 / 5
I would use this model of teaching	0 (0%)	0 (0%)	1 (6%)	0 (0%)	17(94%)	6.71	18	4.89 / 5

<b>Trainees should use before practicing on patients</b>	0 (0%)	0 (0%)	0 (0%)	3 (17%)	<b>15(83%)</b>	5.82	18	4.83 / 5
<b>It is a useful training aid for novice trainees</b>	0 (0%)	0 (0%)	0 (0%)	1 (6%)	<b>17(94%)</b>	6.71	18	4.94 / 5
<b>Model reasonably resembles the real thing</b>	0 (0%)	0 (0%)	2 (11%)	5(28%)	<b>11(61%)</b>	4.13	18	4.5 / 5
<b>Model reasonably substitutes the official arterial line simulator in the SIM lab</b>	0 (0%)	1 (6%)	0 (0%)	5(29%)	<b>11(65%)</b>	4.22	17	4.53 / 5
<b>I am now more confident with arterial line kit</b>	0 (0%)	0 (0%)	2 (12%)	7(41%)	<b>8 (47%)</b>	3.44	17	4.35 / 5

**Discussion:** The dexterity required to successfully manipulate the ultrasound probe and negotiate a needle into a target vessel needs to be taught and practiced prior to its application on a real patient. For this training, a model or phantom is required. An ideal phantom should replicate the texture and resistance of human soft tissue, it should withstand multiple needle punctures, have a long shelf life, be easily transportable, easily reproducible, be inexpensive, simple to construct and finally be reusable. The simulator created by our team has all the above mentioned attributes.

**Conclusion:** It is possible to construct a high fidelity arterial line access simulator phantom device that functions as an effective teaching tool. We believe that formal training, using this simulator will boost trainee's confidence, reduce the failure rate of ultrasound-guided radial artery cannulation and ultimately improve patient safety.

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## Visibility of Pulse Pressure Variability in Spontaneously Breathing Patients

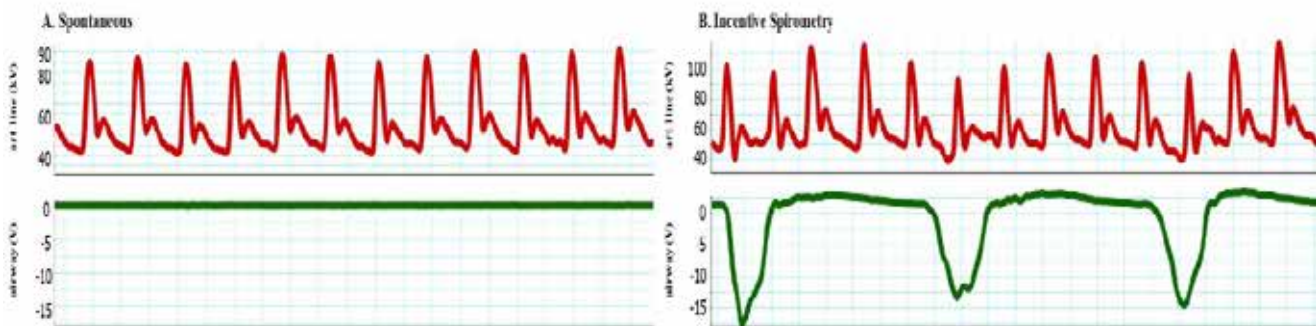
**Presenting Author:** Christopher Choi, MD, Yale-New Haven Hospital

**Co-Authors:** Aymen Alian, MD, Yale-New Haven Hospital; Kirk Shelley, MD, PhD, Yale-New Haven Hospital

**Background/Introduction:** As a clinician, assessing a patient's intravascular volume is often a challenging task. It has become clear that traditional measures such as central venous pressure and pulmonary artery occlusion pressures poorly predict one's fluid responsiveness<sup>1</sup>. Over the past decade, dynamic hemodynamic variables such as pulse pressure variation, which use heart-lung interactions, have been found to be predictive for fluid responsiveness<sup>2</sup>. However, one of the limitations of these variables is that they are accurate only under volume controlled mechanical ventilation. This brings us to the question: can we assess intravascular volume status in spontaneously breathing patients? Lung recruitment maneuvers in ventilated patients have been found to depress central hemodynamics<sup>3</sup>. Moreover, the degree of decrease in stroke volume seen is related to preexisting fluid responsiveness<sup>4</sup>. We hypothesize that incentive spirometry, a lung recruitment maneuver used widely in spontaneously breathing patients, can be a tool to assess the cardiovascular-pulmonary interaction.

**Methods:** 10 patients POD#1 from CABG surgery post-extubation were enrolled in this study. These patients were potentially hypovolemic due to IV furosemide 40-80mg administration in order to optimize extubation conditions. They were monitored with pulse oximeter, arterial, and CVP waveforms. Waveforms were recorded during both spontaneous breathing and IS. Waveform analysis was then conducted using LabChart v7.3.7 (ADInstruments).

**Results:** PPV significantly increased during IS compared to spontaneous breathing ( $p < .01$ ) by an average of 395%.



Conclusion:



Incentive spirometry, through rapid changes in intrathoracic pressure, affects venous preload<sup>5</sup>. These changes in preload throughout the cardiac cycle should result in increased dynamic indices. Our pilot data shows that incentive spirometry is a promising tool for assessing for hypovolemia in spontaneously breathing patients.

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### 3D Printing the Affordable Video Laryngoscope

**Presenting Author:** Joshua Christiansen, MD - R4 Virginia Mason Medical Center

**Co-Authors:** Stephen Swank, MD - R4 Virginia Mason Medical Center  
Robert Hsiung, MD Virginia Mason Medical Center

**Background/Introduction:** Direct Laryngoscopy has seen little change since it was first described over 100 years ago, and remains the most common method for endotracheal intubation. In the last 20 years, airway management has seen significant technological advances, most notably, the video laryngoscope (VL). Studies have shown that the VL improves laryngoscopic views, increases first-attempt success rates, and is a valuable aid in education for inexperienced providers.<sup>2,3</sup> High costs associated with this equipment have restricted its complete adoption as standard of care and limited its availability for training/education as well as for medical missions and healthcare in impoverished nations. This presentation will demonstrate how a simple VL can be made with easily available affordable technology.

**Methods:** I designed an open source, 3-D printed blade which accommodates an affordable widely available waterproof camera that can be displayed on any compatible Android based device or nearly any personal computer. The blade was trialed on intubating simulators and found to be effective at providing a good intubating view. Prototype blades and cameras will be inspection and demonstration.



**Results/Conclusions:** The author hopes that this will ultimately stimulate discussion that will encourage innovation and lead to superior equipment with decreasing costs, ultimately benefiting patients. An affordable VL using easily available equipment and technology is feasible and effective.

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## **Comparison of a Low-cost 3D Printed Video Laryngo-Borescope Blade versus Direct Laryngoscope for Simulated Endotracheal Intubations**

**Presenting Author:** Theodore Cohen, MD, University of Illinois Health, University of Illinois at Chicago

**Co-Author:** Hokuto Nishioka, MD, University of Illinois Health, University of Illinois at Chicago

**Introduction:** Direct laryngoscopy (Macintosh, Miller blades) is technically more challenging than video laryngoscopy due to a limited viewing angle (approximately 15 degrees for Macintosh blade) and requirement of aligning the glottic, pharyngeal and tracheal axes.<sup>1</sup> Existing video laryngoscopes have a wider viewing angle of 50-60 degrees and do not require the alignment of the airway axes for successful intubation.<sup>2</sup> Previous studies have demonstrated video laryngoscopes (e.g. Glidescope) have increased first pass success rates and improved Cormack-Lehane (CL) views.<sup>3-5</sup> However, video laryngoscope systems can cost several thousand dollars and have limited blade options. Using three dimensional (3D) printing technology a blade can be designed and fabricated at an extremely low cost and accepts a low cost video borescope providing both the light and video source. In addition, the use of 3D printing technology opens the possibility of a wider variety of blade designs and blades tailored to individual patients' anatomy.

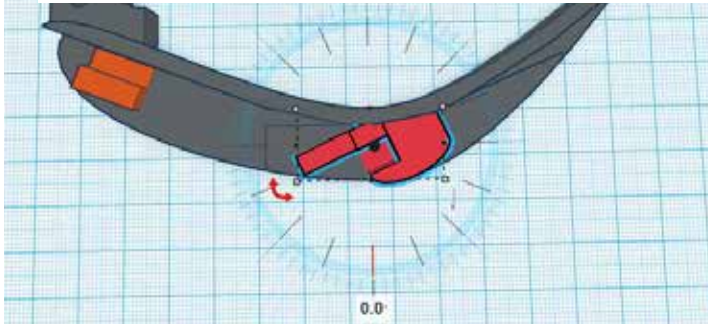
**Purpose/Study objective:** The purpose of this study was to compare the performance of a low-cost, 3D printed video laryngo-borescope blade (Image) and a standard Macintosh blade for endotracheal intubation. The two types of blades were compared for success rate and time to intubate on a difficult airway simulator.

**Materials and Methods:** A randomized control trial was conducted on physicians in an anesthesiology department in an academic medical center. The two primary outcomes examined were first pass intubation success rate and time to intubation. In addition, the best Cormack-Lehane view reported by the participants and the time to obtain the laryngeal inlet was recorded.

**Results:** A total of 64 physicians, 34 physicians in the Video Laryngo- Borecope blade (VLB group) and 30 physicians in the Mac blade (Mac group) were recruited for the study. The VLB group had a higher first pass intubation success rate with 94.1% compared to 60% with the Mac group,  $P = 0.003$ . The VLB group had a lower time to successful intubation with mean of 63.9 sec (SD 55.4 sec) than the MAC group with a mean of 108.2 sec (SD 91.8 sec),  $P = 0.042$ . One hundred percent of the VLB group had a Cormack-Lehane grade view of 1 or 2 compared to the Mac group of 21%,  $P$  value = 0.000. The VLB group had a lower average time to see the laryngeal inlet of 16.6 sec (SD 9.9 sec) compared to 39.1 sec (SD 41.1 sec) in the Mac group,  $P$  value = 0.001.

**Conclusion:** In the hands of anesthesia providers, the 3D printed blade showed superiority with first pass success rate, Cormack-Lehane view, and time to see laryngeal inlet. The data also suggests the 3D printed blade could be superior for time to intubate. In this preliminary study, the 3D printed video laryngo- borescope blade could be a feasible, low-cost option for difficult airway situations.

Image: Video laryngo-borescope blade in computer-aided design and actual 3D printed form.



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## The Value of the Pulse Oximeter in the Prediction of Beach Chair Position Induced Hypotension During Shoulder Surgery

**Authors:** Anna F. Dikstein, BA<sup>1</sup>, Hesham M. Ezz, MBChB<sup>2</sup>, Feng Dai, PhD, MS<sup>3</sup>, Kirk H. Shelley MD, PhD<sup>3</sup>, Aymen A. Alian, MD<sup>3</sup>

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**Background:** Beach chair position (BCP) is commonly used in arthroscopic and open shoulder procedures to improve intraarticular visualization and to reduce the potential for intraoperative neurovascular damage<sup>1</sup>. Assuming beach chair position (BCP) under general anesthesia may result in intraoperative hypotension and cerebral hypoperfusion which may result in neurologic injury as well as postoperative cognitive dysfunction<sup>2-4</sup>. It has been shown by several investigators that PPG baseline respiratory modulation has been related to the movement of venous blood and preload<sup>5,6</sup>. Monitoring of arterial blood pressure reflects changes in vascular tone. In this study we investigate the ability PPG waveform modulation induced by incentive spirometry as well as the preoperative hemodynamic variables to predict intraoperative BCP-induced hypotension.

**Methods:** With IRB approval, forty-two adult patients (aged  $53 \pm 15$  years, BMI  $28.2 \pm 5.9$  Kg/m<sup>2</sup>, 42% female, 58% male) undergoing shoulder surgery were monitored pre induction and post BCP with noninvasive blood pressure measurement (NIBP) and finger PPG. Preoperatively the incentive spirometry (IS) was used to induce respiratory variability of PPG waveform. PPG waveforms were analyzed using frequency and time domain analysis; frequency analysis of PPG waveforms utilizing Fast Fourier transform (FFT) resulted in two modulations: 1) respiratory modulation induced by incentive spirometry (known as PPG DC modulation) and 2) cardiac modulation corresponds to cardiac pulse frequency. PPG DC% is the ratio of respiratory and cardiac frequency amplitude densities of PPG % (See **Figure 1**). Time domain analysis of PPG waveforms (amplitude modulation of PPG waveforms) induced by incentive spirometry ( $\Delta$ POP) was calculated. Baseline systolic blood pressure (SBP), mean arterial pressure (MAP), pulse pressure (PP) and heart rate (HR) were also recorded. Intraoperative hypotension for BCP induced hypotension defined by MAP drop >25% from baseline, drop of SBP < 90 mmHg or the warranted use of pressors. The ability of preoperative MAP, SBP, PP, HR, PPG DC%, and  $\Delta$ POP to predict intraoperative hypotension was investigated. The area under the receiver operator curves (ROC) were used to measure the discriminative power of a prediction model. Statistical significance was accepted for  $p$  value < 0.01.

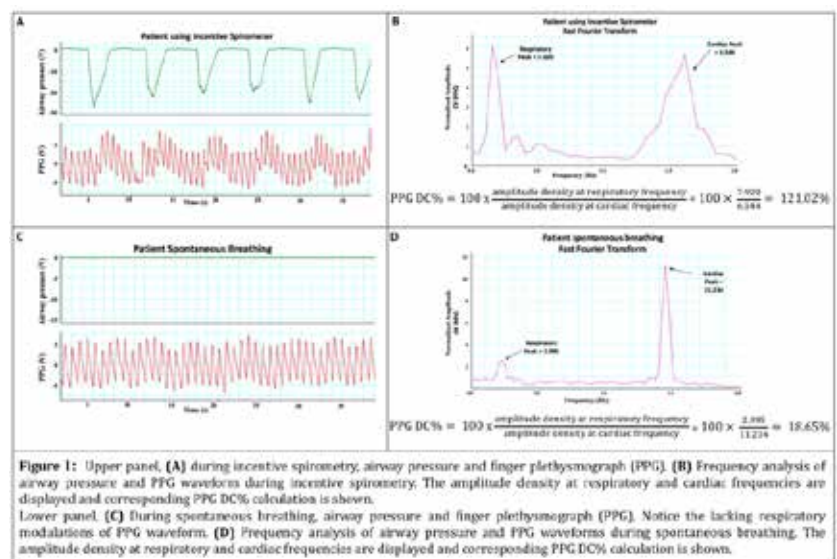
**Results:** Among the 42 patients, 31 developed hypotension during intraoperative positioning into BCP (75.6%). The areas under the receiver operator curve (ROC) values for predicting BCP-induced hypotension were: 0.61 for PP (95% CI: 0.45-0.76, p-value = 0.2268), 0.65 for HR (95% CI: 0.49-0.79, p-value = 0.1857), 0.70 for  $\Delta$ POP (95% CI: 0.57-0.86, p-value = 0.008), 0.79 for PPG DC% (95% CI: 0.63-0.95, p-value = 0.0006), 0.81 for MAP (95% CI: 0.67-0.94, p-value <0.0001), and 0.81 for SBP (95% CI: 0.70-0.95, p-value <0.0001). A HR >71bpm showed sensitivity and specificity of 61.3% and 72.7% respectively. MAP > 91mmHg showed sensitivity and specificity of 74.2% and 63.6% respectively while SBP > 120 mmHg showed sensitivity and specificity of 87.1% and 54.6% respectively. With the use of incentive spirometry preoperatively,  $\Delta$ POP with a threshold >30 showed a sensitivity and specificity of 77.4% and 54.6% respectively, while PPG DC% with a threshold of > 64 showed sensitivity and specificity of 77.4% and 90.9% respectively.

**Conclusions:** Functional hemodynamics variables (such as pulse pressure variability (PPV) and systolic pressure variability (SPV)) are not predictive of fluid responsiveness in spontaneously breathing patients. In spontaneously breathing patients the utilization of incentive spirometry with its resulting respiratory modulation of PPG waveforms (preload related) and preoperative systolic blood pressure (vascular tone indicator) were helpful in predicting intraoperative BCP hypotension. It is hoped that these observations may help the anesthesia provider in directing the appropriate therapy (fluid, pressors or both) to address BCP-induced hypotension during shoulder surgery.

**Key Words:** Beach chair hemodynamics, Pulse oximeter waveform analysis, Hypotension, functional hemodynamics

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## **Obstetric Anesthesia App: Development of a Mobile Application for Obstetrical Anesthesia Education**

**Presenting Author:** Ryan Durk, MD, Washington University in St. Louis

**Co-Authors:** Allison Mitchell MD, Washington University in St. Louis, Swarup Varaday, MD, Washington University in St. Louis

**Introduction:** The obstetrical anesthesia rotation is a unique experience in anesthesiology training. There are special considerations for complications, physiology, anatomy and pharmacologic agents. Furthermore, anesthesiologists care for both the mother and fetus at once. Among residents, these considerations are commonly addressed by independent study, or by consulting senior providers and reference materials. Independent study is a staple in resident learning; however learners may have difficulty prioritizing learning topics prior to gaining experience first. Consulting more experienced clinicians provides useful and targeted information, but these providers are not always immediately available. References such as review books and notes may be difficult to organize and carry at all times. Mobile applications have a virtually unlimited capacity for holding clinically relevant information, without increasing bulk or being otherwise difficult to carry. We sought to develop a mobile application to serve as a reference for anesthesia trainees.

**Methods:** The Android and iOS applications were developed with React Native, a framework with the tagline “learn once, write anywhere.” The underlying logic and graphical implementation was written in JavaScript which runs in a background WebView. Distinct from platforms like Cordova and Ionic, native components are drawn on the screen, as opposed to drawing web components into a WebView. A separate program was developed for updating content based on the Electron framework. We created content for the application based on needs discussed in interviews with providers, our personal experience and the established educational topics at our institution. We store all application content on Google Firebase and distribute the application directly to mobile devices.

**Results:** We developed a cross-platform application for use by trainees. Clinicians may easily update the application using software we created for administration of the app. This allows changes without needing to know the details of the underlying implementation. Storing content on Google Firebase allows for immediate propagation of updates to all devices. This foregoes delays with acquiring app-store approval for future updates, as content is dynamically downloaded from highly-available servers without requiring upgrades. All content updates are reflected in the app in real-time.

**Conclusion:** Mobile applications can be viable teaching tools for residents. With real-time databases content can be changed quickly, keeping it up-to-date and allowing for timely correction of errata. With the ubiquity of mobile phones among residents, mobile applications are still underutilized and provide an opportunity to improve resident education. This app will provide evidence-based obstetric anesthesiology clinical information, drug summaries, calculators and more for educating residents and for use at the point-of-care in labor ward. Future enhancements include providing links to Washington University in St. Louis library-subscribed obstetric anesthesiology journals and textbooks in a browsable format on iPad, iPhone or Android tablet and interactive quizzes.

## A New Programming Language for Computer Simulation

**Author:** Thomas, Engel, M.D.

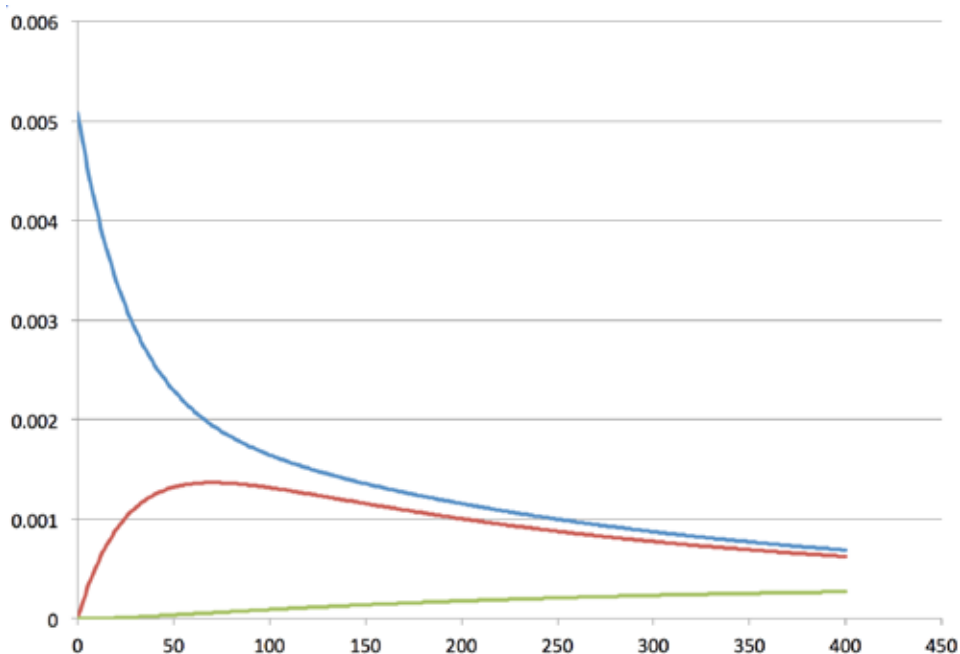
This project is a new programming language for computer simulation, with a parser and an interpreter for the language. The language is as simple as possible. The idea is that a practitioner can write only the equations for a system and the interpreter will handle all of the details of numerical integration, programming, input and output.

The simulation language is designed to be as simple and clear as possible. The language is line-oriented and has a very regular syntax.

This is a simple example program:

```
# Simple rocket.  
mass_of_rocket = 100  
thrust = if time < stop / 2 then 1000 else 0  
gravity = 9.8 * mass_of_rocket  
acceleration = (thrust - gravity) / mass_of_rocket  
velocity = integral of acceleration, initial 0  
altitude = integral of velocity, initial 0, minimum 0
```

This is the result of running a three compartment pharmacokinetic model for 100 mg injection of propofol in a 70 kg adult.



The simulation language capability is in a separate software library that can be embedded in other applications. The library supports iterated function systems, fuzzy logic, parametric equations, integrals, derivatives and complex models. The software is complete. A command line tool is included with the library.



## Perioperative Temperature Measurement Considerations Relevant to Reporting Requirements for National Quality Programs

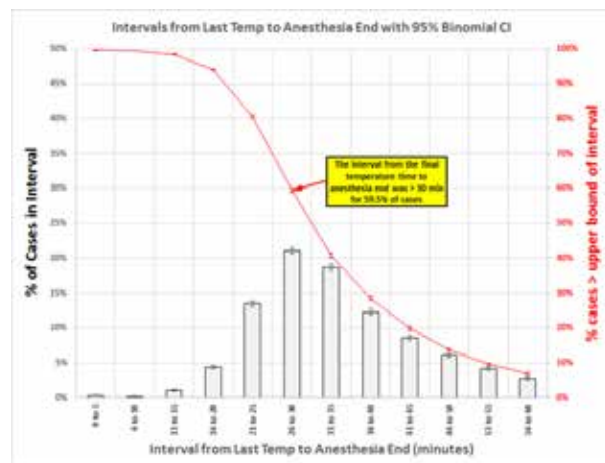
**Presenting Author:** Richard H. Epstein, MD, Miller School of Medicine, University of Miami, Miami, FL

**Co-Authors:** Franklin Dexter, MD, PhD, University of Iowa, Iowa City, IA, Ira Hofer, MD, University of California Los Angeles, Los Angeles, CA, Luis I. Rodriquez, MD, University of Miami, Miami, FL, Eric S. Schwenk, MD, Thomas Jefferson University, Philadelphia, PA, Bradley J. Hindman, MD, University of Iowa, Iowa City, Iowa

**Introduction:** Perioperative hypothermia may increase the incidences of wound infection, blood loss, transfusion, and cardiac morbidity.<sup>1-5</sup> National quality programs for perioperative normothermia specify a temperature  $\geq 35.5^{\circ}\text{C}$  during the interval from 30 min before to 15 min after the anesthesia end time.<sup>6</sup> Using data from 4 academic hospitals, we evaluated timing and measurement considerations relevant to the current requirements for both the Physician Quality Reporting System (PQRS #424) and the National Quality Forum (NQF 2681).

**Methods:** Electronic databases at 4 academic hospitals were queried to obtain intraoperative temperatures and intervals between the end of anesthesia and: discontinuation of temperature monitoring; end of surgery; and extubation. Inclusion criteria included age  $> 16$ , use of a tracheal tube or supraglottic airway, and case duration  $\geq 60$  min. The fractions of cases with intervals  $> 30$  min were determined. The effect of signal processing of temperatures<sup>7</sup> on the fraction of cases with temperatures  $< 35.5^{\circ}\text{C}$  was determined.

**Results:** Among the hospitals, averages (binned by quarters) of 34.5% to 59.5% of cases had temperature monitoring discontinued  $> 30$  min from the end of anesthesia. Even if temperature measurement



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- <sup>6</sup> [http://www.qualityforum.org/Projects/s-z/Surgery\\_Measures\\_2014/Final\\_Report.aspx](http://www.qualityforum.org/Projects/s-z/Surgery_Measures_2014/Final_Report.aspx)
- <sup>7</sup> Sun Z, et al. Anesthesiology 2015; 122:276–85

had been continued until extubation, averages of 5.9% to 20.8% of cases would have exceeded the 30-minute window. Disregarding the interval until the end of anesthesia, averages of 10.0% to 21.8% of cases had final intraoperative temperatures  $< 35.5^{\circ}\text{C}$  (i.e., a performance failure). Not signal processing temperatures increased the performance failure rate by averages of 1.4% to 3.3%.

**Conclusions:** Because of timing considerations, a substantial fraction of cases would have been ineligible to use national quality programs' reporting of intraoperative temperature, thus requiring retrieval of post anesthesia care unit temperatures. A large percentage of patients had final intraoperative temperatures below the  $35.5^{\circ}\text{C}$  outcome threshold, which would also require postoperative measurements to meet the quality metric. Institutions considering reporting on these metrics should recognize the difficulties in meeting national quality metrics for perioperative normothermia.

## Methods for Analyzing Clinical Utility of Respiratory Rate Monitors

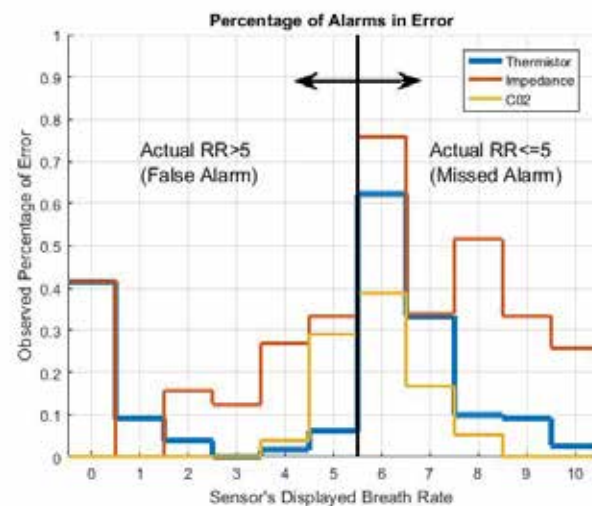
**Authors:** Sean Ermer B.S., Lara Brewer Ph.D, Joe Orr, Ph.D, Ken Johnson M.D, M.S.  
University of Utah

**Introduction:** With growing concern over opioid induced respiratory depression in the postoperative period, many have begun discussing continuous respiratory monitoring as a means of mitigating adverse respiratory events. Several different respiratory monitoring methods have been presented in the literature, and yet none have emerged as a standard for non-intubated respiratory monitoring. One reason for a lack of standard for non-intubated respiratory monitoring comes from the difficulty in defining what statistical analysis could define a respiratory monitor as ‘adequate’ for clinical use. This research project focused on potential methods for discussing viability of monitors for use in patients with low respiratory rates. With that in mind, data were specifically analyzed from periods of low respiratory rate with statistics that identify how often a clinical monitor might incorrectly influence a clinical decision.

**Methods:** With IRB approval, data were collected from 26 volunteers who were administered target controlled infusions of Remifentanyl and Propofol in order to induce low respiratory rates. Data were collected from a suite of sensors which were analyzed using a standard breath detection algorithm. Breath rates derived from a capnometer, oronasal thermistor, and impedance respiratory sensor were compared against breath rates derived from the reference standard of respiratory inductance plethysmography bands at low breath rates ( $RR \leq 10$ ). A Bland-Altman analysis was performed for each signal. This was followed by an analysis which calculated the probability of alarm error (either a false positive or false negative message) for hypopnea (defined as  $RR \leq 5$ ).

**Results:** 407 minutes of data were collected and analyzed. The results of the Bland-Altman analysis and percentage of error based on the collected data are also reported in the figure below.

	Capnography	Impedance	Thermistor
Bias (BPM)	0.18	0.64	0.51
Std (BPM)	1.18	3.96	2.09
Upper 95% Confidence Interval	2.5	8.39	4.61



(BPM)			
Lower 95% Confidence Interval (BPM)	-2.13	-7.12	-3.58

**A**
**B**

**Figure 1:** Panel A: Bland-Altman statistics for all three sensors. Values are reported as breaths per minute and are calculated as ‘test-signal’ minus ‘reference signal’. For example, a positive bias means too many breaths were detected by the test signal. Panel B: The observed percentage that a given sensor’s alarm message was in error about the presence of hypopnea ( $RR \leq 5$ ). For example, roughly 40% of the time that the capnometer reported a breath rate of 6, the true breath rate was 5 or lower. Similarly, roughly 7% of the time the thermistor reported a breath rate of 5, the true breath rate was 6 or higher.

**Discussion:** Most publications attempting to evaluate different signals for clinical use focus on Bland-Altman statistics such as bias and standard deviation. While useful, these statistics don’t always tell the whole story with respect to clinical decision making. While it’s useful to know that a monitor has a 95% confidence interval of  $\pm 2$  BPM, this information may not be impactful at large respiratory rates ( $RR > 12$ ) and may not be specific enough at low respiratory rates. For example in the figure above, one can see how assuming a normal distribution might lead to incorrect diagnoses; All three monitors are much more likely to have a false negative error than a false positive one. An analysis such as the one proposed here could be used to better inform clinicians about when it is safe to trust the reported value or displayed message on a given monitor. In the case of the capnogram, the only errors occur within -2 to +3 breaths of the hypopnea threshold, and outside of  $\pm 1$  breath of the threshold the number of errors decrease drastically.

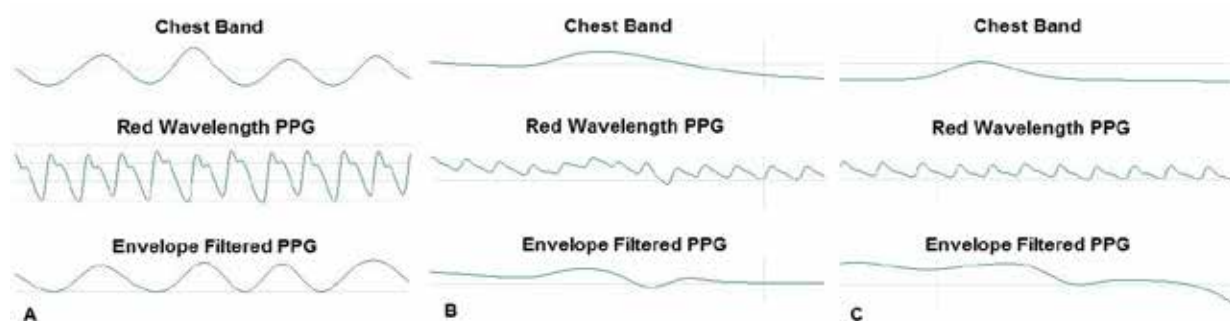
## Using Photoplethysmography to Detect Low Respiratory Rates

**Authors:** Sean Ermer B.S., Lara Brewer Ph.D, Joe Orr, Ph.D, Ken Johnson M.D, M.S.  
University of Utah

**Introduction:** Photoplethysmography (PPG) has been suggested numerous times as a method for detecting respiration in patients wearing a pulse oximeter. Though it's known that respiration produces measurable changes in the PPG waveforms, the exact mechanism of these changes is still debated; generally it is believed to be the result of both intrathoracic pressure changes from inspiration and expiration, and from a reduction in cardiac output [1]. We investigated the potential for using a PPG-based respiratory rate monitor at low respiratory rates.

**Methods:** With IRB approval, 26 healthy volunteers were recruited and administered target controlled infusions of remifentanyl (0.25-0.5 ng/mL) and Propofol (0.75 – 2 mcg/mL) in order to induce low respiratory rates. Subjects were instrumented with a pulse oximeter located on the finger and respiratory inductance plethysmography (RIP) bands which recorded data at 100 Hz. An envelope filter was used to obtain the baseline signal (related to respiration) from the PPG. The RIP band (as the reference respiratory rate signal) and the PPG signal were analyzed in Matlab R2016B (Mathworks, Natick, MA) in order to explore the potential for using PPG to monitor respiratory rate below 10 breaths per minute (BPM).

**Results:** Three different cases are presented in the figure below. The first represents the high respiratory rate scenario. The other two are both cases where the respiratory rate was less than six BPM.



**Figure 1:** **A:** Chest band, PPG, and filtered PPG signals for a respiratory rate of 20. As expected, the envelope of the PPG signal modulates in time with the chest band signal. **B:** Chest band, PPG, and envelope PPG signals for a respiratory rate of 5. A Large deflection in the envelope PPG signal occurs at the same time as the breath. **C:** Chest band, PPG, and envelope PPG signals for a respiratory rate of 5. The envelope PPG signal deviates out of sync with the chest band.

**Discussion:** The appearance of the ventilation-related change in the PPG signal at low respiratory rates is different from the appearance of the signal at high respiratory rates. This could be due to a number of reasons. Sympathetically mediated vasoconstriction is known to present in the PPG at large tidal volumes, which may be more pronounced at low respiratory rates. Additionally, there are a number of physiological changes unrelated to respiration that cause baseline fluctuations in the PPG. These may mask the true signal at low respiratory rates. Overall, a more advanced algorithm may be required to properly identify respiration at low respiratory rates as opposed to high ones.

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doi:10.3109/03091902.2011.638965.



## Complications Associated with Mortality in the National Surgical Quality Improvement Program Database

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**Introduction:** Attributing causes of postoperative mortality is challenging, as death may be multifactorial. A better understanding of complications which occur in patients who die is important, as it allows clinicians to focus on the most impactful complications. We sought to determine the postoperative complications with the strongest independent association with 30-day mortality.

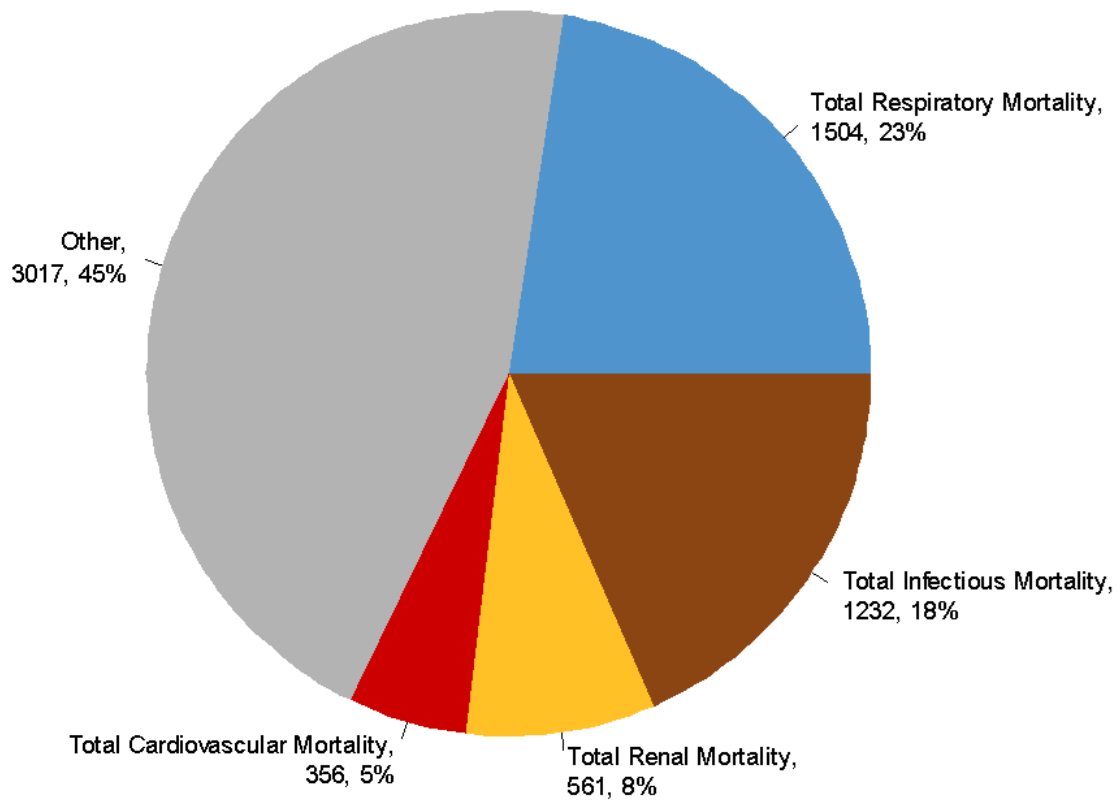
**Methods:** Data were obtained from the 2012-2013 National Surgical Quality Improvement Program (ACS-NSQIP) Participant Use Data Files. All inpatient or admit day of surgery cases present in the database were eligible for inclusion in this study. A multivariable parsimonious, hierarchical logistic regression analysis was used to adjust for patient preoperative and intraoperative risk factors for mortality. Attributable mortality was calculated using the population attributable fraction (PAF) method: attributable mortality = number of complications  $\times ((P(D|C+) - P(D|C-)))$ , where  $P(D|C+)$  is the probability of death given a complication and  $P(D|C-)$  is the probability of death without a complication. E.g., if  $P(D|C+)$  is 5% (0.05) and  $P(D|C-)$  is 1% (0.01) and 1000 patients had the complication, then the attributable mortality is  $1000 \cdot (0.05 - 0.01) = 40$  deaths. Patients were separated into ten age groups to facilitate analysis of age-related differences in mortality.

**Results:** A total of 1,195,825 patients were analyzed. 9,255 were deceased within thirty days (0.77%). A complication independently associated with attributable mortality was found in 5635 cases (60.9%). The most common causes of attributable mortality were respiratory failure, septic shock, bleeding, and renal failure. Some complications, such as deep venous thrombosis (DVT), failure to wean, and pneumonia, were associated with attributable mortality only in older patients. When grouped by organ system, respiratory complications accounted for the largest share of attributable mortality ( $n = 1805$ , 19.5%) followed by

infectious (n = 1478, 16.0%), renal (n = 673, 7.3%), and cardiovascular (n = 427, 4.6%) complications. After adjustment for both age and frequency of fatal complications, reintubation (28487 [25995, 30674] years [95% confidence interval]), bleeding (23809 [16847, 29938] years), and septic shock (23408 [19205, 27080] years) were associated with the greatest number of years of life lost.

**Conclusions:** We found that 61% of all 30-day mortality is independently attributable to a postoperative complication. The most common are reintubation, septic shock, and bleeding, which are associated with the greatest number of years of life lost. Resources should be focused on preventing and better treating complications associated with the largest attributable mortality, such as respiratory failure, infections, and hemorrhage. This is particularly important for complications that disproportionately impact younger patients, given their longer life expectancy.

## Attributable Mortality in Population, by Complication



## Virtual Reality for Proton Therapy - Child-Life Guided Interactive Tour for Adolescents

**Presenting Author:** Jorge A. Gálvez

**Co-Authors:** Melanie Eisenhower, William England, Elicia Wartman, Allan Sempao, Mohamed Rehman, Robert Lustig, Michelle Hribar.

**Introduction:** Proof-of-concept study to determine feasibility of incorporating a virtual reality (VR) facilities tour for children scheduled to receive radiation therapy without anesthesia. Secondary objective will consist of qualitative description of the VR experience.

**Methods:** Children ages 13 or older scheduled to receive proton radiation therapy were included in the study. The study used a VR headset, the Oculus Rift Software Development Kit 2. Subjects watched the VR tour with a child life therapist experienced in coaching children receiving radiation therapy and completed a survey after the tour.

**Results:** Eight subjects were consented for participation and 6 completed the post-VR tour survey. All of the patients that started the tour completed it successfully.

Two subjects took advantage of pausing the tour to spend more time exploring individual scenes. Five subjects said the VR tour was helpful preparation to undergo proton radiation therapy. Subjects stated that the tour was helpful because “it showed me what’s to come” and “it was helpful to see what it’s like to lay in the machine”. One subject said “it made me feel less nervous.” Six subjects stated that they would like to see this type of tour available for other areas of the hospital, such as diagnostic imaging rooms. None of the subjects experienced nausea or vomiting.

**Conclusion/Discussion:** The VR video tour allowed patients to explore the treatment facility in a comfortable environment without interrupting the proton therapy treatment schedule. Participants expressed that the tour was beneficial and would appreciate seeing other parts of the hospital in this way.



**Figure.** The virtual reality (VR) tour is demonstrated by a child life therapist. The video is displayed on the laptop. The VR headset allows the user to experience the tour in an immersive environment. The user can look around the room as the VR tour progresses. The VR tour can be paused from the laptop to allow the user to spend more time in any given scene. The elastic headstraps were adjusted to the front

of the device to minimize contact with the subject’s head. Subjects were instructed to hold the device and to remove it if they became uncomfortable.

## **Neural Network Classifier for Automatic Detection of Invasive Versus Noninvasive Airway Management Technique Based on Respiratory Monitoring Parameters in a Pediatric Anesthesia**

**Presenting Author:** Jorge A. Gálvez, MD MBI, Assistant Professor, Section of Biomedical Informatics, Department of Anesthesiology & Critical Care Medicine, The Children's Hospital of Philadelphia, University of Pennsylvania Perelman School of Medicine.

**Co-Authors:** Ali Jalali, Ph.D., Luis Ahumada, Ph.D, (Enterprise Analytics and Reporting, The Children's Hospital of Philadelphia) Allan F. Simpao, MD MBI, Mohamed A. Rehman, MD

**Introduction:** Children undergoing general anesthesia require airway monitoring by an anesthesia provider. The airway may be supported with noninvasive devices such as face mask or invasive devices such as a laryngeal mask airway or an endotracheal tube.

**Methods:** We retrieved three sets of consecutive patients that received general anesthesia in 2015 with either mask, laryngeal mask airway or endotracheal tube from a clinical data warehouse. Patients were limited to the following procedure groups: myringotomy, tonsillectomy, adenoidectomy or inguinal hernia repair. We retrieved measurements for end-tidal carbon dioxide, tidal volume and peak inspiratory pressure. We calculated statistical features for each data element per patient and applied machine learning algorithms (decision tree, support vector machine and neural network) to classify patients into two categories: noninvasive or invasive airway device support.

**Results:** We identified 300 patients per group (mask, laryngeal mask airway, and endotracheal tube) for a total of 900 patients from the clinical data warehouse. The neural network classifier performed better than the boosted trees and support vector machine classifiers based on the test data sets. The sensitivity, specificity, and accuracy for neural network classification are 97.5%, 96.3%, and 95.8%. In contrast, the sensitivity, specificity and accuracy of support vector machine are 89.1%, 92.3%, and 88.3% and with the boosted tree classifier they are 93.8%, 92.1%, and 91.4%.

**Discussion:** We describe a new method to automatically distinguish between noninvasive and invasive airway device support used in a pediatric surgical setting based on respiratory monitoring parameters. The results show that the neural network classifier algorithm can accurately distinguish between noninvasive and invasive airway device support.

## The Case for an Oxytocin Infusion Safety-Interlock System for Active Management of Labor (POSI)

**Author:** Ariella R. Goldman, MD, Icahn School of Medicine Department of Obstetrics and Gynecology and Reproductive Sciences; Julian M. Goldman, MD, Dept. of Anesthesia, Critical Care and Pain Medicine, Massachusetts General Hospital, Harvard Medical School, MD PnP Research Program

The following case report illustrates the potential clinical benefits of implementing a safety interlock for oxytocin infusion during active labor management.

**Report of case:** A 32yo G1P0 at 41weeks gestational age was admitted with ruptured amniotic membranes (ROM). She had no significant medical or surgical history and had had an uncomplicated prenatal course. Oxytocin was started four hours after ROM due to irregular contractions and titrated per protocol while the patient was monitored with continuous external fetal monitoring and external tocometry. Nine minutes after increasing the oxytocin infusion, fetal heart deceleration correlating with a tetanic contraction was noted by an MD monitoring the tracings at the nursing station. The MD immediately went to the patient's room and stopped the oxytocin infusion two minutes into the deceleration. As the MD arrived at the bedside, the patient's RN was preparing to call the MD regarding the deceleration. A prolonged six-minute deceleration was followed by subsequent reassuring tracings after resolution of the tetanic contraction. [See Figure]



In this case, the RN did not stop the oxytocin, and had the MD not observed the deceleration, the additional delay in stopping the oxytocin would have been several minutes (based on the time to page the MD + time for the MD to reach the bedside or call the RN in the room).



Parturient Oxytocin Safety Interlock (POSI): We propose that a safety interlock, capable of automatically stopping the oxytocin infusion under these conditions, could increase the margin of safety during active management of labor. Between the 1960's and 1980s<sup>1,2,3,4,5,6</sup>, several studies were published on the use of automated oxytocin infusion systems to titrate contraction frequency with feedback from both external tocometers and internal pressure transducer catheters. None used fetal heart monitoring into their algorithms. Today, these systems would be classified as "physiologic closed-loop control systems" (as defined in standard IEC 60601-1-10), that adjust oxytocin rate to a contraction state. They were not commercially adopted.

We are proposing a "safety interlock" that will stop (and not re-start) the oxytocin infusion when indicated. The POSI would be inherently safe, as there is no significant clinical risk caused by automatically pausing an oxytocin infusion used for active management of labor. Conversely, there are significant risks in poor fetal outcomes with prolonged decelerations, recurrent late decelerations, and fetal bradycardia<sup>7</sup>. A smart "real-time clinical decision support" system (RT-CDS) that uses fetal heart and uterine contraction data to automatically pause oxytocin infusion has the potential of decreasing both maternal and fetal morbidity and mortality. The POSI could be implemented in compliance with ASTM F2761, the standard for an Integrated Clinical Environment (ICE), in a manner similar to the ICE-based PCA infusion safety interlock research prototype, implemented by the MGH MD PnP research program.<sup>8,9</sup>

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## Development and Validation of an Artifact Rejection Method for use in a Cardio-Respiratory Coherence Monitor

**Authors:** Rotem Moshkovitz, Klaske van Heusden, J Mark Ansermino, Guy Dumont, Matthias Görges

**Background:** Previously, our team developed a nociception detection algorithm, to detect and quantify stress responses exhibited by the body in reaction to a noxious stimulus during general anesthesia [1]. This algorithm quantifies the coherence between respiratory sinus arrhythmia and respiratory frequency, providing a single feedback variable (NI) indicating the nociceptive state of the patient; a high NI is indicative of increased nociception. Short artifacts in either heart rate (HR) or respiratory rate (RR) distort the NI value for over one minute, due to the delay introduced by filtering [2], invalidating the signal for an unacceptably long period for real-time clinical use.

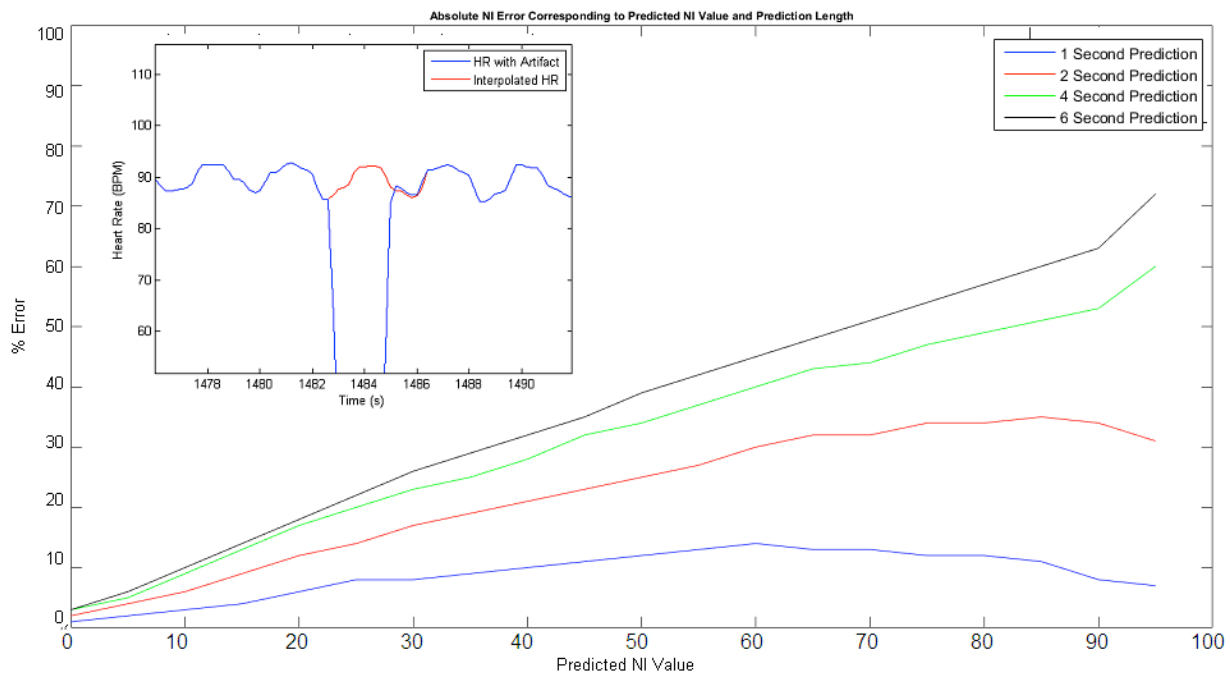
The aim of this work is to implement and validate an approach for a) predicting heart rate when artifacts are detected, b) removing capnography-zeroing artifacts, while maintaining the coherence and limiting the effect on the NI, and c) establishing a signal quality index (SQI), ranging from 0 (unusable) to 100 (uncompromised), as a measure of signal reliability during real-time clinical use.

**Methods:** A real-time auto-regressive HR prediction function was developed to predict missing or replace incorrect HR data (see example in Figure 1). Auto-regressive modeling can capture the frequency content of the signal and was expected to maintain coherence. The prediction accuracy was optimized using previously recorded anesthetic cases [2], leading to a 20<sup>th</sup> order model with an identification signal of 150 samples, or 30 seconds. Artifact-free data were used to evaluate the effect of HR prediction on the calculated NI values; at each second of data, artifact-free NI were calculated for the next minute, and 4 NI values were calculated using 1 to 6 seconds of predicted HR. These predicted NI values were compared to the artifact-free NI to evaluate the accuracy of predicted NI values (NI error) and explore possible indicators of large NI errors. To mitigate the effects of capnography zeroing artifacts, compromised data segments were replaced by the average of the three previous breaths.

**Results:** NI errors were calculated for 64 cases corresponding to 99.6 hours of anesthetic data. HR prediction lengths, and predicted NI values, were determined to be the strongest predictors of the NI error (see Figure 1). They were therefore used to define the SQI. For a 1 second prediction, the error remains below 15 for any predicted NI, while for a 6 second prediction it exceeds 30 for high predicted NI values. An NI error of 30 was established as the maximum tolerance before the data is no longer deemed to be of acceptable quality, and the SQI is set to zero until new valid data are acquired.

**Conclusion:** The HR prediction algorithm and respiratory interpolation successfully mitigated the effect of artifacts, improving the overall response of the CRC algorithm by reducing NI signal distortion when artifacts are present. This will allow for real-time operation of the NI in the OR. Future steps include validation and verification of the algorithm and the SQI during general anesthesia.

**References:** [1] Conf Proc IEEE Eng Med Biol Soc.;2012:3813-6. [2] J Clin Monit Comput. 2013;27(5):551-60



**Figure 1: Nociception Index (NI) error for varying HR prediction lengths.** Data are split by the length of predicted HR samples used in the NI computation. Predicted NI values were sorted into bins, in increments of 5, and the NI error (predicted NI - artifact-free NI) distribution of each bin was evaluated. These plots represent the 99<sup>th</sup> percentile error of each bin. The inset subplot shows an example of an episode of heart rate artifact, which was substituted with a predicted heart rate.

## **Simplifying Anesthesia Supply Management Using a Cloud-Based Service**

**Presenting Author:** James Han, MD

**Co-Authors:** Richard Banchs, MD; Hokuto Nishioka, MD

All authors from the University of Illinois at Chicago, University of Illinois Hospital and Health Sciences, Department of Anesthesiology

**Background:** Many institutions still rely on paper, pagers, and IP phones to communicate equipment and supply requests during operating room (OR) turnovers, but these methods have limitations. Technology companies such as Google and Apple are now regularly introducing new products and services which are designed to enhance productivity. Utilizing these new, cost-effective technologies in the OR could help improve anesthesia supply management during turnovers.

**Methods:** Google Keep, a cloud-based service for creating notes and lists, was used to create a standardized list of all anesthesia-related equipment used at our institution for each OR (see Figure 1). Each list was titled according to the OR number and the case number. Within the list, a checked item signified a completed task while an unchecked item signified an actionable task. Participants accessed Google Keep using mobile devices (e.g., smartphones, tablets) and computers. It was the responsibility of the anesthesia provider (i.e., residents, CRNAs, attendings) to uncheck items as needed for their next case. During OR turnover and each morning, the anesthesia technicians would complete unchecked items. After a week-long trial, feedback and comments were obtained from 3 technicians and 6 providers regarding the ease of use, participant satisfaction, and convenience.

**Results:** Participants reported that Google Keep was easy to use since all that was required was checking and unchecking items and updating the case number on the title of the list. Users also commented on its convenience to be accessed from anywhere on a mobile device. Technicians also appreciated how they were not being called as often. All participants emphasized its utility for the first case. A common complaint was the lack of notification/alert system for when a change was applied.

**Conclusion:** The cloud-based service, Google Keep, seemed to provide a simpler and more convenient method of communication between anesthesia providers and technicians during OR turnovers and morning setups. Future work will aim to further improve cloud-based communication by attempting to create a notification system, installing tablets in frequently visited locations within the OR, and expanding its use to offsite locations. Moreover, a

comparison study looking at OR efficiency and anesthesia ready time before and after implementation of Google Keep will be explored.

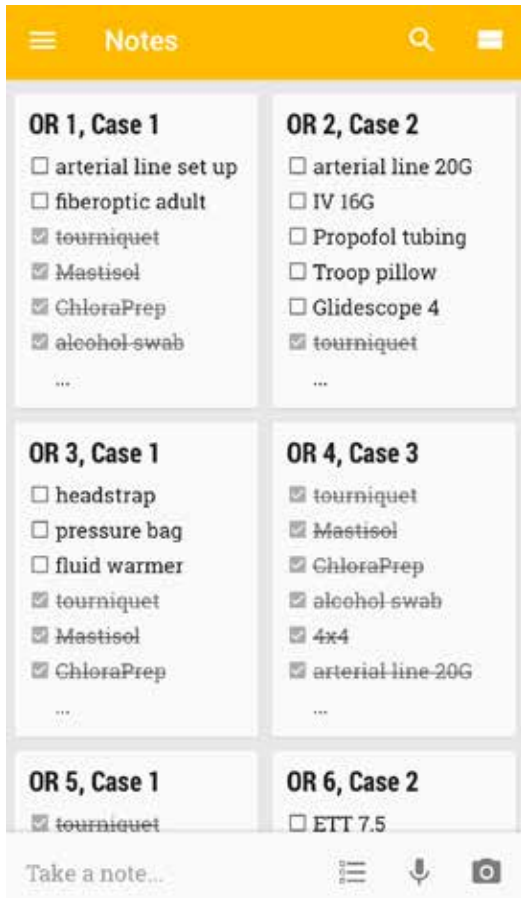


Figure 1

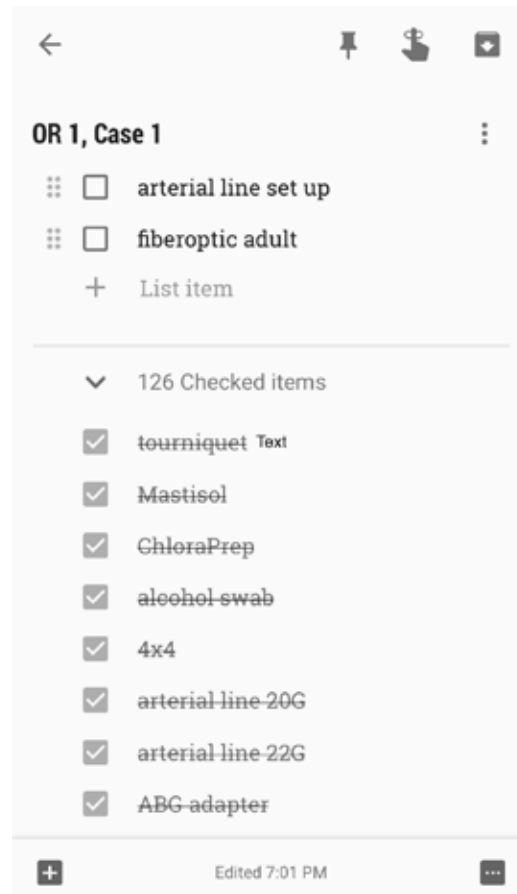


Figure 2

## Evaluation of a Non-Invasive Respiratory Volume Monitor in Subjects Under Non-Invasive Ventilatory Support

**Presenting Author:** Brian Harvey, PhD, Respiratory Motion, Inc.

**Co-Authors:** Martin Dres, MD, Domenico Luca Grieco, MD, Irene Telias, MD, Michela Rauseo, MD, Laurent Brochard, MD, St. Michael's Hospital, Keenan Research Centre, University of Toronto.

**Introduction:** Non-Invasive Ventilatory Support (NIVS, e.g., CPAP, BiPAP, High-flow O<sub>2</sub>) is currently used across the continuum of care. This has created a unique challenge for clinicians who need to be able to evaluate not only the need but also the effectiveness of NIVS. We wanted to test the ability of a recently developed non-invasive respiratory volume monitor (RVM, Exspiron, Respiratory Motion, Waltham, MA, USA) that provides continuous measurement of minute volume (MV), tidal volume (TV), and respiratory rate (RR) to provide this monitoring in such conditions of ventilation. The RVM has previously been shown to have better than 10% accuracy for MV, TV, and RR in both non-intubated and intubated patients.[1,2] Here, we evaluated the RVM's accuracy when monitoring healthy subjects under NIVS.

**Methods:** Six healthy subjects completed this pilot study (3 males, BMI=21.1 kg/m<sup>2</sup> (19.1-23.1)). MV, TV, and RR data were simultaneously recorded by the RVM and ventilator (vent) for 3, 5min-long trials under different vent settings: CPAP 0 cmH<sub>2</sub>O (CPAP0), CPAP 5 cmH<sub>2</sub>O (CPAP5), and pressure support 5cmH<sub>2</sub>O with PEEP 2 cmH<sub>2</sub>O (PS5). Relative errors between RVM and vent measurements of MV, TV, and RR were calculated over 1min segments and bias, precision, and accuracy were calculated using Bland-Altman analyses. All data are presented as mean±SEM.

**Results:** Subjects maintained an average MV of 7.1±0.9 L/min, with individual breath TV ranging from 81 to 1371mL and RR ranging from 5.0 to 35.7bpm. During spontaneous breathing (CPAP0) measurement bias in TV measurements between the RVM and the vent was 3.5±3.1% with a precision of 4.3±1.4% and an overall accuracy of 8.3±1.5%, corresponding to measurement error of 51.6±9.4mL. During the NIVS trials (CPAP5 and PS5) the measurement bias, precision and accuracy remained practically unchanged (p=0.66, 0.42, and 0.54, respectively, 1-way ANOVAs, see Fig 1A). Fig 1B shows the strong correlation between RVM and ventilator measurements whereas Fig 1C depicts their Bland-Altman plot.

**Conclusion:** We show that the RVM provides clinically-relevant accuracy when monitoring healthy subjects under non-invasive ventilatory support with various settings.



**References:** [1] Voscopoulos, C et al. Anesth Analg 117:91-100, 2013; [2] Voscopoulos, C et al. J Clin Monit Comput 29:223-39, 2015

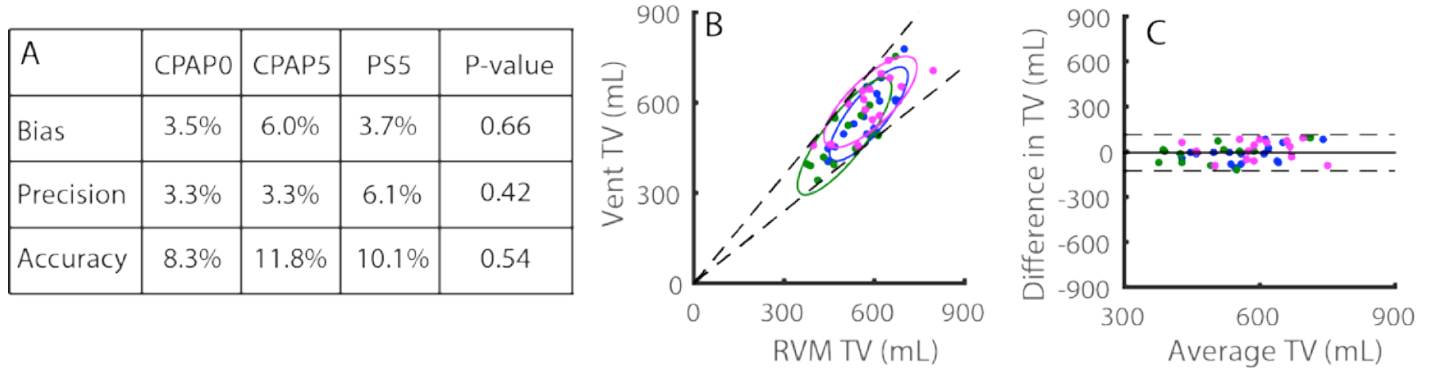


Figure 1. Measurement analysis for 6 subjects. A: Average biases, precisions, and accuracies. B: Correlation plots between RVM and ventilator TV measurements under three vent settings (CPAP 0 cmH<sub>2</sub>O (blue), CPAP 5 cmH<sub>2</sub>O (green), PS 5 cmH<sub>2</sub>O with PEEP 2 cmH<sub>2</sub>O (pink). Markers: 1 min averages; dashed lines: 20% relative error; confidence ellipses: ±1 SD. C: Bland-Altman error analysis. Solid line: average bias: -1.5 mL; dashed lines: 95% limits of agreement: -125 to 128 mL.

## Evaluation of a Non-Invasive Respiratory Volume Monitor Without Patient-Specific Calibration

**Presenting Author:** Brian Harvey, PhD, Respiratory Motion, Inc.

**Co-Authors:** Jaideep Mehta, MD, MBA, University of Texas Medical School, Jordan Brayanov, PhD, Respiratory Motion, Inc., Agustin Florian, MD

**Introduction:** Continuous monitoring of respiratory status is important for identifying potentially life-threatening respiratory compromise, performing clinically appropriate interventions, and monitoring patient recovery. Recently, a non-invasively Respiratory Volume Monitor (RVM, ExSpirom, Respiratory Motion) was developed and has been shown to have better than 10% accuracy for minute ventilation (MV), tidal volume (TV), and respiratory (RR) in both non-intubated and intubated patients.[1,2] The current RVM requires a patient-specific, single-point calibration with a spirometer in order to make quantitative measurements of MV and TV. To facilitate broader use of the technology and eliminate error introduced by variability in the use of the spirometer itself, the RVM has been updated to make quantitative measurements of MV and TV without the need for a patient-specific calibration. Here, we evaluated the accuracy of the RVM without patient-specific calibration compared to three different FDA-cleared in healthy volunteers.

**Methods:** Twenty subjects from a broad ambulatory population completed the study (11 males, BMI=26.8 kg/m<sup>2</sup> (18.7-41.8), 49.2 yrs (22-80)). MV, TV, and RR were simultaneously recorded by the RVM without patient-specific calibration and an FDA-cleared device. On Day 1, each subject completed 3, 10 min trials with different devices: Pneumotachometer (Heated FVL, Morgan Scientific), Wright Spirometer (Mark 14, nSpire Health, Inc.), and RVM with patient-specific calibration (ExSpirom, Respiratory Motion). After the completion of the breathing trials, subjects kept the RVM electrode pads on and the same 3 breathing trials were repeated 24 hours later (Day 2). Relative errors between RVM without patient-specific calibration and predicate device measurements of MV, TV, and RR were calculated over 30s segments and bias, precision, and accuracy were calculated using Bland-Altman analyses. Paired-difference equivalence tests were performed with equivalence margins of 10% relative error. As a secondary test of the agreement between devices, we performed repeated measures single-factor ANOVAs with the differences between MV, TV, and RR measurements as the response variable. The null hypotheses were that the differences between the measurements were not different than zero.

**Results:** Combined across Day 1 and Day 2, the RVM's mean measurement biases for MV and TV were within 2.2% compared to all three predicate devices and within 0.2% for RR (Table 1).

The mean measurement accuracies were better than 11.6% for MV and TV compared to the predicate devices and better than 4.1% for RR. The equivalence tests rejected the null hypotheses that the RVM and predicate devices have different means values of MV, TV, and RR and therefore conclude the measurements are equivalent within  $\pm 10\%$ . Repeated measures ANOVAs revealed no significant effect of factor “Day” on MV, TV, and RR measurement errors ( $p > 0.14$ ).

**Conclusion:** We showed the RVM without patient-specific calibration provides substantially equivalent accuracy compared to three FDA-cleared devices in human subject testing.

**References:** [1] Voscopoulos, C et al. *Anesth Analg* 117:91-100, 2013; [2] Voscopoulos, C et al. *J Clin Monit Comput* 29:223-39, 2015

**Table 1.** Mean Bias, Precision, and Accuracy of RVM without patient-specific calibration compared to three FDA-cleared devices.

Predicate Device:	Pneumotachometer				Wright Spirometer				RVM with Patient-Specific Calibration		
	MV	TV	RR		MV	TV	RR		MV	TV	RR
Bias, mean, %	2.2	2.2	0.0		-1.8	-1.5	-0.2		2.2	2.2	0.0
Precision, mean, %	7.2	7.3	4.0		8.4	8.4	1.7		7.0	6.9	0.1
Accuracy, mean, %	11.0	11.2	4.1		11.6	11.5	1.7		11.5	11.4	0.1

## Disaster Recall: Optimizing Hospital Surge Capacity

**Presenting Author:** Ali Hassanpour, M.D. Texas Children's Hospital, Baylor College of Medicine, Houston, Texas

**Co-Authors:** Franklyn Cladis, M.D., Peter Davis, M.D.

**Introduction/Study Question:** When disaster strikes, and triggers an influx of patients, rapid recall of critical staff is a key limiting factor in the surge capacity of a hospital.<sup>1</sup> At most institutions, staff recall in the event of a disaster involves a fragmented communication system in which everyone is contacted separately via a combination of pages, emails, and phone calls. This process is slow and inefficient, making it less than ideal for disaster management. Our objective is to create an efficient system that, in the event of an emergency, would alert critical staff simultaneously and recall them to their posts.

**Methods:** A survey of Anesthesiology departments in U.S. children's hospitals was created to determine if the departments have a disaster recall system in place. If so, details regarding the existing systems were sought. Text messaging, or short messaging services (SMS), is a preferred method of communication during and immediately after a disaster.<sup>2</sup> Multiple tests were performed to determine the most reliable technique to deliver a message to the Public Switched Telephone Network (PSTN) which delivers text messages. In addition, a web application was developed to store and maintain staff contact information, allow designated staff members to activate the alert, record and tally responses, and perform post-disaster analysis.

**Results:** A disaster alert system was developed and deployed at a large children's hospital. The system could easily and rapidly contact critical members of the anesthesiology department, inform them of a disaster situation, request their return to the hospital, and record a response. Responses of all staff are automatically recorded and tallied without human intervention in real-time. This system is secure, reliable, multiplatform, easy to use and readily accessible. It is frequently tested at the current test site to ensure all staff receive the text-messages and responses are accurately recorded.

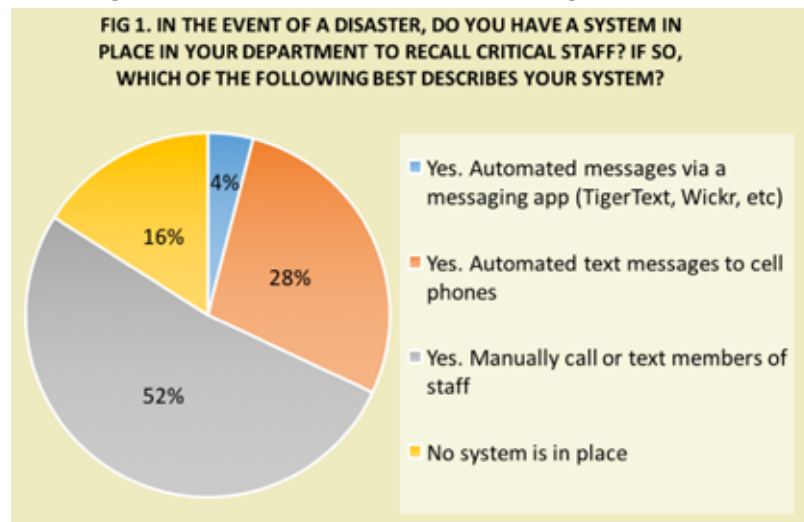
**Discussion:** Many children's hospitals lack disaster recall systems altogether, or have systems and protocols in place that are inefficient for disaster situations because they are time consuming, prone to interruptions and may lead to inadvertent omissions of critical staff. This is a major limiting factor in the surge capacity of the hospital. Further, when responses are manually recorded, real-time reporting and post-disaster analysis are limited. We investigated many different approaches to sending text-messages, and found that a

dedicated SMS server via a reliable SMS gateway is currently considered the most reliable method. Email based text messaging techniques are no longer considered reliable as they have a high latency and failure rate due to abuse by spammers.

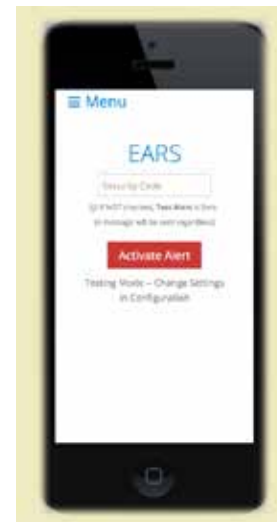
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### Disaster preparedness survey of 50 Anesthesiology Departments in U.S. Children's Hospitals



### Disaster Alert Software



## Bispectral Index Guided Propofol Induction Dose in Patients Preloaded with Crystalloids

**Presenting Author:** Litty John, MBBS D.A

**Authors:** Anto Abey Illickal M.D., Savitha K. S M.D., Department of Anaesthesiology, St. John's Medical College, INDIA

**Background:** Conventional pharmacokinetic compartment model doesn't include cardiac output (CO) as a variable for calculating drug concentration. Studies have now identified CO and central blood volume (CBV) as significant factors in calculating the loading dose of propofol. According to previous studies (1999, 2001), compared to patients with low CO, the initial arterial concentration of propofol is lower in patients with high CO due to dilution, taking a longer time to reach hypnosis, for a given dose<sup>1,2</sup>. However, recent studies (2013) have determined CO to be a negative predictive variable for early phase kinetics of propofol<sup>3</sup>. Although a high CO decreases the drug plasma concentration, an increased CO may accelerate its delivery from the injection site to the target site achieving relatively faster onset of action<sup>4,5</sup>. Crystalloids are routinely used to improve CBV and CO, and are preferred over colloids unless indicated, due to lesser side effects. Their half-life ( $T_{1/2}$ ) is usually 20-40 minutes under physiological conditions but extend to 80 minutes or longer in the presence of preoperative stress, dehydration or blood loss<sup>6</sup>. The longest  $T_{1/2}$  of NS measured to be between 3-8 hours is during general anaesthesia requiring intubation<sup>6</sup>. We aimed to preload patients with NS to enhance the CBV and CO to determine propofol induction dose requirement guided by Bispectral Index (BIS). We hypothesised that a lower dose requirement in patients preloaded with crystalloids could reduce the detrimental effects of propofol on haemodynamic stability.

**Method:** A randomized prospective double blind single center study was undertaken over 18 months. After obtaining hospital ethics committee approval and informed consent from patients, the study was conducted in 46 patients under ASA physical status I, scheduled for elective surgeries. The patients were randomly divided into two groups, the study group and the control group. Study group received 20 ml/kg of NS over 2 hours prior to the induction of anaesthesia and control group did not. All patients were premedicated with midazolam and fentanyl according to body weight and were induced with titrated doses of propofol by administering incremental doses of 20mg over 20 seconds at 30 second intervals until the endpoint was achieved. The induction endpoint was defined as loss of consciousness determined by absence of response to verbal and gentle physical stimulus and BIS value 45-60. Propofol induction dose and hemodynamic parameters (HR, SBP, DBP, MAP) were measured. Awareness during anaesthesia was evaluated using BIS as well as assessed post operatively using Brice questionnaire. Propofol induction dose was calculated as the mean of observations in the study and control groups. The statistical significance of results was analysed using Student t test and Chi-square test for continuous scale and categorical scale respectively between the two groups.

**Results:** Propofol induction dose in study group was  $0.71 \pm 0.16$  mg/kg and in control group was  $1.04 \pm 0.30$  mg/kg (P value < 0.001) (Table 1 and Figure 1). However, there was no clinically significant change in the hemodynamic parameters between both groups. None of the patients

had awareness under general anaesthesia.

**Conclusion:** Crystalloid preloading reduces propofol induction dose during general anaesthesia. This may be explained by an increase in CBV and CO following preloading, which enhances the delivery of propofol to brain.

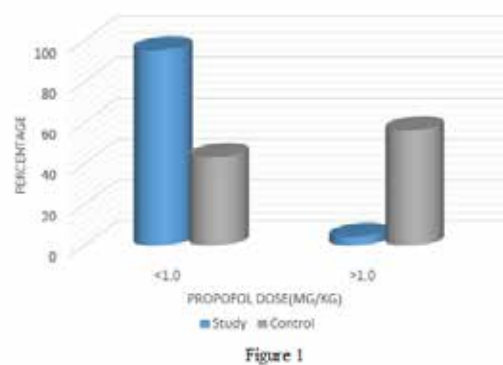
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**Propofol requirement for induction in study and control groups**

Propofol Dose(mg/Kg)	Study		Control	
	No	%	No	%
<1.0	22	95.6	10	43.5
>1.0	1	4.3	13	56.5
Total	23	100.0	23	100.0
Mean ± SD	0.71±0.16		1.04±0.30	
P value < 0.001				

Table 1





## Fully Automated Anesthesia, Analgesia and Fluid Management using Physiologic Closed-loop Systems in High Risk Patients: A Pilot Study

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**Background:** Automated delivery of anaesthesia guided by processed EEG monitoring using a physiologic closed-loop system (PCLS) is no longer a novel concept. The aim of this study was to evaluate the feasibility of fully automated anesthesia, analgesia, and fluid management based on a combination of physiological variables [bispectral index (BIS), stroke volume (SV) and stroke volume variations (SVV)] using two independent PCLS in 13 patients undergoing high risk surgery.

**Methods:** After IRB approval, informed and written consent, patients having major peripheral vascular surgery were enrolled in this prospective observational pilot study. In addition to standard ASA monitoring, we added cardiac output (CO) and SVV monitoring (EV-1000, Edwards Lifesciences, USA) to guide fluid administration, processed EEG (BIS, Covidien, Ireland) to optimize depth of anesthesia and titrate opioid administration (Fig 1). We also recorded the ANI values independently (MDoloris, Lille, France). Propofol (Prop) and Remifentanyl (RF) were used throughout induction and maintenance of anaesthesia using target control infusion (TCI) pumps (Base Primea, Fresenius Kabi, Belgium). Prop and RF concentrations were coadministered by a PCLS (Infusion Toolbox) guided by a BIS monitor. All patients received a baseline 3 ml/kg/h of Plasmalyte® (Baxter, Belgium). Additional fluid requirements were administered using the information from EV-1000 and consisted in 100 ml boluses (3% modified gelatin, Baxter, Belgium) delivered by a PCLS using a Q-Core Sapphire Infusion Pump (Q-Core, Netanya, Israel).

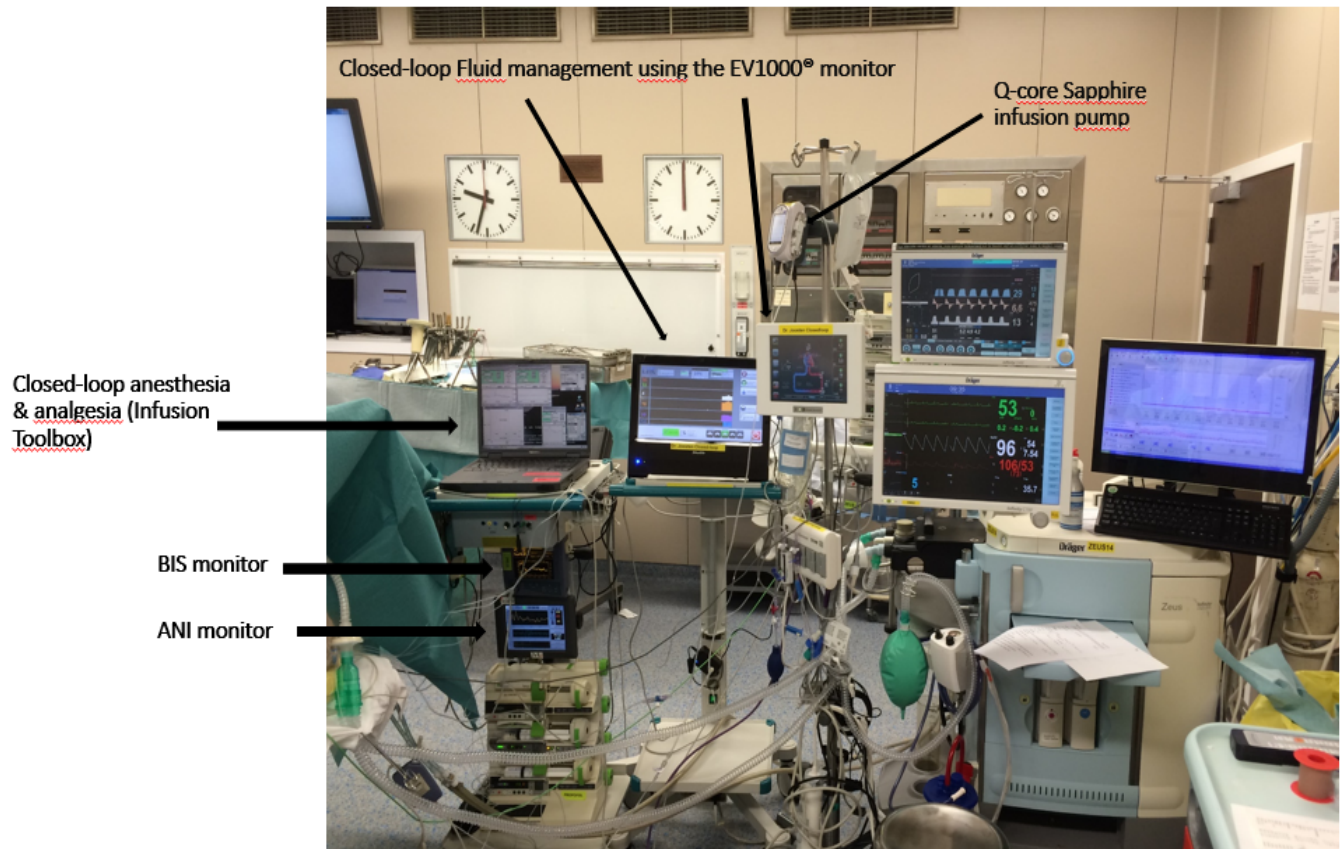
The primary objective was to reach a BIS target between 40 and 60, a SVV < 13% and/or a cardiac index (CI) > 2.4 L/min/m<sup>2</sup> and a mean arterial pressure (MAP) > 70 mmHg for more than 85% of the maintenance surgical time.

**Results:** To date, ten patients have been recruited (Table 1). On average, patients spent 82 % of the surgical time with a BIS value within the target 40-60 , 83 % with a SVV < 13%, 86% with a CI > 2.4 L/min and 91% with a MAP > 70 mmHg. No manual intervention over both PCLS was ever needed.

**Conclusions:** This study demonstrates the feasibility to combine two independent PCLS for anaesthesia and fluid management in order to provide adequate levels of anesthesia and hemodynamics in high risk surgical patients. Additional research will be required to demonstrate the true benefits of this strategy on patient outcome. In the future, interaction between both PCLS must be investigated in depth.

**Table 1**

case	Age (years)	anesthesia time (min)	EBL (ml)	UO (ml)	Crystalloid (ml)	Colloid (ml)	Fluid balance (ml)	% surgical time with SVV < 13%	% surgical time with CI >2,4L/ min m <sup>2</sup>	% surgical time with BIS 40 - 60	% surgical time with PAM > 70mmHg
1	62	328	1700	825	1330	1700	505	94	86	57	87
2	68	278	300	475	1476	400	1101	100	88	96	96
3	70	375	450	1325	950	1500	925	90	100	81	96
4	72	487	2255	1475	2000	2500	2505	39	100	76	91
5	68	287	300	1300	1100	1100	600	99	95	96	97
6	54	476	1000	1275	1250	2200	1460	57	97	63	85
7	81	250	350	500	925	900	975	97	25	84	92
8	51	530	2900	500	2350	2500	2612	56	99	89	80
9	67	402	500	250	1703	600	1553	100	74	88	86
10	71	575	500	1200	1873	2000	2454	99	99	97	98



**Figure 1: Closed-loop setup**

## **Implementation of a Computer-Assisted Intraoperative Goal-Directed Fluid Therapy in Major Abdominal Surgery: A Before - After Study**

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**Co-authors:** Coeckelenbergh Sean, MD : Department of Anesthesiology, Erasme University Hospital, Brussels, Belgium, Delaporte Amelie: Department of Anesthesiology, Erasme University Hospital, Brussels, Belgium, an Obbergh Luc, MD, PhD: Department of Anesthesiology, Erasme University Hospital, Brussels, Belgium, Cannesson Maxime, MD, PhD: Department of Anesthesiology & Perioperative Medicine, UCLA, Los Angeles, Rinehart Joseph, MD: Department of Anesthesiology & Perioperative Care, University of California Irvine, USA, Van der Linden Philippe, MD, PhD: Department of Anesthesiology, CHU Brugmann-Huderf, Brussels, Belgium

**Introduction:** Goal-directed fluid therapy (GDFT) has been shown to decrease postoperative complications and hospital length of stay <sup>1,2</sup>. However, implementation of GDFT protocols remains low <sup>3</sup> despite growing published evidence of its benefits and the recommendations of multiple societies around the world <sup>4-6</sup>. We have developed a closed-loop fluid administration system designed to help anesthesia providers to consistently apply GDFT protocols during surgery <sup>7</sup>. We aimed to compare fluid administration and incidence of postoperative complications before and after the implementation of this system in a Belgian academic center in patients undergoing major abdominal surgery.

**Methods:** Our closed-loop assisted GDFT system was introduced in April 2015. Patients managed with the system receive a baseline crystalloid fluid therapy of 3ml/kg/h via an infusion pump and additional 100 ml-fluid boluses (of either a balanced crystalloid or colloid) delivered by the closed-loop system according to a predefined GDFT strategy, based on the analysis of the stroke volume and the stroke volume variation (Flo-Trac system, Edwards Lifesciences, Irvine, CA). Patients managed with the closed-loop system were then compared to those managed before its implementation, when anesthesiologists administered fluids without any predefined protocol and based their choice on static variables such as heart rate, invasive arterial pressure, central venous pressure, and diuresis. For this comparison, a one to one matching was used. The primary goal was to compare the amount of fluid administered and the second one the incidence of postoperative complications. Patients were compared using Student-t test and Chi square were appropriate. Data are presented as mean  $\pm$  SD or percentage. A  $p < 0.05$  was considered statistically significant.

**Results:** The study included 214 patients. Baseline characteristics were not different between the 2 groups. Implementation of the closed-loop system was associated with a significant decrease in the total volume of fluid administered and in the net fluid balance (Table 1). Incidence of redo-complications was also significantly reduced.

**Conclusion:** Our study demonstrated that implementation of a computer-assisted GFDT system reduced the amount of fluid administered intraoperatively, possibly resulting in a lower incidence of postoperative complications.

**Table 1**

Variables	Standard of Care n=107	Closed-Loop Group n=107	p-value
<b><u>Baseline</u></b>			
Age (years)	65.3 ± 12.8	62.2 ± 14.6	0.10
Weights (Kg)	74.1 ± 18.2	74.1 ± 15.0	0.99
Height (cm)	169.6 ± 10.2	177.2 ± 9.2	0.33
BMI	25.6 ± 4.8	25.5 ± 5.1	0.91
Female	42 (39%)	49 (45%)	0.35
ASA Classification			
2	59%	64%	0.40
3	41%	35%	
POSSUM predicted morbidity	39.5 ± 22.6	41.3 ± 2.4	0.56
POSSUM predicted mortality	3.8 ± 6.8	3.4 ± 4.2	0.59
<b><u>Outcome Variables</u></b>			
Anesth Time (min)	375 ± 90	363 ± 110	0.40
Surgical Time (min)	294 ± 81	292 ± 102	0.87
Intraop Transfusion	24%	16%	0.086
Post-op Transfusion	29%	20%	0.076
Volume blood product (ml)	199 ± 464	96 ± 335	0.063
EBL	1102 ± 1021	922 ± 710	0.14
Intraop TOTAL Volume (ml)	4350 ± 1575	2950 ± 1550	<b>&lt;0.00001</b>
Intraop Fluid balance (ml)	2850 ± 1120	1450 ± 1300	<b>&lt;0.00001</b>
LOS (PACU or ICU, hours)	22.6 ± 13.0	23.5 ± 20.8	0.29
LOS hospital (days)	13.3 ± 8.4	12.3 ± 8.4	0.70
Total Post-op Volume	3280 ± 1460	3310 ± 1490	0.87
Fluid Balance POD 1	1930 ± 1380	1690 ± 1428	0.21
30-day mortality	1.9%	1.9%	1.00
Redo for complication	11.2%	2.8%	<b>0.0145</b>
Arrhythmia	4%	0%	0.061
90-day readmission	6.5%	4.6%	0.2260

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## A Novel Device to Standardize Infection Control in Anesthesiology

**Author:** Murlikrishna Kannan, MD, FRCA<sup>1</sup>

**Co-Author:** Sushmitha Santhosh, MD<sup>1</sup>

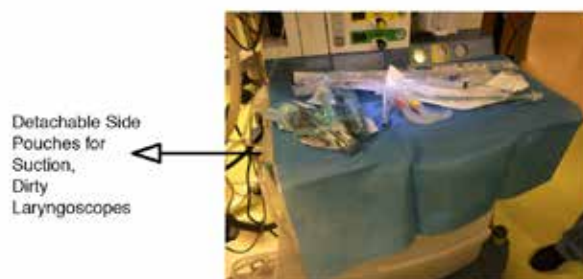
<sup>1</sup>Dept of Anesthesiology, Mt Sinai Medical Center, Miami Beach, Fl USA 33156.

**Introduction:** The contamination in Anesthesia Work Environment is difficult to control. Placing dirty equipment on the Anesthesia Machines, multiple tactile interaction with touch screens, monitors, keyboard and mouse all increase available areas of contamination. Currently there is no systematic approach to address this problem.<sup>1</sup> Transmission of pathogens in Anesthesia Work Environment has been documented by multiple studies.<sup>2,3,4</sup> We present a novel device kits to standardize infection control in Anesthesiology Environment.

### Design of Anesthesia Organizer Kit:

The Anesthesia Organizer and Anesthesia Hygiene Organizer Kits

1. Ensure a clean area to lay out equipment ready for use on a patient
2. Have a non permeable barrier to place contaminated equipment.
3. Organizational pouches to stow safely contaminated equipment.
4. These pouches are detachable to safely remove contaminated equipment from Operating Room.
5. Allow visual separation of clean and dirty areas preventing mixing of supplies between cases.



**Conclusion:** Standardizing infection control with simple barrier techniques could reduce contamination of Anesthesia Work Environment. This reduction in bacterial load could reduce intraoperative bacterial transmission in Anesthesia Work Environment. Further research will



be required investigate the effect of Clean Anesthesia Environment in intraoperative bacterial transmission and Surgical Site Infections.

**Full Disclosure:** Murlikrishna Kannan and Sushmitha Santhosh are majority owners of Anesthesia Hygiene that designs and manufactures Anesthesia Organizer and Anesthesia Hygiene Organizers.

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## **Filling the Gaps of Current Monitoring to Optimize and Individualize Anesthesia Delivery**

**Presenting Author:** Anthony Kaveh, MD<sup>1</sup>

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**Introduction:** Anesthesia delivery is based on population-models without widespread or reliable tools for predicting or optimizing anesthetic care at an individualized level. With surgical advances enabling care of increasingly higher risk patients, new anesthetic techniques and monitoring technologies present an unprecedented challenge and opportunity for providers to efficiently and effectively interpret and integrate all available data in real-time to make the best clinical decisions possible, tailored to each individual patient. Optimal anesthetic management includes not only patient safety, but also effectiveness and economic efficiency throughout the entire perioperative period. This includes medication usage, neuromuscular blockade, post-operative nausea and vomiting (PONV), opioid use, blood product use, emergence time, and post-operative recovery. Despite the availability of extensive electronic medical records (EMR) and high fidelity anesthesia monitors, a cohesive Anesthesia Information Management System (AIMS) and clinical decision support system is not available to this end. To fill this important gap, we reviewed the growing body of literature to determine the shortcomings of current implementations to enable us to design an anesthesia monitoring infrastructure at Brigham and Women's Hospital (BWH) addressing these needs.

**Methods:** An electronic search of the literature was conducted using PubMed with search terms including "clinical decision support", "anesthesia information management systems", "smartpilot", "navigator", and combinations of these terms. Searches were limited to publications related to current information system implementations. Nineteen studies of the methodology, implementation, and perioperative quality measures of current AIMS and perioperative clinical decision support systems were reviewed. A separate set of searches was conducted using PubMed with search terms including "operating room cost per minute", "anesthesia efficiency", and combinations of these terms. Studies were selected with focus on anesthesia-modifiable quality and safety outcomes relevant to AIMS, yielding seven studies reviewing perioperative cost estimates and operating room economic models.

**Results:** Review of AIMS shows technologies that are in early development using EMR codes to improve measures of safety and quality, such as antibiotic use, PONV prophylaxis

medication administration, blood glucose monitoring, blood pressure monitoring, and temperature monitoring. While novel clinical decision support systems using pharmacokinetic and pharmacodynamic models can provide greater insight into drug delivery, few studies were identified validating impact on clinical outcomes. Optimization of medication dosing and emergence times were studied outcomes; however, these population-based models supported a limited number of pharmacologic agents and surgery types, and they lacked the ability to individualize modeling based on patient-specific parameters, such as past medication response, medical history, and laboratory data. A key example for future potential was one preliminary study examining anesthesia optimized for patients with renal disease. Zero studies revealed an integrated system collectively targeting the key variables known to affect perioperative quality outcomes.

**Conclusion:** AIMS and clinical decision support systems can provide clinical and pharmacologic insights that may improve anesthetic delivery. However, more robust models are needed, including more patient characteristics and monitoring data as input variables, in addition to improved automated EMR data extraction, to target key clinical parameters that can improve patient safety and perioperative efficiency. These insights are being used to construct an anesthesia monitoring infrastructure at BWH to enable the creation and testing of mathematical predictive models targeting key clinical variables to deliver expert anesthetic care and improve operating room safety, effectiveness, and patient outcomes.

## The Contribution of the Induction Period to Overall Gas and Vapour Consumption

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**Background / Introduction:** Reducing fresh gas flow (FGF) during volatile anesthesia reduces agent consumption, cost and environmental footprint without reducing drug delivery to the patient. RK and RF have a long interest in this area<sup>1</sup> and are collaborating with GE-Healthcare exploring data collected routinely by anaesthesia delivery systems.

While our work includes all phases of anesthesia some studies exclude induction or the pre-surgical phase from analysis<sup>2,3</sup>. This project allows us to explore the influence of this early phase on total gas flows by investigating and understanding FGF data from a large number of cases; by a simple modelling; and by observing the effect of a simple intervention directed at the early phase on overall gas consumption.

**Methods:** Data is logged from 4 GE-Aisys CS2 Carestations. The high flow period starts when vapour delivery begins and ends when FGF < 5l/min.

Early data suggested that both the flow rate and the duration of the “high flow” phase have a significant influence on overall mean FGF. A simple spreadsheet was constructed to explore this. Over a 2 week period we provided all anesthesiologists with repeated information on the importance of FGF in the high-flow phase. We compared the pattern of flow rates in the 3 months before this information and the 2 months following. Mean FGF is a marker of vapour consumption.

**Results:** We have data on 2089 vapour based anesthetics from 4 OR. Mean FGF decreased from 920ml/min to 860ml/min associated with a decrease in the mean duration of the high flow period from 3.3min to 2.3min.

For a single OR with a consistent, case mix, mean FGF decreased from 1.102 l/min to 0.871 l/min ( $p < 0.0001$ ). The median [IQR] for FGF during the high flow phase were 6 [6,6] l/min before and 6 [0,6] l/min after and the median durations of the high flow period were 2 [0, 4]min and 0 [0, 3]min ( $p < 0.0001$ ).

Simulation shows that for a 90 min case with a maintenance FGF 2l/min and a high flow

period FGF 6l/min, reducing the duration of the high flow period from 10 to 2 min reduces mean FGF from 2.44l/min to 2.09l/min, or 14%. If the maintenance flow is 1 l/min, the overall reduction is 29%.

**Conclusions:** The primary focus of FGF reduction efforts is on maintenance. We have identified that the duration and gas flows during the early phase can have a significant effect on total consumption with the FGF used for pre-oxygenation frequently maintained after induction. We were able to produce an additional 10% reduction to our already low average flows. Modelling suggests that even in an environment where maintenance flows are moderately high, attention to the early / induction phase can produce additional, useful reductions in gas flows and vapour consumption.

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## Using Differential Pressure to Determine Isoflurane Gas Concentration

**Presenting Author:** Patrick Kolbay, B.S., University of Utah

**Co-Authors:** Joseph Orr, Ph.D., University of Utah; Kai Kück, Ph.D., University of Utah

**Introduction:** Knowing the inspiratory and expiratory concentration of volatile anesthetics is essential when administering inhalational anesthesia. Current technology predominantly uses side stream infrared analysis to identify the anesthetic agent as well as its concentration with high accuracy. However, this technology contributes to a large portion of the capital cost of anesthesia machines. Thus, these machines become cost prohibitive for both small-office practices and low-resource areas, causing clinicians to seek alternative forms of general anesthesia. Alternative approaches exist to determine anesthetic concentrations, using more economic technologies. Anesthetic gases are approximately five times denser than oxygen and nitrogen and have an impact on the fluid dynamic properties of the flowing gas. Based on the Bernoulli Effect, a flowing fluid that changes density alters the internal pressure. Using this principle, this study aimed to determine whether the pressure difference before and after a constriction, the differential pressure, would change as anesthetic concentration changes and whether this could then be used as an alternative to infrared analysis for determining anesthetic concentration.

**Methods:** A fixed orifice flow module (Respironics Fixed Orifice Flow Module, Philips, Amsterdam, Netherlands) was used in conjunction with a differential pressure sensor (DLVR-L01D E1NS-C, All Sensors, Morgan Hill, CA) in a custom rebreathing circuit. A radial blower (U51DL-012KK-4 Miniature Radial Blower with Integrated Electronics, Micronel, Tagelswangen, Switzerland) was used to drive the rebreathing circuit gas at rates of 2-12 liters per minute (measured using the integrated electronics of the radial blower, independently verified using a VT-Plus Gas Flow Analyzer, Fluke Corp., Everett, WA). Isoflurane (Piramal Healthcare Limited, Andhra Pradesh, India) was introduced to the rebreathing circuit with a custom vaporizer, at concentrations ranging from 0-3.5% measured using a standard side stream infrared gas bench (Datex-Ohmeda, Helsinki, Finland). Baseline measurements at all flow rates were used to calibrate the differential pressure system. As isoflurane was introduced to the rebreathing circuit, deviations from this baseline were attributed to changes in the isoflurane concentration. A model was generated to estimate the isoflurane concentration and compared to actual isoflurane concentrations in real time.

**Results And Discussion:** Isoflurane concentration estimations were highly correlated to measured isoflurane concentrations ( $R^2 = 0.99$ ). In a sample size of  $N=53$ , the mean error was

0.016% isoflurane with a standard deviation of 0.089% isoflurane (Figure 1). Further tests will include dynamic conditions by ventilating a test lung.

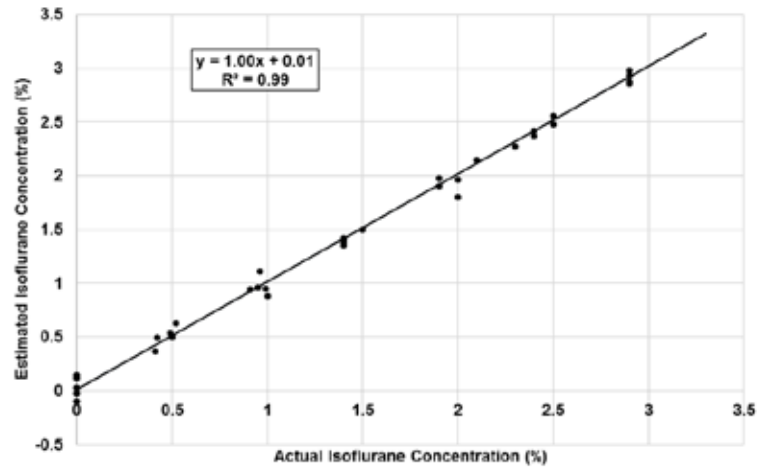


Figure 1 - Estimated isoflurane concentration using differential pressure versus actual isoflurane concentration with accompanied linear regression.



## Reducing Volatile Anesthetic Waste Using Activated Charcoal

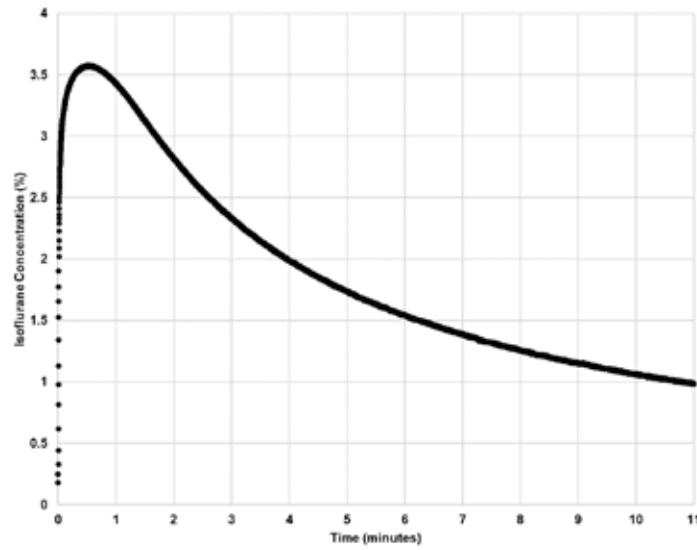
**Presenting Author:** Patrick Kolbay, B.S., University of Utah

**Co-Authors:** Joseph Orr, Ph.D., University of Utah; Kai Kück, Ph.D., University of Utah

**Introduction:** Volatile anesthetics are largely unmetabolized in the body, and as a result the exhaled gases can be redelivered back to the patient. Current anesthesia machines attempt to accomplish this through a rebreathing circuit with limited success as the rate of exhaled anesthetic gas must be removed from the system at the same rate as the incoming fresh gas flow. This waste has both financial and environmental consequences, costing a mid-sized hospital approximately \$500,000 in anesthetic waste annually and a 2% contribution to ozone depletion. Thus, creating an alternative method to capturing and redelivering anesthetic gases would be highly beneficial. The porous surface of activated charcoal has been shown effective in absorbing and removing anesthetic gases from anesthesia machines for patients susceptible to malignant hyperthermia. This study aimed to determine if activated charcoal under different conditions could also be a suitable material in both absorbing and desorbing anesthetic gases to ultimately reduce anesthetic waste.

**Methods:** A 5 liter per minute flow of oxygen and 5% isoflurane (Piramal Healthcare Limited, Andhra Pradesh, India) was delivered through a cylindrical vessel containing 42 grams of activated charcoal (Oxpure 1220C-75, Oxbow Activated Carbon, West Palm Beach, FL) until 0.5% isoflurane pushed through the charcoal. Flow was then reversed through the vessel at 2 liters per minute with pure oxygen and the concentration of isoflurane leaving the vessel was monitored using a standard side stream infrared gas bench (Datex-Ohmeda, Helsinki, Finland).

**Results and Discussion:** Isoflurane was released at concentrations suitable for anesthesia maintenance for a significant amount of time, approximately 10 minutes. Once saturated, the activated charcoal had absorbed approximately 60% of its total weight in isoflurane, and was capable of repeatedly reflecting 10% of its total weight in isoflurane or about 3.2 mL of liquid isoflurane. This volume of isoflurane capable of being reflected is the equivalent of anesthesia maintenance at 1 MAC for 1 hour at a fresh gas flow rate of 1 liter per minute. Based on these results, activated charcoal has proven to be a feasible material in reflecting and conserving anesthetic gases. Future work will include creating a system using this material that is able precisely deliver a set concentration based on the principles shown here.



*Figure 1 - Average concentration of isoflurane released when flow was reversed through vessel. The concentration released was above 1.0 MAC for approximately 10 minutes.*

## Applying 360-Degree Videos to Interdisciplinary Training and Simulation

**Presenting Author:** Chad Lee, M.D.<sup>1</sup>

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**Background:** In order to deliver safe and effective patient care in the operating room, staff must work together as a team. Teamwork requires closed-loop communication and the ability to anticipate events. Studies have shown that interdisciplinary simulation exercises improve the efficiency with which health care providers and other ancillary staff respond to high-acuity situations. Additionally, studies have demonstrated that multimedia resources help learners recall and retain information. 360-degree video is an emerging multimedia platform, which allows users to be visually immersed in a video. Using this technology and these premises we are working with the OR nursing staff to create high-fidelity simulations and recording them in 360-degrees.

**Methods:** Quarterly group simulations were held with members of the nursing staff, surgical team, and anesthesia team. Participants were notified in advance that a simulation exercise was planned but details of the scenario were not disclosed. To date we have done a pediatric surgery scenario and a pediatric post-anesthesia care scenario in 360-degree video. To create a realistic experience the perioperative environment was set-up in the normal fashion using standard equipment and a mannequin patient. A 360-degree, six GoPro camera mount was positioned in the center of the room to record the simulation. Individual videos were then downloaded to a VR-capable, custom build PC and stitched together using Autopano Video Pro. The final video was uploaded to Youtube, allowing anyone with a mobile phone or computer to view it in 360-degrees.

**Results:** Rendering 360-degree videos from six GoPro cameras was successful with good resolution and sound. The video could be viewed from a computer, mobile device, or virtual reality headsets. Initial reception of the 360-degree recordings of the simulation was positive. OR staff who viewed the videos stated that the ability to view everything occurring simultaneously allowed them to better understand the overall scenario. Learners commented that it enabled them to discern their own individual roles within the group as well as the ongoing interplay between different services.

**Conclusion:** 360-degree videos provide distinct advantages over traditional videos when used for interdisciplinary simulation because it provides the participant a vantage point otherwise unobtainable. Being able to view the entire room through one video stream allows an individual from any service or even hospital administration to review safety protocols in place and ascertain if there are deficiencies in training or resources needed to respond appropriately to high-acuity situations. Additional work is required to ascertain the optimal positioning of the camera as well as improving the stitching and processing of the video.

## Deep Learning for Predicting in Hospital Mortality

**Presenting Author:** Christine Lee, MS, UC Irvine Department of Biomedical Engineering

**Co-Authors:** Ira Hofer, MD, UCLA Department of Anesthesiology ; Maxime Cannesson, MD PhD, UCLA Department of Anesthesiology; Pierre Baldi, PhD, UC Irvine Department of Computer Science

**Introduction:** Patients undergoing surgery are often at higher risk of instability during surgery as well as poor postoperative outcomes. Being able to identify patients at higher risk for poor outcomes would allow for more effective care and allocation of hospital resources, and ideally avoid complication altogether. Current risk scores such as the ASA, POSPOM, and RQI have shown success in identifying patients at risk of mortality, however, they are limited to preoperative information. The Surgical Apgar score utilizes intraoperative data, however, has been shown to have limited accuracy. We hypothesize that deep neural network models (DNNs) can leverage the complexity of intraoperative data to improve the classification of in hospital mortality in surgical patients.

**Methods:** Data used in these experiments came from UCLA Medical Center with IRB approval. The data consists of 59,985 patients with 87 features calculated at the end of surgery. These variables include intraoperative vital signs, interventions, and anesthesia events. The data included all surgical procedures performed since March 1, 2013. Cases not done with general anesthesia, and patients  $> 89$  or  $< 18$  years of age were excluded. Missing values were filled with the means for that feature. Values that were greater than a clinically normal maximum were set to that maximum possible. Finally, all variables were rescaled to have mean 0 and standard deviation 1. The % occurrence of in hospital mortality was 0.81%. Thus, training data was augmented 100x for a mortality occurrence of  $\sim 45\%$  by adding Gaussian noise with a standard deviation of 0.0001 to mortality patients only. All DNNs were trained on 80% of the data ( $n=47,988$ ) with five-fold cross validation. 20% of the data was held out as a future test set. All DNNs were feedforward networks with a sigmoid output, and were trained using stochastic gradient descent with momentum. Dropout, L2 weight decay and early stopping were used to prevent overfitting. We also assessed improvement of the DNN with adding ASA as a feature, and robustness of the DNN to a reduced feature set of 46. A logistic regression model with the 87 features was also trained for comparison. Performance was assessed using mean and standard deviation of AUROC from cross validation. For comparison, the AUROC of ASA, Surgical Apgar, RQI, and POSPOM were also calculated on the training data. It should be noted that RQI could not be calculated for 25,621 training patients due to lack of RQI score weights for their CPT codes.

**Results:** The final DNN architecture consisted of 4 hidden layers with 300 neurons in each layer. RQI outperformed Surgical Apgar, POSPOM, ASA, logistic regression, and the DNN with all 87 features (Table 1). DNN with ASA added as a feature and DNN with the reduced feature set performed comparably to RQI. However, RQI could not be calculated on approximately half of the data, while the DNNs do not have this limitation. In addition, we see that there is improved performance with the addition of the preoperative feature ASA and DNNs are robust to a reduced feature set.

**Table 1.** Risk score AUC results and model 5 fold cross validated AUC results (mean  $\pm$  std) on training data (n=47,988). \*RQI could not be calculated for 25,621 patients.

<b>Risk Score</b>	<b>AUC</b>
Surgical Apgar	0.58
POSPOM	0.74
ASA	0.85
RQI Score*	0.92
<b>Model</b>	<b>5 Fold Cross Validated AUC</b>
Logistic Regression	0.87 $\pm$ 0.02
DNN w/ 87 Intraop Features	0.90 $\pm$ 0.01
DNN w/ 87 Intraop + ASA Features	0.92 $\pm$ 0.01
DNN w/ 46 Intraop + ASA Features	0.92 $\pm$ 0.01

**Conclusion:** In conclusion, DNNs exhibit potential for being able to not only classify patients at risk for inhospital mortality, but also for improving upon and leveraging preoperative risk.

## **A Prospective Clinical Study of Tom-Stylet, Its Safety, Efficacy for Intubation, Accuracy in Measuring, Guiding ETT Position**

**Authors:** Thomas D. Lei, MD, Department of Pulmonary and Critical Care Medicine, Regional Medical Center of San Jose, CA, USA. Bin Yi, MD PhD, Kaizhi Lu, MD, PhD, Department of Anesthesiology, South West Hospital, Third Military Medical University, Chongqing, China.

**Background/Introduction:** Intubation is a common procedure to secure a patient's airway and to initiate mechanical ventilation. Proper placement of the endotracheal tube (ETT) is essential to mitigate any potential complications associated with intubation and to achieve adequate ventilation. Post intubation CXR to confirm ETT position, a current common practice, incurs significant cost and radiation exposure to both patients and staffs. A real-time and alternative means to facilitate ETT placement and test ETT tip position is urgently needed. The targeted positioning the ETT tip is between 2 cm and 5 cm from the carina. Tom-Stylet, a novel dual function stylet, was prospectively evaluated in current study. This study was set out to validate the clinical efficacy and safety of Tom-Stylet, i.e. its ability to facilitate oral intubation, to confirm and guide the endotracheal tube (ETT) position and its safety impact on endobronchial mucosa.

**Methods:** A prospective, single center observation study was conducted blindly on 26 adult patients. Any adult patients requiring general anesthesia for elective surgical procedures (general surgery, ENT, neurosurgery, OB-GYN and urology procedures) meet the inclusion criteria, the only exclusion was patients scheduled for thoracic surgery. 14 females, 12 males were included: mean age 49.4 (17-72); mean height 5'4" (4'11"-5'7"); mean weight 129.4 lb (88.2-220.46). All study subjects were intubated orally by their attending anesthesiologists using Tom-Stylet. The ETT were initially positioned based on physicians' experience and auscultation. Bronchoscopy was performed by investigator physicians only to exam and photograph the baseline endobronchial mucosa on each subject. Tom-Stylet was again inserted, its balloon deployed to measure the ETT position, and the ETT was adjusted accordingly. Post bronchoscopy was performed on each subject to confirm ETT position, to evaluate Tom-Stylet balloon safety on the mucosa and to photograph for records.

**Results:** Of the 26 subjects, all were successfully intubated orally using Tom-Stylet. 7 cases (27%) were placed in satisfactory position (2- 5cm above the carina) solely based on anesthesiologists' experience, auscultation. 19 cases (73%) required adjustment by using Tom-Stylet guidance. One ETT was required to be pulled back 1 cm; in 18 cases, ETT were pushed down average 2.4 cm (0.5 cm-4 cm). No bronchoscopic injury on trachea mucosa was observed on all study subjects.

**Conclusions:** Tom-Stylet is a novel and effective stylet for oral intubation. Not only does it facilitate intubation, it also provides real-time ETT position and guides ETT positioning at



point of care. Application of Tom-Stylet can reduce radiation exposure to patients and staff while cutting down care cost.

**Acknowledgement:** The device, Tom-Stylet, was generously donated by Zeus Medical, Mountain View, California for current study.

## **Blood Pressure Analysis on ICU Patients Receiving Vasopressor Therapy from the MIMIC II Database**

**Presenting Author:** Michael Ma, Department of Anesthesiology & Perioperative Care, UCI Medical Center, Orange, CA

**Co-Authors:** Michael-David Calderon, Joseph De Los Santos, Roberta Andreatta MD, Joseph Rinehart MD  
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**Background:** Blood pressure management in the ICU frequently involves vasopressor therapy especially in patients with septic, neurogenic, or cardiovascular shock. Too low of a blood pressure risks organ failure secondary to hypoperfusion while too high of a blood pressure risks ischemic injury. Currently, vasopressor therapy is hand-titrated to a target mean arterial pressure. In an ideal setting, changes in vasopressor infusion rates quickly follow changes in blood pressure measurements. However, due to a variety of nursing, workflow, and patient factors, this may not be the case. Few studies, if any, have examined blood pressure variability in a large number of ICU patients who receive vasopressor therapy.

**Methods:** The clinical data used in this study was obtained from the MIMIC II Database (1). The MIMIC II Database contains extensive clinical data of ICU patients who were admitted to Beth Israel Deaconess Medical Center. Blood pressure data was derived from the numerics record of the MIMIC II database. Patients who had valid blood pressure data (values >250 mmHg were considered to be invalid MAP values and were excluded from the study) while on at least a single dose of norepinephrine, vasopressin, or neosynephrine (or any combination of these) were included in this study. For the purposes of this study, the ideal mean arterial pressure was considered to be 60-80 mmHg. The targeted MAPs were unknown in this study.

**Results:** A total of 581 ICU patients were included in the study. The average MAP for all patients was 75.51 with a standard deviation of 17.04. The average standard deviation for each patient was 12.65. Patients spent 63.12% of total time (in which blood measurements were recorded) with a MAP between 60 and 80, 9.25% of time with a MAP less than or equal to 60, 27.63% of time greater than or equal to 80, 1.41% of time less than or equal to 50, and 12.31% of time greater than or equal to 90.

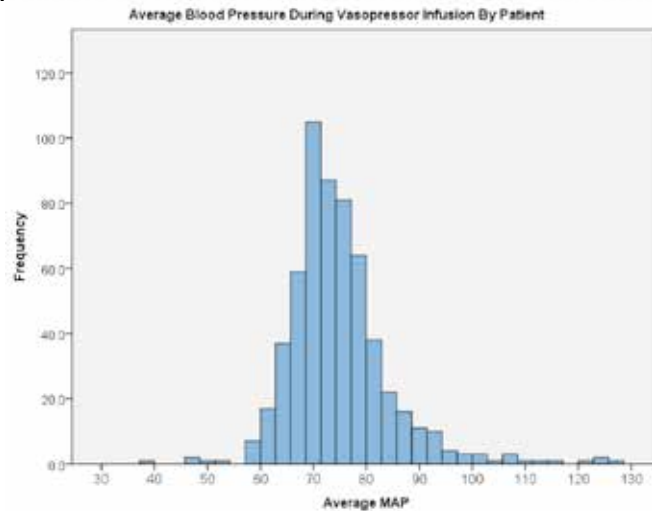
**Conclusion:** Preliminary findings on this data set suggest that ICU patients on vasopressor infusions spend significant time with a MAP greater than 80 mmHg. This may be due to unnecessary vasopressor infusion which may be a result of significant lag between blood pressure changes and vasopressor infusion rate changes. The data suggests that there is

room for improvement in the blood pressure management of patients receiving vasopressor therapy and that there may be a need for more accurate titration.

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**Figure 1. Average Blood Pressure During Vasopressor Infusion By Patient**



## **A Low-Cost and Novel App for Improving Anesthesia Operating Room Equipment Supply**

**Presenting Author:** Clyde Matava, MD<sup>1</sup>

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**Background:** Pediatric anesthesiologists are dependent on the immediate availability of specialized drugs and equipment for urgent and regular patient care. Commonly used equipment and drugs are kept in an anesthesia cart in the operating room. The non-availability of these items may erode efficiency, result in delays of cases, negatively impact the work environment and lead to unsafe delivery of patient care.

At our institution, missing items in the anesthesia cart were traditionally documented on paper for later review. There was poor uptake of the paper reporting. Our project created a low-cost app to be used for real-time tracking of bedside equipment shortages. This would assist us in identifying the scope and patterns of shortages and inform recommendations to each respective group (anesthesiologists, nurses, attendants, administration) on how to mitigate and manage any ongoing supply issues.

In October 2015, the app was made available on mobile phones and desktop computers for reporting and tracking anesthesia supply shortages. The app sent out an SMS alert to the attendants for immediate re-supply.

**Methods:** Following institutional approval from the Quality Initiative Review Board, data collected from the last two months of paper documentation (September and October 2015) and the first two months from a database created via the app (November and December 2015) was extracted to identify patterns. Comparative statistics was used to assess the effectiveness of the app compared to the paper method of reporting.

The primary outcome was the number and location of reports made. Secondary outcomes include the impact of missing items on operating room efficiency and patient safety, the most commonly reported missing items, and the most common actions taken following the discovery of missing items.

**Results:** There was a 400% increase in reporting of missing items with the launch of the app. 28 reports of missing items were made during the last two months of paper reporting and 120 reports were made in the first two months of the app. The locations reporting increased from 9/24 to 22/24. The most commonly reported missing items reported via

the app were Wisconsin Size 1 laryngoscope blades and the most common times for shortages were 4am to 8am (morning). Rooms with most shortages were dental and the 'emergency OR'. Anesthesiologists perceived shortages to have high impact on efficiency 27% of the time and high impact on patient safety 18% of the time. Data was also processed using SPC charts and led to 5 changes in staffing/supply chain routine to mitigate supply issues. There were over 529 reports over 12 months with decreasing incidence of shortages per month.

**Conclusions:** The introduction of an app has resulted in increased reporting of missing anesthesia supplies while providing robust data that has useful for advanced analytics leading to QI changes. The lack of reporting by anesthesia fellows and residents suggest a significant number of incidents are still not reported and increased efforts are needed to increase awareness of the app.

## **Patient Monitoring Quality Improvement Program: Impact on Respiratory Compromise**

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**Background/Introduction:** Acute respiratory compromise events are common on inpatient hospital wards<sup>1</sup>. Analyses of closed claims related to postoperative opioid-induced respiratory depression specifically have demonstrated that 97% were deemed preventable with improved patient monitoring and intervention<sup>2</sup>. Continuous patient monitoring of oxygenation and ventilation has been recommended for such patients<sup>3</sup>; however, there are currently limited data evaluating how this change in practice affects patient outcomes. Therefore, the purpose of this study was to assess the impact of a quality improvement program (QIP) that established continuous capnography and pulse oximetry monitoring in recovery settings for high-risk patients.

**Methods:** A hospital Patient Safety Committee instituted a QIP with continuous capnography and oximetry monitoring in October 2013 on the Orthopedic, Medical/Surgical, Intensive Care and Post-Anesthesia Care Units for patients with STOP-BANG scores  $\geq 3$ . Subsequently, 38 months of data on 2,258 postoperative discharges were analyzed using UB04 billing data. Respiratory adverse events (RAE) were evaluated as: 1) all respiratory events including any secondary respiratory diagnosis of hypoxemia, asphyxia, respiratory arrest and failure, 2) PSI-11 (secondary diagnosis of respiratory failure and/or re-intubation/mechanical ventilation), 3) postoperative respiratory failure, and 4) cardiac arrest/resuscitation. Changes in length of stay for RAE, ICU transfers and mortality were also determined. Comparisons were made between all metrics at the start (2013-2014) and at the end of the QIP monitoring period (2015-2016).

**Results:** Following QIP initiation, the total number of RAE changed from 90 (6.84% of hospital events) to 87 (9.22% of hospital events) ( $p < 0.05$ ). Postoperative respiratory failure and cardiac arrest/resuscitation events decreased from 6 (0.45% of hospital events) to 0 and 7 (0.52% of hospital events) to 0 ( $p < 0.05$ ), respectively. PSI-11 related events did not significantly change (1 to 0;  $p = 0.38$ ). Length of stay for all respiratory event with from 9.2 to 6.5 d ( $p < 0.05$ ), while ICU transfers and mortality did not significantly change ( $p > 0.05$ ). Documented compliance with continuous monitoring went from 22% at the start of the program to 97% at the end.

**Conclusions:** The implementation of a hospital-based QIP that established continuous monitoring with capnography and pulse oximetry was associated with a decrease in postoperative respiratory failure, cardiac arrest/resuscitation events and length of stay from a respiratory event. This program did not result in changes in PS-11, ICU transfers or mortality. These data suggest that continuous monitoring with a both capnography and pulse oximetry may play a role in quality improvement by helping to reduce severe respiratory adverse events and length of stay for high risk patients.

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## **Development of a Compact, Versatile and Low Cost Mechanomyography Device for Quantitative Train of Four Assessment**

**Presenting Author:** Kelly Michaelson, M.D., Ph. D.<sup>1</sup>

**Co-Authors:** T. Andrew Bowdle, M.D., Ph. D.<sup>1</sup>, Bala G. Nair, Ph. D.<sup>1</sup>, Justin Hulvershorn, M.D., Ph.D.<sup>2</sup>

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Mechanomyography (MMG) for assessment of residual paralysis has been in existence since the 1960s<sup>1</sup>, and has been considered the gold standard technique for evaluating muscle response. However, there are no current commercially available systems. Despite longstanding use in research, the technique never gained widespread clinical acceptance due to bulky and cumbersome setup. Accelerometry (AMG) has gained some traction in clinical use and measures the acceleration of the thumb during contraction to determine the force. However, absolute measurements are not easily comparable since there is still variation between MMG and AMG results. Additionally, AMG results in consistently overestimates train of four (TOF) measurements and even at a TOF ratio of 1, impaired respiratory function has been observed<sup>2</sup>.

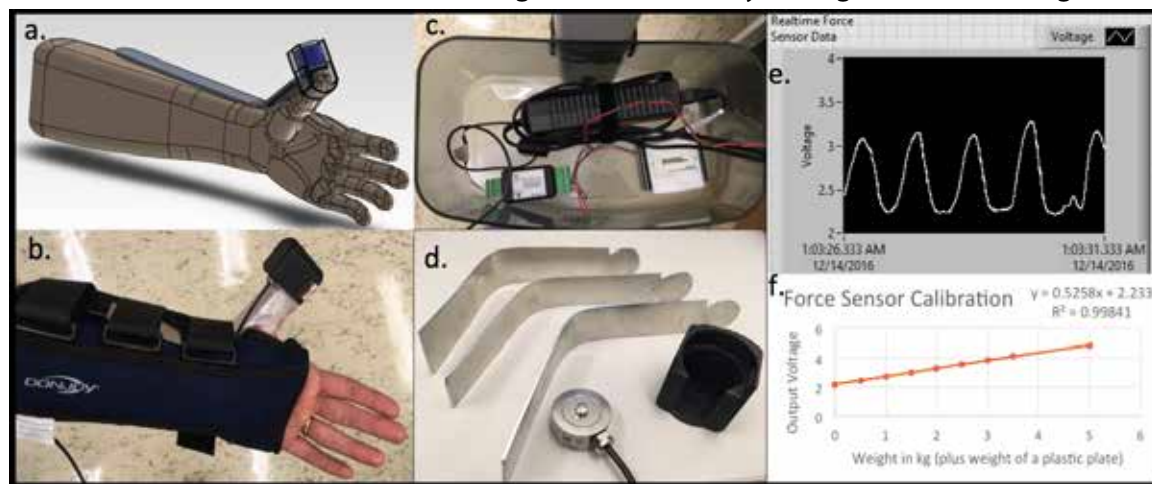
Electromyography (EMG) is another technique that has shown good correlation with MMG<sup>3</sup> and measures electrical response rather than mechanical. EMG is far easier to setup than MMG but proper placement of the electrodes is essential. EMG and MMG have been studied and compared extensively in the past<sup>4</sup>, however clinical use of EMG based systems has lagged.

The objective of this project was to develop a compact, easy to use and low cost MMG system that could be integrated with an EMG based system currently in development for clinical use. These two techniques can be directly compared with simultaneous measurements in the same muscle and will be used to evaluate the new EMG based system against the gold standard MMG technique.

Electronic components were selected based on measurement precision, size, and price and include a force transducer, amplifier and analog to digital signal converter. The force transducer is secured to the thumb via a custom 3D printed holder that slings around the palmar side of the digit. In between the thumb and transducer are three pieces of aluminum. Individually, the technician can easily mold each layer by hand to the appropriate angle of the

thumb of the patient in order to hold a preload force of 200-300g. When stacked, the higher resistance can maintain isometric conditions needed to accurately record MMG signals, preventing thumb movement. The hand is further immobilized using a commercial wrist splint.

Due to technological advances since the earliest MMG systems were developed, it is now possible to build a device with a slim profile, easily customizable for individual patients at a cost less than \$1,000 that can be used simultaneously with EMG for precise comparison and evaluation of the new EMG based system. The new system was developed and demonstrates expected linearity in measurements for with precision to 5g and accuracy to 25g for measurements examined from 0 to 5kg with a sensitivity to 10g within that range.



The figure demonstrates the development of the mechanomyography system. Several designs were proposed and modeled in CAD before the model shown in (a) was selected. A commercial wrist splint by *Donjoy* (b) immobilizes the wrist, essential to allow force transmission to the sensors. Electronic components were selected based on small size, expected measurement range and error tolerances as well as price (c). Aluminum splints can be molded for each patient and provide additional strength when stacked together (d). Data is collected on a laptop computer using National Instruments Labview software (e). Force sensor calibration shows excellent linearity in the range of expected forces from muscle contraction (f).

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## Use of Google Glass for Interactive Live Streaming in Medical Student Education

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### Background:

While wearable smart glass devices had mixed results in the consumer sector, certain industries such as manufacturing, insurance, inspection, and healthcare have started incorporating these devices in daily use. These devices are commonly used to help with documentation, live feedback, and instruction. Currently, there has been an increased popularity of live streaming in the consumer sector popularized by companies such as Facebook, YouTube, and Snap Inc. owned Snapchat. While commercial hardware is sparse, eventual widespread adoption of live streaming will change this. Use of this new service, creates a whole new venue to enhance the medical educational experience that was not previously able to be achieved.

**Methods:** Google Glass units were tested out in two different clinical settings. A headset unit was placed on an anesthesiologist prior to performing a post-operative femoral catheter placement in the PACU. This was live streamed to a lecture hall composed of approximately two hundred M1 students using the Pristine EyeSite application available for Google Glass. Medical students could ask questions to both the anesthesiologist performing the procedure as well as to the one present in the lecture hall. The headset unit was also tested out on the OB floor where an anesthesiologist was performing a labor epidural. The procedure was live streamed to M4 students who asked questions while the procedure was being performed.

**Results:** The initial trial to incorporate Google Glass and interactive live streaming into medical school curriculum was successful. Medical students reported satisfaction with video and audio quality of the live stream. Specific comments indicated being content with the unobstructed view of the procedure. Headset wearers reported ease of use of simultaneously wearing the headset and performing the procedure with minimal interference with patient care. Issues occurred with initial setup of the live stream feed while connecting to the Pristine EyeSight application. However, there was no issues after a connection was established. Other issues, included rapid head movements and poor line of sight of the procedure when the practitioner was not directly looking at the procedure. This was remedied by training the practitioner to make slower head movements and adjust their field of view.

**Conclusions:** A new way in incorporating technology into medical school education was explored. The advantages of using Google Glasses for interactive live streaming is the ability to provide an unobstructed view of the procedure with minimal interference on the practitioner. Other advantages include the ability to live stream to another location when having a larger number of observers are not feasible. Future exploration by the medical school includes testing out headset units in other medical specialties such as pathology, surgery, medicine, and ER. Further studies need to evaluate effectiveness of interactive live streaming versus traditional viewing.



## **Development and Pilot Evaluation of a Real-Time Clinical Decision Support Module Integrated with an Enterprise Anesthesia Information Management System**

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**Introduction:** Real-time clinical decision support (CDS) mediated through Anesthesia Information Management System (AIMS) has been shown to improve quality of care and revenue capture. However, the adoption of real-time anesthesia CDS is currently limited to a few institutions that have developed and customized such systems to work with their institution's AIMS<sup>1,2</sup>. Additionally, these CDS modules have been typically developed to work with standalone AIMS that are not part of an enterprise electronic health record.

**Objective:** Our objective was to integrate a real-time decision support module, Smart Anesthesia Manager (SAM), with an enterprise AIMS - SurgiNet Anesthesia (Cerner Inc., N. Kansas City, MO). A second objective was to perform a pilot evaluation of SAM in a hospital different from where it was originally developed.

**Method:** SAM, originally developed at the University of Washington (Seattle, WA), is a real-time decision support for anesthesia care. It was at first developed to work with a stand-alone AIMS (Merge AIMS, Hartland, WI). Based on predefined decision rules SAM generates real-time "popup" reminders on the AIMS computer screen if ongoing clinical or documentation issues are detected. SAM is built in a modular fashion and uses an AIMS independent data dictionary and rule definitions. Hence, for SAM to integrate with different AIMS, only data exchange interfaces and data translators need to be developed. Through a 3-way partnership between University of Washington (Seattle, WA), Virginia Commonwealth University (Richmond, VA) and TransformativeMed Inc. (Seattle, WA) we developed a data interface (Restful calls using Cerner Command Language scripts) to obtain real-time data from an enterprise AIMS - SurgiNet Anesthesia. Decision support alerts were presented using a SAM client program. The system was piloted in Virginia Commonwealth University Medical Center with decision support activated to improve redosing of perioperative antibiotics and documentation of invasive lines. Compliances to antibiotic (Cefazolin) redose and complete documentation of invasive lines were compared for 3 months each before and after SAM implementation.

**Results:** SAM successfully interfaced with enterprise SurgiNet Anesthesia system extracting comprehensive intraoperative data in real time with no negative impact on AIMS operation. The time required for data extraction per anesthetic record averaged 2 seconds. SAM could provide real-time decision support with minimal data latency (< 5 seconds). Compliance to redosing antibiotic (Cefazolin) for long duration cases (> 4 hours) improved from 69% (N=252) to 89% (N=276) with SAM reminders ( $p<0.001$ ). Similarly, with SAM alerts, compliance to complete documentation of arterial and central venous lines increased from 31.6% (N=659) to 75.8% (N=669) ( $p<0.001$ ) and 38.0% (N=166) to 89.1% (N=147) ( $p<0.001$ ) respectively.

**Summary:** Recent consolidation of AIMS market has resulted in most hospitals migrating to enterprise AIMS systems. Enterprise systems are mostly marketed by a handful of electronic health record vendors as Epic (Epic Inc. , Verona, WI) and Cerner (Cerner Inc., N. Kansas City, MO). Hence, integration of real-time decision support systems with enterprise AIMS is important for its wider dissemination and benefit. In this study we show that through proper design considerations a real-time decision support system can be integrated with an enterprise AIMS. We also show that such a system has the potential to improve quality of care and revenue capture even in hospitals where the system was not originally developed.

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## **Factors Contributing to Anesthesia Residents' Learner Engagement and Learning Experience in a Mobile App: A Mixed-Method Design Study**

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**Co-Authors:** Karen Wang, MA, Lynn Ngai, MD, Larry Chu, MD, MS, Stanford University School of Medicine

**Background/Introduction:** The rapid expansion of mobile technology in medical education has provided postgraduate medical trainees the opportunity to access their learning content anytime, anywhere. Despite the unique affordances offered by mobile technology to improve medical education, little is known regarding how learners use and engage with mobile learning content.

Learnly | Foundations is a yearlong curriculum in the anesthesia basic sciences consisting of daily lessons, quizzes, and flashcards hosted on a web-based learning management system (LMS). To take advantage of the mobile technology available and meet the changing learning needs of anesthesia residents, the Stanford Anesthesia Informatics and Media (AIM) Lab initiated the development of a proposed companion mobile application for the Learnly curriculum. Our goal in this study is to understand “when,” “where” and “how” today’s anesthesia residents are using mobile learning solutions, and develop a systematic model for the design, development, implementation and evaluation of mobile learning solutions.

**Methods:** The study is part of the protocol approved by Stanford IRB (#27444). A mixed-method (qualitative and quantitative) approach is utilized to explore postgraduate anesthesia residents’ usage and preference for mobile learning tools. A focus group was conducted with 13 Stanford Anesthesia residents (PGY2-PGY4), followed by a Qualtrics survey.

The AIM Lab will also conduct a broad online survey of 1,333 anesthesia residents currently enrolled in Learnly in January 2017, which will prompt information on respondents’ background demographics, mobile device ownership, mobile device usage, and perceived benefits and barriers of utilizing mobile devices in medical education.

**Preliminary Results:** Focus group participants reported that pressure to pass the board exam, recommendations from peers, and access to high-yield ABA-format test questions are factors that motivate them to use a mobile learning application. Factors preventing residents from using mobile learning tools include demanding OR rotations and varied expectations regarding mobile device usage from different attendings.

Data from the survey indicates that the feature that residents plan to use most often on the mobile device is quiz-taking (49%), followed by reading (42%) and flashcards (9%). When asked, “how would you like to access learning content: through a personal computer or a mobile device?” 57% of respondents said they would be more likely to access learning content through a mobile device. 35% said they would split their access 50/50 between mobile and computer devices. Only 8% responded that they would be more likely to access content through a computer.

**Conclusion:**

Collectively, the results provide preliminary evidence that mobile devices offer unique learning opportunities for residents outside of the classroom setting. Mobile devices also present challenges for medical educators, including the design and development of content optimized for the mobile platform, technical barriers such as connectivity and compatibility, and professionalism and privacy concerns in clinical settings. Residency programs and educators need to include learners as part of the instructional design team to fully utilize advantages of mobile learning while avoiding unintended consequences.

## Adjunctive Intrathecal Morphine Analgesia for Postoperative Pain in Adult Spinal Surgery

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**Introduction:** Adjunctive intrathecal morphine (ITM) has been suggested for spinal surgery due to potential to provide adequate analgesia at low dosages and ease of access to the thecal sac<sup>1-2</sup>. However, early studies have been limited by small sample sizes or conflicting results<sup>3-4</sup>. Also, ITM has been associated with adverse events such as pruritus and respiratory depression, deterring widespread use<sup>2</sup>. As a result, the goal of this study was to determine the effectiveness of ITM for reducing postoperative pain.

**Methods:** A search of PubMed, Web of Science, Clinicaltrials.gov, and Cochrane Central Register of Controlled Trials was conducted for randomized controlled trials. The results were screened independently by two reviewers based on pre-determined inclusion-exclusion criteria. Postoperative opioid consumption, pain scores, length of stay and adverse events were documented. Standard mean differences (SMD) were applied to continuous outcomes and Odds Ratios (OR) to dichotomous ones.

**Results:** A total of 8 randomized controlled trials with 393 subjects were included in the quantitative analysis. Compared to control, patients that received adjunctive ITM had significantly reduced morphine equivalent consumption and less pain in the 24 hours following surgery ( $p < 0.001$ ). Although there was no significant difference between the ITM and control groups in terms of occurrence of nausea, vomiting, sedation, or respiratory depression, the ITM group did experience more pruritus ( $p < 0.0001$ ). Although the ITM group had a shorter stay at the facility, this difference was not considered statistically significant.

**Conclusions:** Adjunctive intrathecal morphine provides a significant opioid sparing effect and reduction of pain in first 24 hours following spinal surgery despite an increase in incidence of pruritus.

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**Table 1. Postoperative opioid consumption, pain scores, length of stay**

Outcomes (# trials included)	# intrathecal morphine patients/ # control	Analysis Method	SMD (95% CI)	p-value
Opioid consumption (5)	150/100	Random effects	-1.07 (-1.71 to -0.42)	<b>0.001</b>
Pain scores (3)	85/57	Fixed effects	-0.55 (-0.90 to -0.20)	<b>0.002</b>
Length of stay (3)	107/63	Random effects	-0.69 (-1.58 to 0.20)	0.13

**Table 2. Postoperative complications**

Outcomes (# trials included)	Intrathecal morphine events (total patients)	Control events (total patients)	Analysis Method	OR (95% CI)	p-value
Respiratory depression (8)	6 (231)	0 (162)	Fixed effects	3.48 (0.41 to 29.32)	0.25
Nausea (4)	36 (105)	35 (77)	Fixed effects	0.86 (0.44 to 1.68)	0.67
Vomiting (4)	21 (105)	16 (86)	Fixed effects	1.22 (0.55 to 2.70)	0.62
Pruritus (6)	44 (189)	9 (126)	Fixed effects	4.09 (1.84 to 16.35)	<b>&lt;0.001</b>
Sedation (4)	17 (124)	19 (77)	Fixed effects	0.54 (0.22 to 1.32)	0.18

## Infection Rates with Use of Adjunctive Intrathecal Morphine in Posterior Instrumented Spinal Fusion Surgery: Preliminary Findings of a Retrospective Study

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**Introduction.** Intrathecal morphine (ITM) may be used as a supplement to opioid-based postoperative pain control regimens in spine surgery. In fact, ITM has been reported to reduce opioid consumption and pain scores in the first 20 hours following spine surgery<sup>1</sup>. ITM constitutes an attractive adjuvant treatment for postoperative pain due to ease of access to the thecal sac and the potential to produce an analgesic effect at low dosages<sup>2-3</sup>. However, the occurrence of surgical site infections may pose a deterrent to widespread adoption of ITM if associated infection rates are determined to be too high. As a result, the goal of this study was to compare rates of surgical site infections between those administered ITM and the control group among patients undergoing posterior instrumented spinal fusion surgery.

**Methods.** A retrospective review of the electronic medical records of patients that underwent posterior instrumented fusions between 2010 and 2016 was conducted. Patients that were given a single injection of intrathecal morphine prior to wound closure were compared to the control group (no ITM) in terms of the incidence of surgical site infections. Fisher's exact test was used to compare rates of infection.

**Results.** A total of 479 patients were incorporated into the analysis. Surgical site infections were found in 1.4% of patients in the ITM group compared to 1.2% in the control group. Although the infection rate was slightly higher in patients that were administered ITM, the difference between groups in terms of infection rates was not considered statistically significant ( $p=1.000$ ).

**Conclusions:** There was no significant difference between surgical site infection rates between the ITM and control groups in 479 patients that underwent posterior spinal instrumented fusion surgery between 2010 and 2016. These preliminary findings suggest that

the use of ITM for control of postoperative pain may not increase the occurrence of surgical site infections in posterior instrumented fusion.

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Incidence of Surgical Site Infections			
Patient Groups	Infection	No Infection	p-value
<b>Intrathecal Morphine</b>	1	72	1.000
<b>Control</b>	5	401	

## Air-Driven Syringe Pump for Anesthesia in Low-Resource Settings

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**Introduction:** There is a need for the delivery of safe anesthesia in low resource settings [1]. Intravenous anesthesia can be delivered safely, with less equipment (i.e. a syringe pump), than volatile anesthetics. Syringe pumps are however complex and costly. Low-cost (\$100) 3D printed pumps [2] have poor usability and no encoder feedback, thus unsuited for clinical use. Here we present a \$10 pump that addresses these obstacles.

**Method:** A 3D printed adapter holds two disposable syringes against each other (Fig 1a). An inexpensive diaphragm air pump (\$3) and solenoid release valve (\$2) drive one syringe, while a copper strip based capacitive encoder reads the drug level in the second syringe. Pump, valve and encoder interface directly to a small Field Programmable Gate Array (FPGA) chip (\$3). The entire device is powered via USB.

**Results:** The capacitive encoder for piston position feedback showed excellent linearity (Fig 1b). After preliminary calibration, flow rates were tested with a precision scale, showing an accuracy of >95% at a flow rate of 60mL/h (Fig 1c). At low rates an encoder quantification of 0.5mL caused a staircase-like spread in the infusion profile. This is a limitation in the current prototype and is not fundamental to the design. Syringes are easily swapped, as the system is not pressurized when idle.

**Conclusion:** We have made a \$10 infusion pump from a 3D printed adapter with encoder feedback, which allows easy replacement of syringes, two key requirements for practical clinical use. The performance of the prototype can be significantly improved, and the fluid sensor may be used to identify the drug in the syringe (e.g. distinguish Propofol from Remifentanyl). With a closed-loop controller onboard the FPGA, an ultra-low cost hardware-only automated anesthesia system may be feasible.



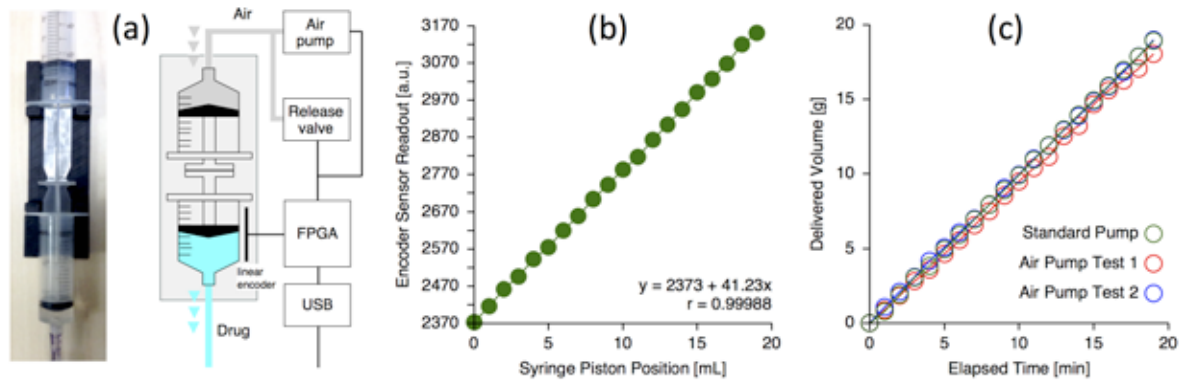


Fig.

1: 3D printed syringe clamp and schematic (a), encoder linearity (b) and 60mL/h flow accuracy (c).

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## Concurrent Piezo- and Photo-Plethysmography for Enhanced Signal Context

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**Introduction:** The plethysmogram (PG), in old times measured by mechanical displacement, is now typically captured in a finger photoplethysmogram (PPG). The PPG is sensitive to motion artifacts, and an accelerometer on the sensor can be employed to estimate signal quality [1]. In this work we consider an alternative: Having a piezoelectric transducer mounted inside the sensor finger boot generate a concurrent mechanical PG that can be used to detect motion through correlation with the PPG.

**Method:** A brass disk with a ceramic piezoelectric coating, commonly used as a "buzzer" in consumer electronics, was mounted inside a regular PPG finger boot (Fig. 1a). The voltage generated from finger pulsatile blood engorgement was sent to an oscilloscope through a high input-impedance pre-amplifier and filter (Fig. 1b). The PPG sensor was connected to a standard pulse oximeter, and the timing of the oscilloscope scan was chosen to be comparable to the PPG waveform readout on the pulse oximeter.

**Results:** Simultaneous measurements were performed with the pulse oximeter and the oscilloscope. The readings from the mechanical sensor were more sensitive to vibrations than the optical readings, as expected. Under static conditions the output from the two sensors correlated well (Fig. 1c). It was feasible to obtain a strong signal from both sensor elements simultaneously. However, the positioning of the mechanical sensor is important, with the strongest signal appearing from the fingertip.

**Conclusion:** Our findings show that a piezoelectric transducer can register mechanical blood pulsations inside a typical PPG finger boot sensor, concurrently with the optical PPG measurements. This opens for a new regiment of measurements in which the coherence of the PG readouts carry signal quality information, and possibly even new physiological information. For example, the relative timing of the two waveforms could potentially be used to detect changes in peripheral blood pressure.

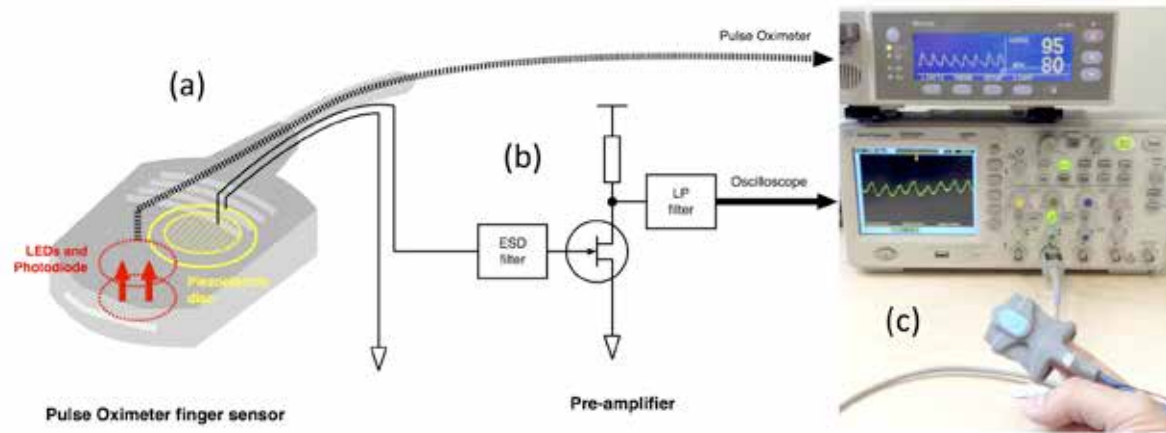


Fig.

1: Dual piezo- and photo-plethysmogram sensor (a), pre-amplifier (b), and picture of operation (c).

[1] Tamura T, Maeda Y, Sekine M, Yoshida M. Wearable Photoplethysmographic Sensors - Past and Present. Electronics 2014, 3, 282-302 (2014).

## **Pharmacy Labeling Can Cause, Rather Than Prevent, Drug Errors: An Unintended Consequence of Poor Design**

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**Introduction:** Hospital pharmacies rely on printing software for labeling drugs. The software typically interfaces with the electronic medical record to reduce error by automation, producing an adhesive label. Pharmaceuticals that require dilution, doses prescribed to pediatric patients, and drugs administered by syringe pump all run a risk of labeling error because they must be dispensed to the user in containers that are not labeled by the manufacturer. We report a 10-fold drug overdose caused by a design and usage flaw in pharmacy labeling, and discuss the ergonomic issues related to labeling intravenous drug preparations in high intensity and acuity environments like the operating room.

**Report of case:** A 15-year-old healthy girl with scoliosis underwent thoracic posterior spinal instrumentation and fusion. Anesthesia was induced with sevoflurane and converted to total intravenous anesthesia with propofol and remifentanyl infusions after establishing vascular access. Tranexamic acid was administered, first a loading dose of 10mg/kg over 20 minutes, followed by an infusion of 5mg/kg/h. This dose has been shown to maintain therapeutic levels in children, and was administered by a syringe pump (Medfusion 3500, Smiths Medical ASD Inc., St. Paul, MN, USA) from a 60ml syringe that was dispensed from the operating room pharmacy. Although these pumps have "drug libraries" which load preset parameters for each drug, the hospital has not implemented that software; instead the pumps are programmed manually by the user. After completion of the loading dose, the maintenance infusion was begun after confirming that the pump was programmed in accordance with the information on the syringe label, which depicted a concentration of 5mg/ml. Soon after starting surgery the pump alarmed, indicating a near empty syringe, which alerted the anesthesiologist that there was a problem, as the syringe should have lasted the entire case. Upon close inspection, it was noted that the label was ripped and stuck back on the syringe, obscuring the "0" in the drug concentration, which should properly have read "50mg/ml" rather than 5mg/ml. The infusion was stopped, and the patient suffered no consequences of the error.

**Discussion:** There are many regulations that stipulate how manufacturers must design drug vial labels, however despite numerous studies and advisories about optimal labeling of syringes

and infusions, there is no standardized labeling practice after dilution, reconstitution, or preparation of drugs for administration. Indeed, there is often no communication between the pharmacy and end-user (anesthesiologist or nurse) regarding the formatting or use of drug labels on these products to enhance safety and identification. Labels can emphasize data of little use to the clinician while obscuring the information that is critical for safe administration of the drug. Labels not specifically designed to fit on syringes further obscure these data, and orientation of print and international standardized color codes may be ignored.

**Conclusions:** Hospital pharmacies and anesthesiologists must work together to utilize drug labels that are designed to enhance readability and instantaneous recognition of clinically important drug information, especially when syringes are mounted in pumps. Labeling of syringes with stickers not optimized for this purpose compound the risk of drug errors. This is of greater importance as anesthesiologists rely on pharmacies to mix and prepare drugs. Standardized concentrations with pre-programmed pump drug libraries, use of barcodes or RFID may also be effective strategies to reduce errors.

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## **Comparison of Hemodynamic Responses and Upper Airway Morbidity Following Orotracheal Intubation in Hypertensive Patients - Macintosh Direct Laryngoscope Versus Glidescope Videolaryngoscope**

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**Background:** Laryngoscopy and tracheal intubation is associated with a hemodynamic response caused by sympathetic reflex provoked by stimulation of orolaryngopharynx and is more pronounced & unpredictable in hypertensive patients due to increased activity of sympathetic nervous system. Various techniques and drugs have been used to reduce the pressor response with variable success. Glidescope®videolaryngoscope(GVL) is a video intubation system with 60° angle blade that provides excellent laryngeal view, does not require alignment of oral, pharyngeal and laryngeal axes for visualization of glottis thus, causing less stimulation of orolaryngopharynx. The aim of this study was to compare hemodynamic responses (Blood pressure and heart rate) and airway morbidity using the Macintosh direct laryngoscope(MDL) and the Glidescope® videolaryngoscope.

**Methods:** Fifty hypertensive patients controlled on antihypertensive medications scheduled for elective surgery under general anaesthesia were randomly assigned to one of the two groups group GVL(n=25) or group MDL(n=25). All patients were induced with a standard anesthetic regimen and all the tracheal intubations were performed by experienced anesthesiologists skilled in the use of both intubation techniques. Heart rate(HR), Systolic blood pressure (SBP), Diastolic blood pressure(DBP), Mean blood pressure (MBP) were recorded at baseline, after induction, pre intubation, at intubation, 1, 2, 3, 4 and 5 min after intubation. Time to intubation, number of attempts, complications during intubation and postoperative airway complications (sore throat, hoarseness, dysphagia, and cough) assessed 24 h after the surgery were also recorded.

**Results:** There was a statistically significant increase in SBP, DBP and MBP at intubation (( $P=0.003$ ,  $0.013$ ,  $0.03$ ), 1 min ( $P=0.001$ ,  $0.012$ ,  $0.02$ ), 2 min ( $P=0.04$ ,  $0.02$ ,  $0.04$ ) and 3 min ( $P=0.02$ ,  $0.01$ ) in the MDL group as compared to GVL group. There was no significant difference in HR between two groups at all time points. The time to intubate was significantly greater in the GVL group as compared to MDL group ( $P=0.0006$ ). There was no significant difference in the incidence of intraoperative and postoperative complications between the two groups except for dysphagia which was more in GVL group as compared to MDL group.

**Conclusion:** In the hands of an experienced anaesthesiologist,,the use of Glidescope® Videolaryngoscope in controlled hypertensive patients is associated with less hemodynamic response as compared to Macintosh Laryngoscope despite the longer intubation time required with Glidescope® Videolaryngoscope.

## Patient Controlled Sedation and Changes of EEG During Dental Treatment

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**Purpose:** The demand for sedation in dental practice is increasing due to fear and anxiety in dental clinic. Patient controlled sedation can reduce the risk for the patient's depression of cardiovascular function, respiratory depression, and airway obstruction as the injection of medication can be controlled by the patient. However, proper bolus dose and lock-out time in sedation has not been widely documented. Hence, the aim of the study is to produce an adequate protocol by evaluating the patients' EEG.

**Method:** The study was approved by the Institutional Review Board(IRB). Healthy adult participants were recruited, and randomly divided into two groups: 30 participants with propofol and 30 participants with midazolam. In each group, participants were categorized into three subgroups: 10 participants of low bolus dose and short lock-out time, 10 participants with middle bolus dose and short lock-out time, and 10 participants with high bolus dose and long lock-out time. Patient controlled sedation was performed using a basic patient monitoring and respiration monitoring such as EEG and CO<sub>2</sub>. The clinical research procedure was conducted in two steps. First, the participants were required to push the demand button without dental scaling. Subsequently, participants pushed the demand button with dental scaling. During sedation, we evaluated the patients' vital signs, degree of operators' satisfaction and EEG level.

**Results :** Total 60 people participated in this study. Adequate sedation was carried out in both midazolam and propofol group. In propofol groups, those with high bolus dose injected patients showed 50% failure of scaling due to patient's agitated reaction during the treatment.

Temporary hypoventilation occurred in high propofol dose group. The low dose did not progress to deep sedation stage and frequently pressed the button. Midazolam group had more outstanding outcome than propofol group in practitioner's evaluation. Both groups showed increased beta wave powers in EEG findings during conscious sedation. And in case of unconsciousness both groups showed increased upper alpha wave powers in EEG findings. Among 6 groups, midazolam low bolus dose(0.002mg/Kg) and short lock-out time (1 min) group presented the most effective dental sedation state.

**Conclusion:** When performing dental treatment under patient controlled sedation, midazolam is better than propofol. Furthermore, setting midazolam bolus dose as 0.002mg/Kg and lock-out time as 1 minute were found to retain good sedation state for the patients, and high satisfaction for the practitioners.



## Augmented Index of Finger Pulse Oximeter During Mild Hypovolemia

**Presenting Author:** Tiantian Shi, M.D.

**Co-Authors:** Tiantian Shi, M.D., Christopher Choi, M.D., Kirk H. Shelley, M.D.Ph.D., David G. Silverman, M.D., Aymen A. Alian, M.D. Anesthesiology, Yale University School of Medicine, New Haven, CT, USA.

**Introduction:** Lower Body Negative Pressure (LBNP) is a known method for simulating hypovolemia. The forehead is relatively immune to the sympathetically mediated vasoconstriction, while the finger has rich sympathetic supply. The position of the dicrotic notch of the arterial waveform is a sensitive indicator of vascular tone.<sup>1</sup> We herein calculate the augmentation index (AI) of the plethysmographic (PPG) waveform, defined as the ratio between PPG peak height after dicrotic notch ("DNP")/ PPG pulse amplitude ("Pulse")(figure1A). LBNP on the order of -15 mmHg seems to be equivalent to blood loss of 333 ml, while LBNP of -30 mmHg equivalent to blood loss of 666 ml, LBNP of 45 mmHg seems to be equivalent to blood loss of 1000 mL.<sup>2</sup> During hypovolemia, the increase in sympathetic tone is usually expressed by changes in heart rate (HR) and heart rate variability (HRV). LF represents sympathetic tone, HF represents parasympathetic tone, while LF/HF represents sympatho-vagal balance.<sup>3</sup> The present study compares the PPG AI of the forehead and finger, together with changes in HR and HRV during LBNP.

**Methods:** With IRB approval, 17 healthy volunteers age 23-39 underwent a LBNP protocol consisting of a 3 min baseline and successive 5 min intervals at -30, -60 and -75mmHg. Heart rate and PPG signals were recorded at finger and forehead at 100 Hz. Heart rate variability (HRV) was calculated using AHA definitions (LF 0.04-0.15 Hz; HF 0.15-0.4Hz) with commercially available software (Chart 5.5.5, ADInstruments). During each phase of LBNP, ratio of DNP/Pulse (=AI) was determined for 20 successive PPG beats. Average percentage change was calculated from baseline:  $=100 \times (\text{post-baseline}) / \text{baseline}$ . Comparisons were made with ANOVA and data was expressed as median (1<sup>st</sup> quartile to 3<sup>rd</sup> quartile). P value <0.008 was considered significant (Bonferroni correction).

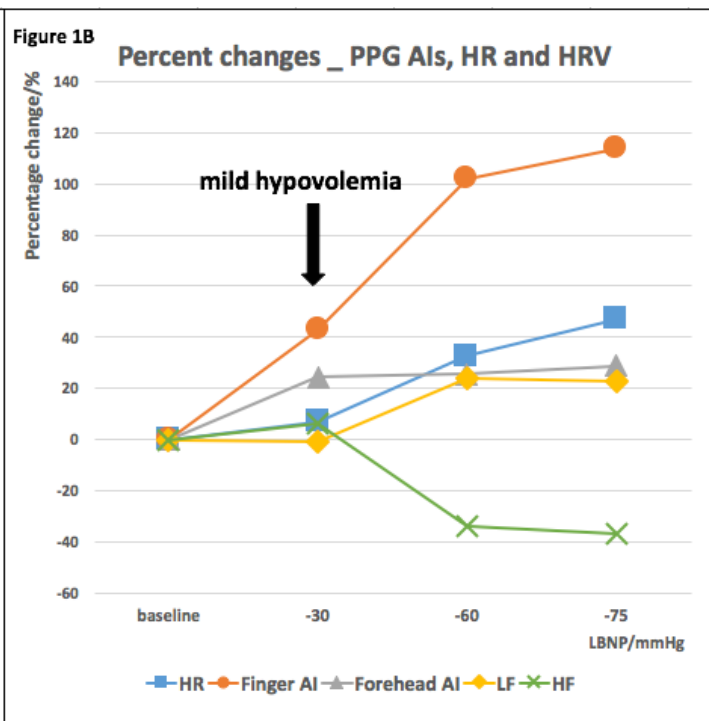
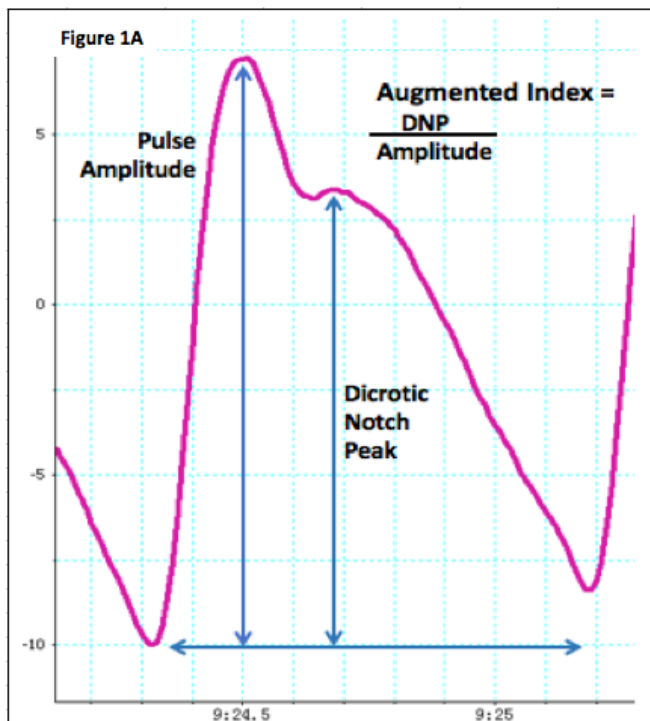
**Results:** As summarized in figure1B, both HR and AI increased with progression of LBNP. At -30 mmHg ( $\approx 666\text{mL}$  of blood loss  $\approx 10\%$  of blood volume), the relative increases in HR, HRV (LF, HF, LF/HF) were 7%(2% to 9%), 2%(-8% to 12%), -8%(-31% to 26%), 10%(-22% to 61%)( $p=0.0005$  for HR,  $p=0.44$  for LF,  $p=0.50$  for HF and  $p=0.43$  for LF/HF). Whereas the percent changes of finger AI and forehead AI were 43%(30% to 90%), 24%(13% to 31%), respectively ( $p<0.002$  for interparameter difference).

**Conclusion:** The data show that AI clearly distinguished between the responses of the Finger and Forehead to progressive hypovolemia. Finger PPG AI is preceding in changes in HR and HRV during mild to moderate hypovolemia (-30 mmHg). With the progress of LBNP to -60, the HRV changes in the same direction as in the finger PPG AI. Thus PPG AI is a useful tool to detect mild to moderate hypovolemia.

**References:** 1. Am Heart J 138 (3 Pt 2), 220-224. 9 1999

2. J Appl Physiol 116: 406-415, 2014

3. Science 1981 Jul 10;213(4504):220-2



## Effect of Phenylephrine on PPG Augmented Index and Local Vascular Compliance

**Presenting Author:** Tiantian Shi, M.D.

**Co-Authors:** Tiantian Shi, M.D., Kirk H. Shelley, M.D.Ph.D., David G. Silverman, M.D., Aymen A. Alian, M.D. Anesthesiology, Yale University School of Medicine, New Haven, CT, USA.

**Introduction:** The pulse oximeter is one of the standard monitors used in the operating room. It is designed to monitor the patient's arterial oxygen saturation and heart rate. Study of the pulse oximeter waveform (PPG) provides valuable information regarding patient physiology.

Phenylephrine is a direct-acting, predominantly  $\alpha(1)$  adrenergic receptor (AR) agonist, produces systemic vasoconstriction.

The position of the dicrotic notch of the arterial waveform is a sensitive indicator of vascular tone.<sup>1</sup>We are calculating Augmented Index (AI) from the PPG waveform as shown in figure(1) to describe the notch position.

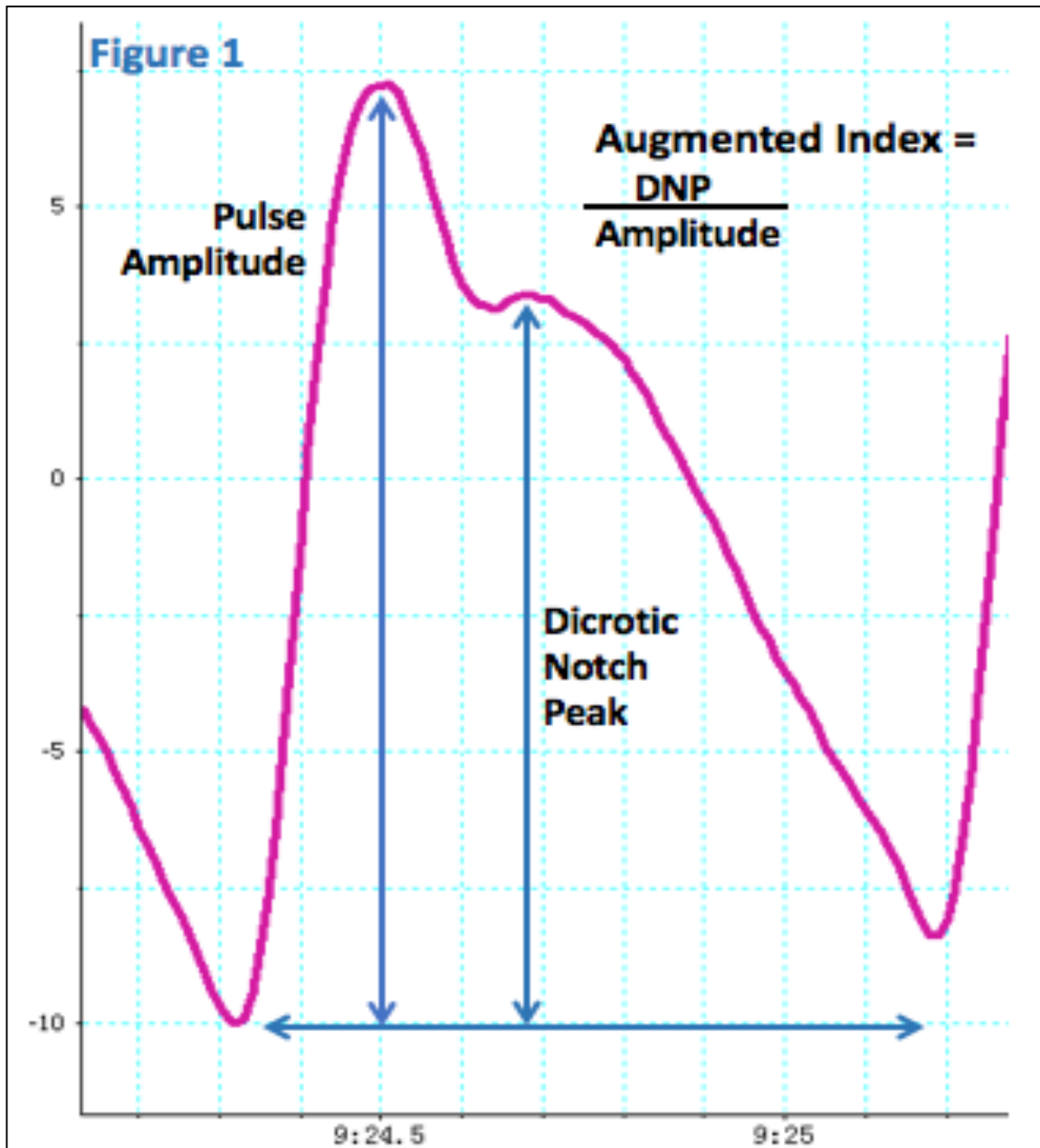
The present study compared the PPG augmented index, arterial compliance (PPG amplitude/arterial pulse pressure), together with other vital signs (heart rate and blood pressure) during multiple episodes of phenylephrine administration.

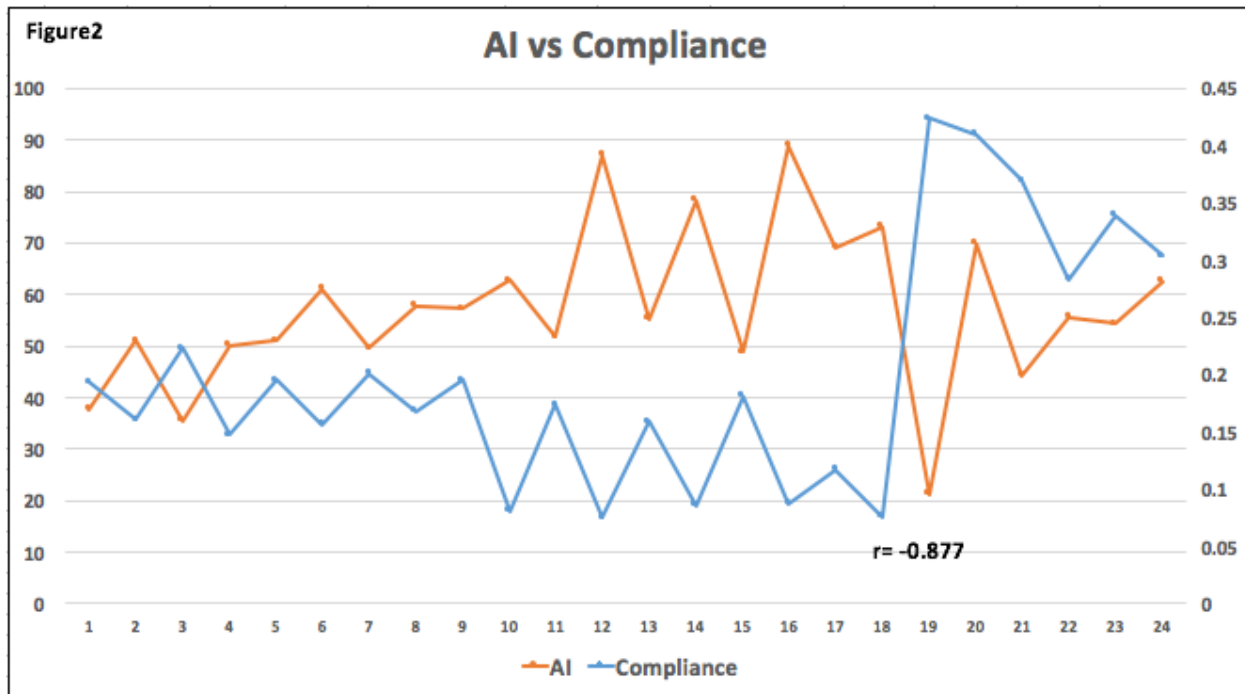
**Methods:** With IRB approval, this observational study was conducted. Arterial blood pressure (BP), finger PPG were recorded at 100 Hz from clinical monitors (GE; Fairfield, CT) with a data acquisition system (Collect 5/S – GE; Fairfield, CT). We used LabChart 7.37 (ADInstruments, Boulder CO) to analyze these waveforms. PPG augmented index is calculated as shown in figure (1) for 20 successive PPG beats. Comparisons were made with Wilcoxon signed-rank test. P value<0.05 was considered significant.

**Results:** After bolus of phenylephrine, BP and AI are all increased and compliance is decreased (all p values<0.05). HR didn't significantly change (p value=0.26). PPG augmented index tracked well the changes in the Systolic BP (SBP), Diastolic BP (DBP), Pulse BP (PP) and Mean BP (MAP), the correlation was 0.83, 0.81, 0.83 and 0.82 respectively. There was a very good negative correlation between the arterial compliance derived from PPG and SBP, DBP, PP and MAP, the correlation was - 0.96, - 0.94, -0.97 and - 0.96 respectively. The correlation between compliance and AI was 0.-87(Figure2).

**Conclusions:** PPG waveform provides valuable information about local compliance and vascular tone.

**References:** 1. Am Heart J 138 (3 Pt 2), 220-224. 9 1999





## The Effect of Phenylephrine on Peripheral Pressure Volume Loops

**Presenting Author:** Tiantian Shi, M.D.

**Co-Authors:** Tiantian Shi, M.D., Kirk H. Shelley, M.D.Ph.D., Aymen A. Alian, M.D.  
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**Introduction:** The left ventricular pressure-volume area (PVA) represents the total mechanical energy generated by ventricular contraction. The meaning of peripheral pressure-volume area is to be determined. The compliance of the PV loop is related to the slope of the loop<sup>1</sup>. While the “fish-tail” of the loop appears to correspond to venous pulsations.<sup>2</sup> Phenylephrine is a direct-acting, predominantly  $\alpha$  (1) adrenergic receptor (AR) agonist, produces systemic vasoconstriction. The present study compared the changes before and after the use of phenylephrine bolus on peripheral arterial PV loop and peripheral venous PV loop.

**Methods:** With IRB approval, this observational study was conducted. Arterial blood pressure (BP), finger PPG were recorded at 100 Hz from clinical monitors (GE; Fairfield, CT) with a data acquisition system (Collect 5/S – GE; Fairfield, CT). We used LabChart 7.37 (ADInstruments, Boulder CO) and Mathematica 10.4.0.0 for analysis and calculation. Arterial BP and PPG high pass (derived from PPG waveform) are mixed to form the arterial pressure-volume loop. PVP low pass (derived from PVP waveform) and PPG low pass (derived from PPG waveform) were mixed to calculate venous PVA, as shown in Figure (1).

**Results:** As shown in Figure2, after bolus of phenylephrine, there was significant increase in the arterial (2-A) PVA with significant reduction the venous (2-B) PVA (p values<0.001) Figure 2 showed an example of the effect of phenylephrine on both loops. There is a strong negative correlation between arterial PVA and venous PVA( $r=-0.88$ ).

**Conclusion:** Simultaneous analysis of the arterial and venous loop provide more information about the compliance and the volume status.

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Figure 1

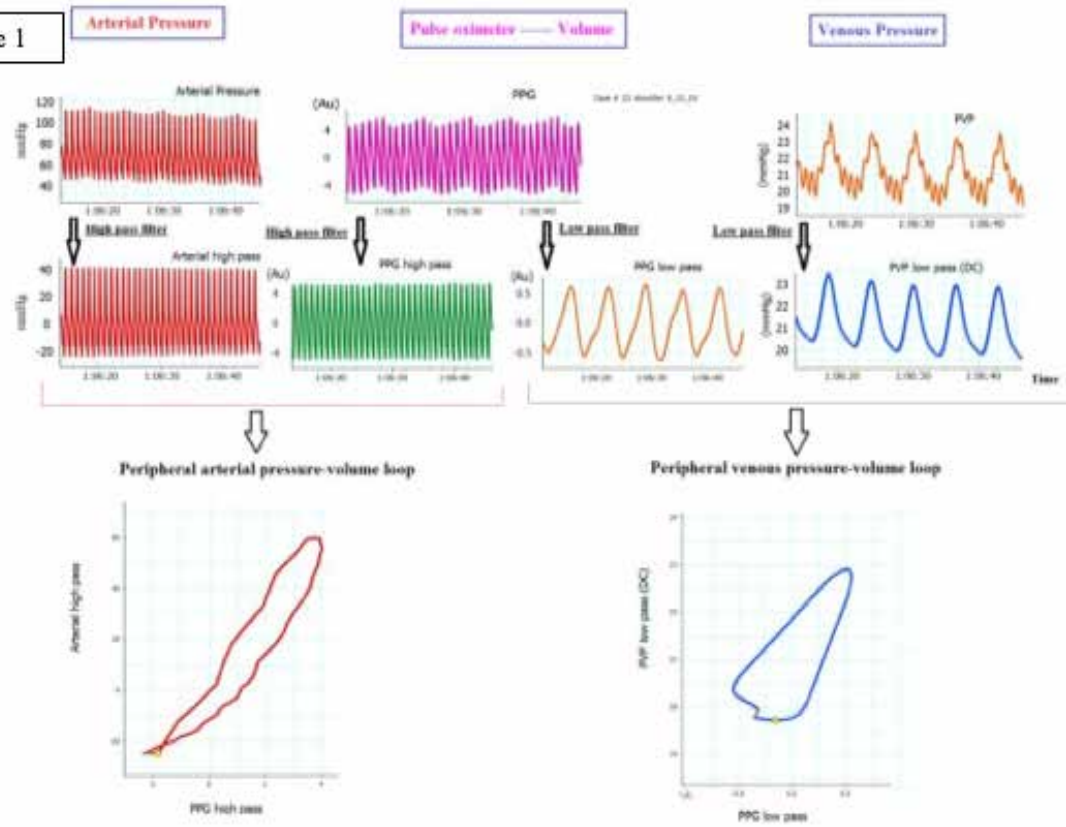
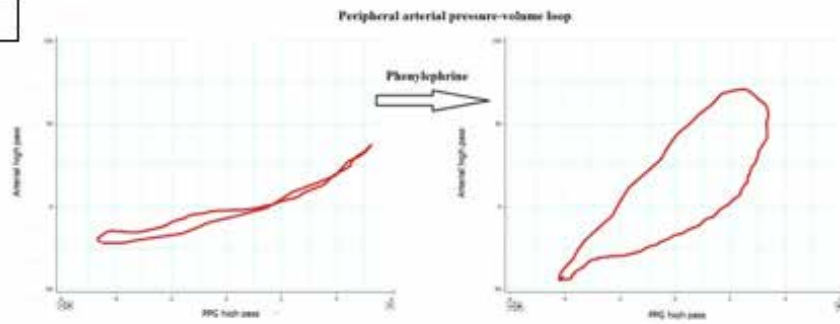
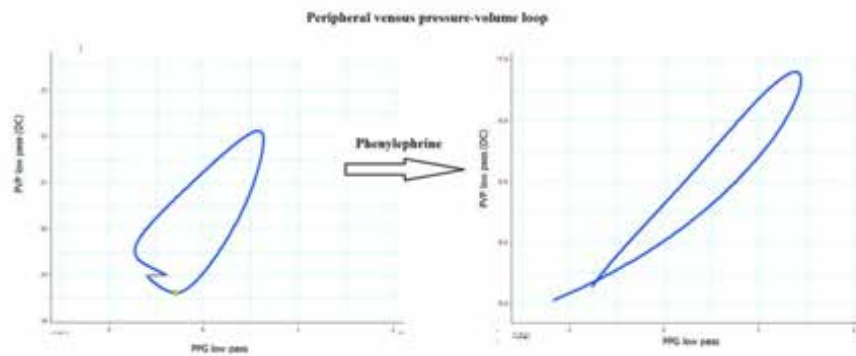


Figure 2

A



B



## **When Technology Hurts Instead of Helps: The Impact of Supraglottic Airway Devices on Neck Masses During Magnetic Resonance Imaging in Children**

**Presenting Author:** Allan Simpao, MD, MBI, The Children's Hospital of Philadelphia

**Co-Authors:** Vladislav Obsekov, University of Pennsylvania; Jorge Galvez, MD, The Children's Hospital of Philadelphia

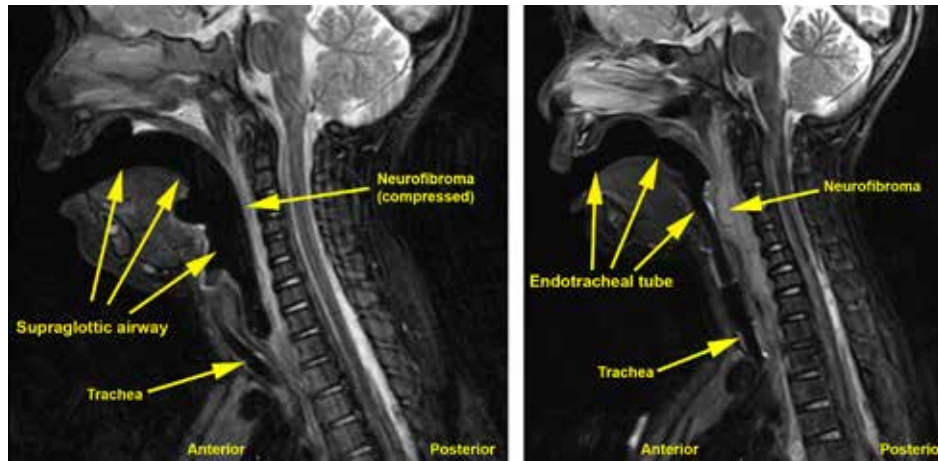
**Background/Introduction:** General anesthesia (GA) with an airway device is used for radiological studies in children to limit excessive motion and improve image quality; however, scant literature exists describing the potential for devices such as supraglottic airways (SGAs) to cause *in vivo* magnetic resonance imaging (MRI) artifact and misdiagnosis. We conducted a retrospective observational study to determine how often at our institution SGAs affected the appearance of neck masses in children who received GA for MRIs.

**Methods:** We queried our electronic databases for patients less than 18 years of age who had neck MRIs under GA with 1) at least one MRI with an SGA and 2) at least one MRI with either a natural airway or endotracheal tube (ETT) during January 2005 to January 2015. Magnetic resonance angiograms were excluded. Two reviewers [VO, AFS] reviewed radiologists' reports and MRI images to assess the impact of the SGA on neck masses.

**Results:** Over 8000 patients had MRIs with GA during the study period. Twenty-eight patients had at least one neck MRI with a SGA and at least one MRI with an ETT or natural airway. Ten of the 28 patients did not have neck masses and were excluded from the study. Of the 18 patients with neck masses and an airway device change, 12 had masses that were in areas that could be affected by an SGA; of these 12 patients, 11 had a documented change in fibroma appearance. Of the remaining six patients, three had a mass that was on the dorsal neck, and three patients had masses that were distal to the SGA's tip and therefore unaffected by the SGA.

**Conclusion:** Airway device changes to or from an SGA in patients with neck masses were a rare occurrence at our institution during a recent ten-year period. However, when an SGA is used in a patient with a neck mass where an SGA is typically seated, the appearance of the neck mass is almost always significantly impacted. SGAs may affect the appearance of the submandibular, retropharyngeal and prevertebral cervical regions, creating the potential for diagnostic error during MRIs and treatment issues during radiation therapy. Our findings support avoiding SGAs in children who are undergoing imaging studies and possibly radiation therapy for neck masses.





**Figure 1.** Sagittal images from two serial magnetic resonance imaging (MRI) studies to assess a 6-year-old child's head and neck neurofibromas. The child underwent general anesthesia and placement of an airway device for both studies. The left panel shows the use of a supraglottic airway during the child's 2012 MRI. The right panel shows the child's 2015 MRI during which a tracheal tube was used. Both MRI images are oriented with the child's anterior on the left and posterior on the right.

## **Building a Natural Language Processing Tool to Identify Acute Chest Syndrome in Children with Sickle Cell Disease**

**Presenting Author:** Allan Simpao, MD, MBI, The Children's Hospital of Philadelphia

**Co-Authors:** Brian Park, MS3, Drexel University College of Medicine; Luis Ahumada, PhD, The Children's Hospital of Philadelphia; Jorge Galvez, MD, MBI, The Children's Hospital of Philadelphia

**Introduction:** Acute chest syndrome (ACS) is a debilitating complication of sickle cell disease (SCD). Studies have reported the prevalence of perioperative ACS based on billing codes, but not on actual clinical reports. Natural language processing (NLP) is a method by which computers use algorithms to analyze and understand the human language. NLP tools can be used to analyze clinical documentation to identify disease presence and can potentially reduce time and error in processing manual clinical reports. One example of a clinical NLP application is in identifying venous thromboembolism from ultrasound reports. However, in order to apply and validate the NLP tool, a curated data set must be built and key words and phrases must be identified. Thus, we performed a review of anesthesia information management system (AIMS) and electronic health record (EHR) data to build a curated data set of ACS in SCD patients undergoing general anesthesia for surgery.

**Methods:** The AIMS and EHR databases were queried to identify patients with sickle cell disease who underwent general anesthesia at The Children's Hospital of Philadelphia between Jan 1, 2009 and May 1, 2014. Two individuals independently reviewed patients' charts manually for the ACS clinical criteria, and then recorded keywords in the clinical documentation that were associated with the diagnosis.

**Results:** A total of 327 SCD patients met the study criteria; the study cohort was 54% male, median weight was 32.9 kg (IQR 18-48), and median age was 8.8 years (IQR 4-14). Sixteen cases of ACS were identified. The most frequently occurring terms in the ACS patients' documentation belonged to three categories: signs/symptoms ("fever", "febrile"), radiographic findings ("infiltrate"), and medications ("ampicillin", "azithromycin").

**Conclusion:** Reviewing the AIMS and EHR databases manually for clinical documentation of ACS was feasible yet laborious and time consuming. The curated data set will be used to validate the NLP tool and apply it to other clinical documentation. Successful application of the NLP tool will facilitate mining the AIMS and EHR for future data-driven outcomes and quality assurance projects involving sickle cell patients and ACS. The same methodology can be applied to other clinical diagnoses in future studies.

## Screening and Monitoring of Postoperative Respiratory Compromise to Reduce Code Blues

**Authors:** Dennis Jensen RRT<sup>1</sup>, Joseph Williamson RRT<sup>1</sup>, Greg Allen MD<sup>1</sup>, Bryan Wales MD<sup>1</sup>, Cari Pearson MN RN-BC<sup>1</sup>, Edna Zeller MSN RN-BC CDE<sup>1</sup>, Shanna Myers MSN RN<sup>1</sup>, Linda Foist MSN RN CNRN CRRN<sup>1</sup>, Diane Damitio BSN RN MBA<sup>1</sup>, Michelle James MM BSN RN MBA CCRN<sup>1</sup>, Greg Spratt BS RRT, CPFT<sup>2</sup>

**Background:** Respiratory Compromise (RC) is a state in which there is a high likelihood of decompensation into respiratory insufficiency, failure or death, but in which specific interventions (enhanced monitoring and/or therapies) might prevent or mitigate decompensation.<sup>i</sup> RC is the leading cause of ICU admissions,<sup>ii,iii</sup> rapid response calls<sup>iv,v</sup>, and code blues<sup>vi,vii</sup>. Costs for RC are among AHRQ's '*Top 5 Most Rapidly Increasing Hospital Costs*'.<sup>viii</sup> General Care Floor patients who develop RC have 29 times higher mortality.<sup>ix</sup> In an analysis of primary respiratory arrests, 64% were classified as potentially avoidable.<sup>x</sup>

Despite recommendations from many organizations including APSF<sup>xi</sup> and the Joint Commission<sup>xii</sup> recognizing the importance of continuous electronic monitoring for patients receiving opioids, many hospitals still rely on intermittent vital sign checks which may leave patients at risk of unrecognized RC.

**Methods:** A retrospective quality analysis was performed for a program designed to reduce 'code blue' events from RC on 3 postoperative GCFs. Data was collected for a period of 20 months prior to, and 36 months following, the program implementation. The program consists of STOP-BANG screening and continuous capnography/oximetry monitoring for those patients with a score of  $\geq 5$ . Patients with an Integrated Pulmonary Index™ (IPI) score of  $\leq 7$  based on capnography/oximetry received further assessment and intervention per hospital protocol (Figure 1).

### Results:

	<b>Total Non-ICU Code Blues at Hospital (per month)</b>	<b>Code Blues on 3 postoperative general care floors included in program (per month)</b>
<b>Prior to program implementation</b> (20 month baseline) - January 2012- August 2013.	107 total codes / 20 months =  5.35 codes/ month	43 total codes / 20 months =  <b>2.15 codes/month</b>

<b>After program implementation</b> (36 month period) September 2013-August 2016.	293 total codes/36 months 8.13 codes/month	31 total codes/36 months <b>0.861 codes/month</b>
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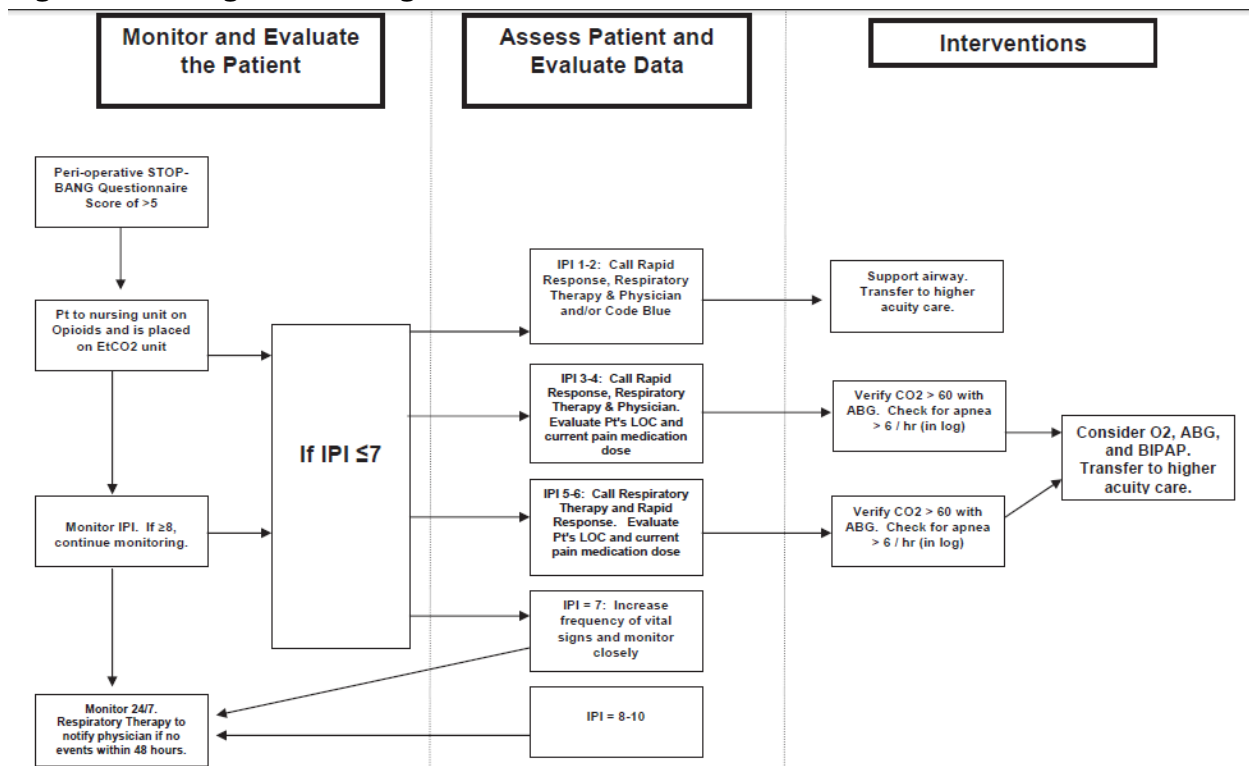
Prior to program implementation, there were 2.15 codes per month on the floors included. Following program implementation, there were 0.861 codes/month representing a 60% reduction in codes/month on postoperative floors in the program. No capnography-monitored patients experience a code blue.

**Conclusions:** Upon implementation of STOP-BANG screening and capnography/oximetry monitoring with IPI of those at increased risk, there was a 60% decline in code blue events on the postoperative GCFs. Broader application of this protocol to patients receiving opioids may result in reductions in serious adverse patient outcomes.

#### Author Notes:

- 1- Affiliated with Providence St. Peter Hospital in Olympia, WA.
- 2- Director of Market Development at Medtronic.

**Fig 1. Screening, Monitoring, and Intervention Protocol**



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## Usability Evaluation of Panda, a Smartphone Application Designed to Support Pediatric Post-Operative Pain Management at Home

**Presenting Author:** Terri Sun MD,

**Co-Authors:** Ian Miao BSc, Dustin Dunsmuir MSc, Nicholas West MSc, Matthias Görges PhD, Gregor M Devoy, Gillian R Lauder FRCA, J Mark Ansermino FRCPC

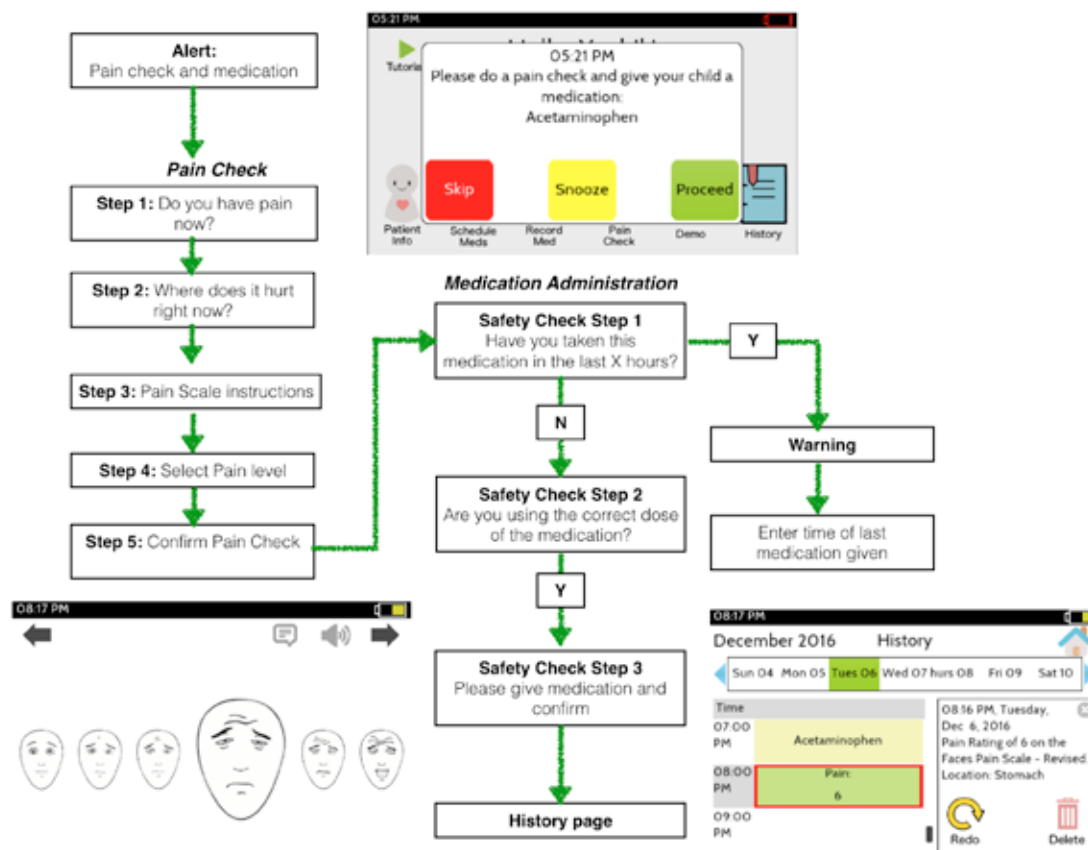
**Introduction:** The growing trend towards ambulatory surgery has shifted the burden of post-operative pain management from health care providers to families [1]. However, studies suggest that a child's pain is often poorly managed at home [2-4]. Inadequate acute pain control can lead to slower functional recovery, poor oral intake, sleep disturbances and behavioural changes. It can contribute to post-traumatic stress disorder and chronic pain [5-7]. Support for parental decision-making, in the form of an accessible and user-friendly smartphone app, has the potential to reduce unnecessary and severe post-operative pain experienced by children: *Panda* is such an app, designed to aid parents in 1) the assessment of their child's pain, 2) administering pain medications at appropriate times, and 3) tracking pain and medications given. The purpose of this study was to assess the usability of *Panda* with potential users to evaluate its ease of use and display of information.

**Methods:** With REB approval and informed consent, parents, nurses and adolescents were enrolled into the study. After watching a 2-minute tutorial video on how to use the app, the user was given a simulated scenario of managing a child's post-operative pain. Usability issues were identified from observations while each user performed 4 tasks. Users were encouraged to 'think aloud' [8]. Written feedback and a Computer Systems Usability Questionnaire (CSUQ) [9] were completed. The Usability Problem Taxonomy (UPT) [10] was used to structure and code errors. Severity of each problem was graded on a 1 (low) to 4 (critical) scale.

**Results:** Twelve nurses, 13 parents, and 5 adolescents were recruited for 3 rounds of usability (n=30, 10 per round). The design team modified *Panda*, based on usability data, after each round. A total of 103 problems were identified and organized into 19 discrete usability issues, with a median (range) severity rating of 3 (1-3), or "serious". These problems occurred mostly during the setup of medication alerts (33%), editing a given medication (16%), adding a new medication (13%), and safety checks for medication administration (10%). Most problems were classified as artifact issues (19 total) within the visual (53%), language (16%) and manipulation (16%) categories. Overall, users felt the app was usable, as shown by CSUQ median (range) score of 2 (1-4). Overall 67% (20) of users indicated that they would use *Panda* for management of their child's post-operative pain.

**Conclusion:** Initial usability testing of the *Panda* app yielded usability issues mostly related to medication scheduling, recording and editing. The majority of these usability issues pertain to visual presentation, language within the app, and user manipulation of the interface. A feasibility trial in hospital is currently underway to assess how parents and their child interact with the app in a supervised, but safe, setting, in order to identify further usability issues and barriers that may hinder safe and effective use at home.

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**Figure 1:** Flowchart of *Panda* App Pain Assessment and Medication Administration Functions. It illustrates the flow of a user's response to an alert to perform a pain check and give medication through to their completion with a review of the documented values.

## A Novel Mandibular Advancement Bite Block Prevents Hypoxemia During Sedative Endoscopy

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**Co-Authors:** Chien-Kun Ting, MD, PhD<sup>1</sup>; Ming-Chih Hou, MD<sup>2</sup>; Chun-Li Lin, PhD<sup>3</sup>, Huihua Chiang, PhD<sup>3</sup>, Mei-Yung Tsou, MD, PhD<sup>1</sup>

<sup>1</sup>Department of Anesthesiology, Taipei Veterans General Hospital, <sup>2</sup>Department of Medicine, Taipei Veterans General Hospital, <sup>3</sup>Department of Biomedical Engineering, National Yang-Ming University, Taipei, Taiwan

**Introduction:** During sedated endoscopic examinations, upper airway obstruction often occurred due to respiratory depression and airway collapse resulting in hypoxemia. Airway management with oxygenation, Larson maneuver, jaw thrust, or insertion of nasal airways by trained anesthetic personnel is required during upper airway obstruction emergencies. Mandibular advancement devices have been widely used to treat mild to moderate obstructive sleep apnea syndrome. A modified mandibular advancement bite block (Figure 1) that provides protrusion of mandible and inlet for upper gastrointestinal endoscopy could prevent airway obstruction during sedated upper gastrointestinal endoscopic examinations. Purpose of this study is to evaluate the efficacy of this novel mandibular advancement bite block for prevention of hypoxemia, decrease airway obstruction and decrease airway intervention events.

**Methods:** Patients eligible for enrollment were randomly assigned to standard bite block (0mm mandible advancement) or 6 mm mandibular advancement bite block groups. After anesthetic induction, upper gastrointestinal endoscopy was performed. Primary endpoint was area under curve of oxygen desaturation at 95% (AUCdesat) (Figure 2). Secondary endpoints were degree of upper airway obstruction and number of rescue events.

**Results:** 60 Patients were enrolled. AUCdesat was significantly lower for 6 mm advancement bite blocks vs standard bite block ( $18 \pm 11.19$  vs  $176 \pm 61.49$  sec%,  $p=0.044$ ). The 6mm bite block also showed significant reduction in adverse events such as subclinical airway obstruction, severe airway obstruction requiring chin lift or jaw thrust, or hypoxemia ( $p=0.007$ ) (Figure 3). The incidence of adverse events was 70% in standard bite block group and 33% in the mandible advancement group.

**Conclusion:** The mandibular advancement bite block can decrease hypoxemia, provide smoother entry of endoscope, prevent airway obstruction during upper gastrointestinal examination under sedation and prevent adverse events.





Figure 1. A modified mandibular advancement bite block that provides protrusion of mandible and inlet for upper gastrointestinal endoscopy.

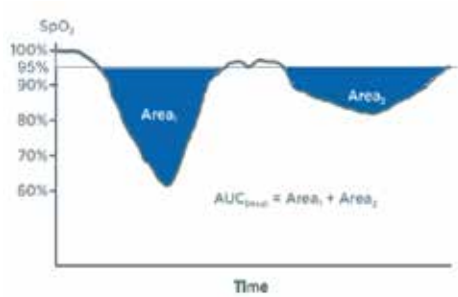


Figure 2. Area under curve of oxygen desaturation at 95%

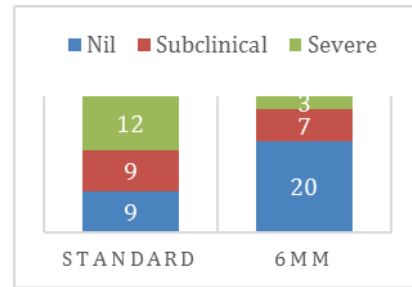


Figure 3. Adverse events. Number of events during endoscopic examination.  
 Nil: no apnea, obstruction or hypoxemia;  
 Subclinical: apnea, obstruction or events requiring chin lift/ jaw thrust that did not result in hypoxemia;  
 Severe: apnea, obstruction or events requiring chin lift/ jaw thrust that resulted in hypoxemia.

## **The Impact of Alertwatch®, a Multifunctional Decision Support System, on Intraoperative Process Measures and Postoperative Outcomes**

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**Co-Authors:** Sachin Kheterpal, MD, MBA, University of Michigan; Amy Shanks, PhD, University of Michigan

**Background/Introduction:** We hypothesized that AlertWatch®, an intraoperative multifunction alerting decision-support system, may improve clinical process measures and postoperative outcomes.

**Methods:** AlertWatch®, a FDA-cleared alerting and decision support system, was evaluated in a six-year single-center observational study of surgical patients at an academic medical center, Figure.<sup>1,2,3</sup> Electronic record data were compared for a 22-month period prior to implementation (historical control group) and a four-year period after the implementation (parallel control group). Use of the system was at the discretion of the anesthesia provider. Inclusion criteria were adults under general anesthesia, advanced medical disease, surgical case duration  $\geq 60$  minutes, and inpatient length of stay  $\geq$  two days. The process measures were adherence to accepted intraoperative process measures (avoidance of intraoperative hypotension, ventilator tidal volume  $\leq 10$  ml/kg, and crystalloid administration in ml/kg/hour).<sup>4,5</sup> The outcome measures were occurrence of postoperative complications (myocardial ischemia, acute kidney injury, or 30-day all-cause mortality) and resource utilization (length of stay and hospital charges).

**Statistical Analysis:** Univariate analyzes (Mann-Whitney U test and Pearson Chi-Square) were used to determine statistical significant associations for process of care measures and non-risk adjusted outcomes between experimental cases and controls. Risk adjusted analyzes were performed to determine if AlertWatch® use was independently protective for minutes of hypotension, length of stay, myocardial ischemia, acute kidney injury, and 30-day all-cause mortality using either linear or logistic regressions as appropriate. A p-value of  $<0.05$  was considered statistically significant.

**Results:** 27,109 patients were evaluated: 8,046 experimental cases were compared to 11,055 parallel and 8,008 historical controls. All process measures were improved for both control groups. For historical controls all outcome measures significantly improved. For the parallel control group myocardial ischemia was reduced (2.1% to 1.5%) as well as median hospital length of stay (6 days to 5 days) and hospital charges by \$3,471 although acute kidney injury and 30-day all-cause mortality were not significantly reduced.

**Conclusion:** The use of AlertWatch® during general anesthesia in adults was associated with improved process and outcome measures including myocardial ischemia, hospital length of stay, and hospital charges.

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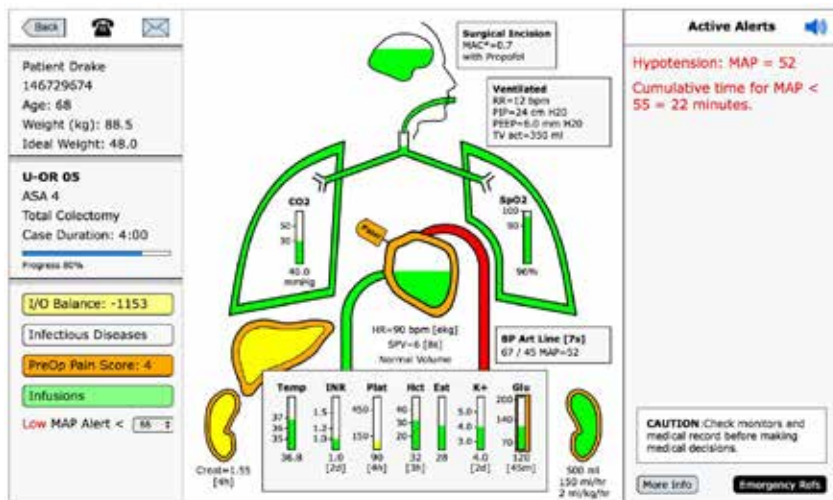


Figure. The aortic arch is red (the mean arterial pressure is <55mmHg and there is a red text alert), in addition there is a red text noting the cumulative time the mean arterial pressure has been <55mmHg (in this case 22 minutes).

## Operating Room Fires: Drapes and Oxygen Contamination of the Surgical Field

**Presenting Author:** Kenisha L. Webb, MD, Scott & White Hospital, Texas A&M University College of Medicine, Temple, Texas

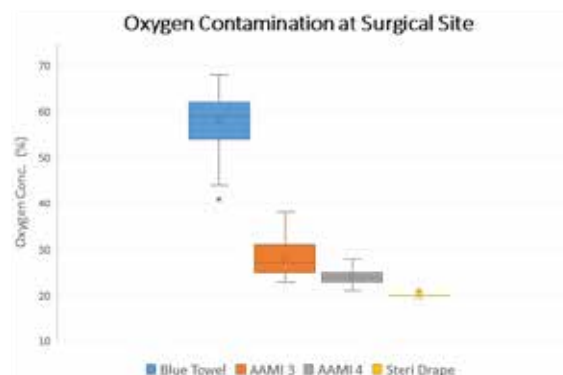
**Co-Author:** William C. Culp, Jr., MD, Scott & White Hospital, Texas A&M University College of Medicine, Temple, Texas

**Introduction:** Surgical fires are a high-profile, preventable threat causing patient morbidity and mortality and occur more than 600 times per year. Ninety-percent of these fires are associated with open oxygen sources (such as the simple face mask and nasal cannula) leading to oxygen-enriched atmospheres about the face and neck. The degree to which oxygen potentially collects or pools under the surgical drapes and on the operating field through surgical drapes is not well described. Surgical drapes are composed of varying materials, therefore, we hypothesized that oxygen permeability would vary with each drape. We sought to measure under-drape pooling and surgical site oxygen contamination by measuring oxygen concentration under simulated clinical conditions with various drapes.

**Methods:** Experiments took place in an operating room environment with high air turnover (15-20 room exchanges/hour) to represent clinical conditions. A negative pressure ventilation mannequin model was utilized with a respiratory rate of 12 BPM and TV 500 mL. Oxygen was administered at 10 LPM via simple face mask, and the model draped in the standard fashion for a surgical procedure at the glabellar region. A multi-gas analyzer (Dräger Inc., Telford, PA) was used to measure oxygen concentration at two locations: at the surgical site and under the drape nearest the surgical site. Four commercially available surgical drapes were tested. Oxygen concentration was measured at both locations every five seconds over one minute for a total of twelve measurements, and repeated for thirty trials with each drape.

### Results:

Of the four drapes tested, Cardinal Hill Standard Disposable Woven 100% Cotton OR Blue Towel (no AAMI level), Cardinal Hill AAMI level 3 Utility Drape, Cardinal Hill AAMI level 4 Procedural Drape, and 3M™ Steri-Drape™ 1030 Medium Drape with Adhesive Aperture, the under-drape oxygen concentration average was 64.49%



and was not statistically different among drapes. In contrast, oxygen concentration at the surgical site was moderately elevated with AAMI 3 and AAMI 4 drapes, and extremely elevated with OR blue towels (mean oxygen concentration 58%,  $p=0.0001$ ). The 3M™ Steri-Drape™ provided an impermeable protective barrier with no surgical site oxygen contamination.

**Conclusions:** Surgical draping can lead to under-drape oxygen pooling with very high oxygen concentrations and does not significantly differ among tested drapes. Oxygen contamination of the surgical site varied widely based on drape material, with surgical towels leading to high oxygen contamination while plastic occlusive drapes did not. Drape selection may impact operating room fire risk.

**References:**

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