STA Annual Meeting

Innovation in a Crisis

January 11-14, 2023

Four Seasons Hotel • Las Vegas, Nevada

#STA23LV

Program Co-Chairs:

Calvin Gruss, MD, MS & Patrick Kolbay, PhD

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Welcome

Welcome to the Society for Technology in Anesthesia's (STA) 2023 Annual Meeting! We are wholeheartedly looking forward to our first in-person meeting in 3 years! Our program co-chairs, Drs. Calvin Gruss and Patrick Kolbay, and abstract Co-Chairs, Drs. Priya Ramaswamy and Elie Sarraf, have developed an outstanding program. On behalf of the co-chairs and myself, we invite you to re-engage face-to-face and inspire one another with new developments in anesthesia technology. This year's meeting theme, "Innovation in a Crisis", will cover key technology areas, including Artificial Intelligence, Healthcare Supply Chain and Labor Economics, Open Anesthetic Records, the Opioid Crisis, and Medical Device Creation. We are offering 16.25 *AMA PRA Category 1 Credits*™ through participation in this meeting.

New this year is the opportunity to take advantage of our new STA Mentorship Program. Make sure to scan the QR code at the registration table and submit your contact information online so you can chat in person during the meeting with your mentor or mentee and be part of the kickoff meeting during the third week of January!

We will continue to prioritize engagement with our Corporate Members through dedicated meeting time with Corporate Members in speed networking and industry spotlight events. A return to in-person interactions and networking among technology-focused specialists in anesthesia throughout industry, academia, private practice and government will also be possible during the breaks with exhibitors and evening receptions. I want to extend my deepest gratitude to our Corporate Members for their continued and sustained support of our Society. Without you, the STA Annual Meeting would not be possible. Thank you also to Marie Odden and her team for their excellent and important management work throughout the year.

Remember to tag STA in your Annual Meeting social media posts (@STAhq and #STA23LV), and please, enjoy the meeting!

Lara Brewer, PhD
President, Society for Technology in Anesthesia

Invited Faculty

Luis Ahumada, MSCS, PhD
Johns Hopkins All Childrens

Ramin Bighamian, PhD
U.S. Food and Drug Administration

Christina Boncyk, MD, MPH
Vanderbilt University

Lara Brewer, PhD
University of Utah
President, STA

Maxime Cannesson, MD, PhD
University of California, Los Angeles

Talmage Egan, MD
University of Utah

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

David Feinstein, MD, MSBME
Beth Israel Deaconess Medical Center

Jeffrey Feldman, MD, MSE
Children's Hospital of Philadelphia

Jonathan Gal, MD, MBA, MS, FASA
Icahn School of Medicine at Mount Sinai

J Gálvez, MD, MBI
Children's Hospital & Medical Center, University of Nebraska Medical Center

Daniel Gessner, MD
Stanford University

Dave Giarracco, MA
Noninvasix, Inc

Jessica Goeller, DO, FAOCAq
University of Nebraska Medical Center / Children's Omaha

Nate Greenbaum, MD
Beth Israel Deaconess Medical Center

Julian Goldman, MD
Massachusetts General Hospital

Calvin Gruss, MD, MS
Vanderbilt University
Co-Chair, 2023 Annual Meeting

Thomas Hemmerling, MD, MSc, DEAA
McGill University

Ira Hofer, MD
Icahn School of Medicine at Mount Sinai

Craig Jabaley, MD, FCCM
Emory University

Patrick Kolbay, PhD
University of Utah
Co-Chair, 2023 Annual Meeting

Christos Koutentis, MBChB, MS
Montefiore Medical Center

Kai Kuck, PhD
University of Utah

Matthew Levin, MD
Icahn School of Medicine at Mount Sinai

Hannah Lonsdale, MBChB, FRCA
Vanderbilt University

Jeffrey Mandel, MD, MS
Mandel Anesthesia Innovations, LLC

Patrick McCormick, MD, MEng
Memorial Sloan Kettering Cancer Center

Joseph Orr, PhD
Dynasthetics, LLC

John Pawlowski, MD, PhD
Beth Israel Deaconess Medical Center

Christopher Quartararo, MD
Winchester Hospital

Priya Ramaswamy, MD
University of California, San Francisco
Co-Chair, 2023 Annual Meeting Abstract

Mark Rice, MD
Vanderbilt University

Branden Rosenhan, MD
MedMountain Ventures

Brian Rothman, MD
Vanderbilt University

Sean Runnels, MD, CEO
University of Utah

Joseph Schlesinger, II, MD, FCCM
Vanderbilt University

James Selby, BMBS, FRCA
UK Society for Computing and Technology in Anaesthesia

Allan Simpao, MD, MBI
Perelman School of Medicine at the University of Pennsylvania

Jonathan Tan, MD, MPH, MBI, FASA
Children's Hospital Los Angeles, Keck School of Medicine at the University of Southern California, Spatial Sciences Institute at the University of Southern California

Andrewston Ting, DO
USF Health Morsani College of Medicine

Fuchiang Tsui, PhD, FAMIA
University of Pennsylvania and Children's Hospital of Philadelphia

Jonathan Wanderer, MD, MPhil, FASA
Vanderbilt University

James Xie, MD
Stanford University

Matthew Zapf, MD
Vanderbilt University

Meeting Accreditation Information

Activity Overview

The Society for Technology in Anesthesia (STA) 2023 Annual Meeting will provide a platform for anesthesia researchers to present their findings and developments in an effort to improve practices in anesthesia. Specific topics will include advances in machine learning, supply chain impacts on healthcare, device development and location-based outcomes.

Educational Objectives

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

- Understand the benefits and limitations of machine learning and its uses in anesthesia care.
- Understand the ramifications location may have on patient outcomes.
- Describe the process on how medical devices develop from ideas at the benchside to real devices at the bedside.
- Describe how supply chains can impact healthcare and research development.
- Summarize the issues surrounding the ongoing opioid epidemic.
- Summarize current research being pursued by engineers, anesthesiologists and scientists alike both in industry and academia.

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.

Joint Accreditation Statement

JOINTLY ACCREDITED PROVIDER™
INTERPROFESSIONAL CONTINUING EDUCATION

In support of improving patient care, this activity has been planned and implemented by Amedco LLC and Society for Technology in Anesthesia. Amedco LLC is jointly accredited by the Accreditation Council for Continuing Medical Education (ACCME), the Accreditation Council for Pharmacy Education (ACPE), and the American Nurses Credentialing Center (ANCC), to provide continuing education for the healthcare team.

Physicians (ACCME) Credit Designation
Amedco LLC designates this live activity for a maximum of **16.25 *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 ONLY)

Wednesday, January 11, 2023 • 0800 - 1200

Experienced anesthesiologists have developed this course for Annual and Sustaining 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. PRE-REGISTRATION REQUIRED.**

Schedule of Events

Wednesday, January 11, 2023

0700-0800 *Desert Willow*
Challenges & Opportunities Registration & Breakfast *(For Industry ONLY – Pre-Registration required)*

1200-1700 *Four Seasons Ballroom I/II*
Exhibitor Registration & Setup

0800-1200 *Desert Willow*
Challenges & Opportunities in Developing Anesthesia Products *(For Industry ONLY – Pre-Registration required)*
David Feinstein, MD, MSBME, Jeffrey Feldman, MD, MSE, John Pawlowski, MD, PhD, Christopher Quartararo, MD, Nate Greenbaum, MD, Christos Koutentis, MBChB, MS

1800-2000 *Four Seasons Ballroom I/II*
Registration & Welcome Reception

Thursday, January 12, 2023

0700-0800 *Four Seasons Ballroom I/II*
Registration & Breakfast

0800-0815 *Four Seasons Ballroom III/IV*
Welcome Address
Lara Brewer, PhD, Calvin Gruss, MD, MS & Patrick Kolbay, PhD

Session 1: Keynote Address
Moderator: Calvin Gruss, MD, MS & Patrick Kolbay, PhD

0815-0915 *Four Seasons Ballroom III/IV*
The Bromance of Morton and Mendelssohn – Music and Medicine Research to Improve Patient Care and Safety
Joseph Schlesinger, II, MD, FCCM

0915-0930 *Four Seasons Ballroom I/II & Prefunction*
Break with Exhibitors & Abstract Posters

Session 2: Artificial Intelligence, Machine Learning and Big Data in the New World/ Modern Age
Moderator: Jonathan Wanderer, MD, MPhil, FASA

0930-0950 *Four Seasons Ballroom III/IV*
Artificial Intelligence: Hype, Hope and Hurdles
Hannah Lonsdale, MBChB, FRCA

0950-1010 *Four Seasons Ballroom III/IV*
Translating Machine Learning into Clinical Workflows: Designing Real Time Applications
Matthew Zapf, MD

1010-1030 *Four Seasons Ballroom III/IV*
Federated Learning - Multi-Center Results Without Sharing Data
Ira Hofer, MD

1030-1040 *Four Seasons Ballroom III/IV*
Panel Discussion

Session 3: 2022 Supply Chain and Labor Economics' Impacts on Healthcare Contribution Margins, Operations and Innovation
Moderator: Brian Rothman, MD

1040-1100 *Four Seasons Ballroom III/IV*
What Happened to the Supply Chain?
Craig Jabaley, MD, FCCM

1100-1120 *Four Seasons Ballroom III/IV*
The Supply and Demand Mismatch of Healthcare Labor Economics
Jonathan Gal, MD, MBA, MS, FASA

1120-1140 *Four Seasons Ballroom III/IV*
How Current Market Forces Have Impacted the Peri-Operative Environment
Mark Rice, MD

1140-1150 *Four Seasons Ballroom III/IV*
Panel Discussion

1150-1215 *Four Seasons Ballroom I/II & Prefunction*
Break with Exhibitors & Abstract Posters

1215-1315 *Four Seasons Ballroom III/IV*
Industry Spotlight Luncheon

Session 4: Patient Engagement and Safety in the Era of Open Anesthetic Records
Moderator: Priya Ramaswamy, MD

1315-1335 *Four Seasons Ballroom III/IV*
Open Anesthetic Records: The Past, Present, and Future
Priya Ramaswamy, MD

1335-1355 *Four Seasons Ballroom III/IV*
21st Century Cures Act and Anesthetic Record Data Transparency in Pediatric Anesthesiology: Opportunities to Engage Patients and Families
James Xie, MD

1355-1415 *Four Seasons Ballroom III/IV*
What Do Patients Want to Know About Their Anesthetic Record? An Analysis of Open-Ended Qualitative Interviews
Daniel Gessner, MD

1415-1425 *Four Seasons Ballroom III/IV*
Panel Discussion

1425-1455 *Four Seasons Ballroom III/IV*
Posters in a Minute: Moderated Poster Summaries Group A

1455-1525 *Four Seasons Ballroom I/II & Prefunction*
Break with Exhibitors & Abstract Posters

Session 5: Abstract Awards & Presentations
Moderator: Thomas Hemmerling, MD, MSc, DEAA

1525-1540 *Four Seasons Ballroom III/IV*
Best Clinical Application Award Presentation
Dave Giarracco, MA

1540-1555 *Four Seasons Ballroom III/IV*
Best of Show Award Presentation
Andrewston Ting, DO

1555-1610 *Four Seasons Ballroom III/IV*
Q&A

1610-1710 *Desert Willow*
Speed Networking with Corporate Members
Moderator: Patrick Kolbay, PhD

1710-1830 *Four Seasons Ballroom I/II*
Cocktail Reception with Corporate Members

Friday, January 13, 2023

0715-0815 *Four Seasons Ballroom I/II*
Registration & Breakfast

Session 6: Tackling the Ongoing Opioid Crisis - Innovative Opportunities to Save Lives
Moderator: J Gálvez, MD, MBI

0815-0835 *Four Seasons Ballroom III/IV*
Non-Pharmaceutical Methods to Increase Opioid Prescription Safety
Lara Brewer, PhD

0835-0855 *Four Seasons Ballroom III/IV*
Prescription Drug Monitoring Programs

Schedule of Events *continued*

Friday, January 13, 2023 cont.

0855-0915 *Four Seasons Ballroom III/IV*
Opportunities and Lessons Learned from Technologies Designed to Improve Opioid Prescription Safety in the US
Jessica Goeller, DO, FAOCAq

0915-0925 *Four Seasons Ballroom III/IV*
Panel Discussion

Session 7: Power Talks: Anesthesia in 2050: How International Experts Envision the Future
Moderator: Thomas Hemmerling, MD, MSc, DEAA

0925-0935 *Four Seasons Ballroom III/IV*
Anesthesia in 2050: Patient Monitoring
Kai Kuck, PhD

0935-0945 *Four Seasons Ballroom III/IV*
Depth of Consciousness Monitoring and Beyond
Maxime Cannesson, MD, PhD

0945-0955 *Four Seasons Ballroom III/IV*
Remote Monitoring
Ira Hofer, MD

0955-1005 *Four Seasons Ballroom III/IV*
Robotic Anesthesia
Thomas Hemmerling, MD, MSc, DEAA

1005-1015 *Four Seasons Ballroom III/IV*
Social Media in Anesthesiology and Critical Care Medicine: Past, Present and Future Impact
Jonathan Tan, MD, MPH, MBI, FASA

1015-1025 *Four Seasons Ballroom III/IV*
Public Health Informatics
Brian Rothman, MD

1025-1100 *Four Seasons Ballroom I/II & Prefunction*
Break with Exhibitors & Abstract Posters

Session 8: From Idea Formation to Device Creation and Beyond
Moderator: Joseph Orr, PhD

1100-1120 *Four Seasons Ballroom III/IV*
Product Development for Fun and Profit
Joseph Orr, PhD

1120-1140 *Four Seasons Ballroom III/IV*
Healthtech: an MD to VC Perspective
Branden Rosenhan, MD

1140-1200 *Four Seasons Ballroom III/IV*
Hobby, Charity or Business - Don't Mistake One for the Other
Sean Runnels, MD, CEO

1200-1210 *Four Seasons Ballroom III/IV*
Panel Discussion

1210-1240 *Four Seasons Ballroom III/IV*
Posters in a Minute: Moderated Poster Summaries Group B

1240-1400 *Four Seasons Ballroom III/IV*
STA Business Luncheon & 2023 J.S. Gravenstein Award Presentation
Lara Brewer, PhD & Richard Epstein, MD

1400-1430 *Four Seasons Ballroom I/II & Prefunction*
Break with Abstract Posters

Session 9: Concurrent Sessions

1430-1530
Remote and Autonomous Medical Systems
Four Seasons Ballroom III/IV

- **Remote Control of Ventilators and IV Pumps: Lessons from the National Emergency Tele Critical Care Network (NETCCN) Initiative**
  Julian Goldman, MD
- **Physiologic Closed Loop Control Medical Devices: Regulatory Science Update**
  Ramin Bighamian, PhD

1430-1630 *Desert Willow*
Medical Device Maker Faire
Patrick Kolbay, PhD

Join us in this workshop learning basic tools for DIY medical device prototyping. The workshop will start with a crash course in creating a simple medical device, followed by a hands-on session exploring basic programming, circuit prototyping, 3D printing, and more. Attendees will be able to take home their prototypes and continue inventing beyond the workshop.

Saturday, January 14, 2023

0730-0815 *Four Seasons Pre-Function*
Registration & Coffee

STA Engineering Challenge
Moderator: Jeffrey Mandel, MD, MS

0815-1000 *Four Seasons Ballroom III/IV*
Engineering Challenge

1000-1020 *Four Seasons Pre-Function*
Break with Abstract Posters

Session 10: Applications of Data Science and Analytics for a Changing World
Moderator: Jonathan Tan, MD, MPH, MBI, FASA

1020-1040 *Four Seasons Ballroom III/IV*
Multi-Stage Evaluation of Clinical Deterioration Prediction Using Data-Driven Machine Learning of Electronic Health Records
Fuchiang Tsui, PhD, FAMIA
Allan Simpao, MD, MBI

1040-1100 *Four Seasons Ballroom III/IV*
How Do You Measure Organizational Wellness?
Luis Ahumada, MSCS, PhD

1100-1120 *Four Seasons Ballroom III/IV*
Spatial Analytics for Health Care Systems in a Changing World
Jonathan Tan, MD, MPH, MBI, FASA

1120-1130 *Four Seasons Ballroom III/IV*
Panel Discussion

Session 11: Society for Computing and Technology in Anesthesiology (SCATA)

1130-1200 *Four Seasons Ballroom III/IV*
Opentiva: Open Source Simulation of Target Controlled Infusions
James Selby, BMBS, FRCA

Session 12: Innovation During the Pandemic
Moderator: Patrick McCormick, MD, MEng

1200-1220 *Four Seasons Ballroom III/IV*
Too Many Patients and Not Enough Vents: Split Ventilation During COVID-19
Matthew Levin, MD

1220-1240 *Four Seasons Ballroom III/IV*
An Academic Anesthesiology Department Response to the COVID-19 Pandemic
Talmage Egan, MD

1240-1300 *Four Seasons Ballroom III/IV*
COVID-19 Lessons from Vanderbilt
Christina Boncyk, MD, MPH

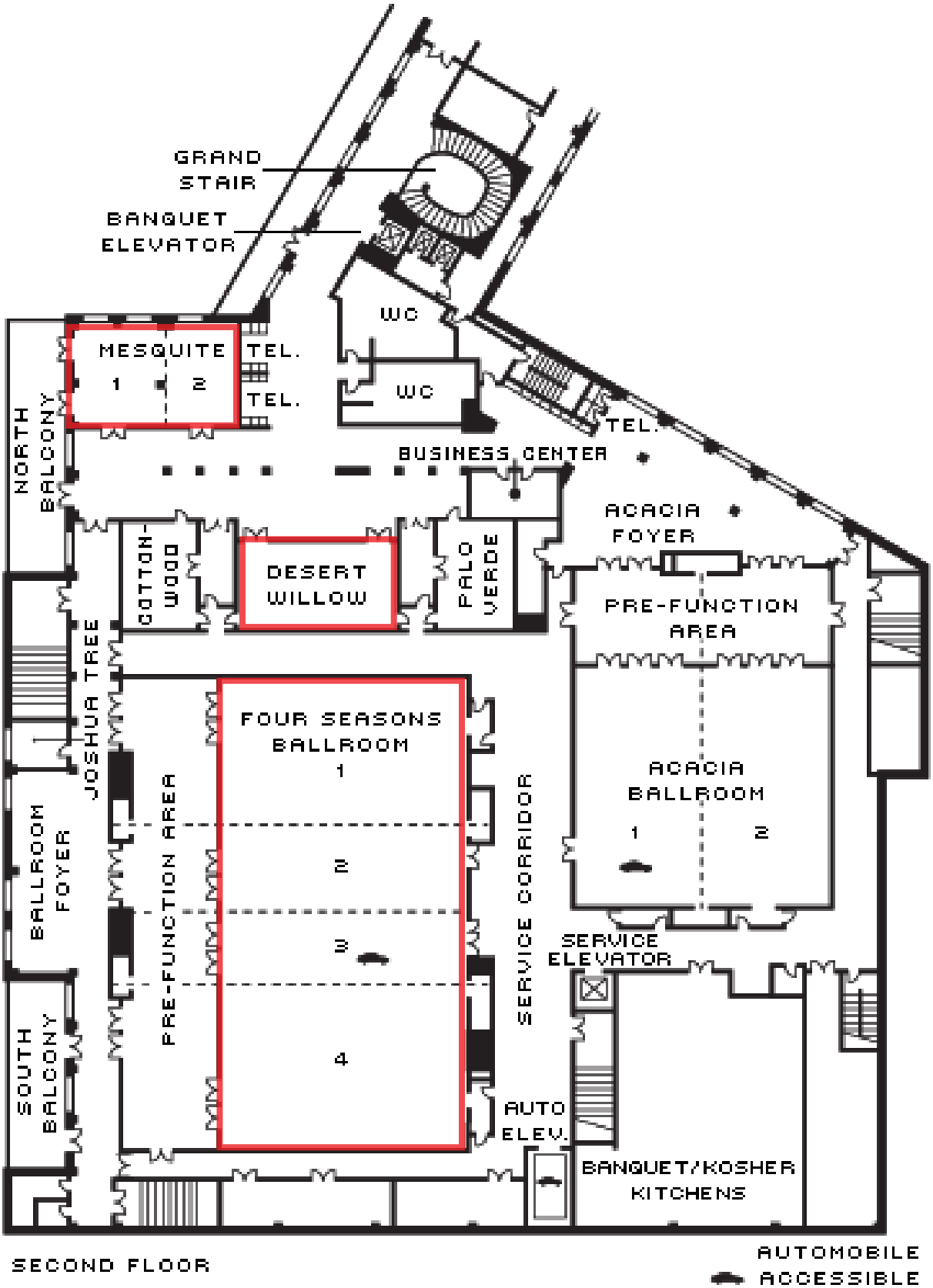
1300-1310 *Four Seasons Ballroom III/IV*
Panel Discussion

1310
Meeting Adjourned

Four Seasons Hotel

WiFi Network: FourSeasonsMeeting

Password: sta2023



Sustaining & Annual Corporate Members

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Extrico Health
Micropore, Inc

Entrepreneur Silver
AlertWatch
Blink Device Company
Neurowave Systems
Noninvasix

Company Descriptions

AlertWatch • www.alertwatch.com

AlertWatch, now a subsidiary of BioIntelliSense, develops clinical intelligence and triaging solutions to help anesthesiologists improve quality, safety, and efficiency across the entire continuum of care. The software integrates device and medical record information to produce near real-time alerts and algorithms focused on improving outcomes and reducing length of stay. At the STA meeting, we will be demoing the following AlertWatch solutions, as well as the BioIntelliSense wearables that integrate into our RPM solution:

AlertWatch:OR - This application consolidates hundreds of real-time and historical data elements onto intuitive multi- patient and single-patient dashboards. With AlertWatch:OR, clinicians can track real-time patient status and case progress at a glance, including sophisticated alerts and clinical decision support built for the perioperative workflow. The solution is now being used, under IRB, to monitor hundreds of rooms from a Tele-OR facility. Reach out to learn more about this innovative use case.

AlertWatch:OB - This application tracks each mother throughout the entire labor, delivery and post-delivery process, automatically assessing hemorrhage risk and related clinical issues and alerting for emerging clinical issues. By providing a complete clinical picture for each patient, AlertWatch:OB will become a key piece of your maternal safety efforts. Research has shown that our proprietary alerting algorithms are more effective at identifying hemorrhages than the existing national guidelines.

AlertWatch:AC - This FDA-cleared solution helps clinicians oversee all types of acute care patients in the ICU. The solution has powerful clinical decision support built for ECMO and ventilated patients, and decision support specifically for sepsis care. AlertWatch:AC will be the foundation to your future telehealth initiatives.

AlertWatch:PACU - This application, pending FDA clearance, helps anesthesiologists remotely monitor and discharge PACU patients. The solution passes on useful analysis from intraoperative data and helps the entire care team provide more consistent care. This solution is now being used, under IRB, to remotely sign out PACU patients. Reach out to learn more about this innovative use case.

AlertWatch:RPM: Anesthesia departments across the country have started to use BioIntelliSense and AlertWatch to monitor patients post-op, as a part of reimbursable hospital to home and hospital at home programs. The FDA-cleared BioIntelliSense wearables, monitored in AlertWatch, provide continuous vitals and biometrics, and have helped to reduce readmissions for several facilities.

Company Descriptions

Becton Dickinson • www.bd.com

BD is one of the largest global medical technology companies in the world and is advancing the world of healthTM by improving medical discovery, diagnostics and the delivery of care. The company supports the heroes on the frontlines of healthcare by developing innovative technology, services and solutions that help advance both clinical therapy for patients and clinical process for healthcare providers. BD and its 75,000 employees have a passion and commitment to help enhance the safety and efficiency of clinicians' care delivery process, enable laboratory scientists to accurately detect disease and advance researchers' capabilities to develop the next generation of diagnostics and therapeutics. BD has a presence in virtually every country and partners with organizations around the world to address some of the most challenging global health issues. By working in close collaboration with customers, BD can help enhance outcomes, lower costs, increase efficiencies, improve safety and expand access to healthcare.

Blink Device Company • www.blinkdc.com/twitchview

Makers of the TwitchView train of four (TOF) monitor, the only quantitative neuromuscular monitor clinically validated against gold standard mechanomyography (MMG). TwitchView utilizes expert-recommended electromyography (EMG) to reliably guide management and antagonism of neuromuscular blockade to prevent postoperative residual muscle weakness.

Codonics • www.codonics.com

Meet the new ISMP Guidelines with Safe Label System (SLS), a medication verification safety system used in perioperative and procedural settings to improve anesthesia workflow and patient safety. During preparation, when a drug is scanned on SLS, it electronically reads the manufacturer's vial/ampoule barcode and visually and audibly identifies the drug name and concentration, acting as a second set of eyes to ensure safety, then prints a full-color TJC-compliant syringe label. Every label includes a barcode, enabling integration with AIMS/EHR (Epic/Cerner), providing additional safety and 'hands-free' documentation at administration. Additionally, the syringe label barcode enables smart infusion pump interoperability that allows the pump to be programmed with a scan of the label and just four clicks. Changes made to the pump are automatically documented into Epic without any additional interaction, increasing documentation accuracy, clinician efficiency, and patient safety. Once the syringe is wasted and returned, it can be scanned into WasteLog™ from Codonics, a drug assay device which instantly identifies the expected narcotic, concentration and preparer, plus analyzes and reports what's actually in the syringe in <4 seconds, helping to detect and deter drug diversion. Together, we can eliminate medication errors. Visit us for a demonstration.

Draeger Medical • www.draeger.com/en-us_us/home

Dräger is an international leader in the fields of medical and safety technology. Our products protect, support, and save lives. We optimize OR workplaces for efficient anesthesia delivery using innovative equipment with intuitive user interfaces. Our proven anesthesia machines are uniquely designed to protectively ventilate patients and help reduce the risk for postoperative pulmonary complications. Our perioperative care portfolio supports your surgical teams because it's technically sophisticated without being complicated. With advanced workplace designs, anesthesia machines, accessories, monitoring, service, and clinical information management solutions, we promote safety and efficiency in your OR.

Edwards Lifesciences • www.edwards.com

Edwards Lifesciences is a global leader in patient-focused medical innovations for structural heart disease, as well as critical care and surgical monitoring.

Driven by a passion to help patients, the company collaborates with the world's leading clinicians and researchers to address unmet healthcare needs, working to improve patient outcomes and enhance lives.

Extrico Health • www.extricohealth.com

The Extrico platform simplifies and standardizes the extraction and utilization of data from the electronic health record in three stages, extracting of raw data from the EHR, cleaning and standardizing the raw data to allow for scalability, and transformation of the standardized data into actionable insights. Foundational to the Platform is Extrico's phenotype* technology - called InfoTypes, that combine multiple data points to create a single piece of usable information, such as identifying patients with a given chronic illness by looking at past lab results, medications taken, and billing codes simultaneously.

Extrico's Perioperative KnowledgeBase

Perioperative reporting in analytics is a complex domain requiring expertise in OR operations, procedural nomenclature and understanding of the unique medical issues that affect operative patients. Perioperative care does not start or stop at the operating room door, and neither does the KnowledgeBase. Extrico's platform contains all the data in the EHR, allowing integration of preoperative baselines and tracking of postoperative outcomes even well past discharge.

The KnowledgeBase was built by practicing anesthesiologists with deep knowledge of OR operations and analytics. The Extrico Platform has been validated in peer reviewed literature, is easy to deploy and is successfully being used by anesthesia departments and OR management at top 10 academic medical centers to facilitate or participate in multi-center studies, conduct retrospective research, improve OR operations, optimize staffing decisions and improve patient outcomes.

Fresenius Kabi • www.fresenius-kabi.com/us

Fresenius Kabi is a global healthcare company that specializes in lifesaving medicines and technologies for infusion, transfusion and clinical nutrition. Our products and services are used to help care for critically and chronically ill patients.

GE Healthcare • www.gehealthcare.com

GE HealthCare is a leading global medical technology, pharmaceutical diagnostics, and digital solutions innovator, dedicated to providing integrated solutions, services and data analytics that make hospitals more efficient, clinicians more effective, therapies more precise, and patients healthier and happier. Serving patients and providers for more than 100 years, GE HealthCare is advancing personalized, connected, and compassionate care, while simplifying the patient's journey across the care pathway. Together our Imaging, Ultrasound, Patient Care Solutions, and Pharmaceutical Diagnostics businesses help improve patient care from diagnosis, to therapy, to monitoring. We are a $18 billion business with 51,000 employees working to create a world where healthcare has no limits.

Getinge • www2.getinge.com/us

With a firm belief that every person and community should have access to the best possible care, Getinge provides hospitals and life science institutions with products and solutions that aim to improve clinical results and optimize workflows. The offering includes products and solutions for intensive care, cardiovascular procedures, operating rooms, sterile reprocessing, life science, and Applikon bioreactor systems. Getinge employs over 10,000 people worldwide and the products are sold in more than 135 countries.

Medtronic •www.medtronic.com/us-en/healthcare-professionals/products/patient-monitoring.html

Medtronic Patient Monitoring & Respiratory Interventions offers medical devices & services, VBHC programs and education to healthcare professionals working in the Emergency Department, OR, ICU, Medical-Surgical as well as post- acute settings.

Together, we strive for zero adverse events, contributing to patient safety and reducing healthcare costs.

Micropore, Inc. • www.spiralithusa.com

Micropore, Inc. makers of SpiraLithCa is located in Elkton, MD. Micropore packages fine powder chemistries into solid absorbent cartridges that are used to absorb CO2 in rebreathing and life support systems. Our SpiraLithCa for Anesthesiology has solid cartridge technology which out performs all granular CO2 absorbents. The patented technology is the first major advance in CO2 absorbent technology in over 100 years, providing superior performance advantages vs. existing granular absorbents. For more information please contact Gail Feltham gail.feltham@microporeusa.com

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Mindray North America • www.mindray.com

Spanning patient monitoring, anesthesia, and ultrasound, Mindray empowers healthcare professionals through innovative, high-value solutions that help create the next generation of lifesaving tools. But Mindray is more than just products and services. We believe in solutions that address your biggest perioperative challenges, such as patient safety, improved patient outcomes, and streamlined workflow in the Operating Room. We recognize the human side of healthcare and your role in providing best-in-class patient care, which is why we create products suited to your clinical needs in this environment.

Our portfolio of perioperative products optimizes your OR workflow through intuitively designed systems and enhances patient care with reliable and safe functionality. Our team of perioperative specialists ensure that your clinical teams are educated, trained, and up-to-date on these solutions. Trust Mindray for your complete perioperative solution. Together, we are creating a higher standard for healthcare.

Mindray is a leading developer, manufacturer, and supplier of medical device solutions and technologies used in healthcare facilities around the globe. Mindray maintains its global headquarters in Shenzhen, China; Mindray North America is headquartered in Mahwah, New Jersey. Our Ultrasound Innovation Center is located in San Jose, California with additional facilities in major international markets around the world.

Neurowave Systems • www.neurowavesystems.com

NeuroWave Systems is dedicated to developing innovative brain monitoring and drug delivery medical devices, powered by state-of-the-art signal processing and control engineering technologies. Our vision is to pioneer automation in anesthesia for improved and safer patient care.

NeuroWave is proud to offer the NeuroSENSE® Monitor with EasyPrep™ electrodes, the latest generation of brain monitors for patient-customized anesthesia and sedation delivery. The NeuroSENSE Monitor represents the latest generation of brain monitors for patient-customized anesthesia and sedation, powered by leading-edge signal acquisition and processing technologies. This unique bilateral brain monitor calculates and displays independent indices of anesthetic effect for each side of the brain, with an instantaneous response to changes in patient state.

For the first time, physicians in the OR and ICU can track simultaneously, and without delay, anesthetic effect measures for each brain hemisphere. Unlike monitoring a single index derived from one or both hemispheres, independent bilateral indices allow clinicians to easily spot any hemispheric differences due to, e.g., underlying pathologies or unrecognized artifacts. This added insight into the patient's brain assists anesthesia providers to make optimal decisions for safer and improved patient care.

NeuroWave R&D efforts are dedicated to adding to our growing portfolio of innovative medical device technologies. We are pioneering systems that will automate anesthesia and sedation delivery. Our portable and easy-to-use research platforms vertically integrate proprietary infusion pumps with clinically tested closed-loop control algorithms and state-of-the-art signal processing of brain waves to achieve continuous, automated drug delivery based on reliable assessment of the patient brain state.

Noninvasix • www.noninvasix.com

Noninvasix recognized that there are no continuous and noninvasive monitors of the "right side of the heart." We will break this status quo by being the first company to measure central venous oxygen saturation noninvasively and continuously. In doing so, Noninvasix will monitor the severity of sepsis and septic shock non-invasively, enabling clinicians to diagnose and monitor the response to treatment of tissue hypoxia in real time. Incorporating Noninvasix into the ICU workflow allows clinicians the potential to more quickly and accurately diagnose critically ill patients and tailor treatments to improve outcomes.

Future developments, enhancements, and evidence will expand our technology's use and clinical impact in other patient populations, indications and settings.

Noninvasix is backed by 15 years of optoacoustic research and more than $6.5 million in research grants.

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Abstract Title: Reddit Users' Questions and Concerns about Anesthesia

Presenting Author: Khalid El-Jack, BS, Perelman School of Medicine, Philadelphia, PA

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Background/Introduction: Patients utilize social media in search of support networks. Reddit is one of the most popular social media sites and allows users to anonymously connect. Anesthesia patients are actively using Reddit to discuss their treatment options and experiences within the medical system.

Methods: Posts published on an active Reddit forum on Anesthesia (i.e., */r/Anesthesia*) were used. Big Query was used to collect posts from */r/Anesthesia*. We collected 3,288 posts published between December 2015 and August 2019. We collected a control group of 3,288 posts from a Reddit forum not related to Anesthesia (*/r/AskReddit*). Using latent Dirichlet allocation (LDA) we extracted 20 topics from our data set. The LDA topic themes most associated with posts in */r/Anesthesia* compared to the control group were determined.

Results: LDA analysis of posts in */r/Anesthesia* relative to a control group produced 6 distinct categories of posts: "Patient-Physician Experience, Medication, Health Care Infrastructure, Procedures, Personal Inquiries, and Uncertainties." The posts most associated with */r/Anesthesia* when compared to a control group were posts belonging to the "Physician-Patient Experience" category (Cohen's d= 0.389) while the posts least associated with */r/Anesthesia* were from the "Uncertainties" category of posts (Cohen's d= 0.147). Example experiences from members of the */r/Anesthesia* forum highlight subjective experiences of patients undergoing anesthesia.

Conclusion: The language used on social media can provide insights into an individual's experience with anesthesia and inform physicians about patient concerns. Anesthesiologists are poised to address these concerns and prevent anonymous misinformation by providing verified physician insights on the forum */r/Anesthesia*.

Images: Table 1: Latent Dirichlet Allocation Topics associated with */r/Anesthesia* Posts with Correlated Words Used to Highlight the Topic and Redacted Illustrative Examples

Category/Theme	Operational Definition	Cohen's D	Correlated Words	Redacted Illustrative Posts
Patient-Physician Experience	Posts surrounding relationships between members of the care team and patients	0.389	Anesthesia, surgery, procedure, sedation, anesthesiologist, patient, anesthetic, surgeon, pain, experience	Hello everybody, I underwent a procedure this morning while sedated. I came and read the pinned post in this subreddit since I had been worrying about it for weeks, and it truly helped me relax. I generally struggle with quite severe anxiety relating to my health. While getting ready this morning, I was still a little on edge, but my amazing and caring anesthesiologist basically informed me that given my health, she wouldn't even bother describing extreme risks; she only said that I might feel nauseous and have a sore throat after. I was asleep with one of the nurses holding my hand, and when I awoke, I was overjoyed. After roughly 4 hours of being awake, I feel great! The fear of the unknown made me worried, but I now get that it is truly okay. Thank you for your help across this forum.
Uncertainties	User posts regarding patient worries and fears	0.147	I'm, don't, shit, stop, smoking, give, smoke, week, anxiety, die	Help me. I spent three weeks without doing any drugs. A friend of mine invited me out to drinks last Thursday (also something I must stop, but anyway). I let him know that I stopped doing drugs and that I needed to keep clean (especially for two weeks) since I am scheduled to undergo major surgery on April 15… Does anyone here have any information on whether I should be able to have the surgery? Has anyone ever smoked meth and felt sick afterwards?

Title: Non-clinical Database for Dynamic Characterization of Pulse Contour Cardiac Output Monitoring Systems
Presenting author: Masoud Farahmand, U.S. Food and Drug Administration
Coauthors: Gavin A. D'Souza; Luke H. Herbertson; Christopher G. Scully

Background: Pulse contour cardiac output monitoring systems allow real-time and continuous estimation of hemodynamic variables such as cardiac output (CO) and stroke volume variation (SVV) by analysis of arterial blood pressure waveforms [1]. Clinical use of these systems has involved tracking rapid changes in CO, and SVV to monitor patient responses to treatment, distinguish between fluid responders and non-responders, and guide fluid therapy. However, evaluating the performance of CO monitoring systems to measure the small variations in these variables is a challenge due to limitations in clinical reference methods for tracking the hemodynamics in patients. We developed a non-clinical database of pressure and flow waveforms with known perturbations as a potential tool for assessing the dynamic attributes of pressure-based CO monitoring systems, including CO response time, and CO and SVV resolutions.

Methods: We developed a mock circulatory loop (MCL) that can simulate rapid changes in different parameters, such as CO and SVV (Figure 1A). The MCL was configured to simulate three different hemodynamic states (i.e., normovolemic, cardiogenic shock, and hyperdynamic) representing a range of flow and pressure conditions. For each state, we simulated controlled stepwise changes in the MCL flow and collected a dataset for characterizing dynamic attributes of pressure-based CO systems. Nine datasets were generated in all, which contain several hours of central (aortic) flow, central pressure, and peripheral (radial) pressure waveforms. We demonstrate how the database can be used to characterize dynamic attributes with a bench top system (Figure 1B). The bench system (referred to as the system under test or 'SUT') consists of fluid-filled tubing, a disposable pressure transducer, a pressure monitor, and a pulse contour algorithm (i.e., CO = k×(MAP/60)× ln(SBP/DBP)×PR; where MAP is mean arterial pressure, SBP is systolic pressure, DBP is diastolic pressure, PR is pulse rate, and k is a calibration constant calculated from MCL flow data) implemented in MATLAB. Pressure-based CO measurements were calculated via the SUT using MCL-generated pressure waves in each step and were compared to the MCL flow data.

Results: Three types of datasets were collected for each hemodynamic state: 1) CO resolution, 2) SVV resolution, and 3) CO response time datasets. Overall, the nine datasets contain peripheral pressure, central flow and central pressure waveforms for the three hemodynamic states (Figure 1C). We have plotted the datasets for the normovolemic state in Figure 1D. The database was used to determine the dynamic attributes of the SUT. Following a Bland-Altman analysis, we determined the upper and lower limits of the CO resolution of the SUT as 8.4% (95% CI: [6.1%, 9.9%]) and -9.1% (95% CI: [-11.0%, -7.2%]), respectively. A similar analysis was performed to determine the SVV resolution of the SUT. For the SVV resolution, the upper and lower limits were 5.0% (95% CI: [4.0%, 5.9%]) and -3.8% (95% CI: [-4.7%, -2.9%]), respectively. The CO response time of the SUT was 10 seconds.

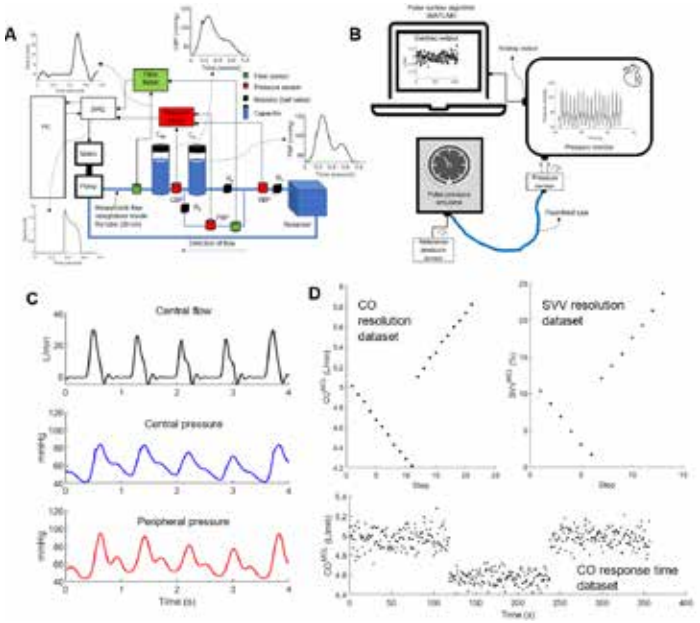

Figure 1. (A) Schematic diagram of the mock circulatory loop (MCL). (B) Schematic diagram of the setup for evaluating a bench pulse contour CO monitoring system. **(C)** Example flow and corresponding pressure waveforms produced by the MCL. **(D)** Normovolemic datasets for quantifying three dynamic attributes of pulse contour CO monitoring systems.

Conclusions: We presented nine MCL-generated datasets for evaluating key dynamic attributes of pressure-based CO monitoring systems and demonstrated how the database can be used for evaluating the dynamic attributes of a benchtop pulse contour monitoring system. This benchtop testing approach enables the characterization of a CO monitoring system and accounts for the effects of different equipment (e.g., sensors and monitors with different settings, bandwidths, resolutions, accuracies, fluid-filled tubing with different damping properties, and different interface connections) on the dynamic attributes of the system. This database is intended to be a potentially useful tool for characterizing dynamic attributes of pressure-based CO monitoring systems and algorithms (i.e., CO response time, CO resolution, and SVV resolution) and provides insight into the performance of these attributes.

Disclaimer: This article reflects the views of the authors and should not be construed to represent FDA's views or policies.

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Predictive Capability of a Mathematical Model of Heart Rate Response to Fluid Perturbation

Presenting Author: Ramin Bighamian, PhD, U.S. Food and Drug Administration

Co-Authors: *Varun Kanal, PhD, Christopher Scully, PhD, U.S. Food and Drug Administration*

Background: Physiological closed-loop controlled (PCLC) medical devices control the state of patients by using physiological feedback in a closed-loop manner. These devices are complex systems with a large number of failure modes and parameters that affect performance. In addition, PCLC devices minimize human adjustment of parameters compared to current clinical care, and thus, assessing the performance of this type of device is essential. Validated mathematical models can be used to create virtual patient cohorts to study the performance of PCLC devices under different simulated physiological conditions. However, in silico assessment of PCLC devices raises its own challenges due to the lack of transparent and validated models available and methods for demonstrating their credibility. This research evaluates the predictive capability performance of a physiological mathematical model of heart rate (HR) response to hemorrhagic shock and fluid infusion for the potential role of testing automated fluid resuscitation systems. The initial version of the model was presented at the 2022 Annual STA meeting.

Method: We used our previously developed mathematical model of HR response to blood loss and fluid infusion, built based on a control-oriented modeling approach. The model is evaluated in terms of model predictive capability performance via a leave-one-out procedure (21 sheep subjects) and an independent dataset (6 sheep subjects) collected under a different experimental protocol. The data collection protocols were approved by the Institutional Animal Care and Use Committee (IACUC) at the University of Texas Medical Branch [1]. A novel compartment-based virtual cohort generation tool as well as one based on the uniform distribution of individual model parameters were used in each analysis.

Result: Analysis performed using the leave-one-out approach (i.e., 21 subjects) showed that, out of 16000 simulated subjects, the model was able to generate at least one simulated subject that was close to the real subject within an error margin of 9.6+/-3.2% normalized root mean square error (NRMSE). Furthermore, analysis on the independent data collected using a different experimental protocol revealed that, out of 18522 simulated subjects, the model was able to generate at least one simulated subject within an error margin of 11.1+/-1.2% NRMSE for each real subject. The generated envelope of simulated subjects showed that 95% of the testing datasets presented simulated HR patterns that were close to the real data and within a deviation of 50% from the observed data.

Conclusion: We evaluated our previously developed mathematical model of HR in terms of its predictive capability performance. It was shown that the model is able to replicate the normal- and worst-case conditions within the testing dataset. The results show that the model can be incorporated into our existing hemodynamic models to create a virtual cohort of patients for testing PCLC devices for hemorrhagic applications.

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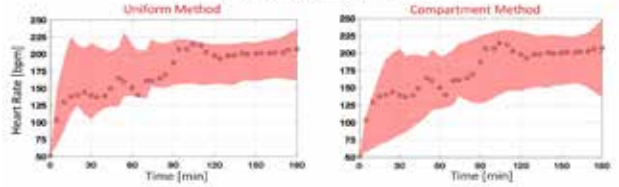

Figure 1: Predictive capability assessment for a fully virtual subject. The plots depict the envelopes of simulated virtual subjects using the independent dataset with the uniform method (left) and the compartment method (right) of cohort generation.

Abstract Title: Digital Feedback Control of Mask Pressure using a Venturi Flow Generator

Presenting Author: Trey Blackwell, BS, University of Utah Department of Anesthesiology

Co-Authors:
Joseph Orr, Ph.D., University of Utah Department of Anesthesiology
Derek Sakata, MD, University of Utah Department of Anesthesiology

Introduction

Recent research has demonstrated that using CPAP on patients undergoing moderate sedation can reduce the risk of obstructive apnea and oxygen desaturation [1]. Providing CPAP in a sedation setting requires an expensive non-invasive ventilator that may not be readily available for use in a sedation setting. An alternative is an inexpensive and portable device that uses a venturi flow generator, which amplifies oxygen flows by combining high-pressure wall oxygen and entrained ambient air to produce high-flow output capable of overcoming mask leaks and producing CPAP pressures. When a typical venturi flow generator is used to achieve the desired airway pressure, mask pressure is selected by applying a set input oxygen flow using a flow-to-pressure table provided by the manufacturer. This method does not account for variable mask leakage, changes in oxygen supply pressure, or patient inhalation flow rate. We evaluated a digitally controlled oxygen flow meter that uses feedback control to automatically adjust the oxygen flow rate to achieve the desired airway pressure. This study hypothesized that digital feedback control utilizing a venturi flow generator can be used to control airway pressure and administer CPAP as needed during procedural sedation.

Methods

A venturi flow generator's input flow port was connected to a proportional valve connected to the output of a high-pressure oxygen source. The proportional valve was connected to a microcontroller, and the pressure sampling line connected the pressure in the mask to a pressure sensor that was digitally interfaced with the microcontroller. A PID feedback controller was implemented on the microcontroller, which adjusted the flow out of the proportional valve to control the pressure measured through the sampling line. The venturi flow generator was interfaced with a mask and placed on a manikin face attached to a test lung using a corrugated hose to simulate a patient's airway. In the first test, the mask was held on the manikin so there was no leak flow. The controller was set to various pressures (4 cmH_2O, 6 cmH_2O, 8 cmH_2O, 10 cmH_2O, 12 cmH_2O, 16 cmH_2O), and the average pressure at each was recorded over a 30-second interval using an analyzer (VT-plus, Fluke Biomedical, Everett WA) that sampled the pressure from the simulated airway. The procedure was then repeated with the mask strap loosened such that there was approximately 15 L/min of mask leak flow at each test pressure.

Results

The measured average pressure versus the desired set pressure is plotted in Figure 1. The correlation coefficient was computed as $r^2 = 0.9999$ both with and without mask leak. The ideal least squares line would be $y = x$. The least squares line for the measured pressures without leak was calculated as $y = 1.009x – 0.22$. The least squares line was calculated with mask leak as $y = 1.008x – 0.23$. The ideal and computed least squares lines are included in Figure 1. The average and standard deviation of the difference between the set mask pressure and the measured mask pressure was 0.133 ± 0.047 cmH_2O without mask leak and 0.150 ± 0.050 cmH_2O with mask leak.

Conclusion

It is observed that a digital feedback controller can be combined with a venturi flow generator to control airway pressure and administer CPAP effectively. The user can choose the desired pressure, and the system will effectively maintain that pressure in the airway by adjusting the flow out of the venturi adapter accordingly, regardless of the mask leak flow present.

Figure

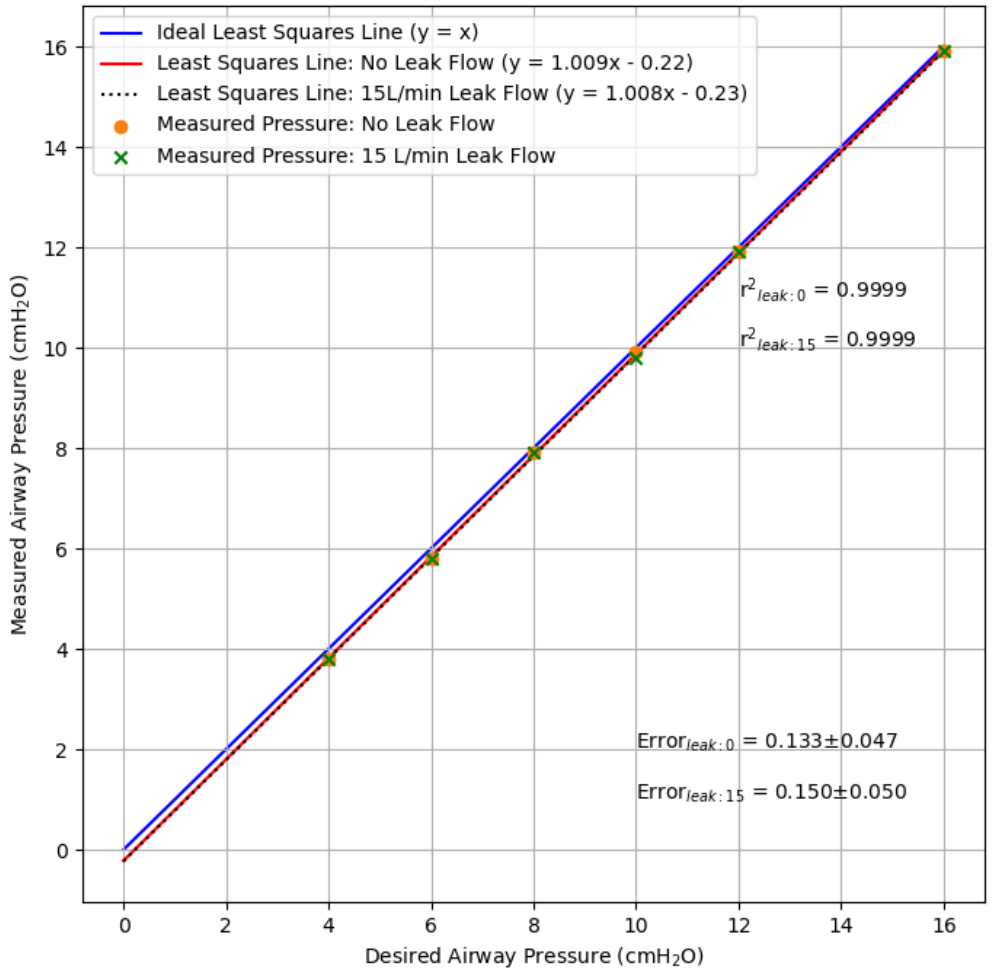

Figure 1: Measured Airway Pressure vs. Desired Airway Pressure with Ideal Least Squares Line, Calculated Least Squares Line, and Correlation Coefficient

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ASSOCIATION OF MECHANICAL POWER WITH REINTUBATION IN THE CRITICALLY ILL: MACHINE LEARNING OUTPERFORMS LOGISTIC REGRESSION

Presenting Author: Kartikeya M. Menon BA, Icahn School of Medicine at Mount Sinai
Co-Authors: *Pranai Tandon MD, Hung-Mo Lin ScD, Yuxia Ouyang PhD, Matthew A. Levin MD*

Background: Mechanical power (MP) estimates the energy delivered to the lung parenchyma using respiratory rate, driving pressure, tidal volume, and peak pressure. Higher MP during ventilation has been correlated with greater risk of postoperative respiratory failure, as well as greater mortality in the critically ill and those with acute respiratory distress syndrome.[1,2] The existing literature examines this relationship with logistic regression. We hypothesized that a machine learning approach would better demonstrate the predictive ability of higher mechanical power with reintubation in critically ill patients.
Methods: Single-center retrospective study of medical intensive care patients intubated >48 hours at a tertiary care hospital from 2011-2019. MP (J/min) was calculated using the equation: $MP = 0.098 * RR * V_t * (PEEP + \Delta P)$. Two models predicting 72-hour reintubation were evaluated: a random forest (RF) classifier and logistic regression (LR). The data were split 80/20 for training/testing and synthetic minority oversampling was employed to adjust for class imbalance. Comorbidities included in the model were age, body mass index, rapid shallow breathing index (RSBI), intubation duration, P/F ratio, and level of consciousness. Demographics were assessed with the Mann Whitney test for continuous variables and ANOVA for categorical variables. Models were evaluated with sensitivity, specificity, F1 score, AUC, k-fold cross-validation, and odds ratios (ORs). For the LR, ORs were calculated by exponentiating log-odds coefficients. For the RF, ORs were imputed by computing individual conditional expectations (ICEs) for discretized MP ranges (<8, 8-13, 13-18, 18-23 J/min), and then transforming the average ICEs into probabilities via inverse logit. Feature saliency was assessed with mean decrease in impurity (MDI), a measure of how important a variable is to the information gain achieved by a node in a RF classifier.
Results: 894 patients met inclusion criteria, of which 136 (15.2%) required reintubation. Univariate analysis showed no statistically significant differences in comorbidities aside from RSBI (55.1 [38.7-88.6] vs 46.5 [28.8-71.6], p<0.01). The median MP was higher in the reintubation cohort (12.7 [10.0-16.2] J/min vs 11.8 [9.5-14.9] J/min, p<0.01) than in those who were successfully extubated. In the test set, traditional LR had a sensitivity of 25%, specificity of 64%, AUC-ROC of 0.52, AUC-PRC of 0.46, and F1 score of 0.32. In the test partition, the RF achieved a sensitivity of 55%, specificity of 76%, AUC-ROC of 0.71, AUC-PRC of 0.74, F1 score of 0.61. In the whole original data set, 10-fold cross-validation accuracy was 84.71% ± 0.01%. Feature analysis found peak MP (MDI=0.16) over duration of ventilation to be the most important variable, followed by median P/F (MDI=0.15) and median MP (MDI=0.15). The LR found the risk of reintubation to be 25% higher for each 5 J/min increase in median MP (OR 1.25, 95% CI 1.10-1.43, p<0.001). The RF-implied average reintubation risk per 5 J/min increase in median MP between 8 J/min and 23 J/mi was 20% (odds ratio 1.20, 95% CI 1.19-1.21, p<0.005).
Conclusion: Machine learning outperforms LR in predicting the association of higher peak and median mechanical powers with reintubation in critically ill patients. Further, the median MP delivered to ICU patients in this cohort is lower than values previously reported in the literature,[2] suggesting a correlation between MP and reintubation risk regardless of absolute MP value.

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Clustering Surgical Procedures Using Clinically Significant Pre-operative Information

Christopher P. Cheng, AB[1]; Ira S. Hofer, MD[2]

[1]Department of Medical Education, Icahn School of Medicine at Mount Sinai

[2]Department of Anesthesiology, Perioperative and Pain Medicine, Icahn School of Medicine at Mount Sinai

Background: Surgical classification methods are necessary for at-large comparisons of the outcomes, costs and incidence of patient care to generate actionable insights for improving patient care. The codes used in the Healthcare Cost and Utilization Project are nationally used for research on the impact of natural disasters, access to care, quality of care and more. This abstract proposes applying clustering analysis to clinically significant pre-operative information to facilitate clinically meaningful surgical procedure classification.

Methods: 199463 procedures that took place in the Mount Sinai Health System from March 12, 2018 to September 22, 2021 were pulled with clinically significant features including but not limited to patient age and sex, surgeon ID, surgeon specialty, operating room, American Society of Anesthesiologists (ASA) score, surgical admission number, scheduled length of surgery, and patient class. These data were preprocessed as follows: null values were dropped from the dataset, numerical and ordinal data were min-max scaled, and categorical data underwent one-hot encoding. Subsequently the dataset was clustered using the KMeans function of scikit-learn 1.0.1 with the random state set to 0 and all other parameters set to their default values with cluster values ranging from 5 to 450. Each cluster number's performance was evaluated using a scree plot elbow method as well as a silhouette score under both Euclidean and correlation distance metrics. The silhouette score of the optimal cluster number was then compared with that of the CCS codes.

Results: Applying the elbow method to the scree plot suggests the optimal cluster number is about 50, and its silhouette scores were accordingly found to be 0.803 and 0.715 according to the correlation and Euclidean distance metrics, respectively. Conversely, CCS code silhouette scores were found to be -0.349 and -0.264 according to correlation and Euclidean metrics, respectively. Figure 1 illustrates the scree plot and silhouette score plot of this clustering method across all cluster numbers.

Conclusion: Using clustering to leverage clinically significant features for more clinically meaningful classification of features shows promising performance compared with current standards in the field. Further work will focus on developing quantitative methods for feature selection and practical applications for clustering classifications.

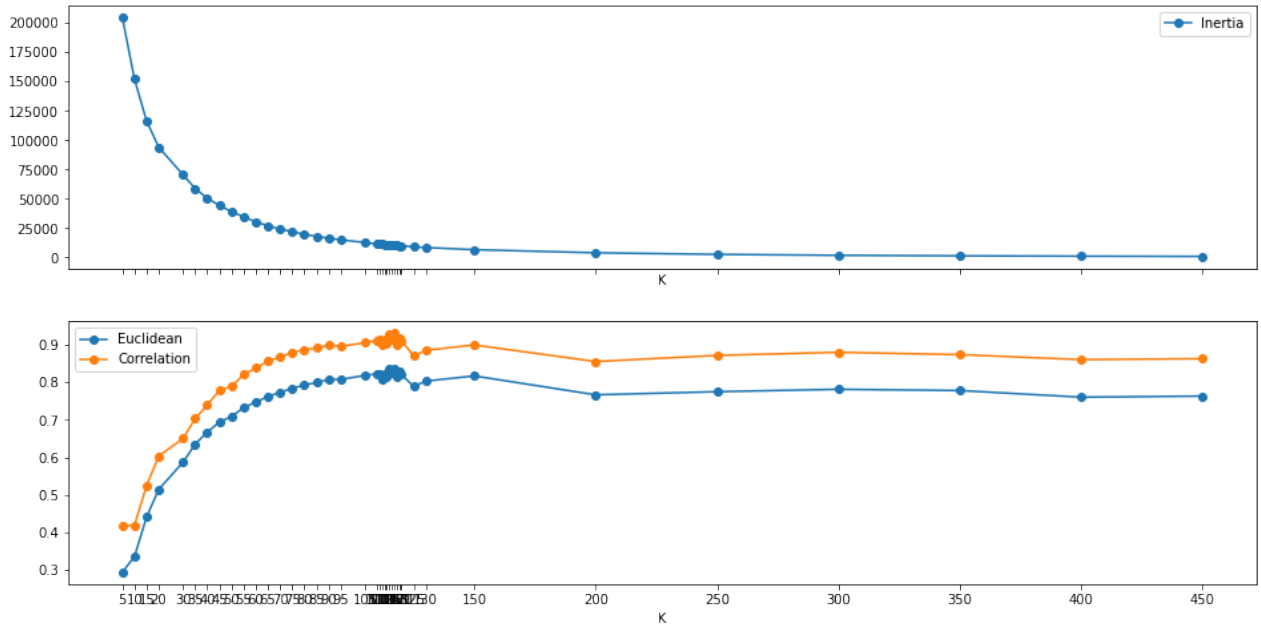

Figure 1. (Above) Scree plot plotting cluster number against proportion of variance explained within the dataset. (Below) Silhouette scores plotted for each cluster number using both Euclidean and correlation distance metrics.

References:
Number references in the order in which they appear in the abstract. The journal, volume and page number are required.

Abstract Title: Perioperative Risk Factors Associated with Unplanned Escalation of Care after Post-Anesthesia Care Unit Discharge

Presenting Author: Ryan L. Melvin, M.A., Ph.D., University of Alabama at Birmingham, Department of Anesthesiology and Perioperative Medicine

Co-Authors: Ryan Godwin, MS, PhD, University of Alabama at Birmingham, Department of Anesthesiology and Perioperative Medicine, Department of Radiology; Andrew B. Barker, M.D., University of Alabama at Birmingham, Department of Anesthesiology and Perioperative Medicine; Brant Wagener, M.D., Ph.D., University of Alabama at Birmingham, Department of Anesthesiology and Perioperative Medicine

Following Post-Anesthesia Care Unit (PACU) discharge, a number of patients require unexpected escalations in clinical care leading to transfer to intermediate care or the intensive care unit (ICU) setting. This study seeks to determine modifiable risk factors before PACU discharge and apply Artificial Intelligence/Machine Learning to predict patients that require escalations in clinical care to provide more effective patient care in the perioperative period.

We collected data from all non-cardiac surgical patients (n=58,931) discharged from the University of Alabama at Birmingham PACU between 2016 and 2019 in this single-site, retrospective study. Escalation of care was defined as patient transfer from the inpatient floor to either an intermediate care unit or ICU within three midnights of PACU discharge. A “credit scorecard” [1] modeling system was then applied as a set pre- and post-processing step layered on top of logistic regression. Continuous variables were binned into discrete categories and extant categorical variables were grouped using weight-of-evidence (WoE) binning [2]. Post-regression, WoE values were translated from model coefficients to scorecard points. Elastic-net regularized logistic regression served as both a variable selection method and hedge for colinear variables [3]. The final scorecard model range of values (0-100 points) was enforced upon the model by solving a mixed-integer programming problem.

Many of the top risk factors were simply the missingness of charted vital sign data within the last hour before discharge, suggesting immediately modifiable behavior that may improve patient outcomes. When applying the credit scorecard model to the clinical model, the best candidate model’s predictive ability places it in the acceptable range (AUC of 0.75, see Figure 1) on holdout data. In holdout data, there was a statistically significant ($p<0.01$) relationship between the model’s suggested score bins and the fraction of actual escalations that occurred for patients falling within those bins.

This model is intuitive in that the most important variables (by statistical significance and Shapley Additive Explanations [4,5]) match clinician intuition. Additionally, while there are too many variables to practically calculate by hand, the linear nature of a scorecard model makes it sufficiently simple and explainable that one could calculate the model’s output using pencil and paper addition. The ability to understand the modifiable risk factors that lead to increased patient risk of an escalation of care with three midnights of PACU discharge may lead to improved perioperative optimization and bed utilization, translating to improved patient outcomes and more efficient bed flow.

Images:

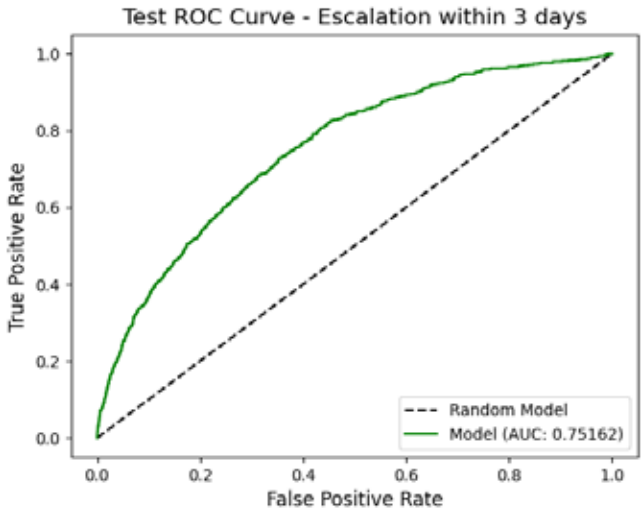

Figure 1: Receiver operating characteristic (ROC) curve is shown for the final model using holdout/ test data not used in model training. The corresponding area under curve (AUC) is presented in the figure legend. An AUC of 0.75 puts this model in an acceptable range of performance.

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Abstract Title: Prediction of Neonatal Hypoglycemia Risk from Maternal Continuous Glucose Monitoring Data Using Transfer Learning

Presenting Author: Ryan L. Melvin

Co-Authors: Ryan C. Godwin, Akila Subramaniam, Ashley N. Battarbee, Vivek V. Shukla

Neonatal hypoglycemia is a major complication in infants born to diabetic mothers. Hypoglycemia in neonates can cause neuronal injury and result in neurodevelopmental morbidities. The available data consisted of a 1-dimensional timeseries of maternal glucose readings every 5 minutes during pregnancy via continuous glucose monitoring (CGM) from a retrospective single-site study of mother-infant pairs monitored using CGM during prenatal care at the University of Alabama at Birmingham (UAB) from 9/1/2018 to 3/31/2022. The primary outcome was neonatal hypoglycemia, defined by serum/point of care glucose measurement of <40 mg/dl in the first 24 hours after birth. The study hypothesis was that a deep learning model with transfer learning could identify neonates at risk of hypoglycemia using maternal CGM data with good predictive ability (area under the receiver operating characteristic curve, AUC-ROC >0.70).

Given a small sample size (n=90), we employed a transfer learning [1,2] artificial intelligence (AI) framework to assign probabilities of the primary outcome using maternal CGM data. Searching for publicly available models trained on 1-dimensional sequence data led us to a convolutional neural network (CNN) [3] trained on the “FordA” dataset available from the UCR (University of California Riverside) archive [4]. We acquired the pretrained network from a Hugging Face repository [5] in a TensorFlow 2 implementation [6].

Model importing with pre-trained weight plus parameters and (re)training was conducted in Matlab 2022b using the Deep Learning Toolbox, which includes functions for importing trained TensorFlow models. For training with the UAB data set, the model input was the 1-dimensional CGM data for each mother with neonatal hypoglycemia as the binary target variable. During retraining, the “Weight Learn Rate Factor” and “Bias Learn Rate Factor” of the network’s last fully connected layer were set to 10 times that of all others, so that retraining would change this layer significantly more than any of the other pretrained layers.

The predictive ability of the model was assessed using the AUC-ROC, as this was a relatively balanced data set (44% in the positive – hypoglycemic neonate – class) with probabilities (rather than strict classification) being the desired output. For this feasibility study, understanding the ability of the model (re)training pipeline rather than a particular set of final model parameters and weights was judged most important. Therefore, we optimized model training parameters using a Bayesian parameter search and ran multiple training and testing cycles of this model using 5-fold cross validation (CV). The optimal training parameters resulted in a model with average CV AUC-ROC of 0.72 (95% confidence interval of 0.53 to 0.91), meeting our initial criteria for a successful feasibility study.

Predicted neonatal hypoglycemia at or before birth may lead to better infant outcomes via enhanced (and better allocated) monitoring and testing enabled by model predictions such as ours. Having proved the feasibility of our model-building pipeline, a prospective collection of more patient data for model training is underway. Future work will incorporate basic patient demographics and medical history on a larger patient population.

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Abstract Title: Pulse Oximetry Signals on the Wrist

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Introduction: Wearable sensors have emerged as an attractive method of patient monitoring that can bridge the gap between the hospital and home.[1] Typical wearable sensors include heart rate, body temperature and motion. Accurate pulse oximetry, which is a critical tool for clinicians to monitor patient blood oxygenation,[2] has remained an elusive parameter to incorporate into a wearable device.[3] Here, a wearable optical sensor is constructed to fit on the wrist.

Method: Optical physiological signals from the wrist and finger were collected on 10 subjects. A novel mechanical housing was constructed with a 3D printer and used to secure the optical components to the wrist with a band (Figure 1). The prototype device was plugged into a standard Nellcor™ pulse oximeter (N600x). On the same hand, a finger clip probe was placed on the index finger and used as a reference. Optical physiological signals were collected from the wrist and finger simultaneously.

Results: Pulse rate and SpO_2 were recorded from both devices during a stable period of no motion for 5 minutes. The signals collected on the wrist are shown to match the finger within +/- 1.2 BPM for heart rate and +/- 2.3 for SpO_2 (both measures are calculated as the root mean square difference from the finger measurement). The photoplethysmogram (PPG) from the finger was compared to the wrist and the wrist was found to produce on average 15.2 times lower percent modulation. An example PPG is shown in Figure 2 where the wrist signal modulation is approximately 15 times lower than the finger.

Conclusions: The wrist is a low perfused location and the optical physiological signals are weak when using spectral bands common for pulse oximetry. The lower modulation of the PPG on the wrist indicates a lower level of perfusion relative to the finger and the likely cause for difficult integration of pulse oximetry into a wearable. Noise, such as motion, can easily interfere with weak physiological signals and presents significant technical challenges for accurate pulse oximetry at the wrist. However, our early-stage results are promising and indicate that by utilizing a high-quality oximetry system and controlling for motion, physiological parameters (heart rate and SpO_2) measured on the wrist closely matched measurements on the finger (where the signal was 15x greater).

Figure1. Prototype wrist-worn sensor

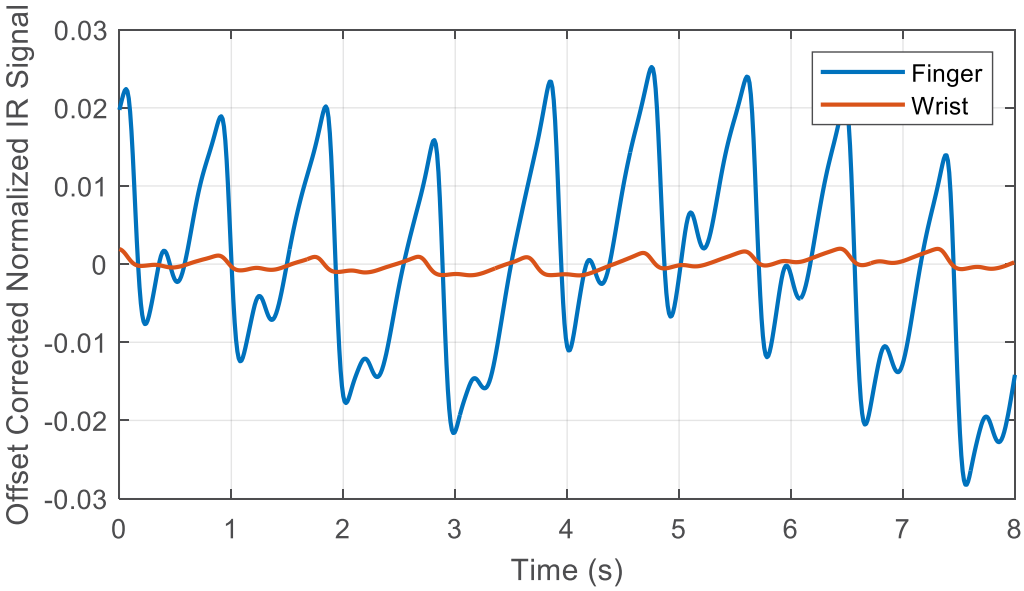

Figure 2 Offset corrected and normalized IR signals from the wrist, blue solid line, and finger, red solid line.

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Long-term effects of complex surgery and hospital stay on adolescents' sleep patterns.

Giovanni Cucchiaro MD, Geoffrey Gray Ph.D., Mohamed Rehman MD

AIM

This study aimed to assess sleep patterns in adolescents undergoing a Posterior Spine Fusion (PSF).

BACKGROUND

Sleep disturbance is one of the determinants of poor postsurgical outcomes. General anesthesia and complex operations can result in the total elimination of rapid eye movement (**REM**) sleep and changes in deep sleep, changes that can last for months. We enrolled adolescents scheduled for PSF, and gave them a Fitbit Charge 4 to wear before and during the hospital stay, and for 3 months after the PSF. The device recorded total sleep time (**TS**), duration of **REM** and **DEEP** sleep phases, and sleep efficiency.
Patients were given a PROMIS sleep questionnaire delivered to their cellular phone using Qualtrics the week before the hospitalization, during the hospitalization, and 3 months after surgery.
Pain scores were obtained every 4-6 hours during the patient's hospital stay using the self-reporting numeric scale.

RESULTS

16 patients (10 girls (62%) and 6 boys (38%)) completed the 3 months study period. Mean age was 16±1.9 years. The average length of the hospital stay was 3 days.

TS

TS time prior to admission was 387±111 minutes. 45% of the patients spent less time asleep while in the hospital compared to the preoperative period (Table 1), 33% of the patients spent more time asleep while in the hospital compared to the preoperative period. TS increased during the follow-up period going back to baseline values by the 3rd post-surgery week in 72% of the cases.

REM sleep

Duration of REM sleep was abnormal (less than 18% of the TS time) in 33% of the patients before their hospital admission and was abnormal in 56% of the patients during their hospital stay. REM sleep normalized within 3 weeks.

DEEP phase (DP)

DP sleep decreased by 50% in 67% of the patients during the hospital stay compared to the pre-admission value. DP increased once patients were discharged home. The duration of DP was never less than 13% of TS time.

Sleep efficiency

The sleep efficiency recorded during the study period was never below the normal value of 85%.

PROMIS

Patients' perception of their quality of sleep worsened during the hospital stay. Scores normalized by the 3rd month after surgery in 86% of the patients. (Table 3).

Pain scores

Pain scores ranged between 2 and 4 on a numeric scale throughout the study period.

DISCUSSION

Sleep phases of adolescents are affected after a major surgery. The changes are short-lived and not consistent amongst patients'. TS and sleep phases were abnormal before surgery in a small percent of cases. PROMIS and Fitbit data correlated.

Table 1: Percent of patients in whom we registered changes in the total sleep patterns at different points during the study with the changes in minutes spent in total sleep compared to pre-admission data. The average duration of total sleep pre-admission was 387±111 minutes

	Hospital	1st week	2nd week	3rd week	3 months
Decreased	45%	60%	33%	28%	20%
Minutes	-172±59	-87±40	-71±43	-100±71	-48±37
Increased	33%	10%	45%	36%	60%
minutes	+130±74	+53±1	+106±101	+127±105	+86±74
unchanged	22%	30%	22%	36%	20%

ABSTRACT TITLE: INTRODUCING GAS MAN ONLINE

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Co-Authors: Timothy Hendricks, Penn State University, Siandra Chelapurath, Penn State University, Ian Eviston, Penn State University, Levi Gerber, Penn State University, Shirui Tian, Penn State University, Mark Vernachio, Penn State University, How-Yeh Wan, Penn State University, James H Philips, ME, MD, Harvard Medical School

Introduction: Gas Man is a desktop application which is widely distributed as a simulation software to teach anesthesia residents and students inhalational gas pharmacokinetics [1] and has found clinical application in pharmacology research [2]. Since its initial development in 1982, the application has evolved and is now commercially available for Microsoft Windows and Apple macOS users. In order to perpetuate the use of this application, we are converting the current application to an open web app.

Methods: The original application was written in C++ using the Qt platform to allow for development in both operating systems. The code was first updated to run on a modern Linux/Ubuntu operating system. Qt for Webassembly (Wasm) module was then used in order to run the application directly in the user's browser with minimal changes to the original source code. Wasm enables deployment on the web for client and server applications and is present in all four major web browsers [3].

Results: The Qt Webassembly module allowed for the creation of standard web files such as HTML, JavaScript, and a binary file that is compiled by the host server. These files are stored locally on the server space and are accessible online. The new web app has a similar look and feel to the original desktop application (Figure).

Conclusion: This new non-desktop way of using Gas Man will make the application more accessible to users in tightly controlled hospital environments. Gas Man Online can be viewed on any web-connected device without the need to download or install additional files. The source code for this new application will be publicly released to allow for community-supported improvements.

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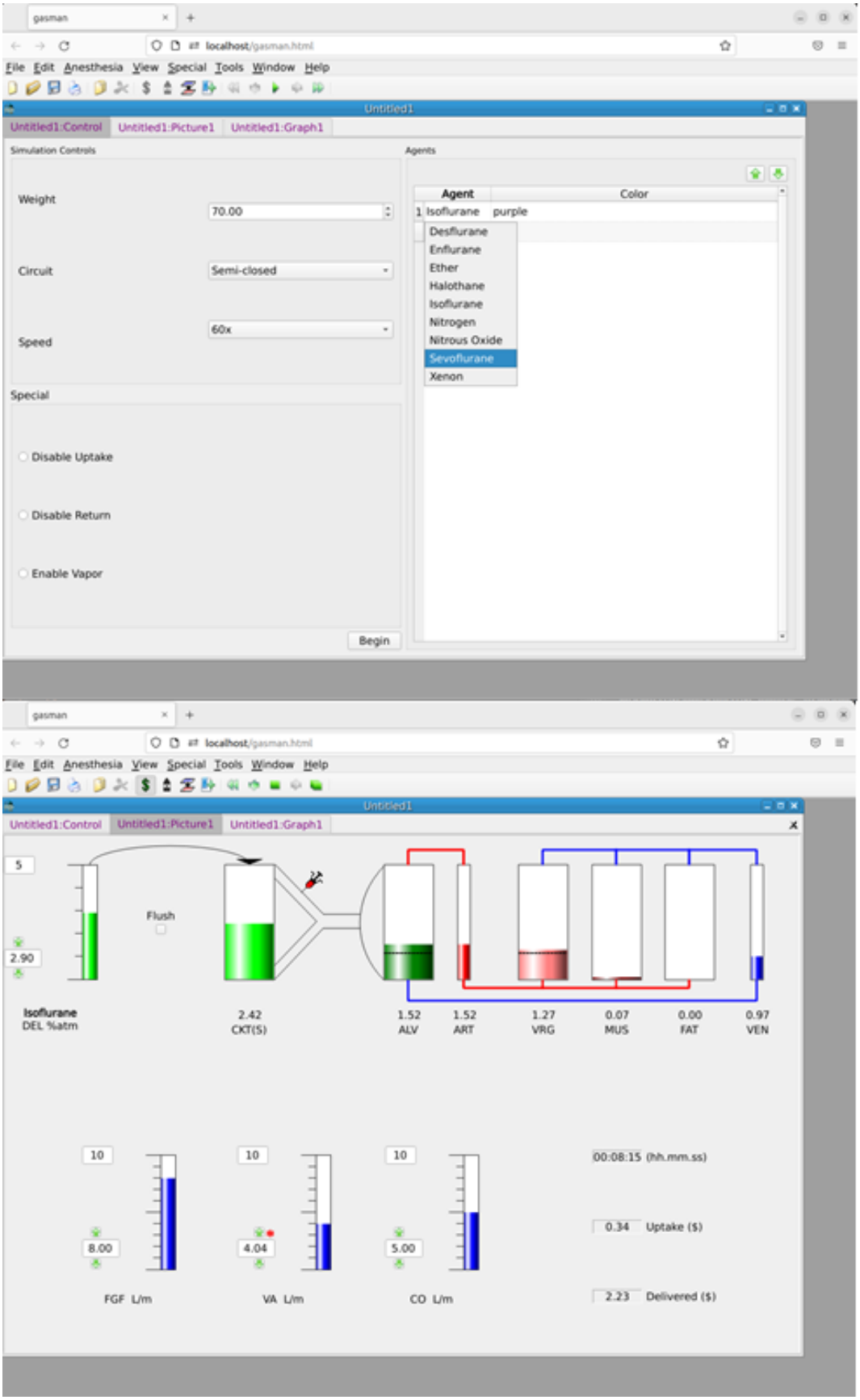

Figure: The following images show the application running in the Firefox web browser. The top figure shows the initial control screen. The bottom figure shows the inhalational gas distribution in the different compartments as a function of the drug delivery, fresh gas flow, alveolar ventilation and cardiac output.

In vitro model of prepacked CO_2 absorber use: development and testing

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Introduction

The canister life of prepacked CO_2 absorbents has been studied in vitro for various brands over a range of fresh gas flows (FGF) using a metric called 'fractional canister usage' or FCU [1]. FCU is the reciprocal of the time (in hours) for the inspiratory CO_2 fraction (F_ICO_2) to reach 0.5% (= the fraction of total canister life used per hour). The FGF - FCU relationship, previously found to be linear, has only been tested with a 160 mL/min CO_2 load (VCO_2) and 5 L/min minute ventilation (MV). We now extend the model to include the effects of VCO_2, target end-tidal CO_2 fraction ($F_{ET}CO_2$), MV, and dead-space ventilation (V_D).

Methods

We derived 4 models from first principles (see Figure 1) and tested them prospectively in vitro. In model A and B, MV was derived from spirometry, in model C and D from the alveolar air equation (Nunn): MV = $(VCO_2/F_{ET}CO_2)/(1\text{-}fVD)$, with fVD (dead space fraction) = 0.29, calculated with Bohr's formula: $fVD=(F_{ET}CO_2\text{-}F_{ME}CO_2)/F_{ET}CO_2$, with $F_{ME}CO_2$ = mixed-expired FCO_2 determined using a mixing bottle. In models B and D, an additional parameter (machine factor), allowing the intercept with the FGF to differ from MV, was empirically determined using Excel's solver function: minimization of squared differences between modeled and observed FCU.
Canisters (Medisorb, Molecular Products, UK, lot # LO1A-00903) were inserted into an Aisys machine (GE, Madison, WI) ventilating a 2 L bag with a known VCO_2 into its tip. To test whether the FCU intercept of the FGF - FCU curve varied proportionally with VCO_2, FCU of 5 canisters was determined with either 80, 120, 160, 240 and 320 mL/min VCO_2 while adjusting MV to 4.2% $F_{ET}CO_2$ with a 0.3 L/min FGF, and linear regression applied to the data. To test whether the FCU intercept was independent of MV, the measurements were repeated with a constant MV (5 L/min) and a paired t-test was performed to compare FCU values amongst this and the previous experiment ($p < 0.05$ denoting statistical significance). Secondly, we hypothesized that an increase in VCO_2 accompanied by a (proportional) increase in MV to keep $F_{ET}CO_2$ constant would shift the straight line describing the FGF-FCU relationship in a parallel manner. To test this, FCU was determined for 19 canisters with different combinations of VCO_2 (80, 160, 240 and 320 mL/min) and FGF (range 0.3 - 5L/min); MV was adjusted to maintain $F_{ET}CO_2$. Model performance when compared to observed FCU was assessed using Varvel's criteria [2], median performance error (MDPE) and median absolute performance error (MDAPE).

Results

FCU is proportional with VCO_2 and independent of ventilation (constant F_ACO_2 group: FCU = VCO_2 * 0.046 - 0.87; $r^2 = 1.00$; constant MV group: FCU = VCO_2 * 0.048 - 1.32; $r^2 = 1.00$). VCO_2-FCU pairs did not differ between the 2 groups ($p = 0.96$) indicating that FCU intercept is ventilation independent. Of the 4 models, model B and D performed best (see Figure 1) and confirmed the hypothesized parallel shift.

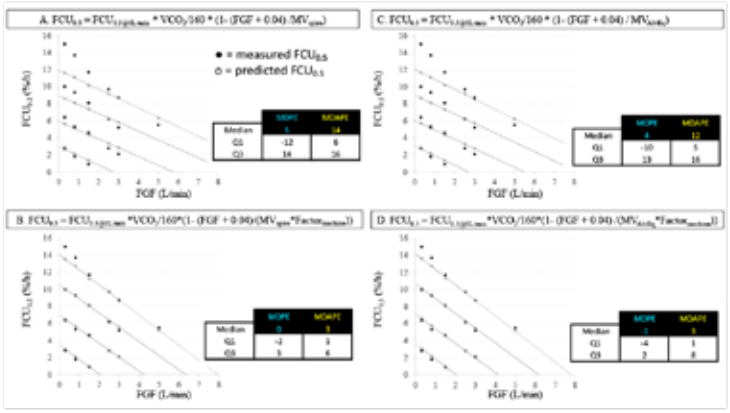

Figure 1 Four models derived from first principles and tested in vitro

Discussion

Over a 20-100% rebreathing range, the FCU-FGF models that allow the FGF intercept to deviate from MV by introducing the machine factor performed very well, with only small deviations from linearity during high FGF and VCO_2 extremes. Why the FGF intercept is lower than MV remains speculative but is possibly related to machine specific flow dynamics. These models will help us determine the economic and ecologic impact of anesthesia.

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A TESTING TOOL FOR THE CEREBRAL AUTOREGULATION COTRENDING ALGORITHM

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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]. Blood pressure outside the intact range of CA is associated with adverse patient outcomes. We have developed a real-time algorithm for the measurement of CA status based on the cotrending of mean arterial pressure (MAP) and regional oxygen saturation (rSO_2) signals, previously demonstrating its performance on a cohort of CVOR patients [2]. Here we describe a novel testing tool to synthesize MAP and rSO_2 to augment our clinical data and allow for robust testing of the algorithm over a wide operating range.

Method: The tool's parameters and operating ranges are provided in the table. The tool allows for the input of a test MAP signal which is matched with a synthetic rSO_2 signal. The two signals can be made to trend together to indicate an impaired autoregulation status or, alternatively, they can be decoupled to indicate an intact status (where systemic blood pressure is not driving flow).

Parameter	Range	Steps
Initial MAP	20-150 mmHg	15 mmHg
Initial rSO_2	15-95 %	10 %
LLA	40-90 mmHg	10 mmHg

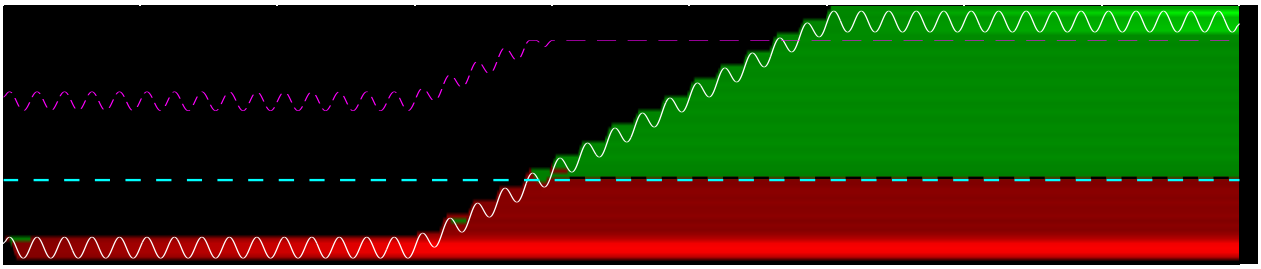

Figure 1

Results: Figure 1 shows a typical cotrending algorithm plot using for input synthetic MAP and rSO_2 signals (white and magenta traces, respectively). The LLA determined by the cotrending algorithm is indicated as the change from red to green shading. It shows excellent agreement with the inputted LLA (horizontal dashed line in the plot) and also indicated by the modulation in the input rSO_2 signal being switched off. We ran a range of parametrized synthetic inputs for a total of 272 algorithm runs and benchmarked the algorithm's accuracy using the Root Mean Square Differences (RMSD) between the input LLA and the algorithm output LLA. The mean of the RMSD for all synthetic datasets was 0.29 ± 0.41 mmHg.

Conclusions: A synthetic model has been presented to test our cotrending algorithm over a wide range of parameters. The results of this parametric study have been presented and demonstrate that the algorithm performs well within our target accuracy of 5 mmHg. We believe this to be a most useful tool for the development of a robust algorithm. Future work may include adding noise to the generated data to further test the robustness of the algorithm.

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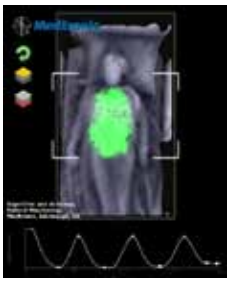
ROBUST RESPIRATORY RATE MONITORED 'TOUCHLESSLY' USING A DEPTH CAMERA

Presenting Author: Paul S. Addison, PhD, Distinguished AI and Data Scientist.
Co-Authors: André Antunes, PhD, Senior AI / Data Science Engineer & Dean Montgomery, PhD, Principal AI Engineer. Patient Monitoring, Medtronic, Edinburgh, Scotland, UK.

Introduction: One of the most common vital signs measured in the clinical setting is respiratory rate (RR). A significant change in RR is often an early indication of a major complication such as respiratory tract infections, respiratory depression associated with opioid consumption, anesthesia and/or sedation, as well as respiratory failure [1–3]. Here, we report on the performance of a depth-sensing camera system [4] for the continuous non-contact 'touchless' monitoring of Respiratory Rate (RR), extending our previous results reported previously at STA [5] from 266 separate rates within a cohort of six volunteers to 908 rates and thirteen volunteers.

Method: Thirteen healthy subjects undertook a range of breathing rates from 4 to 40 BrPM. These were set rates of 4, 5, 6, 8, 10, 15, 20, 25, 30, 35 and 40 BrPM. In total, 908 separate tasks were captured across a range of conditions including posture (prone, supine, lateral), position (center and edge of bed) and coverings (no sheets, sheets, duvet). Depth information was acquired from the scene using an Intel D415 camera. This data was processed to extract depth-changes within the subject's torso region corresponding to respiratory activity (as shown in the figure). A respiratory rate RR_{depth} was calculated using our latest algorithm and output once-per-second from the device. This was compared to a capnograph reference, RR_{capno}.



Results:
The table contains the results for RR_{depth} versus RR_{capno} for all subjects and tests. An overall RMSD of 0.73 BrPM (mean bias of -0.06 BrPM) was achieved across the target RR range of 4-40 BrPM. The table also contains the results across four separate subranges 4-10, 10-20, 20-30 and 30-40 BrPM: all demonstrating adequate performance for the clinical setting. Note also the high uptime of the algorithm (where uptime is defined as the time that a respiratory rate is posted by the algorithm during the study). A high uptime is essential for the development of a clinically viable algorithm for use in a medical device.

Range (BrPM)	RMSD	Bias	uptime	N_tasks	samples
>1 to 10	0.43	-0.06	99.70	288	8602
>10 to 20	0.81	-0.17	100.00	207	6204
>20 to 30	0.93	-0.10	100.00	207	6148
>30 to 40	0.73	0.09	100.00	206	6171
>4 to 40	**0.73**	**-0.06**	**99.90**	**908**	**27125**

Conclusions:
We believe that non-contact monitoring has great potential for the robust monitoring of a range of physiological and contextual parameters. The results reported here indicate the viability of touchless monitoring for the determination of one of these parameters - respiratory rate - over a pertinent clinical range of 4 to 40 BrPM. We are currently exploring other potential uses of the technology including the detection of malignant respiratory patterns and the identification of apnea episodes.

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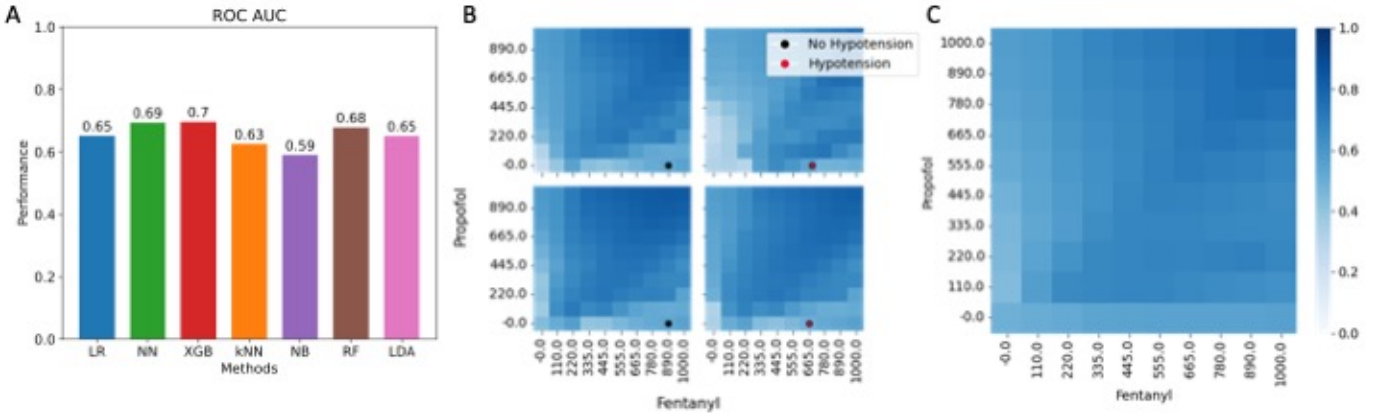
Abstract Title: Recommending Anesthesia Dosages with Neural Networks

Presenting Author: Kathryn Sarullo
Co-Authors: *Muntaha Samad, Samir Kendale, S. Joshua Swamidass, Pierre Baldi*

Abstract Content: It has been shown that anesthesia can have adverse effects if administered improperly and that post-induction hypotension is a well-known risk factor for adverse postoperative outcomes (1). For this study, we define post-induction hypotension as mean arterial pressure (<60mmHG) occurring during the first 20 minutes after anesthesia induction. Anesthesiologists estimate anesthetic dosages based on the patient's weight, age, medical history, surgery, and domain knowledge. There is no set method or guideline for recommending anesthetic doses to patients; instead, different clinicians will reach different findings. Machine learning is becoming more widely applicable, trustworthy, and interpretable for use in predicting post-induction hypotension (2,3). Neural networks can model a wide range of data while remaining robust and accurate. Approximately 201,000 patient records totaling 75 features were gathered for this study. This information includes clinical characteristics, medication history, details of the undergone procedures, and anesthetic doses administered, specifically for the medications fentanyl and propofol. The work aims to use machine learning to suggest anesthetic doses that can be generalized to an average patient population or specialized for a specific patient. We implemented several classification algorithms to model post-induction hypotension. These models were implemented with 5-fold cross-validation and were measured in performance by the area under the receiver operating characteristic curve (AUC ROC). Gradient boosting and the neural network had the best performance (AUC ROC = 69.6%, AUC ROC = 69.4%) (Figure 1A). We decided to proceed with the neural network since the interactions between fentanyl and propofol were closer to monotonic than those of the gradient-boosting approach. To recommend doses and assess patient risk, we quantified features' responses and interactions by fixing the values of fentanyl and propofol. In doing so, we can use our trained model to create a heatmap showing the likelihood of post-induction hypotension of these new values. This technique can be used for a single patient (Figure 1B) or we can average results across patients (Figure 1C).

Images:



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Title: Prediction of cardiac surgery associated AKI using machine learning and noninvasive urine oxygen monitoring

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Kai Kuck, University of Utah Department of Bioengineering; University of Utah Department of Anesthesiology
Natalie Silverton, University of Utah Department of Anesthesiology; Geriatric Research, Education, and Clinical Centre, Salt Lake City VAMC, UT

Background: Acute kidney injury (AKI) is a common complication of cardiac surgery.[1] Due to lack of therapies that enhance renal recovery current clinical care focuses on injury prevention. However, current diagnostic tools, as defined by the Kidney Disease Improving Global Outcomes (KDIGO) guidelines, do not have prognostic value.[2,3] Researchers have shown certain biomarkers demonstrate good discriminatory ability with an area under the receiver operator characteristic curve (AUROC) ranging from 0.7 to 0.8.[4] These biomarkers have limited clinical utility as they require expensive equipment and do not provide immediate results. Recently, researchers have focused on the partial pressure of oxygen in the urine (PuO_2) as a physical biomarker of AKI because it has been shown that renal hypoxia plays an early role in the development of the disease.[5] While studies indicate PuO_2 may be useful for identifying patients who develop AKI there are no real-time algorithms which could be incorporated into a PuO_2 monitor.[6] Thus, the aim of this research was to develop an algorithm based on intraoperative PuO_2 and patient characteristics to predict post-operative AKI.

Methods: Second-by-second intraoperative PuO_2, body mass index (BMI) and baseline serum creatinine values were collected in 86 cardiac surgery patients.[6] Patients were diagnosed with AKI based on the urine output and serum creatinine KDIGO criteria. These data were used to train and test 3 machine learning algorithms: a support vector machine ensemble with bagging, CatBoost (gradient boosted decision trees), and a fully connected neural network.[7] The data were split into training and testing groups, stratified by stage of AKI diagnosis. To identify the best set of hyperparameters 10-fold cross-validation was performed using only the training data. The AUROC was averaged across all 10 folds for every combination of hyperparameters in a defined search space. The set of best hyperparameters was trained on the entire training set and evaluated on the test set. The AUROC was calculated based on the algorithms' predicted probability that the subject developed AKI. This process was repeated 50 times and a vertical averaging method was used to calculate the mean ROC curve and associated 95% confidence interval (CI) and the mean AUROC and associated 95% confidence interval.[8]

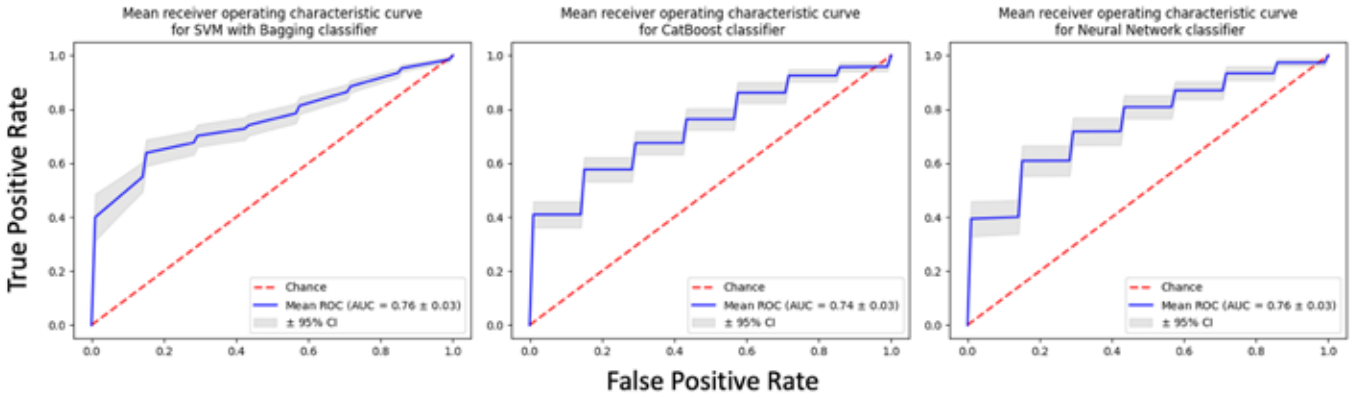

Figure 1 - Mean ROC curve for untrained data for 3 different machine learning algorithms (from left to right: SVM ensemble with bagging, CatBoost and fully connected neural network) trained on PuO_2, BMI, and baseline creatinine data.

Results: Figure 1 shows the mean ROC curve for each algorithm. The average (± 95% CI) AUROC was 0.76±0.03, 0.74±0.03, and 0.76±0.03 for the SVM with bagging, CatBoost and Neural Network classifiers, respectively.

Discussion: This research shows that machine learning algorithms trained with intraoperative PuO_2 data can reliably identify patients who will develop post-operative AKI compared to urinary biomarkers. These algorithms could be deployed in real time and are associated with a relatively low-cost device. One of the major limitations of this research is the small sample size. However, it is likely that as more data is collected the performance of the algorithm will improve as the underlying true distributions of PuO_2 in patients with and without AKI are clearer.

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An Internet of Things (IoT)-Based Wireless Telemetry Aggregation System with Text Message Notifications Using the $3 ESP8266 Micro-controller and Amazon AWS Cloud Computing

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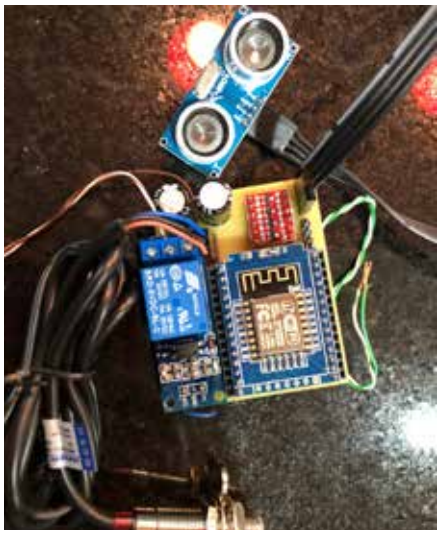
Co-Authors: Nicholas Markin, MD – University of Nebraska Medical Center

Scientific experiments frequently require the collection, aggregation, and logging of telemetry data (e.g. temperature, pressure, voltages, etc.) from multiple sources [1]. An ideal data collection system is one that is low-cost, easy to set up, reliable, and uses wireless connectivity to obviate the need for inconvenient and cumbersome wiring – attributes also desirable in perioperative telemetry systems used to monitor patient vital signs [2].

We present a wireless telemetry system that meets these design goals based on the ESP8266 micro-controller chip (Fig. 1), a micro-controller with capabilities comparable to those of the popular Arduino platform ubiquitous to many Maker communities, which further provides system-on-chip WiFi networking and $3 price point [3]. This system, originally developed in October 2018, leverages both OpenSource and custom software, and has seen continued use since its inception - currently collecting between 60 to 70 data feeds from 15 separate WiFi nodes.

Next, we demonstrate how the next generation of the ESP8266 micro-controller, the dual-core ESP32, can be used to securely interface with Amazon AWS's Cloud Computing platform using industry standard encryption, for data-logging and other purposes. Further, we demonstrate how Amazon AWS services such as Lambda, DynamoDB, and Simple Notification Services (SNS) were used to develop an automated SMS text message notification system for telemetry data.

Finally, we show how similar, low-cost telemetry aggregation and collection systems may be used in various scientific experiments and research of interest to practicing anesthesiologists, and discuss how



such technologies may eventually become transformative to perioperative patient care.

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Abstract Title: Development and Validation of a Semiautomated Process to Retrieve Publications by Faculty Members in Academic Medical Departments

Presenting Author: Dorothee A. Mueller, MD, VUMC
Co-Authors: Carmen D. Manresa, MD, University of Miami; Robert E. Freundlich, MD, VUMC; Jeremy P. Walco, MD, VUMC, Shawn E. Banks, MD, University of Miami; Richard H. Epstein, MD, University of Miami

Introduction: Identifying peer-reviewed, indexed publications to assess academic productivity[1] can be challenging for departments that rely on their faculty self-reporting. Some departments manually search for such citations, which is time-consuming and often not systematic, but is needed for reporting to the Accreditation Council for Graduate Medical Education or for verifying publications as part of an incentive pay structure. We developed and validated a simple, scalable algorithm in Excel (Microsoft) using formulas and Visual Basic for Applications that identified faculty publications.

Methods: Input to the algorithm includes the last name and first initial of the faculty, alternative versions of the anesthesia department's name, and alternative versions of the institution's name. Also, a list of publications where anesthesia faculty typically publish is included to allow potential matches where the department's name was mis-specified or absent. Complex query strings that can be copied into the advanced search field in PubMed and Scopus are generated. The csv output files from the 2 sources are then processed to match the coauthor names to departmental faculty. The workbook collates all the identified references by faculty and sends an email to each for confirmation. The performance of the algorithm was evaluated at two large academic institutions where validated lists of faculty publications were available.

Results: More than 94% of the validated references were identified with less than 6% of references missed. The true positive rates were > 93% and the false positive rate <7%. The typical cause of false positives was where at least one coauthor was from the institution, but not from the department of anesthesiology, and the identified author was from a different institution and matched the last name and first initial of a department member. The most common causes of missed references was because the name of the department was missing and the publication was not in the list of target journals, or the institution was not identified. The workbook to perform the retrieval process is available upon request of the senior author.

Table . Validation of Algorithm to Identify Department References with a PubMed Identifier (PMID)

	Institution 1	Institution 2
Year Published	2020-2021	2019-2021
Validated References (Actual)	143	760
Identified by the queries	137 (95.8)	717 (94.3%)
Missed by the queries	6 (4.2%)	43 (5.7%)
Total Matches from Queries	153	633
True Positive	143 (93.5%)	609 (96.2%)
False Positive	10 (6.5%)	24 (3.8%)

Conclusions: The method we developed has sufficient accuracy to be useful for departments wishing to complete the initial screening of their faculty's publications. Manual checking is still required, but since the workbook returns the link to the digital object identifier (DOI) for each publication where a DOI is supplied (e.g., all PubMed references), this step could easily be performed by an administrative assistant within the department. Furthermore, there are no automated retrieval process which are sufficiently accurate as to not require validation. A limitation is that many references without a PMID will not be found, which would become the responsibility of the faculty to add to their list when confirming the identified references.

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Intraoperative Occult Hypoxemia is an Independent Risk Factor for 30-day and 1-year Mortality

Presenting Author: Blaine Stannard, MD[1]
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Background: Despite the widespread use of pulse oximetry for intraoperative estimation of arterial oxygen saturation, there is growing evidence that certain patient populations may be vulnerable to inaccurate pulse oximetry measurements. Our author group previously investigated the incidence of occult hypoxemia for patients undergoing anesthesia and found that Black and Hispanic race/ethnicity was significantly associated with higher odds of occult hypoxemia relative to White patients [1]. However, the clinical implications of these events have not been established. There is emerging evidence in the critical care literature that unrecognized hypoxemia is associated with end-organ damage and adverse outcomes, such as in-hospital mortality [2,3]. In this investigation, we sought to better elucidate the relationship between intraoperative occult hypoxemia and postoperative mortality among patients undergoing anesthesia.

Methods: Data was collected from our departmental data warehouse for all adult patients (≥18 years) undergoing anesthesia between 2008 to 2019 with at least one intraoperative arterial blood gas recorded. The number of occult hypoxemic events, defined as arterial oxygen saturation (SaO_2) of less than 88% despite oxygen saturation measured by pulse oximetry (SpO_2) greater than 92%, were determined. Demographic (including self-reported race/ethnicity), intraoperative, and comorbidity data were recorded. Mortality data for our cohort was extracted from the United States Social Security Death Index and used to determine thirty-day and one-year postoperative mortality. Multiple logistic regression modelling was utilized to analyze whether at least one occult hypoxemic event was predictive of 30-day and 1-year mortality.

Results: There were 38,475 patients and 128,666 paired readings included in the final analysis. There were 921 patients (2.4%) with at least 1 occult hypoxemic reading. Of these, 849 patients (92.2%) had one occult hypoxemic reading and 72 (7.8%) had two or more occult hypoxemic readings. The overall 30-day mortality rate was 2.9% and one-year mortality rate was 8.3%. In our multiple logistic regression model, patients that experienced at least one occult hypoxemic event had significantly higher odds of both 30-day mortality (Odds ratio [OR] 1.65, 95% confidence interval [CI] 1.14 to 2.36, p=0.007) and one-year mortality (OR 1.60, CI 1.25 to 2.08, p<0.001). Interaction terms between race and occult hypoxemia were tested and found to not be significant for predicting 30-day (p=0.345) and one year mortality (p=0.653) and thus were not included in the final model. This model was repeated after stratifying the cohort into patients with zero, one, and two or more occult hypoxemic events. Two or more occult hypoxemic events had a higher odds ratio for predicting 30-day mortality (OR 3.16, CI 1.28 to 7.77, p=0.012) than only one occult hypoxemic event (OR 1.49, CI 1.00 to 2.23, p=0.048). A similar relationship was observed for predicting one-year mortality for one event (OR 1.54, CI 1.16 to 2.01, p=0.002) and two or more events (OR 2.44, CI 1.63 to 5.10, p=0.018).

Conclusions: Overall, we found that intraoperative occult hypoxemic events were associated with significantly higher odds of 30-day and 1-year mortality. Moreover, the mortality risk appears to rise with two or more occult hypoxemic events.

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An Adaptation of the Eleveld Pharmacokinetic-Pharmacodynamic Model for a Burst Suppression Endpoint

Presenting Author: Carter Lybbert, BS, University of Utah
Co-Authors: Brian J. Mickey MD PhD, Keith G. Jones BS, David Odell MD, Jordan Stanford BS, Scott C. Tadler MD, Jason Huang MS, Kai Kuck PhD, University of Utah

Introduction

Repeated administration of high doses of certain anesthetics, such as propofol, to patients with treatment-resistant depression (TRD) has been shown to produce antidepressant effects in several small clinical trials [1]. These effects can be elicited when the patient's EEG burst-suppression ratio (BSR) is maintained at 70-90% for approximately 15 minutes in repeated treatments [1]. This deep-anesthesia domain lies beyond the range of current propofol pharmacokinetic/pharmacodynamic (PK/PD) models. In this study, we adapt the Eleveld PK/PD model for use at deep anesthesia levels with a BSR endpoint, with the goal of aiding anesthesiologists in estimating the dosage of propofol needed to achieve 70-90 % BSR for 12-15 minutes. We test the ability of the adapted model to predict BSR for these treatments in human subjects.

Methods

Twenty participants underwent 6-9 treatments of high doses of propofol (5-7 of which were included in this analysis) for a total of 115 treatments. To adapt the Eleveld model for this endpoint, we optimized the model PK parameter Ke0 and PD parameters γ and C_e50 for this endpoint. These parameters were then used in the adapted model to estimate second-by-second BSR for each treatment. For periods where BSR was >30 %, estimated BSR was compared with observed BSR for each treatment of each participant. Estimated vs observed treatment duration was also compared. Median absolute performance error (MdAPE) was calculated for each between estimated and observed BSR and treatment duration.

Results

MdAPE between the estimated and observed BSR (25^{th}-75^{th} percentile) was 6.63 (3.79-12.96) % points and 8.51 (4.32-16.74) % between the estimated and observed treatment duration. MdAPE for treatments 2-5 was lower than the MdAPE for treatment 1, for both BSR and treatment duration predictions. Only treatment 3 MdAPE of the treatment duration measurement was statistically significantly lower than treatment 1 ($p = 0.006$).

Discussion

Our results of MdAPE of 6.63 % points for predicting BSR cannot be directly compared to the Eleveld model performance reported by Vellinga *et al.* [2] for predicting BIS, because BSR and BIS are not identical measures of anesthetic depth. Once transformed to an equivalent BIS performance error via BIS = 50-(BSR/2), our MdAPE (25^{th}-75^{th} percentile) is 3.32 (1.90-6.48) BIS [3]. This is considerably lower than the MdAPE (25^{th}-75^{th} percentile) BIS error of the standard Eleveld model reported by Vellinga *et al.* of 7.88 (1.95-17.9) [2]. This better performance may be due to the adaptation of the model parameters for treatments 2-5 of each participant to reflect their individualized pharmacokinetics and pharmacodynamics. Even though the differences between treatments 2-5 and treatment 1 were not statistically significant, their difference nevertheless played a strong role in the excellent BSR estimation performance of our model.

Conclusion

We have shown that the Eleveld PK/PD model can be effectively adapted for use in a high-dose propofol treatment scenario to predict BSR as a PD endpoint. The model performs with excellent accuracy. This tool may be used to provide and improve dosing guidance for high-dose propofol treatments. Future work should further validate these results with larger and more diverse participant populations and with studies specifically designed for PK/PD analysis. Doing so will facilitate the successful implementation of high-dose anesthetic treatments for those suffering from TRD.

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Establishing an Institutional Pediatric Cardiac Anesthesia Data Framework

Presenting Author: J. "Nick" Pratap, MB BChir, MRCPCH, FRCA[1,2]

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Introduction: Survival with congenital heart disease (CHD) is crucially dependent on procedures performed under anesthesia, including surgery, diagnostic and interventional catheterizations, and other cardiac imaging. The recent ACGME accreditation of training programs in pediatric cardiac anesthesiology reflects the pivotal role of skilled anesthesiologists. A detailed understanding of exactly how anesthesiologists contribute to good long-term outcomes, however, is obscured by the heterogeneity of lesions and procedures, details of anatomical repair or palliation, and postoperative critical care management.

Several specialty-focused registries in the US and elsewhere, including the Congenital Cardiac Anesthesia Society's database, curate high-quality data concerning CHD patients. Each registry has particular strengths, which are typically related to the specialty group who created it.

Methods: In order to investigate our specialty's contribution to postoperative outcomes in CHD, we are establishing a pediatric cardiac anesthesia data framework at our institution. We integrate data from the Epic (Madison, WI) Electronic Health Record and Anesthesia Information Management System with curated data submissions to established CHD registries.

Our first step was to establish a categorization of surgical cases at a level equivalent to how we would answer a colleague who asks, "What case are you doing today?" For example, the Society of Thoracic Surgeons (STS) Congenital Heart Surgery Database records anatomical aspects and component parts of surgical procedures exhaustively and reliably, but this level of detail is less well suited to the more pathophysiologic interests of anesthesiologists and intensivists. For example, anesthesiologists might be interested in all cases where VSD closure is the primary part of the surgery, and therefore would want to exclude cases where VSD repair forms a minor part, such as when VSD repair accompanies an arterial switch operation. In addition, we have created linkages to other CHD registries such as American College of Cardiology's IMPACT Catheterization database and the Pediatric Cardiac Critical Care Consortium (PC4) to enhance the availability of high quality data.

Results: We have developed an algorithmic approach to translating STS procedural classification to physiologic groupings of surgeries. A group of subject matter experts mapped 1,888 STS codes down to 150 categories. As a first test of the relevance to anesthesia professionals, we have created a secondary mapping down to the 18 categories of case logs required by the new ACGME pediatric cardiac anesthesiology curriculum. In addition to STS procedural codes, this secondary mapping relies also on fields detailing the patient's age, use of cardiopulmonary bypass, and specialty of proceduralist/surgeon, as well as data from IMPACT, in order to accurately complete such categories as "neonatal procedures for correction/palliation/revision of congenital cardiac lesions on bypass" or "patent ductus arteriosus (surgical or catheterization laboratory) procedures off bypass."

Conclusion: We have demonstrated the feasibility of integrating EHR and AIMS data with pre-existing CHD registries in a way that is meaningful to pediatric cardiac anesthesiology practice. Future uses of our data framework will likely include supporting research, quality improvement, education and workforce planning in pediatric cardiac anesthesiology.

Neurointerventional Room Design - An Iterative Approach

Peter L, Fine, M.D., M.S., Danbury Hospital (Nuvance Health Care Network), Danbury. Connecticut

Background: Over the last 3 years at our institution, we have designed and built 3 neurointerventional suites that are also cardiac catheterization laboratories. These rooms were also designed for advanced cardiac catheterization procedures. The rooms were designed and constructed with multidisciplinary team from initial design to final buildout. Since these rooms were constructed in sequence rather than simultaneously, we applied the lessons learned in design and construction of preceding rooms to the design of the subsequent rooms.

Non-operating room anesthesia is known to complicate the safe delivery of anesthesiology (1,2). Typically, the rooms are distant from the main operating room. The layout of the rooms is awkward for induction and maintenance of anesthesia due to the presence of one or 2 X-ray fluoroscopy arms. Often, the medical gas connections are not at the normal location of the room, cephalad to the patient's right shoulder. Neurointerventional procedures demand anesthesia maintenance with the anesthesia machine at the patient's left foot to keep the anesthesia machine and connections from being struck by the fluoroscopy arms rotating around the patient.

Design and Construction: We provided two anesthesia gas booms in each room, one for cardiac catheterization procedures, the second for neurointerventional procedures. These booms have identical medical gas, electrical and data connections that we have in our institution's operating rooms (3). The anesthesia monitors are integrated into the video distribution system. Each room has connections for cardiopulmonary bypass and nitrogen connections to facilitate ventriculostomy placement.

After opening the first location, we noticed shortcomings with the design. Shifting the anesthesia machine from cardiac to neurointerventional boom takes more than 20 minutes. This room had to be left in the neurointerventional configuration to facilitate in starting emergency cerebral thrombectomy procedures. In this room, the anesthesia connections are on the same boom as the main procedure monitor. When anesthesia is not present, the hoses and cables run across the floor, and the machine is always an obstruction in room. We also found that the non-invasive blood pressure hose limited how far the anesthesia machine could be located away from the procedure table.

In the second room, the anesthesia connections for neurovascular procedures were moved to a dedicated boom. This facilitated moving the anesthesia machine to the head of the room for induction, then moving toward the left foot of the bed for maintenance of anesthesia. The boom also had range to allow parking of the anesthesia machine on the wall at the top left corner of the room..

In the third room, we relocated the cables for the anesthesia monitors to a mount on the rail at the left foot of the table. This remote monitor was linked to two connectors in a box in the floor under the foot of the table. Each of these connectors is routed to each anesthesia boom (cardiac and neurovascular), for connection to the anesthesia monitor display on the anesthesia machine. An anesthesia machine parking space was added on the left side of the room between the supply cabinets. Finally, a remote control anesthesia monitor was added inside the control room to allow the anesthesiologist to monitor the patient from the control room to minimize x-ray exposure. .

Conclusions: By designing each room in sequence, we learned the shortcomings of the preceding design and applied these lessons to the next room. The remaining problem is easing transition from induction to maintenance in neurovascular procedures. It remains a complex dance maneuvering the anesthesia machine, its boom and the main procedure monitor boom. Involving a multidisciplinary team throughout design and construction of interventional suites improves the care of patients and the experience of users.

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Abstract Title: Evaluation of System to Reduce Leak During Manual Ventilation Over Cannula

Presenting Author: Christian Orr, MS-3, University of Utah Department fo Anesthesiology
Co-Authors: Derek Sakata, MD, Trey Blackwell, BS, Joseph, Orr, PhD, University of Utah Department of Anesthesiology

Introduction:
Preoxygenation prior to endotracheal intubation is standard practice to mitigate hypoxemia following induction of general anesthesia.[5] Commonly the delivery method is via anesthesia machine breathing circuit and air-cushioned mask (ACM). The downside of preoxygenation with an air-cushioned mask is that it requires a tight seal, otherwise the air leak results in inferior pre-oxygenation. McQuade et. al found that supplementing a bag-valve-mask (BVM) with O2 administration via nasal cannula (NC) at 15L/min could offset the effects of an imperfect seal as did Hayes-Bradley et. al.[3,4] NC supplementation also offers the added benefit of allowing the clinician to pause BVM ventilation to assess for spontaneous breathing while continuing to oxygenate the patient. We are evaluating a novel O_2 NC delivery system that, upon sensing a positive pressure $\geq$ 2.5 cm H_2O, administers oxygen via NC at 30L/min. The purpose of this study is to evaluate this device's ability to compensate for leak during positive pressure mask ventilation.

Methods:
Positive pressure mask ventilation and associated leak was tested via air-cushioned mask ventilation of a silicon-molded face (EcoFlex 00-10, Smooth-on, Macungie, PA) with a 3-D printed model of a nasal airway. The nasal airway was connected to a test lung (TTL, Michigan instruments, Grand Rapids, MI), set at a compliance of 50 ml/cm H_2O, through a simulated trachea (12mm inner diameter tube) with a 5.6 mm parabolic flow restrictor between the lung and trachea. For consistency, a noninvasive ventilator (V60, Philips-Respironics, Carlsbad, CA) was used instead of a BVM. A flow sensor (NM3, Philips-Respironics, Wallingford, CT) measured volume of gas delivered. Four conditions were tested. In the first, the ACM was applied directly to the face and then in 3 conditions in which a NC was between the ACM and face. In these 3 conditions, the NC was set at 0 lpm, 4 lpm or attached to the novel O_2 delivery device. Each of the 4 conditions were tested under 6 different average downward forces of the mask by using a an elastomeric mask. A Leak was determined by comparing the difference in tidal volumes (TV) without leak, ventilator connected directly to the test lung, and that generated by each mask condition.

Results:

Below are the results for the tidal volume (mls) delivered and percentage leak in each test condition.

Average Downward Force on Mask (lbs.)	Control	Mask only (mls(% leak))	Cannula under mask (mls(% leak))		
			0 lpm	4 lpm	O_2 Device
2.4	650	280 (57%)	49 (92%)	152 (77%)	278 (57%)
3.0	650	384 (41%)	244 (62%)	342 (47%)	392 (40%)
3.4	650	489 (25%)	354 (46%)	432 (34%)	507 (22%)
3.8	650	555 (15%)	425 (35%)	464 (29%)	604 (7%)
4.2	650	575 (12%)	446 (31%)	490 (25%)	650 (0%)
4.7	650	599 (8%)	450 (31%)	533 (18%)	650 (0%)
Avg % Leak	N/A	26%	50%	38%	21%
Std. Dev.	N/A	19.2%	24.2%	21.3%	23.4%

Discussion:

With increased downward pressure, gas leak was minimized but not eliminated. Addition of the nasal canula between the mask and face increased leak and was only partially mitigated with increased downward force and/or addition of 4 lpm. Using the novel O2 device mitigated leak such that masking was comparable or better than that with the mask only. The importance of this is that ventilation requires muscle memory that takes time and much practice to develop proficiency. Additionally, sedation is a balance of comfort and breathing in which a nasal canula is utilized. Should hypopnea or apnea occur, ventilation will be augmented with a cushioned mask. Removing the canula adds one additional step when time is of the essence. Even without a canula, for novices, masking while mitigating leak is difficult. It can even be more difficult when the patient has a beard or is edentulous.

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Abstract Title: Development of a reinforcement learning model for dynamic ventilation control in surgical patients during emergence from general anesthesia

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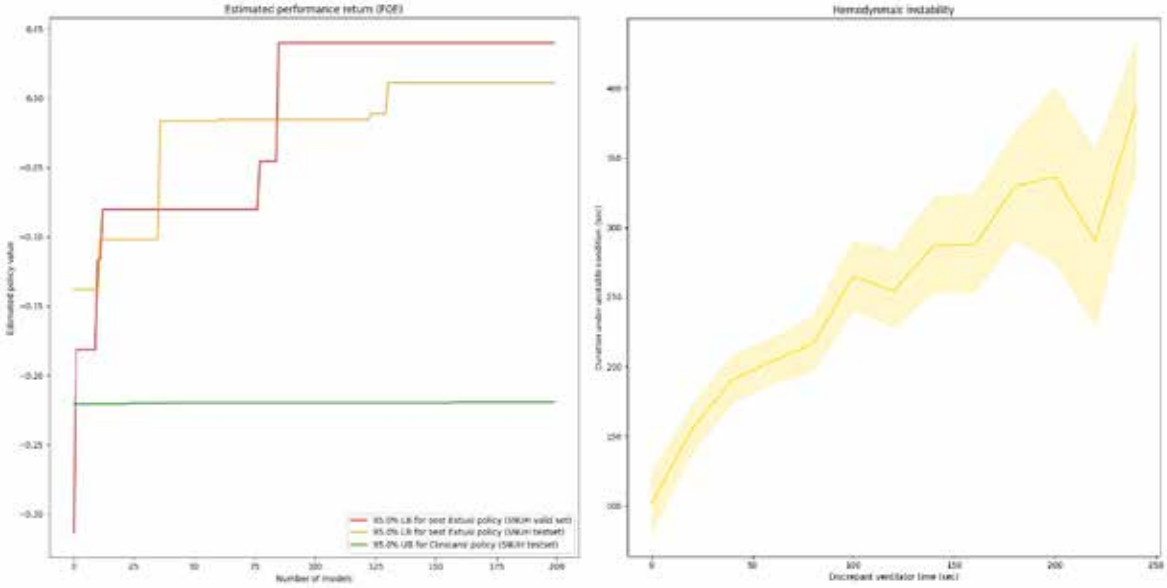
Abstract Content

Since recovery from general anesthesia is dynamic, controlling ventilation at the optimal timing is challenging, reflecting the patient's spontaneous breathing should be sufficiently restored while hemodynamic instability should be minimized. From data from 15,842 surgical cases, we developed a reinforcement learning (RL) model, Smart-Vent, to suggest the optimal timing of ventilation control during emergence and externally validated the model in a different dataset. We adopted conservative-Q learning to optimize mechanical ventilation for patients with inconsistent responses [1]. We evaluated the discrepancy between the model's policy and clinician's policy. The estimated performance return of the Smart-Vent's policy was significantly better than the clinicians' policy. Hemodynamic instability and increased peak inspiratory pressure occurred more frequently when the discrepancy between the policies was significant. PIP and spontaneous breathing were the two most influential factors for ventilation control. In summary, the Smart-Vent can suggest the optimal timing of ventilation control in surgical patients during emergence in the operating room.



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Abstract Title: A non-invasive algorithm for predicting cardiac output using a Convolutional Neural Network

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Abstract Content: Cardiac output (CO) (or stroke volume (SV)) have been estimated based on pulmonary arterial catheters or arterial pressure waveforms (ABP). However, both methods require invasiveness, which may lead to severe complications. In this study, we propose a non-invasive deep learning model for SV prediction. Electrocardiogram (ECG), plethysmography (PPG), mean blood pressure (MBP), pulse pressure (PP), and demographic information were used as input variables. The input waveforms were preprocessed with bandpass filters, and outliers of MBP and PP were excluded. The output variable was the SV from commercially available ABP-based CO device (e.g., EV1000, Edwards Lifesciences, USA). The model was designed as a squeeze-and-excitation-ResNet based model to learn appropriate feature extraction from the 20-second segments of waveforms and other inputs. The model with ECG, PPG, and demographic information showed mean absolute error (MAE) of SV by 12.1ml/beat, limits of agreement (LOA) of SV by 37.4%. When we add MBP and PP as inputs of the model, performance was increased as MAE by 10.0 ml/beat, LOA by 30.9 % (Figure 1). The LOA of the model is close to 30%, which can be an alternative to the existing APCO [1].

Images:

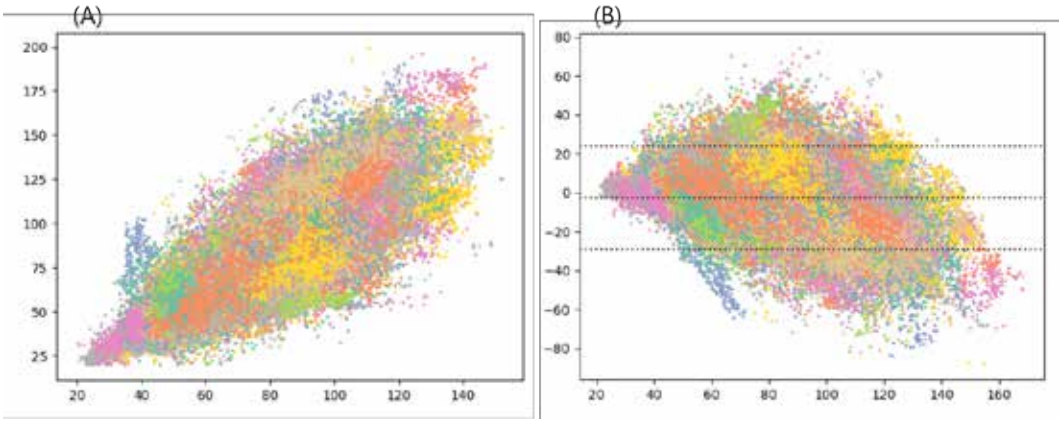

Figure 1. (A) Scatter plot and (B) bland-altman plot between SV from commercially available CO device (x-axis) and predicted SV of our model (y-axis).

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LOW-COST ARTERIAL LINE MODEL IMPROVES PROCEDURAL CONFIDENCE IN TRAINEES

Presenting Author: Andrewston Ting, DO, HCA Healthcare/USF Health Morsani College of Medicine
Co-Authors: *Tianyu Jiang, DO, HCA Healthcare/USF Health Morsani College of Medicine*

Introduction:
Arterial cannulation is a must-have skill in fields such as anesthesiology, emergency medicine, intensive care, and cardiology. Traditionally, medical students and residents undergo the model of see one, do one, teach one to learn most of the procedures, however, those who underwent simulation training had decreased complication and higher success rates compared to traditional methods [1,2]. Current arterial line simulation models may not be universally accessible due to factors such as cost and access to simulation rooms. Our team developed a model using common materials and examined participants' changes in confidence levels after training with this model.

Methods:
We developed a cost-effective novel porcine arterial line model using materials commonly found in the anesthesia supply room and hosted a training session for residents. Eleven residents from internal medicine, anesthesiology, emergency medicine, and surgery participated in this study. They were asked to rate their arterial line pre-training overall confidence (OC), hand-eye coordination (HE), and ability to troubleshoot (TS) on a 0-to-10 scale, with 0 as having no confidence, and 10 being fully confident. Then, each resident was given 5 minutes to perform instructor-guided in-plane and out-of-plane arterial line technique using this model. They were asked to rate each aspect on the same scale post-training .

Results:
All participants were able to show improvement in confidence levels in all three sections. Paired-sample t-test was conducted to compare pre-training and post-training self-assessment values. As per Table 1, We found a significant difference between pre- and post-training OC ($M = 2.09$, $SD = 1.30$); $t(10) = 5.333$, $p = 0.0003$. We also found a significant difference between pre- and post-training HE ($M = 1.36$, $SD = 0.67$); $t(10) = 6.708$, $p = 0.0001$. Lastly, we found a significant difference between pre- and post-training TS ($M = 2.18$, $SD = 1.08$); $t(10) = 6.708$, $p = 0.0001$.

Conclusion:
Arterial cannulation is often one of the more difficult techniques for trainees due to its multi-step process, requiring multiple points of troubleshooting and feedback for a successful placement. The current models on the market are cost-prohibitive, often in the thousands-of-dollars range. Our easily constructed model has ultrasound properties similar to that of real human tissue, and generates flashback that mimics real life and can aid in trainees' troubleshooting and intra-procedural decision making. Additional studies are needed to compare efficacy of commercial products v.s. our DIY kit.

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Table 1. Pre-training vs Post-training Overall Confidence, Hand-Eye Coordination, and Ability to Troubleshoot

Paired Samples Test								
	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair OC post-pre	2.09	1.30	0.392	1.22	2.96	5.333	10	0.0003
Pair HE post-pre	1.36	0.67	0.203	0.91	1.82	6.708	10	0.0001
Pair TS post-pre	2.18	1.08	0.325	1.46	2.91	6.708	10	0.0001

OC = overall confidence, HE = confidence in hand-eye coordination, TS = ability to troubleshoot; post-pre = difference between post-training and pre-training. Higher mean difference correlates with improved confidence level.

HIGH-FIDELITY, LOW-COST PORCINE TRAINING MODEL FOR ARTERIAL LINE PLACEMENT

Presenting Author: Andrewston Ting, DO, HCA Healthcare/USF Health Morsani College of Medicine
Co-Authors: Tianyu Jiang, DO, HCA Healthcare/USF Health Morsani College of Medicine

Background/Introduction:
Ultrasound-guided arterial line technique is a crucial skill in many medical specialties. New trainees can benefit from gaining familiarity in ultrasound maneuvering and arterial line technique in a safe simulation environment. We designed a novel, low-cost, high-fidelity, meat-based model that also incorporates a flashback mechanism that mirrors placement of arterial line in real patients.

Methods:
We used a meat-based vascular access model made from pork shoulder and other common materials found in our anesthesia supply room. This model is low cost and can be easily constructed within 5 minutes. The final setup is as shown in Figure 1. A list of ingredients and materials is as follows:

> Pork shoulder, hemostats, plastic tray, gravity blood set tubing with pressure pump or primary IV tubing, pressure sleeve, 1000mL or 500mL NS, ultrasound gel, arterial line kit, ultrasound, sutures (to enclose IV tubing within pork slices).

We prepared the pork by slicing thinly across roughly 3mm from the surface. Next, the tube is primed partially, making sure to leave some air at the distal tip and capping it off or clamping it off with a hemostat. This column of air generates increased compressibility of the fluid and aids in generation of pulsatile fluid movement within the tube, detectable with ultrasound color mode. The tubing and fluid bag is pressurized in the sleeve, and a syringe is attached at the proximal end to facilitate the generation of pulsations (Figure 2). In addition to the pressurized system, the depressed syringe generates pressure (likened to systolic pressure) on top of the baseline pressure (likened to diastolic pressure), resulting in reproduced pulsatile flashback (Figure 3). Lastly, the tubing is placed between the pork flaps and the layer is filled with ultrasound gel.

Discussion:
Ultrasound guided arterial line placement requires spatial orientation and hand-eye coordination. Radial arterial line is arguably the most challenging and humbling procedure out of the vascular access procedures we commonly perform. Advances in simulation suggest that early exposure to simulation for medical students and residents is beneficial [1-3]. The ideal phantom should be affordable, easy to assemble, have similar tissue texture resistance and tactile feedback to human tissue and arteries. It also needs to have comparable ultrasound appearance as the real thing, not just the vessels but the background echogenicity. Lastly, the phantom should be able to replicate the entire arterial insertion experience from beginning to the end. We believe that the model we have described fits all of the criteria described. Our training model is able to produce ultrasound images and tactile feedback that resemble real human tissue. In addition, the arterial blood flashback mechanism with varying “blood pressure” points can be adjusted mimicking hypotensive patients in shock. Immediate period after getting arterial

puncture can be a common point where trainees panic or freeze up, especially with arterial blood shooting out. This allows trainees to experience the “real deal” in a simulation situation without putting real patients at risk.

Conclusion:

Ultrasound guided arterial line insertion is a must have skill, especially for procedural heavy fields. This procedure can be particularly challenging and frustrating for new trainees. This article describes a cost-effective model that simulates many essential aspects of the arterial cannulation procedure. This concept is intended to help medical students and residents learn and practice arterial line insertion in a low-risk, low-cost, and low-stress environment.

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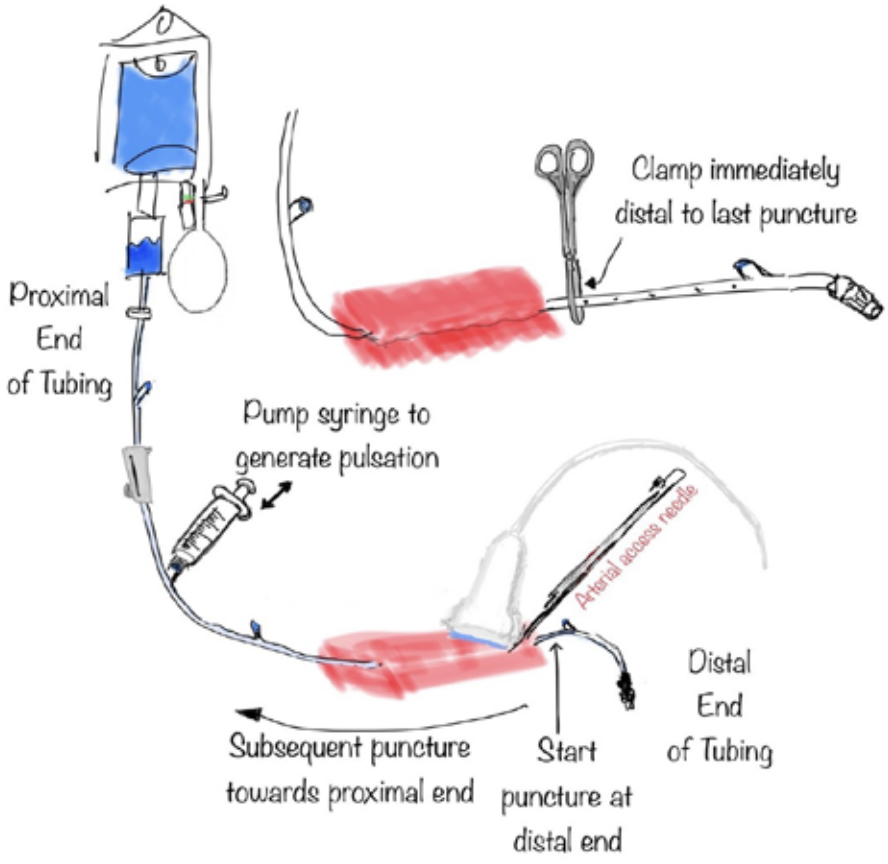

Figure 1. Setup schematic

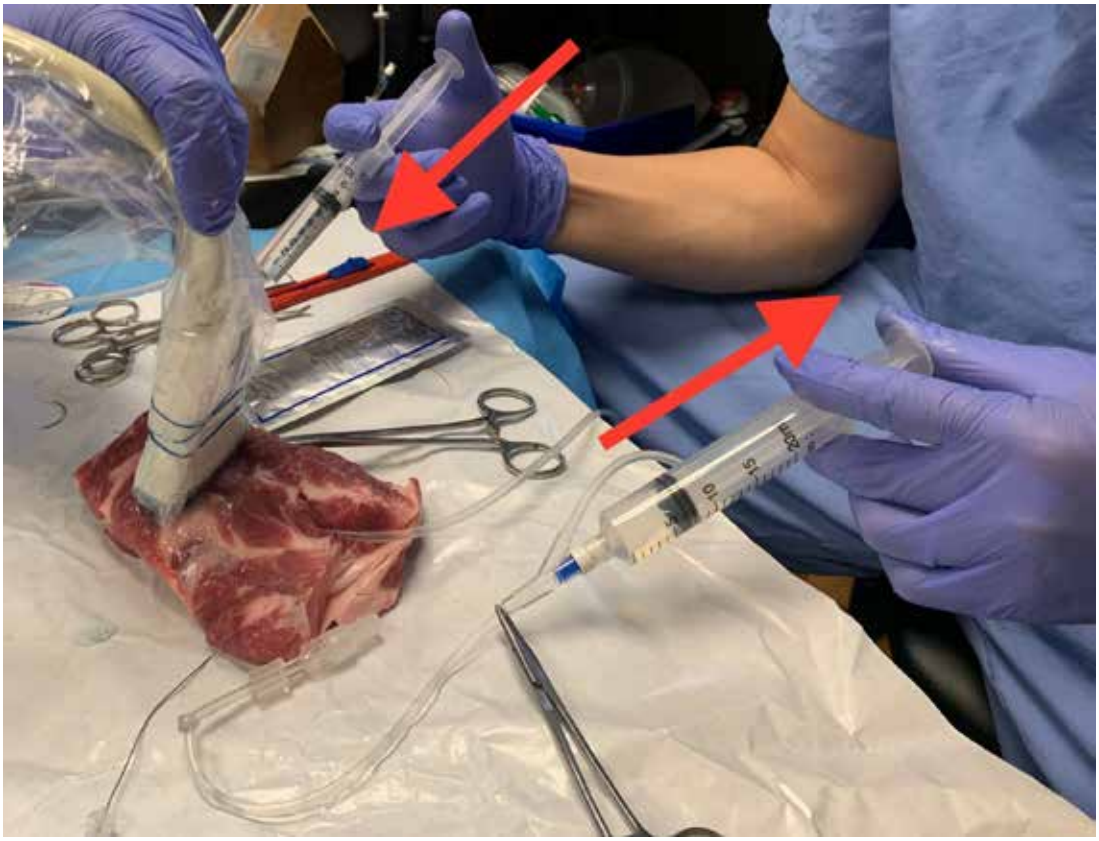

Figure 2. Demonstrates pulse generation with syringes

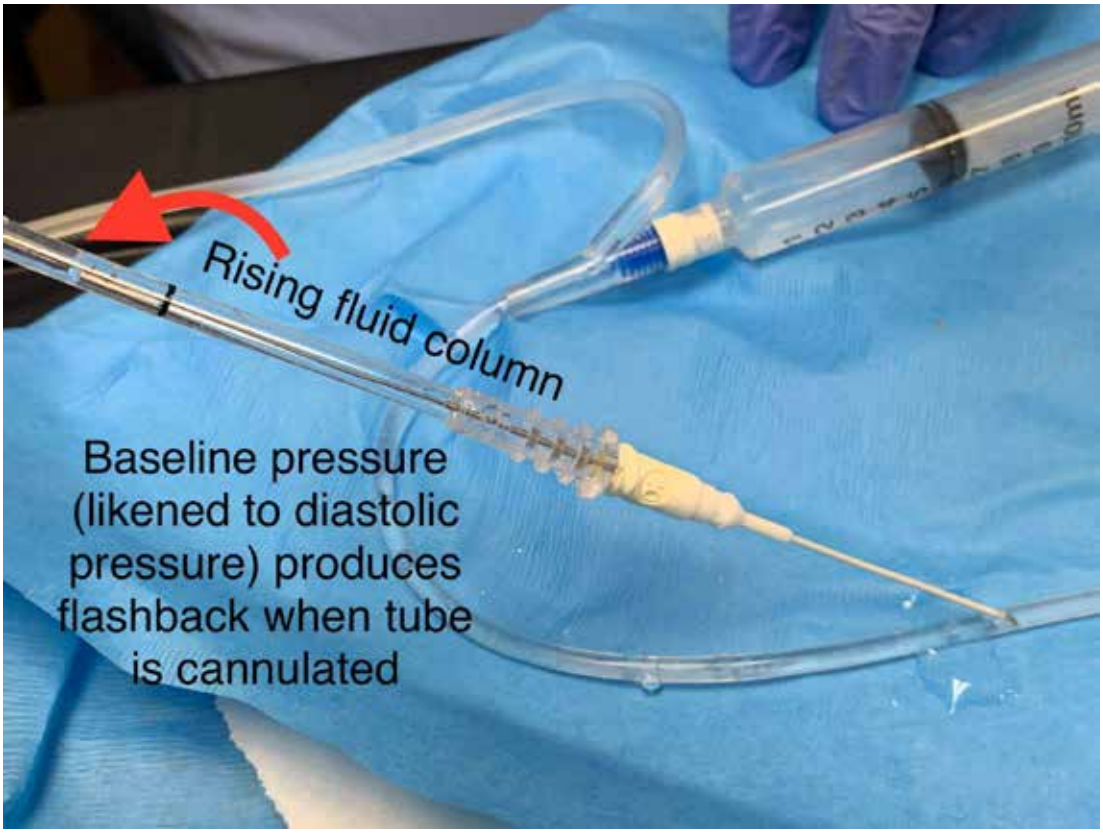

Figure 3. Flash back mechanism simulated

WikiAnesthesia: A Crowd-sourced Anesthesia Knowledge Repository

Authors: Olivia Sutton[a], Tony Y. Wang[a], Barrett J. Larson[b], The-Hung Nguyen[a], Chris A. Rishel[b]
[a]Johns Hopkins ACCM, [b]Stanford Department of Anesthesiology

Commented [1]: Also lmk what you guys think about the title.

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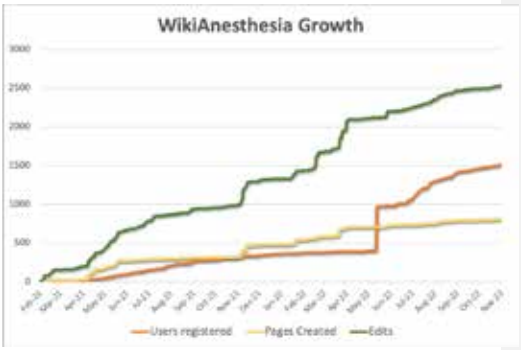
Background: "Crowdsourcing" was coined in 2006 and has since had widespread impact across many industries. Within healthcare, its myriad applications include research, education, and genetics. Traditionally, anesthesia knowledge is sourced from textbooks, online resources, and word of mouth from peers or mentors. There has been a recent push to create institutional standards, such as ERAS (enhanced recovery after surgery) protocols, but the static nature of these resources prevents dynamic updating with changing practice. WikiAnesthesia.org is an open-access non-profit online knowledge collaboration with a goal of making anesthesia knowledge easily accessible, crowdsourced, and constantly updated. WikiAnesthesia was launched with the goal of presenting relevant information in an easily retrievable manner during periods of acute need to meet the goals of the anesthetic provider.

Methods: In partnership with providers at all levels of anesthesia care (attendings, residents, CRNAs) from a multi-institutional background, WikiAnesthesia is a user-friendly platform with initial content centered around surgical case plans. Early articles were curated by core WikiAnesthesia members covering the most common and challenging surgical cases to attract a wider base of interested providers willing to contribute in the future. Subsequently, other types of articles (drug information, techniques, etc.) have been added. In parallel with community content creation, additional features such as drug dosage and physiological calculators were built to support the needs of the users. Outcomes to measure the success of this platform include number of users, number of articles created, and number of total edits. These data were provided by MediaWiki, the engine that drives the site, and Google Analytics, a web service that tracks and reports website traffic.



Results: From its launch 21 months prior, WikiAnesthesia has grown from a core group of a few founding members to >1500 registered contributing members affiliated with at least 16 institutions and from all levels of practice, including attending anesthesiologists, residents, CRNAs, and students. A total of 11,635 public edits have been made over this time, contributing to a total of 261 public articles subject to real-time, continuous crowdsourcing that allows for this content to be produced quickly and on a large scale. These articles have been accessed by a total of >18,000 unique users from a total of >38 countries, and this traffic is continuing to grow at a rapid pace.

Discussion: WikiAnesthesia is rapidly growing, and with future marketing and outreach, we anticipate that this platform will rapidly expand. While initial growth relied on word-of-mouth, ongoing awareness-building strategies include a social media campaign across Instagram, Twitter, and Facebook, a "badge incentive system to encourage contribution, and appearances on podcasts such as ACCRAC, all of which have resulted in tangible growth. Additionally, we plan on growing into the unique needs of other institutions to increase adoption on an institution-wide level. For example, we have moved residency rotation guides into private institution-specific practice groups. In future research, we plan to use the Technology Adoption Model to better understand how users accept and utilize WikiAnesthesia based on perceived usefulness and ease-of-use. This information will help us identify areas which can be targeted to improve adoption of WikiAnesthesia.

ABSTRACT TITLE: OPTOACOUSTIC MEASUREMENT OF BLOOD OXYGENATION IN THE LEFT INNOMINATE VEIN

Presenting Author: David J. Giarracco, Noninvasix, Inc.;

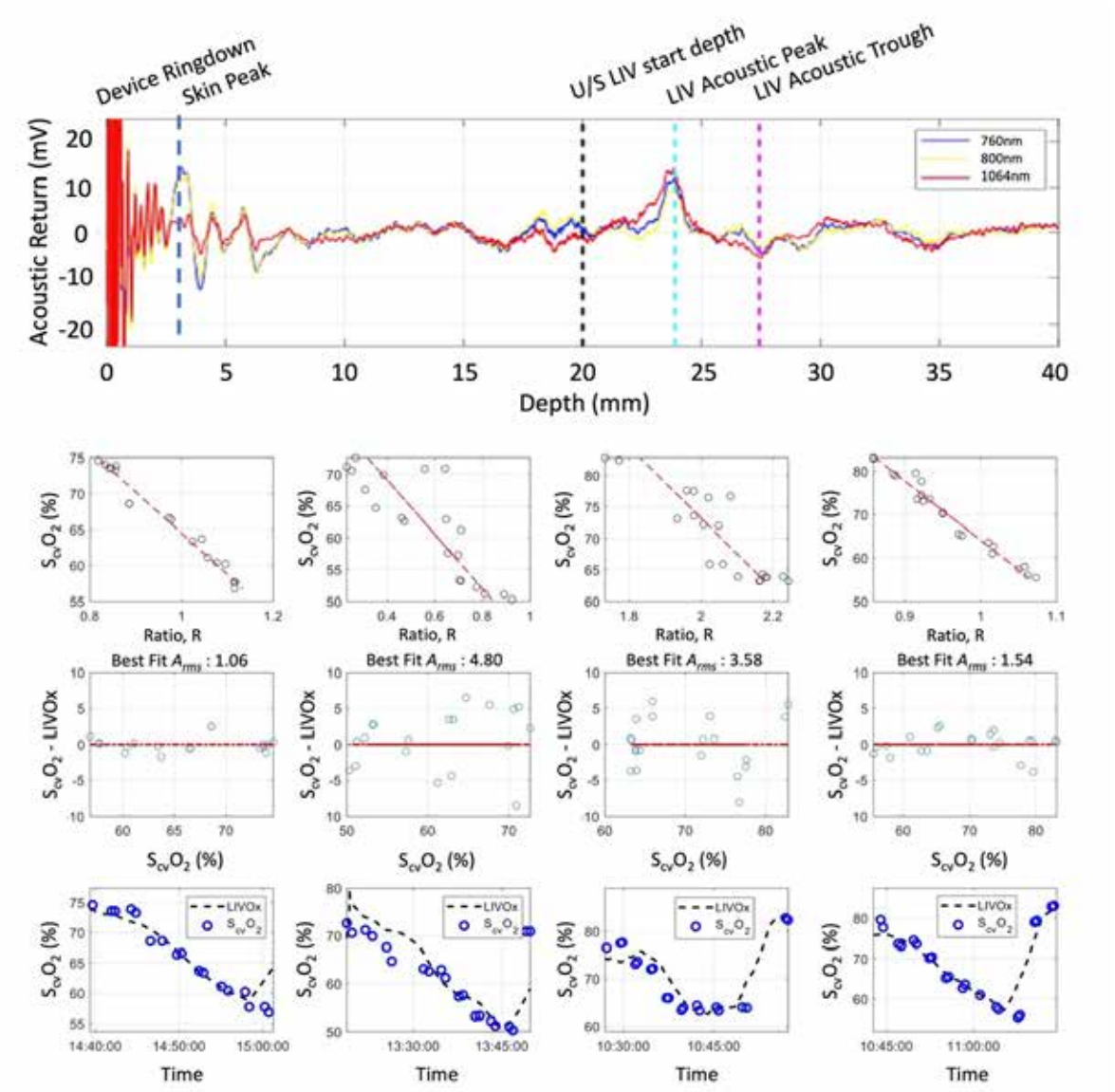
Co-Authors: *David MacLeod, MBBS, Duke University; Graham L. Randall, PhD, Noninvasix, Inc.; James N. Watson, PhD, Noninvasix, Inc.; Tom Wilmering, Noninvasix, Inc.*

Background/Introduction: The standard of care for treatment of shock, consisting of empirical management based on BP, HR and intermittent measurements of serum lactate, could be enhanced by a rapid, noninvasive continuous monitor of the adequacy of O_2 delivery that could be used as soon as shock is suspected and continued throughout therapy. We hypothesize that *immediate, noninvasive* assessment of O_2 saturation in the left innominate vein ($S_{LIV}O_2$), a proxy for $S_{cv}O_2$, will facilitate diagnosis, provide useful prognostic information and permit immediate, rather than delayed, treatment. Towards this goal, we have developed an optoacoustic device (LIVOx™) to measure $S_{LIV}O_2$.

Methods: Since the Summer of 2022, we have been conducting an IRB-approved, single site, non-randomized, study at Duke University to measure the accuracy of an investigational monitor of $S_{LIV}O_2$ compared to blood reference values. To date, 16 healthy, adult volunteers, aged 18 - 45 years old, have been enrolled after informed consent. Subjects were selected to obtain a representative range of gender and skin pigmentation. For each subject, the inspired oxygen concentration was lowered in stepwise fashion to produce a controlled oxygen desaturation sequence. At each plateau, serial LIV blood samples were drawn from a central venous catheter placed in the left internal jugular vein and advanced to the LIV and analyzed by a CO-oximeter.

Results: Analysis of the acoustic traces obtained features consistent with the skin and LIV depths identified during prior ultrasound imaging (see figure, top). Four traces with an LIV peak exhibiting the lowest variation in peak position and highest peak to peak amplitude were selected for further analysis. Results from these traces are shown in a plot matrix (see figure, bottom). The scatter plots (top) show the localized light absorbance ratio (760nm / 1064nm) against reference saturation. This ratio linearly increases as saturation falls with an order of magnitude comparable to that expected for S_PO_2 (where ratio, R≈0.5-2 for sats 100-50%). Best fit calibration curves, created retrospectively for each subject, have been used to generate a 'best case' modified Bland Altman plot for each subject. The pooled Arms for these four subjects is 3.14 % — individual measurements are provided with their respective plots. The bottom row of the matrix shows a real-time simulation of device output with CO-oximeter values overlayed.

Conclusion: Preliminary analysis indicates the potential for the non-invasive optoacoustic measurement of $S_{LIV}O_2$. Acoustic return amplitudes provide absorbance features at depths confirmed as LIV locations by ultrasonic measurement with absorbance ratios comparable to those measured by other oximetry devices. Future work will center on stabilizing the sensor design for improved targeting of the LIV and increasing the data pool to allow the generation of a single calibration curve suitable for all patients.



Top: Sample acoustic profile for 3 laser wavelengths (Acoustic vel. = 1540 m/s).
Bottom: Results matrix for 4 study subjects with CO-oximeter reference v absorbance ratio, R (top); modified Bland Altman (middle); and device time trace (bottom).

EXAMINING THE ASSOCIATION OF AIR QUALITY ON COVID-19 PATIENT OUTCOMES USING AREA LEVEL DATA FROM THE ELECTRONIC HEALTH RECORD

Presenting Authors: Christina S. Boncyk[1], MD, MPH
***Co-Authors*: Karen Y. McCarthy[1], EdD; Pamela Butler [1], BS; Nicholas Flores-Conner[1], MD; Gen Li[1], MS; Robert E. Freundlich[1], MD, MSCI**
[1]Vanderbilt University Medical Center, Department of Anesthesiology

Background: Within the coronavirus 2019 (COVID-19) pandemic, literature has found worsened patient outcomes and increased virus transmissibility associated with reduced air quality. This factor, a structural social determinant of health (SDOH), has shown great promise as a link between air quality and patient outcomes during the COVID-19 pandemic. Researching SDOH within our patient populations is often difficult and limited by poor documentation or extensive questionnaires or surveys. The use of demographic data derived from the electronic health record (EHR) to more accurately represent SDOH holds great promise.

The use of area-level determinants of health outcomes has been shown to serve as a good surrogate for individual exposures. We posit that an area level measure of air quality, the county-level Air Quality Index (AQI), will be associated with disease worsening in intensive care unit (ICU) patients being treated for COVID-19.

Methods: We will calculate AQI using a combination of open-source records available via the United States Environmental Protection Agency (EPA) and manual calculations using geospatial informatics systems (GIS) methods. Subjects will be identified as adult ($\geq$ 18 years) patients admitted to Vanderbilt University Medical Center's ICUs between January 1, 2020, and March 31, 2022 with a positive SARS-CoV-2 laboratory analysis result. We will exclude patients without a home address listed.

Patient demographic and hospital data from ICU admission to 28 days following admission will include: age, sex, home address, race, insurance type, primary language, employment status, highest level of education, and hospital course data. Together these will be collated to produce our primary outcome variable of WHO Clinical Progression Scale score. These validated scores range from 0 (uninfected) to 10 (dead) to track clinically meaningful progression of COVID-19 infected patients.

Our AQI variable will be obtained from the EPA available county-level monitoring station spatial data combined with open-source state/county center point spatial data. These data contain historic cataloguing to determine air quality at both specific time points and averages over time. Where a county's average yearly AQI is not available due to lack of a monitoring station, we will use spatial data tools to calculate an average based on data from nearby stations. We will utilize yearly averages of AQI in the year prior to COVID-19 diagnosis to describe overall impact of air quality on patients' respiratory outcomes as opposed to single day exposures. Linkage of patient data to AQI database will be performed using patient addresses.

Discussion: By combining area level data with electronic health record (EHR) data, we will be positioned to understand the contribution of environmental and social determinants of health on patient outcomes. Our long-term goal is to elucidate which social and environmental determinants of health are associated with worse outcomes from COVID-19 and other respiratory viruses, using data extracted from the EHR.

Title: **Medical Student Authorship for WikiAnesthesia as a Method for Increasing Engagement in Academic Anesthesiology**

Authors: Kenny Kim[1], B.A., Chris A. Rishel[2], M.D., Ph.D, Kiran Guthikonda[1], M.D., Ph.D
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Introduction

The sharing of clinical knowledge between providers in medicine presents many challenges. Articles and conferences have served as traditional means of sharing knowledge, but access to these resources are limited for a variety of reasons. Open-access online repositories have the potential to serve as a more accessible alternative. For example, the WikiAnesthesia project is an online open-access website that shares high-level medical knowledge in the field of anesthesiology. Significant work is required, however, to establish and maintain such a database.

Similar challenges exist when it comes to the education of medical students in anesthesiology. In the limited four-week sub-internship that traditionally exposes medical students aspiring to become anesthesiologists, it can be challenging to provide a meaningful experience in contributing to anesthesiology literature. Given the significant efforts required to help establish the WikiAnesthesia database as a reliable source of anesthesia-related information, we hypothesized that medical students could also benefit by contributing articles to the WikiAnesthesia database. In effect, the learners would become educators, and be provided with an international platform for exposure and impact.

Methods

Students at the Geisel School of Medicine at Dartmouth enrolled in an anesthesiology sub-internship were tasked with completing a short writing assignment. They were given the option of a traditional writing assignment (discussion of anesthetic considerations pertaining to a clinical vignette based on a surgical procedure) or the opportunity to write articles on the WikiAnesthesia website on topics of their choosing. Following review by an attending anesthesiologist at Dartmouth, the articles were then submitted for review on WikiAnesthesia, and approved independently by physicians on the WikiAnesthsia staff.

Students were asked to provide narrative responses regarding their experience working on the WikiAnesthesia project, and these responses were aggregated.

Results

Of the twelve students who enrolled in an anesthesia elective/sub-internship, ten opted in to contribute articles to the WikiAnthesia project. The topics of the articles were chosen by the students with assistance from the clerkship director. Otherwise, any research or review of the literature conducted in order to write said articles was primarily done by the students.

In response to a survey of former sub-interns, 100% of respondents stated that they felt the WikiAnesthesia assignment was a more meaningful and educational assignment when compared with the traditional writing assignment. Students valued the freedom to choose a topic of interest, gained knowledge by researching and writing the article, and felt a sense of accomplishment from contributing to the knowledge of the anesthesiology community.

Discussion

It was clear that Dartmouth students were enthusiastic and serious contributors to the WikiAnesthesia project when provided the opportunity to do so as part of their anesthesia rotations/sub-internships. Their narrative responses suggest that the opportunity to contribute to the field of anesthesia in this manner was a worthwhile intellectual effort, and afforded them the freedom to thoroughly research a topic of their choosing. Given this, students (with appropriate guidance) may be a valuable resource in the establishment of the WikiAnesthesia database, and have the opportunity to contribute to an international audience of anesthesia providers.

Conclusions

Contribution of content to WikiAnesthesia can serve as a useful method of both increasing medical student engagement and providing content to the anesthesiology community on this open-access platform.

PERFUSION INDEX USING ALAR SPO_2 SENSOR MAINTAINED BETTER THAN FINGER LOCATION DURING PERIOPERATIVE CARE IN MAJOR VASCULAR/UROLOGICAL SURGERY

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Background: Perfusion index (PI) is considered to reflect perfusion at that specific measurement site (i.e. local blood volume variation during systole). PI varies among others as a function of local and systemic hemodynamic status. The effective operating range is determined by its location and the light source (transmissive or reflective). Most studies to date have reported peripheral PI values (i.e., finger) and none have examined PI values at the nasal alar by itself or relative to other central or peripheral sites. The nasal alar is a readily accessible and comfortable central site perfused by branches of both the external and internal carotid arteries (1). The purpose of the current study is to describe PI operating characteristics (e.g., typical values and variability) from the nasal alar and to compare it to a finger sensor peri-operatively in surgery with volume shifts.

Methods: The data for this post hoc analysis comes from an observational study on patients scheduled for major abdominal surgery (urological or vascular surgery) in Tilburg, the Netherlands. The study protocol was approved by a regional medical ethics committee and written informed consent was obtained from all patients. Each patient was monitored with ECG, invasive arterial blood pressure (radial artery), with mean arterial pressures between 40 to 120 mmHg, and pulse oximetry. All patients received IV anesthesia induction and maintenance, mechanical ventilation with potentially supplemental oxygen and depth of anesthesia control by bispectral indexing. Additional SpO_2 sensors were applied at the finger “as peripheral” site and at the nasal alar "as central” site. (2)

For this analysis, data from15 adult patients monitored with an alar sensor were used. Measurements included a finger PPG signal (Philips M1191B sensor) and an alar PPG signal (CE marked sensor from Xhale - now Philips nasal alar FAST SpO_2 sensor), as well as each signal’s respective SpO_2 and PI values. These were recorded in a custom-built multi-channel data logger. The dataset was analyzed using the Python scientific, statistical and graphical libraries running under the PyCharm IDE and Excel and the statistics (including mean, standard deviation and % values below a PI threshold of 1%) and non-parametric statistics were computed separately for non-overlapping periods designated as pre-operative, induction, period of surgery and post-operative.

Results: The variance of PI (Figure 1) was strongly significantly different between the finger and alar sensor for the surgical period (p=0.004) (mean variance 4.1 for finger vs 0.51 for alar), nearly significant different for the pre-operative period (p=0.06) (mean variance 6 and1.28) and not significant for induction and post-operative periods (p=0.19 and p=0.46). The percentage of the PI readings less than 1% (Figure 2), which is considered to indicate very low perfusion (3) during induction and surgery were 1% for the alar sensor and 10% for the finger sensor.

Discussion: This is the first study the authors are aware of to report peri-operative PI values from the alar sensor. It illustrates that the PI values from the alar show less variability over the course of these surgical procedures than finger sensors, potentially indicating increased usability and validity. The increase in PI values observed during surgery in the finger sensors seems based on vasoactivity in the peripheral vasculature. The PI values from the alar sensor are similar in magnitude to those from the finger sensor. However, to compare PI from different measurement sites requires further investigation since comparisons between PI from different measurement sites should be done with caution as temperature, vascular tone and perfusion may be different.

Conclusions: This study demonstrates a low variability of alar PI during the peri-operative period despite vascular tone and volume shifts. It supports the value of comparative measurements of peripheral and central PI values to allow comparison of optimal locations.

Acknowledgement: We thank all those involved in the preparation and conduction of the clinical study at the Elisabeth-TweeSteden Hospital, and at Philips Research

References:(1)Arch Facial Plast Surg 2012; 14: 429–36; (2)Br J Anaesth. 2014;112(6):1109-14; (3)ASA Meeting,2022, Abstract A2095.

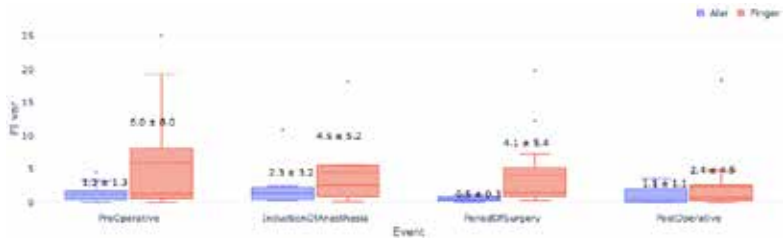

Figure 1 – Variance of PI values during each of the surgical periods (mean ± standard deviation).

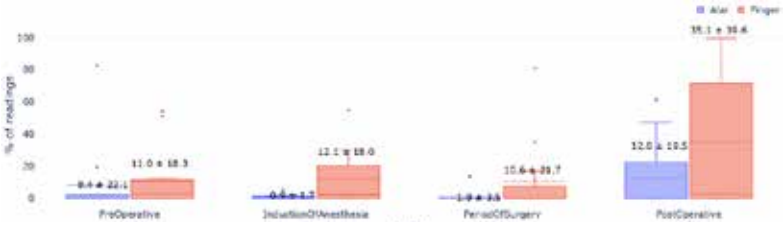

Figure 2 - % of PI readings below 1% during each of the surgical periods (mean ± standard deviation).

Abstract Title: **Porting a Vertically Integrated Closed-Loop Control TIVA System to an Interoperable Platform**

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Co-Authors: David Arney PhD, MPH; Simon Kelly; Braga Aroulmozhi MS, Mosa Al Zowelei MS, Michael Jaffe PhD; Julian M. Goldman MD
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Problem and Motivation. Recent advancements in automation and computational intelligence have enabled increasing development of physiological closed-control control (PCLC) anesthesia systems [1]. Typically, these are vertically integrated systems of sensors, actuators, and processing platforms. Evaluating alternative control algorithms, sensors, and actuators is challenging due to this vertical integration.

Porting integrated PCLC systems onto interoperable platforms can enable rapid development of hardware-in-the-loop (HIL) testbeds. Simulation capabilities can be introduced and alternate actuators/sensors can be easily replaced to facilitate system modification and testing. PCLC anesthesia systems can also benefit from the services offered by interoperability platforms, such as safety fallbacks, security, and data logging, to alleviate R&D and risk management burdens.

Method. We chose the EasyTIVA PCLC anesthesia system from MedSteer [2] as the subject system and ported it onto our OpenICE interoperability research platform [3]. The EasyTIVA system uses two Alaris GH infusion pumps to administer propofol and remifentanil to the patient for anesthesia during surgical procedures, where its control algorithm automatically titrates the infusion rates of both pumps based on the patient's depth of anesthesia measured by a VISTA BIS monitor.

OpenICE follows the standard Integrated Clinical Environment (ICE) architecture [4] to safely coordinate medical devices and software applications ('apps'). We developed two communication apps in OpenICE, one for the Alaris GH pumps and the other for the BIS monitor, to intercept and forward the communication between these devices and the EasyTIVA control algorithm (installed and running on a separate computer). In this ported configuration, the control algorithm and medical devices are 'talking' to the communication apps rather than directly to each other. These apps also broadcast the communicated data and commands to the rest of OpenICE to support testing and future clinical investigation.

Implementing the communication apps only requires the knowledge of the control algorithm's communication protocols with medical devices, including the handshaking procedure, timeout periods of waiting for responses from the devices, and contingency actions upon connection failures. No modification to the EasyTIVA control algorithm is needed.

Result. Preliminary testing of the OpenICE-based EasyTIVA variant using synthesized BIS data confirmed that it performed equivalently to the vertically integrated system under the test protocols we executed. The control algorithm correctly received BIS scores and other data from the BIS monitor and titrated the propofol and remifentanil infusion rates; and the Alaris pumps correctly received and executed control commands from the control algorithm.

We also implemented a simulated BIS monitor app that feeds the EasyTIVA control algorithm with pre-defined BIS trend at the expected frequency. This app allowed us to test EasyTIVA without a physical BIS monitor, which demonstrates the feasibility of leveraging the OpenICE-based variant into a HIL testbed for assessing EasyTIVA.

Conclusion. Our method of porting EasyTIVA onto OpenICE can potentially be generalized to other PCLC systems. Generalization may be limited by the lack of commercial medical devices that support external control or the publicly accessible documentation of their communication protocols. One way to tackle these limitations is to standardize the data interfaces of medical devices, such as in form of Medical Device Interface Data Sheet [5], that include adequate device information to enable safe external control.

Acknowledgement: this research, including the loan of the Medsteer EasyTIVA system and MedSteer technical assistance, was supported under the Medical Technology Enterprise Consortium (MTEC) Research Project Number W81XWH-22-9-0004. The views, opinions and/or findings contained in this paper are those of the authors and should not be construed as an official Department of Defense position, policy or decision unless so designated by other documentation.

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Abstract Title: Feasibility of augmented reality headset use for ultrasound-guided procedures in pediatric perioperative care.

Presenting Author: *Jorge Galvez MD MBI*

Co-Authors: *Marcellene Franzen MD, R Gabe Linke BS RT(R)(MR)(ARRT), Stephanie Shin DO, Thomas J. Lockhart MD, Jorge Gálvez MD MBI*

Background:

Head-mounted displays such as smart glasses are an emerging technology with a wide variety of applications including integration with an ultrasound device. The augmented reality display places the ultrasound image directly in front of the operator's field of view to facilitate visualization of the procedure field and the ultrasound image simultaneously. Jang et al. Demonstrated improved success rates for arterial cannulation in children undergoing cardiac procedures utilizing augmented reality technology.(1) The primary outcome of the project is to identify use cases of an augmented reality display for ultrasound guided procedures in a pediatric anesthesiology training program.

Methods:

The binocular Moverio BT-35E (V11H935051, Epson Co, Japan) was configured with a portable battery and used as a head-mounted display. The video interface box was connected to an ultrasound (Sonosite, Fujifilm Sonosite, Bothell, WA) using a standard HDMI cable (Figure 1A). The battery and video interface box and cables are housed in a 3D printed housing that is placed in the operator's pocket to facilitate operator mobility with the ultrasound unit.

Results:

The ultrasound and head-mounted display configuration is fully mobile and can be incorporated for ultrasound-guided procedures at the bedside. The operator can visualize the ultrasound image in their direct field of view while standing in front of the ultrasound unit (Figure 1B). Operators with corrective lenses can wear a head-mounted display over their corrective lenses. The operator can visualize the procedure field and the ultrasound image in their direct line of sight. The head mount allows the operator to remain close to the ultrasound unit and make direct adjustments to the image. The wire connections between the headset and the ultrasound tether the operator to the ultrasound unit.

Conclusion:

We describe the configuration of an augmented reality display with a portable ultrasound device to facilitate ultrasound-guided procedures. The portable configuration can be utilized throughout the care environment including the operating room and throughout the hospital. Although the operator remains tethered to the ultrasound via the head-mounted display video

connections, they are also tethered to the ultrasound with the ultrasound probe cable. Future studies will focus on optimizing ergonomic design to facilitate routine use in clinical practice.

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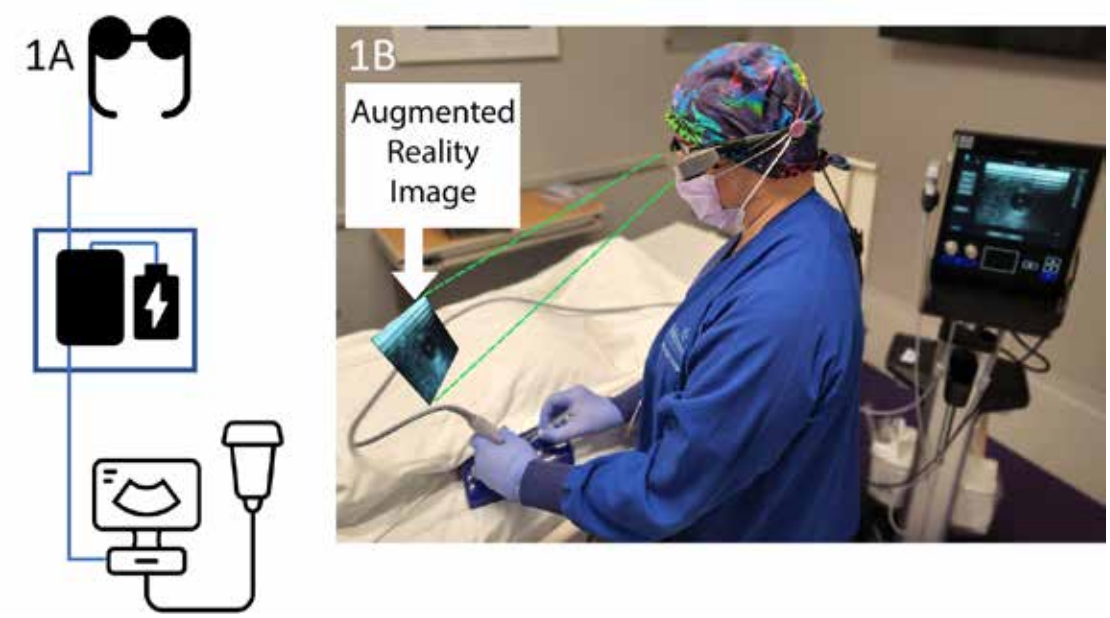

Figure Caption:

(1A) Representation of head mounted display configuration. The head mounted display is connected via a single cable to the video interface. The video interface receives power from a portable battery, both of which are encased in a 3D printed housing. The video interface is then connected to the ultrasound unit with a standard HDMI cable.

(1B) Simulation of the operator performing a bedside ultrasound-guided intravenous line placement. The operator is standing in front of the ultrasound unit and can see a virtual image directly in their field of view. The operator can stand on the same side of the bed as the ultrasound unit.

Disaster Communication Improvement by Integrating Existing Services

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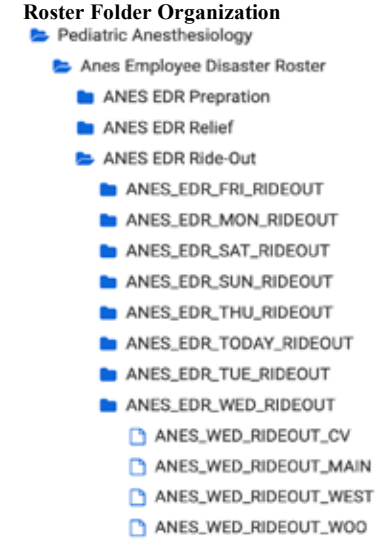
Introduction: Maintaining an up-to-date roster of staff, their locations and their roles with our hospital's emergency response system was a manual labor-intensive task. Because of the burden of this task, and the infrequency of a disaster requiring the use of a disaster communication channels, this task was often ignored.

Methods: A technical assessment of our department's provider scheduling software, QGenda, was performed which demonstrated that the service offers a robust Application Protocol Interface (API)[1]. Our team developed software which consume the QGenda API to capture up-to-date staff assignments, contact information, and locations on an on-going basis and store the information in a relational database. An algorithm was developed to analyze the data and compare the information with data fetched from our hospital's contracted disaster communication service, Everbridge. Using additional algorithms changes were identified and were merged with Everbridge data. Missing or new staff and assignments were also inserted into Everbridge. This analysis is performed multiple times per day to ensure up-to-date staffing data is maintained within the disaster response system. To ensure that the correct staff could be contacted in the case of a disaster, an easy-to-understand roster was developed within Everbridge to allow for rapid communication with staff based on location, roles, and/or day of service an example of which is shown in Figure 1.

Results: By developing a server-side software to gather staff information from QGenda and add the relevant information into hospital's disaster communication partner, Everbridge, we were able to ensure an up-to-date staff contact details, location, and clinical assignment. To test the results of our end analyzed disaster software information from of two recent disasters, one prior to software implementation with the February 2021 Texas Winter Storm, and another after, September 2021 Hurricane Nicholas. We saw that 7% of faculty in the disaster system prior to the software implementation were not in the system, and 100% of the rotating staff, such as residents, pediatric anesthesiology fellows, and SRNAs were out of date.

Figure 1: Provider Disaster Roster Folder Organization



Discussion: Faced with a crisis from a disaster, communication with providers is of the utmost importance. Having to rely on a set of fragmented systems with an unfolding crisis is less than ideal. However, many hospitals have nonintegrated systems which force them to perform time consuming and labor-intensive manual steps when responding to an urgent event. Although siloed and highly specialized software packages and services are ideal in high-risk environments[2], these platforms are designed to perform only a few set of specialized tasks. During a disaster, we find that many of our siloed software and services need to communicate to coordinate to be able to accomplish a more most rapid response. At our institution, maintaining an up-to-date roster of on call staff in our hospital's emergency response system was a labor-intensive task. We sought to develop software to allow for communication between our scheduling software and the hospital's disaster communication system to quickly identify the team members who may be available to respond to a disaster and communicate with them quickly and effortlessly.

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Using Quantitative EEG and Machine Learning to Predict Sevoflurane Concentration in Infants.

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Affiliations: 1: Medical Scientist Training Program, University of Pennsylvania; 2: School of Engineering and Applied Sciences, University of Pennsylvania; 3: Department of Anesthesiology and Critical Care Medicine, Children's Hospital of Philadelphia; 4: Division of Neurosurgery, Children's Hospital of Philadelphia.

INTRODUCTION:
Electroencephalography (EEG) monitors cortical electrical activity and can be used to assess depth of consciousness (DoC) during anesthesia. EEG waveforms require training to interpret and may be subject to interpreter bias. EEG can be processed with mathematical transformations that summarize EEG over a time epoch into an objective and replicable index—quantitative EEG (qEEG). In adults, proprietary qEEG (e.g., BIS index) has been used to prevent awareness under anesthesia and postoperative delirium.[1] However, these proprietary qEEG indices were not developed or validated in children, making them unreliable, especially in infants.[2] This knowledge gap is important since infants are particularly sensitive to the effects of excess anesthesia; 60% of infants ≤ 3mo experienced isoelectric EEG during anesthesia, an electrically inactive cortex associated with excess anesthesia and hypotension.[3] To assess the use of qEEG features to predict DoC in infants, we compared the accuracy of machine learning (ML) models applied to various qEEG features in predicting expired sevoflurane concentrations (eSevo) in infants ≤ 3mo.
METHODS:
EEG and eSevo in infants ≤ 3mo were extracted from a multicenter pediatric EEG study.[3] EEG were recorded on the Masimo Sedline EEG monitor. eSevo were recorded every minute and categorized into four levels: 0.1-1.0, 1.0-2.1, 2.1-2.9, and >2.9%. EEG from intubation to emergence were analyzed as one-minute epochs corresponding to one of four eSevo levels. EEG epochs were assessed for artifacts using NEURAL.[4] Epochs with ≥ 25% artifacts were excluded from analysis. Eligible epochs were processed with NEURAL to extract qEEG features: relative spectral power, connectivity coherence, and spectral entropy across frequency bands: 0.5-4, 4-7, 7-13, and 13-30Hz, in addition to burst percentage, spectral edge frequency 50 and 90%. The qEEG features for each minute epoch and corresponding eSevo levels were used to train eight ML models (Figure 1) using the scikit-learn package in Python. The dataset was randomly split 100 times into training and testing sets (80/20). After training on the training sets, the models' performances on the testing sets were averaged over the 100 iterations. Evaluation metrics include accuracy and F-measure, the harmonic mean of precision and recall.
RESULTS:
42 patients met inclusion criteria, representing 4619 epochs. eSevo levels 1-4 represented 6, 41, 32 and 21% of the data. Figure 1 presents the accuracy and F-measure of each ML model. Support vector machine (SVM), K-nearest neighbor (KNN), and Deep Multi-Layer Perceptron (DMLP) were the top performing models with median accuracies > 0.6 and F-measures > 0.5.
DISCUSSION:
In infants ≤ 3mo, SVM, KNN and DMLP offered higher accuracy in predicting eSevo levels based on qEEG features. Similar studies in adults, where BIS index was used as the gold standard, have yielded prediction accuracies of 89-95%[5,6]. In a study on infants ≤ 4mo, the prediction accuracy using SVM was 67-71%[7], similar to this study. The lower prediction accuracy in this study may be due to 1) infants having limited amplitude and frequency ranges compared to adults, resulting in less discriminatory power between eSevo levels; 2) limited EEG channels and data corresponding to the lowest eSevo level; and 3) lack of a gold standard (BIS) used in adult studies. Future direction will focus on using SVM, KNN, and DMLP on a reduced qEEG feature set, determined by computing *post hoc* feature importance.

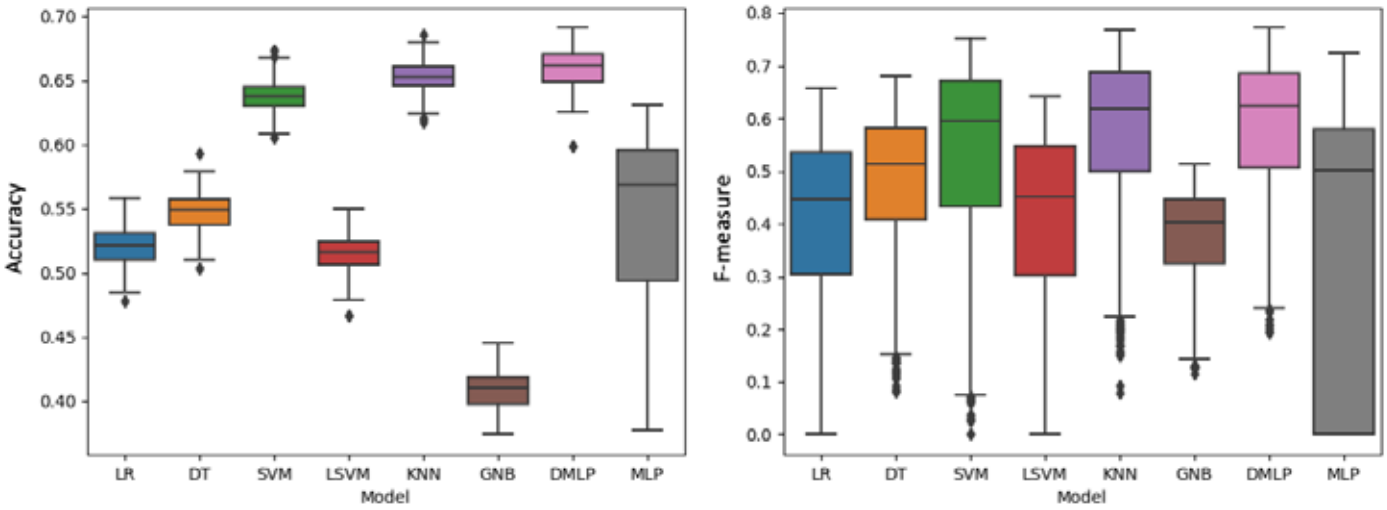

Figure 1: Boxplots of model accuracy (left) and F-measure with beta=1 (right) on holdout sequences over 100 different iterations.
LR = Logistic Regression; DT = Decision Tree; SVM = Support Vector Machine; LSVM = Linear Support Vector Machine; KNN = k-nearest neighbor; GNB = Gaussian Naïve Bayes; DMLP = Deep Multi-Layer Perceptron (with default Adam optimizer); MLP = Multi-Layer Perceptron (with stochastic gradient descent optimizer).

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Abstract Title: End-Tidal Carbon Dioxide Measurement Variations During Mask Ventilation

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Co-Authors: Trey Blackwell BS, Christian Orr MS-3, Joseph Orr PhD, University of Utah Department of Anesthesiology

Introduction: End-Tidal Carbon Dioxide ($ETCO_2$) measurement during mask ventilation of an apneic patient is an important measure of alveolar/therapeutic gas exchange. In the operating theatre, this measurement occurs via side stream sampling at the breathing circuit elbow or at the heat moisture exchange (HME) filter. Alternatively, if a patient is undergoing sedation, they will sometimes have a nasal canula in place. Some nasal cannulas (NC) have an $ETCO_2$ sampling port by which sampling can occur directly from the nares. If a patient becomes too sedated, they may exhibit hypopnea and/or apnea at which point the anesthetist may provide positive pressure mask ventilation over the canula with an air-cushioned mask (ACM). This positive pressure ventilation may occur while maintaining the NC in place which may predispose to leak and/or attenuated $ETCO_2$ signal during the ventilation process. We thus evaluated the effect of sampling location, at the breathing circuit elbow or NC, and tidal volume on the accuracy of the measured $ETCO_2$ with and without a NC between the mask and a simulated face.

Methods: Positive pressure mask ventilation was tested on a silicon-molded face (EcoFlex 00-10, Smooth-on, Macungie, PA) with a 3-D printed model of a nasal airway was connected to a test lung (TTL, Michigan instruments, Grand Rapids, MI) through a simulated trachea. CO_2 gas was continuously injected into the test lung using a mass flow controller (Alicat Scientific, Tucson, AZ). Five conditions were tested. In the first, the ACM was applied directly to the face with CO_2 sampled from the breathing circuit elbow and then in 4 conditions in which a NC, with associated CO_2 sampling, was between the ACM and face. In these 4 conditions, the NC was set at 0 lpm, 2 lpm, 4 lpm or attached to a novel O_2 delivery device that administers increased flow of O_2 to compensate for mask leak during positive pressure ventilation. The measured $ETCO_2$ was compared to a reference CO_2 measured at the simulated trachea.

Results: Across all tested tidal volumes, less attenuated $ETCO_2$ values were measured if sampling was done at the NC under conditions of no O_2 flow or the with the O_2 device only administering O_2 on mask ventilation (Figure 1).

Discussion: This study showed that even though placing the NC between the face and the ACM causes increased mask leak, it has the advantage of improved $ETCO_2$ measurement when there is no O_2 flow to the NC or used with the novel O_2 delivery device. Additionally, the masking mode of the O_2 delivery device improves $ETCO_2$ measurement because it increases exhaled tidal volume by compensating for mask leak during positive pressure ventilation. Also, since the O_2 device disables O_2 flow while the patient is exhaling, it does not dilute the end-tidal gas sample.

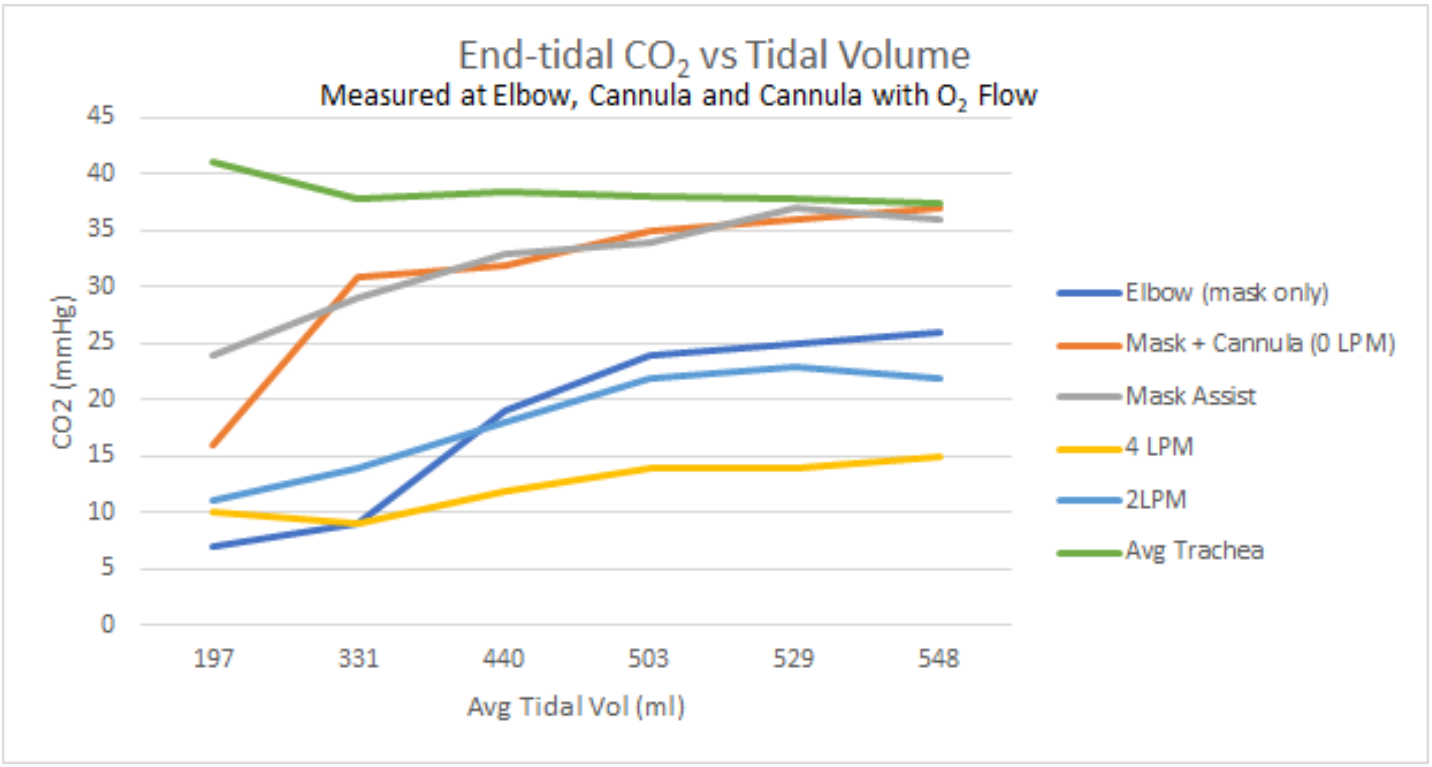
End-tidal CO_2 vs Tidal Volume
Measured at Elbow, Cannula and Cannula with O_2 Flow
CO2 (mmHg)
45
40
35
30
25
20
15
10
5
0
197
331
440
503
529
548
Avg Tidal Vol (ml)
Elbow (mask only)
Mask + Cannula (0 LPM)
Mask Assist
4 LPM
2LPM
Avg Trachea

Figure 1

Can ExSpiron®, a Non-invasive Respiratory Volume Monitor, detect diaphragmatic dysfunction?

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Background: Diaphragmatic dysfunction is a common side effect of brachial plexus blocks (BPB), but a systematic assessment of the dysfunction is an uncommon practice. Spirometry, maximum inspiratory and expiratory pressures, chest x-rays, and ultrasound have been used to evaluate phrenic nerve dysfunction[1,2]. Non-invasive respiratory volume monitor (RVM) ExSpiron® uses bioelectrical impedance and correlates to lung volumes. The objective of this study was to evaluate if RVM could detect diaphragmatic dysfunction and correlate the changes in minute ventilation (MV) to inspiratory flow and airway pressures.

Methods: With IRB approval, adult English-speaking patients without known muscular or nerve disorders or pre-existing phrenic nerve or diaphragm pathology, scheduled to undergo BPB for upper extremity surgery, were evaluated for recruitment. After informed consent, ExSpiron® sensor was applied to the right side of the chest only (manufacturer recommendations) and patients were instructed on how to use an incentive spirometer (IS) connected to a pressure transducer. A pulse oximeter was applied to the respective extremity. Real-time respiratory measurements were recorded prior to sedation, after sedation, and 15-30 minutes after nerve block placement. Patient demographics, MV, maximum negative inspiratory pressure, flows and photoplethysmographic (PPG) amplitude, and peak area were collected. Data was entered into Excel® and pressure waveforms were analyzed in LabChart. T test was used to compare negative pressures before and after BPB and a value of $p<0.01$ was considered statistically significant.

Results: Thirty-four patients were approached for participation from June to October 2022. Two patients declined to participate, and five had incomplete data sets due to technical difficulties. A total of 27 patients were included in the analysis. Demographically, the mean age was 55 years, and 52% were women. Average respiratory metrics are shown in Figure 1A. After right-sided brachial plexus block, the average change in TV increased by 20% during spontaneous ventilation, and it reduced by 26% during organized deep breathing (with IS). Average percentage change in negative pressure decreased by 65% with reduction in airflow on IS (average number of balls decreased from 3 to 2). After left-sided BPB, average percentage change in TV reduced by 28% and 42% during spontaneous and organized deep breathing, respectively. Average percentage change in negative pressures decreased by 44% with reduction in air flow on IS (average number of balls decreased from 2.5 to 2). There was a significant decrease in negative inspiratory pressure before and after BPB ($p<0.00005$).

Conclusion: The objective of this study was to evaluate if RVM could detect diaphragmatic dysfunction. To the best of our knowledge, this is the first study to objectively assess MV changes after BPB. A trend was seen on the RVM with reduction in average percentage change in TV during organized deep breathing, as expected after BPB. However, the ExSpiron® showed a 20% increase in TV after right sided BPB. We think this result is due to ExSpiron® sensor placement as well as the irregularity in the depths of breaths during spontaneous ventilation. The IS showed consistent readings with significant reduction in negative pressures and flows after BPB bilaterally. There was a consistent increase in both PPG amplitude and peak area indicating sympathectomy and successful BPB placement[3,4]. In conclusion, RVMs are not ideal monitors to detect diaphragmatic dysfunction after BPB but flow measurements with IS might be clinically applicable. Moreover, IS has been shown to improve pulmonary function postoperatively so their use could be beneficial in two meaningful ways[5]. Systematic assessment of diaphragmatic dysfunction could contribute to an improved practice to optimize patients´ post-operative management and outcomes. Further research is needed to establish the changes in IS in relation to different approaches of BPB.

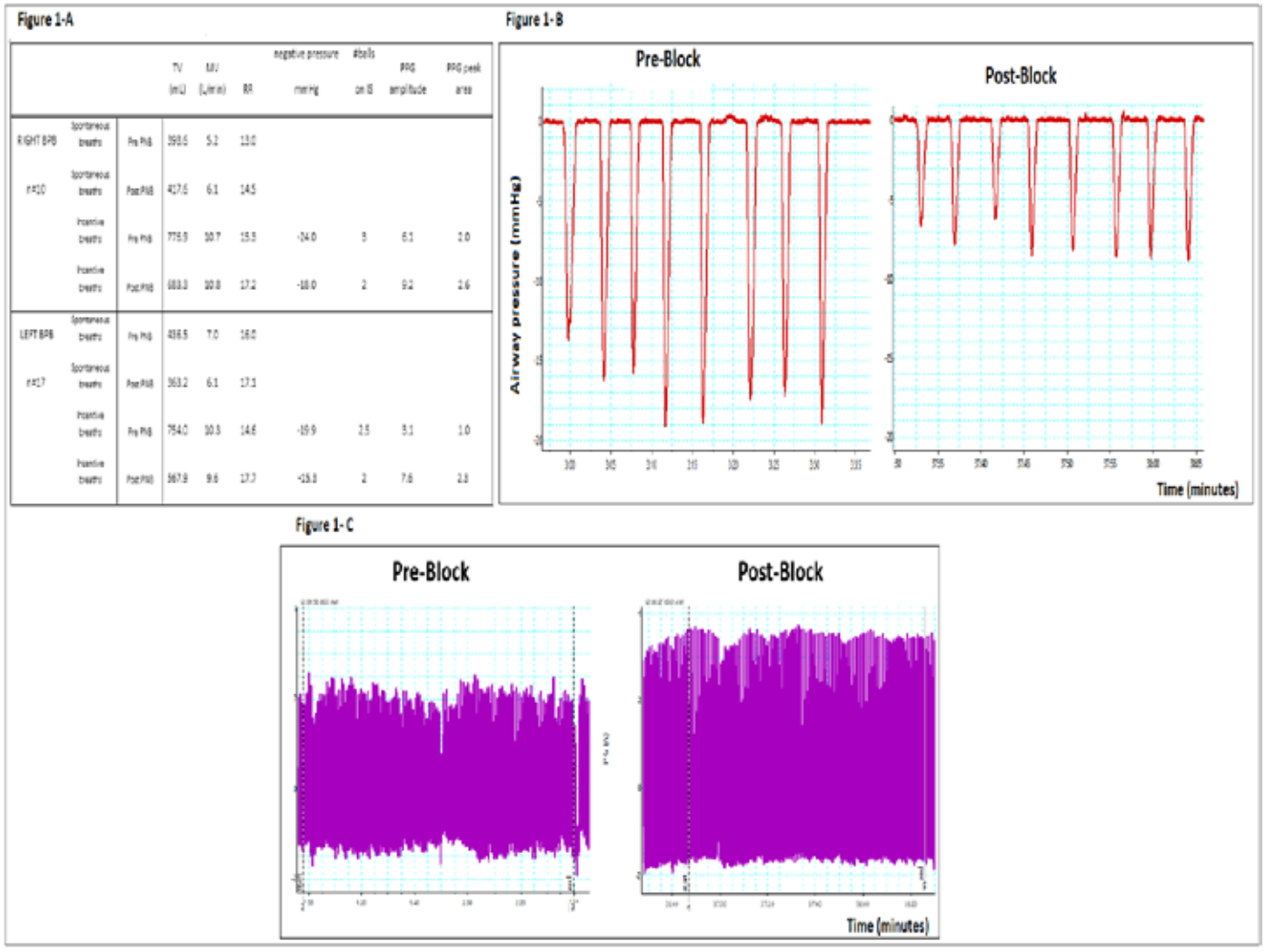

Figure 1. A: Average respiratory metrics categorized by right sided and left sided brachial plexus blocks. **B**: Negative pressure waveforms before and after BPB with spontaneous and organized deep breathing with IS as analyzed in LabChart. **C**: Changes in photoplethysmographic (PPG) amplitude and peak area before and after BPB.

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Incentive Spirometer could be used to detect diaphragmatic dysfunction but sedation could confound the results

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Background: Diaphragmatic dysfunction is a common side effect of brachial plexus blocks (BPB), but a systematic assessment of the dysfunction is an uncommon practice. Spirometry, maximum inspiratory and expiratory pressures, chest x-rays, and ultrasound have been used to evaluate phrenic nerve dysfunction[1,2]. Pere *et* al. showed a clear decreased diaphragmatic motion after continued interscalene nerve block accompanied with restrictive changes observed on spirometry[1]. Incentive spirometer (IS) is an inexpensive and widely used device in the perioperative period but its use is effort dependent. Sedation is a common practice prior to peripheral nerve block placement and can affect patients´ respiratory effort when using IS. The objective of this study was to evaluate the effect of sedation on maximum inspiratory pressures generated on IS after sedation prior to and after BPB placement.

Methods: With IRB approval, all adult English-speaking patients without known neuromuscular disorder or diaphragm pathology, scheduled to undergo BPB for upper extremity surgery, were evaluated for recruitment. After informed consent patients were instructed on how to use an IS connected to a pressure transducer (Figure 1A). The IS has three balls and each ball presents flow volume, with three balls representing 1200 mL/sec, two balls representing 900 mL/sec, and one ball equal to 600 mL/sec flow[3]. A pulse oximeter was applied to the respective extremity. Real-time respiratory measurements were recorded prior to sedation, after sedation and after nerve block placement. Patient demographics, maximum negative inspiratory pressure, flows on IS and photoplethysmographic (PPG) amplitude, and peak area were collected. Data was entered into Excel® and pressure analysis were performed in LabChart (Figure 1B).

Results: Thirty-four patients were approached for participation from June to October 2022. Two patients declined participation, and five had incomplete data sets due to technical difficulties. A total of 27 patients were included in the analysis. Mean age was 55 years, and 52% were women. The average dose of sedation given intravenously was 89 mcg fentanyl and 1.9 mg midazolam. Average negative pressure generated prior to BPB placement was -20.4 mmHg (SD 8.4) with average 2.5 balls on IS. Significant reduction was seen after sedation was given, with average maximal negative pressures of -14.2 mmHg (SD 5.8) ($p<0.0001$) with average 2 balls on IS. Average time from sedation to IS evaluation was 2 minutes and 41 sec (SD 49 secs). Overtime, average maximal negative pressure improved to -16.4 (SD 7.9) with 2 balls on IS. Average time lapsed from BPB placement to post BPB IS evaluation was 25 min and 5 secs (SD 8 min and 14 secs). There was a significant decrease in negative inspiratory pressure before and after BPB ($p<0.00005$). An increase was seen in PPG amplitude from 4.2 to 8.2 and peak area from 1.4 to 2.4 before and after BPB placement, respectively.

Conclusion: Incentive spirometers could play a meaningful role in evaluating diaphragmatic dysfunction after BPB. However, their use is effort-dependent and our results showed that sedation had a significant effect on maximum negative pressure generated. In fact, sedation had a more profound effect than the BPB. It is unlikely that the BPB had not taken a full effect, as there was a consistent increase in both PPG amplitude and peak area indicating sympathectomy and successful BPB placement[4,5]. Improvement might be related to sedation wearing off over time. Pere *et* al. showed that premedication caused a significant decrease in respiratory muscle power (measured as maximal inspiratory and expiratory pressures)[1] so careful timing of a diaphragmatic dysfunction evaluation with IS is paramount in the setting of sedation.

Figure 1-A

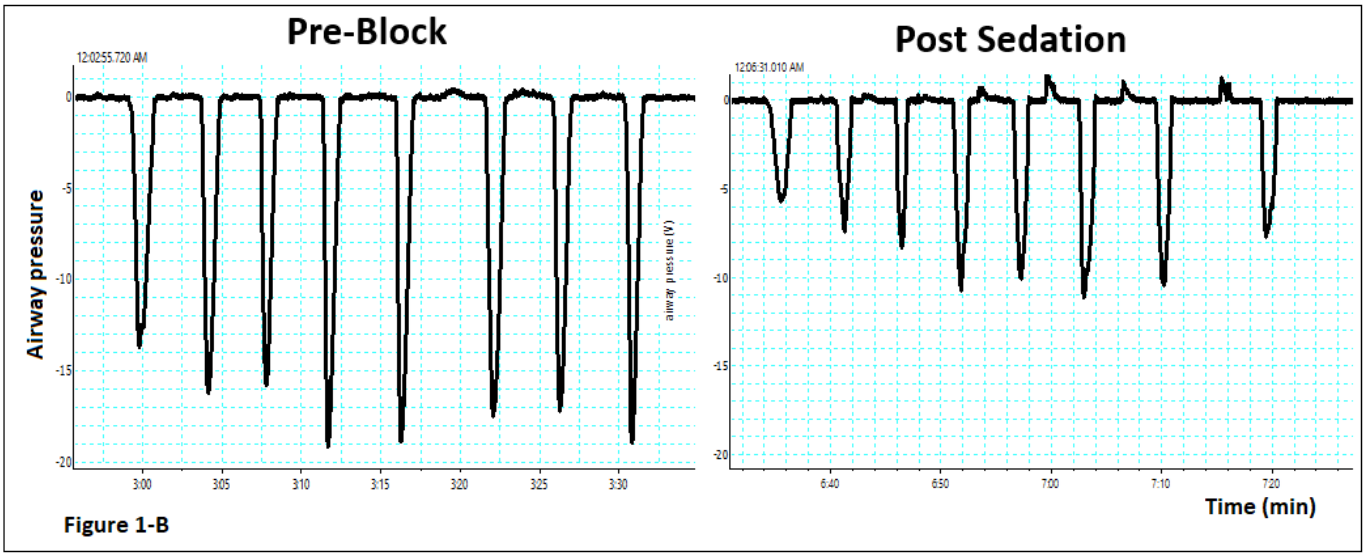

Figure 1-B

Figure 1 A IS connected to a pressure transducer. **B** Negative pressure waves from before and after sedation, respectively.

References:

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Abstract Title: A PROSPECTIVE OBSERVATIONAL STUDY OF EHR-BASED VERSUS VIRTUAL DESKTOP-BASED ACCESS TO PEDIATRIC ANESTHESIA EMERGENCY ALGORITHMS

Presenting Author: TBD (Marks, Johnson, or Simpao), Children's Hospital of Philadelphia

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Introduction: When pediatric anesthesia emergencies occur, situations can deteriorate rapidly. At our hospital, the Society for Pediatric Anesthesia's (SPA) emergency algorithms are used as cognitive aids during crises, and nurses are tasked with accessing the algorithms. Operating room nurses' typical workflow includes continuous display of the of the electronic health record (EHR) intraoperative navigator, which can delay navigating to the virtual desktop window and the algorithms' icon. Thus, we implemented a button in the intraoperative navigator's toolbar to access the algorithms with one click. We conducted an observational study of the time required to access and display overhead an algorithm using the new button and old method. We surveyed participants on usability.

Methods: The quick access button was implemented in the EHR (Epic, Verona, WI) in October 2022. Nurses were oriented to the purpose and function of the new button prior to using it. The study team timed perioperative nurses as they accessed the algorithms using the new button and then with the virtual desktop icon. A usability survey link was shared after each timing session.

Results: Nine nurses completed the timing sessions. Accessing algorithms took significantly less time using the new EHR button compared to the virtual desktop method (16.3 vs. 32.3 s, $p = 0.025$). On the usability survey, 8 of 9 respondents strongly agreed that the new button was easy to use, facilitated access to the algorithms, and was faster than the old method.

Conclusion: EHR-based access to pediatric anesthesia emergency algorithms is feasible and took significantly less time to access algorithms than a virtual desktop icon in a cohort of perioperative nurses. User experience survey responses were highly favorable overall. Plans include additional testing and analyzing the use of the tool during simulation sessions and actual emergencies.

WAKE UP SAFE: (RE)BUILDING A NATIONAL ADVERSE EVENT CASE REPORTING SYSTEM

Presenting Author: Fuchiang Rich Tsui, PhD, The Children's Hospital of Philadelphia (CHOP)

Co-Authors: Lingyun Shi, MS; Sachin Grover, MS, Sifei Han, PhD, Raj S Iyer, MD, Allan F Simpao, MD, Dean Kurth, MD, The Children's Hospital of Philadelphia; Jay Deshpande, MD, Wake Up Safe

Introduction: Wake Up Safe (WUS) is a federally designated Patient Safety Organization and a subsidiary of the Society for Pediatric Anesthesia. WUS mission is to improve care processes and outcomes in children receiving anesthesia. WUS collects data on serious adverse events from 41 member hospitals and reports findings to drive its mission. In 2021, WUS announced the need for a new system to improve data collection and management. Our team of CHOP Quality and Safety leaders, the Biomedical Informatics team, and Tsui Informatics Laboratory at CHOP was awarded the opportunity to build the new WUS system. We built a national case-reporting system using industry and informatics best practices in security, data access, and standard terminologies. We are sharing details of this system to encourage and facilitate similar patient-centered initiatives in other specialties and countries.

System Architecture: The new WUS system operates on the HIPAA-compliant Amazon Web Services (AWS) as a central repository for data on serious adverse events (**Figure 1**). We adopted industry standards for multi-stage development and deployment cycle: alpha, beta, and production. Alpha and beta environments allow new development and tests before the final production deployment. The database engine is PostgreSQL, an open-source database. The core data model adopts from the Observational Medical Outcomes Partnership (OMOP) model, which is commonly used in research communities and multi-center studies. The production environment with continuous monitoring and backups reports statistical analyses to member hospitals. The data dictionary and questionnaires for case reporting were developed and approved by the nationally recognized quality and safety leaders on the WUS committee.

System Features: In the current release, there are eight feature categories: 1) user account management, 2) data security and privacy, 3) interactive case reporting forms, 4) scalable computing resources and data storage, 5) advanced data loss protection (before data submission), 6) data and model standards, 7) comprehensive system logs and user audit, and 8) statistical analysis reporting. The user account management involves email verification, administrative new user review, user role and affiliation management. The new system uses secure HTTPS connections and access control for reporting and retrieving cases. The interactive web-based case-reporting forms use a dynamic list of sub-questions dependent on previous answers and data entry verification (e.g., body mass index [BMI] within an acceptable range). Scalable computing uses on-demand services for alpha and beta environments to minimize costs. The advanced data loss function automatically saves entered data that has not yet been submitted. The data standards include ICD-10 diagnosis codes and CPT-4.0 procedure codes; the case-reporting form enables keyword-based search of those standard codes to minimize the need for free-text data entry. The system routinely records system logs, provides audit options, and reports statistical analyses on patient care and for quality assurance to member hospitals.

Conclusion: Our team at CHOP has developed and deployed a national case reporting system for Wake Up Safe to drive its mission, which is actively being spread internationally with the support of WUS leadership. With its adoption of industry and informatics standards, the new WUS system could serve as a blueprint for national case-reporting systems in other specialties and countries.

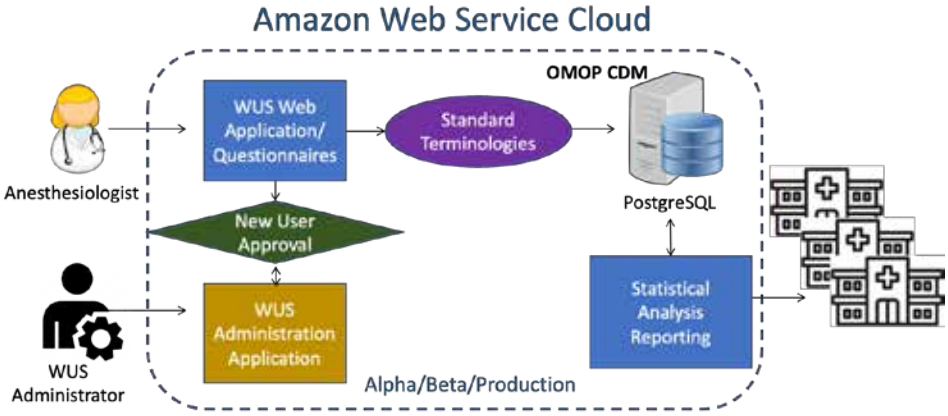

Figure 1. Wake Up Safe Case Reporting Architecture.

Title: Demystifying the Draeger Perseus A500 Anesthesia Machine's Spontaneous Ventilation CPAP Function
Presenting Author: James Xie, MD

Background: The Draeger Perseus A500 anesthesia machine has a convenient feature that allows the anesthesia provider to apply a set positive end expiratory pressure (PEEP) i.e. continuous positive airway pressure (CPAP) in the manual / spontaneous ventilation mode. Notably, this feature is relatively flow independent - i.e. the set PEEP is achieved regardless of what the fresh gas flow (FGF) setting is (unlike using the adjustable pressure valve, which develops pressure in the circuit in a flow dependent manner). The Instructions for Use (IFU) describe the use of this CPAP mode and the corresponding alarm "CPAP changed to "Off"" but does not specify what threshold is used to trigger the alarm. Only a general descriptor of the alarm is provided in the IFU: "The set CPAP pressure could not be achieved due to leakage. The system has changed the CPAP setting to "Off"."

Learning goals: What is the leak threshold that triggers the alarm and forces the CPAP to turn off? How does the Perseus A500 generate the set PEEP/CPAP in spontaneous ventilation mode?

Case Presentation: A 3-year-old male is induced under general anesthesia via inhaled induction technique with sevoflurane. The anesthesia mask is secured on the patient's face with elastic mask straps. To minimize atelectasis, the CPAP setting is set to "5cm H2O." With the FGF reduced to 1 L/min, the patient continues breathing spontaneously and the machine measures a PEEP of 5cm H2O. During the procedure, the patient's head is turned, and a small leak develops. After some time, the "CPAP changed to "Off"" alarm is triggered, and the PEEP setting is reset to zero.

Results: Since publicly available materials on the Perseus A500 do not provide additional explanation on the CPAP mode, direct communication with Draeger was initiated, resulting in a fruitful explanation of its design and function. Per their R&D team: "The alarm regarding the forced deactivation of CPAP in Man/Spon is based on the expiratory pressure sensor. The alarm is raised if the pressure reading is below 75% of the set CPAP for more than 10 seconds. We apply some filtering so that 'ok values' are not considered if the 75% threshold is not exceeded for more than one second again. The bottom line is that we cannot say how much leakage is tolerated because the influence on the expiratory pressure reading depends on the location of a leakage and of course the ability of the blower in conjunction with an adequate fresh gas flow setting to compensate for the leakage." Furthermore, they confirmed that the CPAP mechanism in the A500 is generated via compression: "The turbine is compressing the volume which is inside the breathing circuit already. In theory this works just fine without any gas going into the system at all. Of course, you'll need some fresh-gas to account for eventual leakages and patient uptake." Based on these communications, it can be concluded that the CPAP mode deactivation relies on a sustained relative inability to achieve the set pressure instead of an absolute leak threshold. Furthermore, use of the CPAP mode is achieved even in settings of lower FGFs because turbine driven ventilators can pressurize the gasses already in the circuit.

Discussion: Communication and collaboration with anesthesia machine vendors is crucial for the ongoing understanding of new features and unique failure states in modern anesthesia machines. In the case of the Draeger A500, that has the ability to provide CPAP in low FGF states, it is clinically useful to recognize that increasing FGF can help compensate for small leaks, as long as the expiratory pressure remains > 75% of the set PEEP.

Figure: Draeger A500's main display showing the "CPAP changed to 'Off'" alarm after the set CPAP pressure was not achieved for more than 10 seconds (i.e. < 75% of the set pressure)

References: Instructions for use: Perseus A500: Anesthesia workstation software 2.0n. Draeger. https://www.draeger.com/Products/Content/perseus-a500-sw-203-ifu-9510595-en.pdf

Acknowledgements: Thanks to David Karchner (Draeger Senior Director of Marketing) and Jonas Boerner (Draeger R&D) for contributing their expertise to this case report and the description of the Perseus A500's design and functionality.

WikiAnesthesia Practice Groups: A Solution for Sharing Institutional Anesthesia Knowledge

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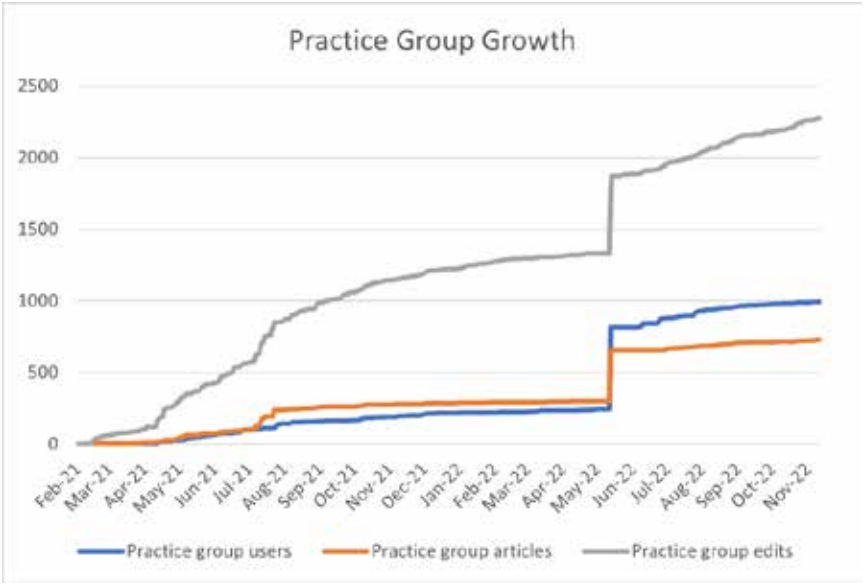
Introduction: For years, anesthesia knowledge has been shared through textbooks, word of mouth, and, more recently, online databases. WikiAnesthesia is the first resource created that allows for the spread of knowledge online through a crowd-sourced model whereby users both consume and contribute content. Although the concept and implementation of WikiAnesthesia were already novel ideas, there are many differences in the practice of anesthesia that exist across different hospitals. These differences remain a barrier to the applicability of generalized anesthesia knowledge as a whole. In addition, specific institutions may implement their own practice methods due to attending preferences, surgical preferences, limitations in workflow or accessibility, and variation in hospital resources.

Methods: We hypothesized that the creation of a wiki-based platform which provides institutions with a private, centralized repository to store and organize information relevant to their practice would help address many of these challenges. Thus, we have created a feature for WikiAnesthesia called "Practice Groups", which we developed as a custom extension for the MediaWiki software package that powers WikiAnesthesia, Wikipedia, and many other Wiki-based websites. In addition, Practice Groups allow private articles to be linked to public articles and allow users to seamlessly switch between public information and detailed institution-specific information. This limits the amount of content that institutions must internally maintain to only what is truly specific to their practice, and distributes the responsibility of maintaining knowledge of general interest across the entire WikiAnesthesia community. Practice Groups also allow institutions to make some of their articles public, enabling the global community to learn about institutional differences in their anesthetic practices.

Results: Since the public launch of the Practice Groups feature in February 2021, 16 Practice Groups have been created, representing mostly large academic centers with residency programs. 996 (65.3%) WikiAnesthesia users are members of a Practice Group and have created 728 articles for their institutions across 2,278 revisions. The demographics of members across all Practice Groups consist of 682 (68.5%) physicians, 118 (11.8%) CRNAs, and 119 (11.9%) students and staff.



Based upon feedback from institutional representatives, Practice Groups have been used to share case protocols, clinical primers, extended recovery after surgery (ERAS) protocols, and surgeon preferences. A particular use case that has emerged is with residency programs to distribute residency-specific materials such as rotation guides, resident policies, and anesthesia attending preferences.

Conclusion/Future Directions: The Practice Groups feature of WikiAnesthesia has successfully addressed many of the challenges with sharing institutional knowledge for multiple institutions, simplifying the process of creating and maintaining information relevant to their practitioners within a centralized private repository.

A Novel, Cassette-Based Nitric Oxide Delivery System Accurately Delivers Inhaled Nitric Oxide via the Anesthesia Machine at Low Fresh Gas Flows

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Coauthors: *Stephanie Anderson, MSBME, Vero Biotech Inc., Atlanta, GA; Aaron Roebuck, MS, RRT, Vero Biotech Inc., Atlanta, GA*

Background: Increased clinical use of inhaled nitric oxide (iNO) has encouraged industry to improve iNO delivery systems to make them safe, portable, and reliable.[1] The ideal system should accurately deliver set iNO dose regardless of ventilator type used. A major difference between ICU ventilators and anesthesia machines is that an ICU ventilator uses an open-breathing circuit with constant bias flow. In contrast, an anesthesia machine uses a semi-closed breathing circuit, removing CO_2 to enable low fresh gas flows (FGF), which conserves anesthetic agent and maintains heat and humidity.[2,3] Tank-based iNO systems (eg, INOmax DS_{IR}®, $NOxBOX_i$®) inject iNO based on measured inspiratory flow through the breathing circuit and do not account for rebreathing in semi-closed anesthesia circuits. This results in measured iNO levels significantly greater than set iNO dose and higher NO_2 levels, unless FGF rates are equal to or higher than minute ventilation (MV).[4] Thus, tank-based iNO systems negate the many benefits of low-flow anesthesia practice and introduce a potential error for the anesthesia provider who is unaware of delivery system limitations.[5] Providers will need to divert their attention from direct patient care to the anesthesia machine to adjust FGF to accommodate tank system limitations. Genosyl® DS (Vero Biotech) is a novel, cassette-based system that measures iNO concentration in the breathing circuit and uses the measured value in an advanced feedback control algorithm to accurately determine how much iNO should be injected when rebreathing in semi-closed anesthesia circuits.[6] The aim of this study was to test the use of the Genosyl® DS with the anesthesia machine under rebreathing conditions.

Methods: Genosyl® DS was tested with GE Aisys CS2 and Dräger Fabius GS Premium anesthesia machines with a test lung to determine if set iNO dose was affected by rebreathing conditions. Volume control, pressure control, and manual ventilation modes were tested with both neonatal and adult breathing circuits and a wide range of ventilatory parameters. The FGF ranged from 0.5–2.0 L/min to test rebreathing conditions.

Results: In the set NO dose range of 1–80 ppm, the Genosyl® DS maintained accurate iNO delivery within ±20% or ±2 ppm (whichever is greater) of set point for both neonatal and adult rebreathing conditions (Fig. 1). Measured O_2 levels remained acceptable at ≤1 ppm under all ventilation conditions when iNO was set to 40 ppm in 60% O_2.

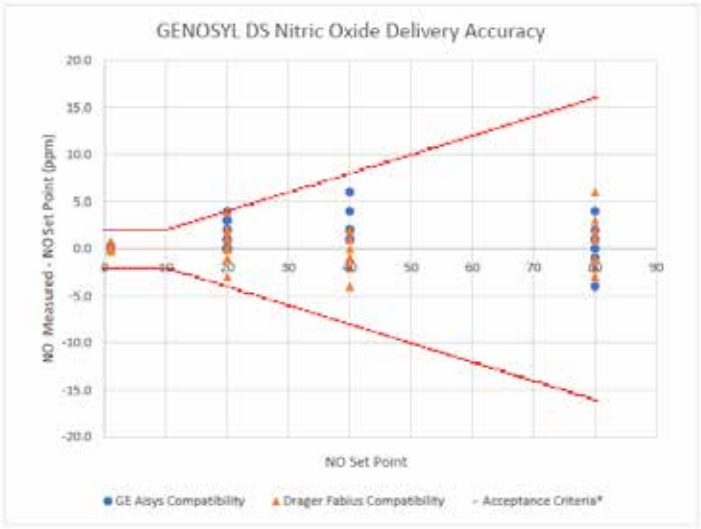

Figure 1: Accuracy of iNO delivery using GENOSYL DS in conjunction with GE and Drager anesthesia machines in mechanical and manual ventilation modes. *Acceptance criteria were according to Guidance for Industry for FDA Reviewers (CDRH, *Guidance Document for Premarket Notification Submissions for Nitric Oxide Delivery Apparatus, Nitric Oxide Analyzer and Nitrogen Dioxide Analyzer.* January 24, 2000.)

Conclusion: The Genosyl® DS is the first iNO delivery system capable of accurately delivering iNO with an anesthesia machine under rebreathing conditions in both neonatal and adult ventilation modes, enabling low FGF anesthesia with all its benefits.

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A Novel, Cassette-Based Nitric Oxide Delivery System Accurately Delivers Inhaled Nitric Oxide via the Anesthesia Machine Independent of Fresh Gas Flow Rate and Volatile Anesthetic Agent

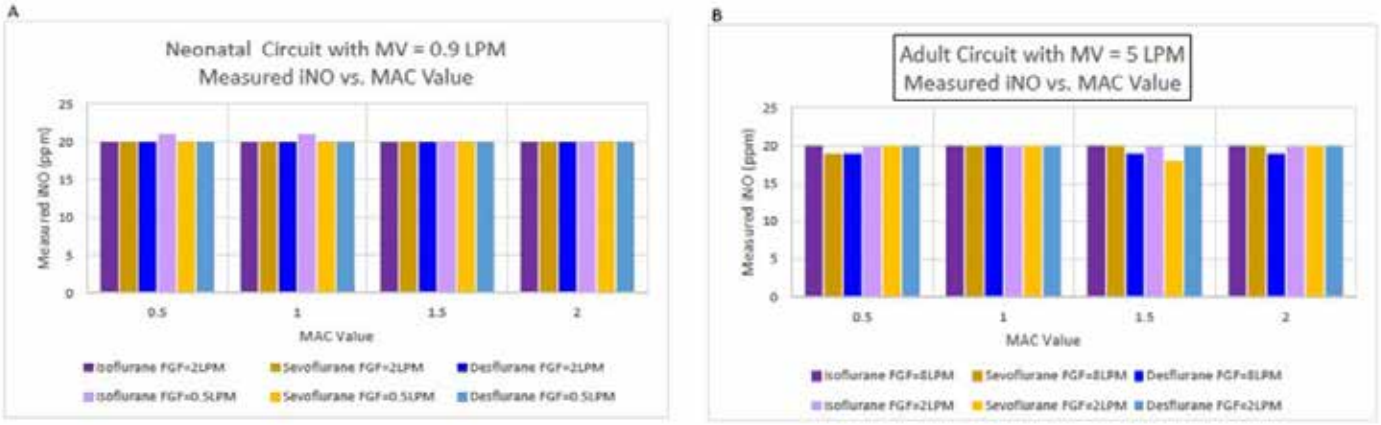
Presenting author: Mark Twite, MD, Children's Hospital Colorado & University of Colorado Anschutz Medical Campus, Aurora, CO

Coauthors: *Stephanie Anderson, MSBME, Vero Biotech Inc., Atlanta, GA; Aaron Roebuck, MS, RRT, Vero Biotech Inc., Atlanta, GA*

Introduction: Increased clinical use of inhaled nitric oxide (iNO) has encouraged industry to improve delivery systems to make them safe, portable, and capable of delivering set iNO dose regardless of delivery mode, eg, ICU ventilator or anesthesia machine.[1] Tank-based iNO systems from Mallinckrodt Pharmaceuticals (INOmax DS_{IR}®) and Linde Gas & Equipment Inc ($NOxBOX_i$®) inject iNO based on inspiratory flow through the breathing circuit and do not account for rebreathing in semi-closed anesthesia circuits. Studies show that when using tank-based iNO systems with anesthesia machines, delivery of iNO is only accurate when fresh gas flow (FGF) is greater than minute ventilation (MV).[2] The INOmax labeling warns that when used with a circle anesthesia system, recirculation of gases should be avoided. The labeling also cautions that nitrous oxide (N_2O) and isoflurane will affect the set iNO dose vs the measured iNO value.[3] The Genosyl® DS (Vero Biotech) is a novel, cassette-based system that measures iNO concentration in the inspiratory limb of the breathing circuit and uses an advanced feedback control algorithm to accurately determine how much iNO should be injected.[4] The aim of this study was to test Genosyl® DS performance with anesthetic agents and FGF.

Methods: The Genosyl® DS was tested with a Flow-i anesthesia machine (Getinge) and a test lung to determine if set iNO dose was affected by FGF or type of volatile anesthetic agent at different MAC values.

Results: The Genosyl® DS maintained iNO delivery within ±20% of set iNO dose when isoflurane, sevoflurane, and desflurane concentrations were incrementally increased up to 2 minimum alveolar concentration (MAC) and when N_2O was used, regardless of FGF and MV (Fig. 1A & 1B). Measured NO_2 levels remained below 0.2 ppm for all test conditions, which is below the allowed threshold of 1 ppm.



Conclusions: The Genosyl® DS cassette-based system is the first iNO delivery system to accurately deliver set iNO dose with a semi-closed anesthesia circuit, independent of volatile anesthetic agent and FGF using the novel advanced feedback control algorithm. Anesthesia providers can simply set the iNO dose without adjusting FGF or anesthetic agent. This decreases provider distractions, maintains focus on the patient, and facilitates the transition of care between the ICU and OR for ventilated patients.

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Novel Pharyngeal Oxygen Delivery Device Preserves Oxygenation Longer than High Flow Nasal Cannula

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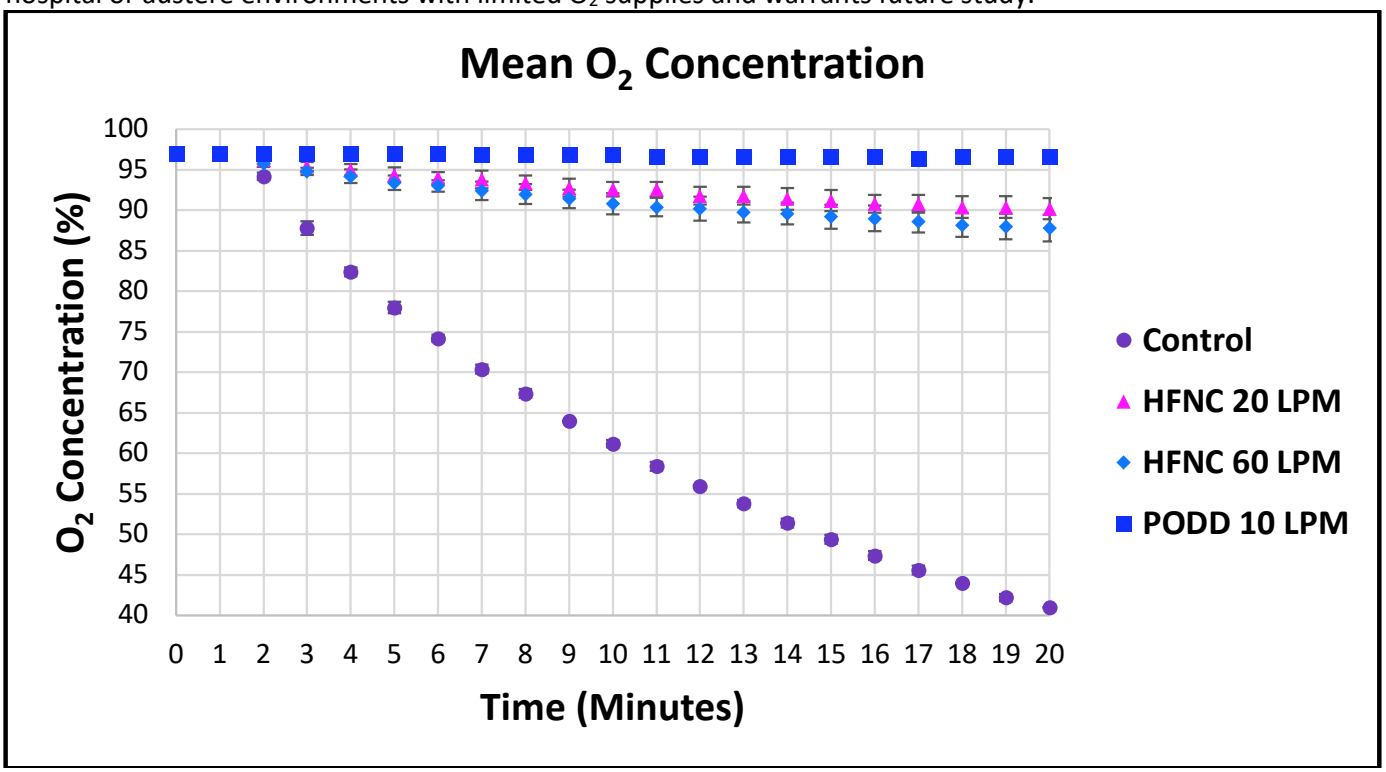
Background: Hypoxemia during apnea and a failed airway scenario is life threatening. High flow nasal cannula (HFNC) prolongs the time to oxygen (O_2) desaturation during laryngoscopy and intubation in pre-oxygenated, apneic patients.[1] HFNC devices have disadvantages that limit routine use, including the need for specialized equipment and complex setup, which are expensive (both in equipment costs and O_2 resources).[2] Further, admixing air in the oropharynx may significantly reduce alveolar O_2 delivery. To mitigate these disadvantages, a novel pharyngeal O_2 delivery device (PODD) was developed to provide O_2 therapy directly above the glottic opening. The device is a curved, dual-channel plastic insert that couples to both O_2 supply and gas analyzer tubing. The PODD readily fits within a traditional oropharyngeal airway. These are easily placed in the patient's airway to provide supraglottic oxygenation. To facilitate intubation, the PODD is uncoupled from the traditional oropharyngeal airway and left in place to provide continuous O_2 delivery during laryngoscopy. We hypothesized that the PODD will provide apneic oxygenation as effectively as HFNC, yet at lower O_2 flow rates.

Methods: Using an airway manikin (Laerdal Airway Management Trainer) and a test lung that approximates an adult functional residual capacity (2.5L), we compared the efficacy of the PODD with HFNC at maintaining O_2 concentration in the pre-oxygenated, apneic lung. In each trial, the test lung was pre-oxygenated to 97% and a multi-gas analyzer measured the O_2 concentration each minute for 20 minutes. Four arms were studied: HFNC flow rates of 20 liters-per-minute (LPM) and 60 LPM, PODD flow rate of 10 LPM, and a control arm with no flow after the initial pre-oxygenation period. Five randomized trials were performed for each arm, for a total of 20 trials. Descriptive statistics and ANOVA were used with statistical significance defined as $P<0.05$.

Results: Mean O_2 concentrations decreased from 97% in the groups as follows: 41±0% for the control, 90±1% for the HFNC 20 LPM, 88±2% for the HFNC 60 LPM, and 97±1% (no change) for the PODD 10 LPM.

Conclusion: The PODD maintained O_2 concentration longer than HFNC in this apneic oxygenation manikin model. The PODD uses lower O_2 flow rates, is less expensive, is more compact, is easily placed, and requires no additional equipment as compared to HFNC. The PODD has potential applications in both controlled airway settings and pre-hospital or austere environments with limited O_2 supplies and warrants future study.



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The relationship between Airway Pressures and Airway Flow using Incentive Spirometry

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Background: Diaphragmatic dysfunction is a potential complication of brachial plexus block (BPB). It has been shown that the incidence of diaphragmatic dysfunction can be 100% after interscalene BPB[1] and as high as 50-67% with supraclavicular BPB[2,3]. There are multiple modalities to assess diaphragmatic dysfunction such as plain radiographs, ultrasound, fluoroscopy and pulmonary function tests[4]. Pere *et* al. showed a clearly decreased diaphragmatic motion after continued interscalene BPB accompanied with restrictive changes observed on spirometry, measured as maximal inspiratory and expiratory pressures[5]. Incentive spirometer (IS) is an inexpensive and widely used device in the perioperative period, but it measures airway flow. The aim of this study is to assess the patient´s effort of breathing (generating negative airway pressure) and airway flow on IS before and after BPB.

Methods: This prospective observational study included all adult patients scheduled to undergo BPB for upper extremity surgery. Patients with pre-existing neuromuscular disease and/or diaphragmatic pathology were excluded. After informed consent, the patients were instructed on how to use an IS, connected to a pressure transducer. The IS has three balls and each ball presents flow volume, with three balls representing 1200 mL/sec, two balls 900 mL/sec and one ball equal to 600 mL/sec (Figure 1-A). The patients were instructed to take eight breaths through the IS before and after BPB and the maximum negative inspiratory pressure and airway flow were recorded. Data was entered into Excel® and pressure analysis was performed in LabChart. Regression analysis was performed to show the relationship between airway pressures and airway flow before and after the BPB.

Results: A total of 34 patients were included in the study. Two patients declined participation and ten patients had incomplete data due to technical difficulties. 22 patients were included in the final analysis. Average age was 55.2 years and 54.5% were female. At baseline, the average negative airway pressure was 21.6 mmHg and the average airway flow rate from IS was 1091 mL/sec. After the BPB the average negative airway pressure decreased to 17 mmHg and the average airway flow rate decreased to 902 mL/sec. The percentage change of airway pressures and airway flow before and after BPB is presented in Figure 1-B.

Conclusion: This report demonstrates that patients´ effort is an important factor in generating enough negative airway pressure to get a desirable flow rate (number of balls being moved) on the IS. There is a linear relation between the negative airway pressure and airway flow as shown in Figure 1-B. In patients who receive interscalene BPB, it is important to evaluate diaphragmatic dysfunction, especially in patients with limited respiratory reserve (such as smokers, chronic obstructive pulmonary disease, interstitial lung disease). IS is a device that is inexpensive and easy to use. Assessment of diaphragmatic dysfunction after different approaches of BPB, as well as different volume of local anesthetic used, is recommended.

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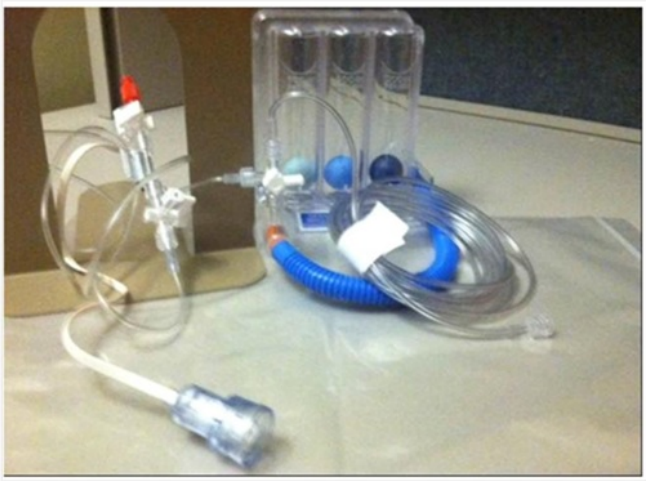

Figure 1-A: Incentive spirometry with pressure transducer

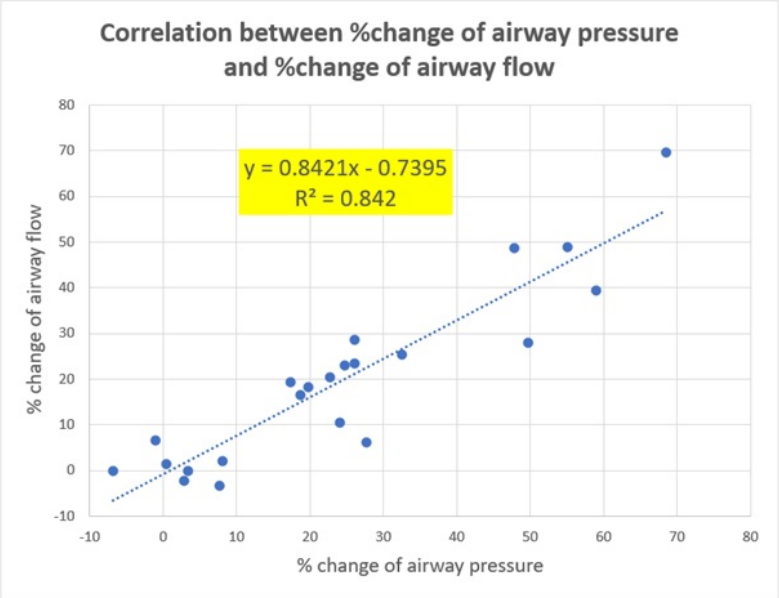

Figure 1-B: The relationship between airway pressure and flow before and after BPB

Studying Upper and Lower Extremities Bioimpedance during Lower Body Negative Pressure induced hypovolemia

Presenting Author: Suthawan Anakmeteeprugsa[1] MD
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Background: Lower body negative pressure (LBNP) is an experimental model for studying the physiologic change of hypovolemia, as -30, -60, and -90 mmHg LBNP approximate average blood losses of 450, 1000, and 1600 mL respectively in a 70 kg human[1,2]. LBNP reduces venous return by sequestrating blood into the lower parts of the body. This leads to rapidly decrease in central blood volume resulting in increasing in heart rate and vasoconstriction, so systemic vascular resistance increases[3]. The Bioelectrical Impedance Analysis (BIA) is based on measurement of electrical impedance (Ω) of a whole body or particular body part estimated by measuring the voltage signal developed across that body part by injecting a constant current signal. As the blood represents the most electrically conductive substance in the body, the blood volume changes can be detected by the impedance measurement of the particular body part. From the electrical current aspect, the blood volume is considered as an extracellular fluid, so the low frequencies (5KHz or less) are recommended for the measurement.[4] The objective of this study is to demonstrate the changes in upper and lower extremities bioimpedance during LBNP-induced hypovolemia and if valid, BIA can be used as a tool to improve the clinical management of volume status during hemorrhage and resuscitation.
Methods: With IRB approval, this study included 14 healthy volunteers underwent gradual LBNP which is consisted of 3-minute at baseline, -15 mmHg, -30 mmHg, -45 mmHg, -60mmHg, recovery at -30 mmHg and recovery at baseline. We connect the Bodystat® Multiscan 5000 (Figure 1-A) to the electrodes that were placed over the right foot and upper part of the leg, the right hand and upper part of the arm as shown in Figure 1-B. We measured bioimpedance at each phase of LBNP and the values were recorded. Data reported as mean (SD), the changes of bioimpedance from both sites from baseline were calculated using student's t-test, P value<0.05 was considered significant. Correlation between changes in leg, arm bioimpedance and estimated blood loss from LBNP was calculated using Pearson correlation.
Results: A total of 14 healthy volunteers were enrolled. one volunteer was excluded because of incomplete data. 13 subjects were in the final of analysis. As we progress in LBNP-induced hypovolemia there was significant increase in the arm bioimpedance and an associated decrease in the leg bioimpedance as shown in Figure 1-C. During recovery -30 phase (where blood is shifted from the leg to the body), there were an increase in leg bioimpedance and a reduction of arm bioimpedance. During Recovery baseline phase, (Figure 1-D) the leg continued to increase while the arm bioimpedance showed significant increase as a result of shift of metabolites from leg to the body resulting in vasodilation and shifting of blood from the arm to the body. The correlation between estimated blood loss and arm bioimpedance (r=0.93) and leg bioimpedance (r=-0.82) as shown in (Figure 1-E and 1-F) respectively.
Conclusion: Using LBNP-induced hypovolemia is effective model for studying the changes in bioimpedance of the extremities during hypovolemia and resuscitation. during. During LBNP, blood sequestration in the leg is associated with decrease in leg bioimpedance while the arm bioimpedance will progressively increase and the reverse happened with recovery. The changes in arm bioimpedance could also give insight about vasoconstriction and increase systemic vascular resistance during hypovolemia.

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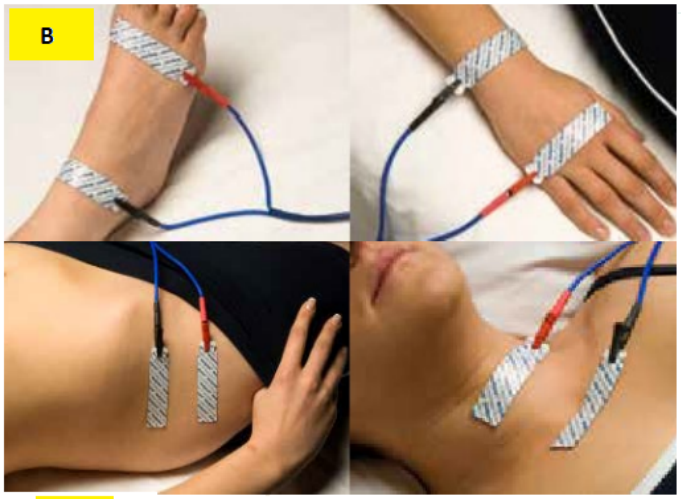

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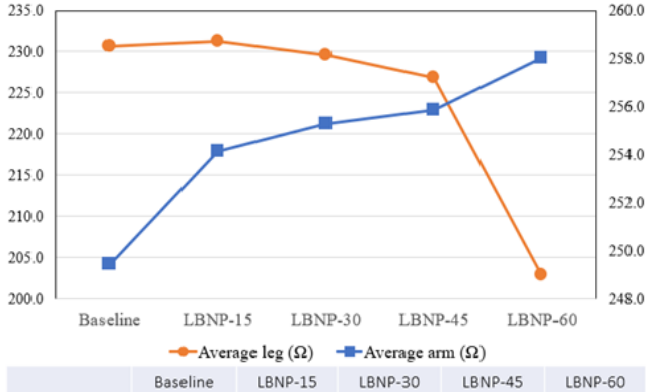

	Baseline	LBNP-15	LBNP-30	LBNP-45	LBNP-60
Average leg (Ω)	230.6 (32.8)	231.2 (33)	229.5 (32.1)	226.85 (30.5)	202.8(20.9)
Average arm (Ω)	249.4(49.5)	254.1(51.8)	255.3(52)	255.8(52.4)	258(52.3)

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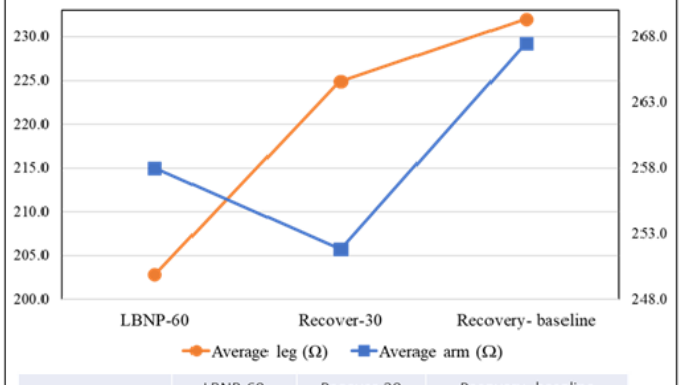

	LBNP-60	Recover-30	Recovery- baseline
Average leg (Ω)	202.8(20.9)	224.9(32.2)	232(32.6)
Average arm (Ω)	258(52.3)	251.8(54.8)	267.5(40.6)

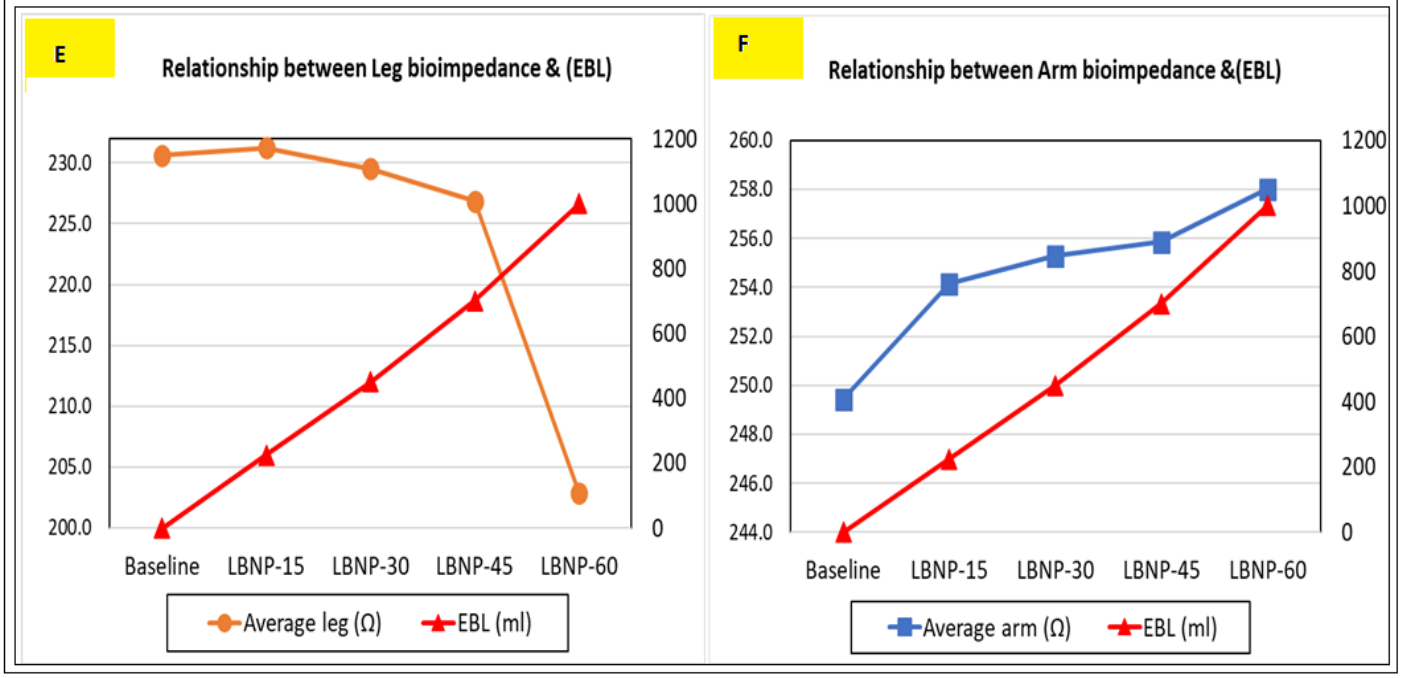

Figure1: A: Bodystat® Multiscan 5000, B: Electrodes placement, C: Leg and arm bioimpedance during gradual hypovolemia, D: Leg and arm bioimpedance during recovery phases, E: Relationship between leg bioimpedance and Estimated blood loss (EBL) F: Relationship between arm bioimpedance and Estimated blood loss (EBL)

Reducing Opioid Harm by Prompting for Breaths

Presenting Author: Lara Brewer, PhD[1]
Co---Authors: Joe Orr PhD[1], Jake Enos MD[1], Soeren Hoehne M Eng[1], Lara Werner[1], Talmage Egan MD[1], Ken Johnson MS, MD[1] 1: University of Utah

Background: Opioids are known to cause harm by inducing ventilatory depression and airway obstruction, especially when administered with a sedative. These events are associated with significant morbidity and mortality during the first 72 hours after surgery.[1] An automated prompting system may be useful in prompting hypopnic patients to breathe when clinician availability is limited. To that end, we explored the feasibility of computer-delivered verbal prompts and tactile stimuli to prompt sedated hypopnic volunteers to breathe. Our aim was to prompt sedated, healthy volunteers to breathe using a recorded voice and a recorded voice together with a tactile stimulus. Our hypothesis was that the device prompting success rate would *not* be inferior to the nurse prompting success rate for each stimulus type.
Methods: After written informed consent, 26 healthy volunteers received escalating doses of remifentanil and propofol target controlled infusions to produce increasing severity of ventilatory depression and increasing sedation. Using a cross over experimental design, once the desired state of ventilatory depression was achieved, prompting was randomized to one of two prompting techniques: a device voice prompt or a live human voice and then repeated using the other technique. Low voice was defined as 65 dB; high voice was defined as 100 dB. The device tactile shake was delivered from a mechanized massager applied to the shoulder. A positive response was defined as an increase in respiratory rate by at least 50%. We compared the proportions of success between the two groups using a 2-sample test for equality of proportions with continuity correction in R (R Foundation for Statistical Computing, Vienna, Austria).
Results: The device voice prompt and live human voice delivered 2,245 and 2,048 prompts, respectively. The device voice prompt was successful on 1,790 prompts (80%) and the live human voice was successful on 1,679 prompts (82%). Individual percentages of success for each prompt type are shown (Fig1). The device was slightly favored for prompts during respiratory depression in a comparison between difference between proportions of success between the device and the nurse. As propofol was increased, volunteers became less responsive to prompts to breathe. As remifentanil was increased, volunteers developed ventilatory depression, but remained responsive to prompts to breathe.

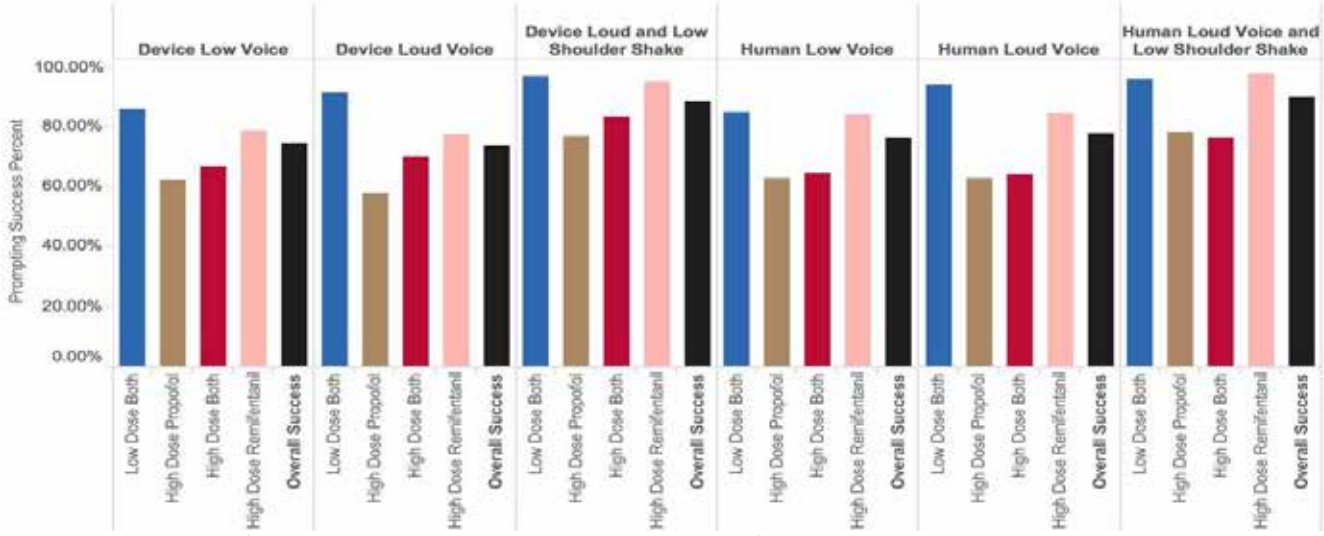

Figure 1: Prompting Success Percent across all prompting types for both the device (recorded voice) and the nurse. Low dose remifentanil (<1 ng/mL) and propofol (<1 ug/mL) marked in blue, high dose remifentanil (>1 ng/mL) marked in pink, high dose Propofol (>1 ug/mL) marked in brown, high dose both drugs marked in red.

Discussion: Our results confirmed our hypothesis; a device voice prompt was not inferior to a live human voice prompt. Neither the live voice nor the device voice prompt was successful in prompting volunteers to breathe once they achieved a sedation level consistent with general anesthesia. Future work is warranted to explore whether device voice prompts can diminish episodes of postoperative ventilatory depression in settings where clinician availability may be limited (e.g. the hospital floor).
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Abstract Title: Developing an Expandable Endotracheal Tube: The Process from Ideation to Patent

Presenting Author: Alessandra Bryan, BS, BA, IDEA Lab, Department of Anesthesiology and Perioperative Medicine, Dartmouth Health
Co-Authors: Alexander Abess, MD, IDEA Lab, Department of Anesthesiology and Perioperative Medicine, Dartmouth Health; Yvon Bryan, MD, IDEA Lab, Department of Anesthesiology and Perioperative Medicine, Dartmouth Health

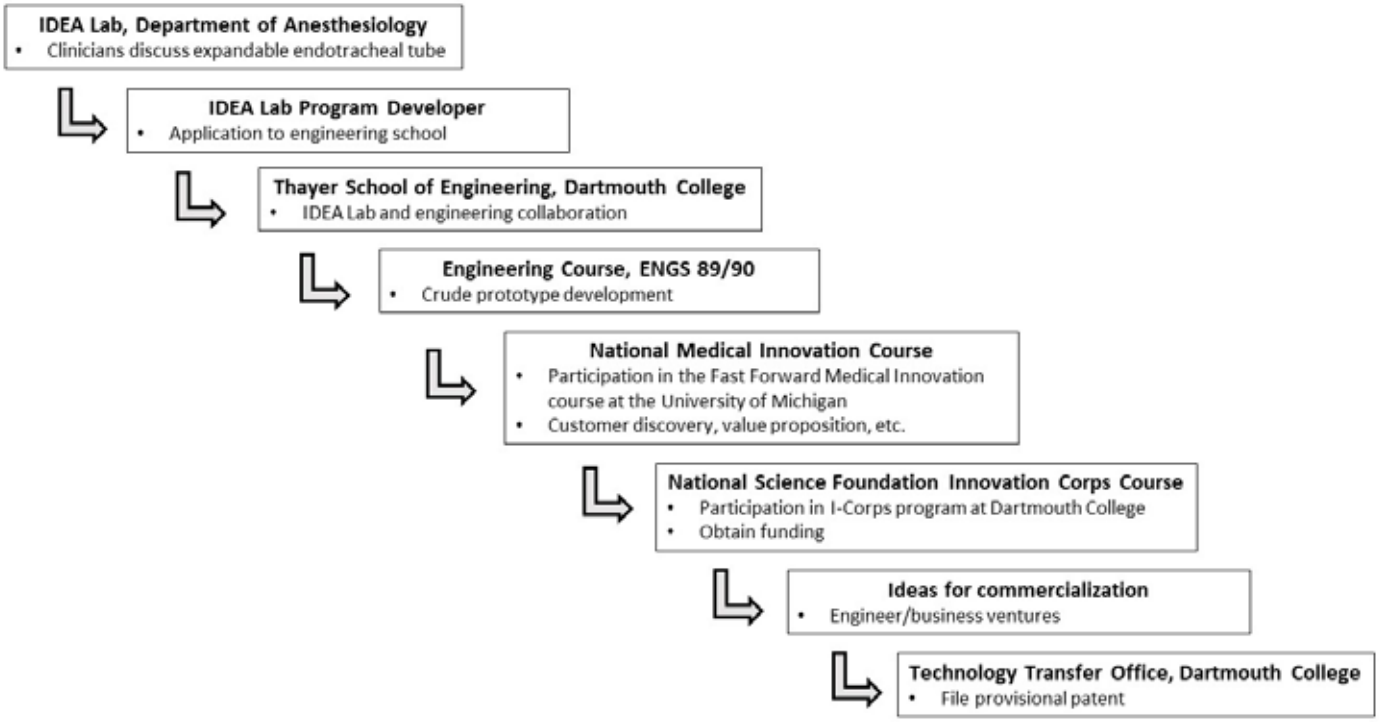
Introduction: Fifty million intubations are performed globally each year with over 20 million done in the United States (1). However, different surgical procedures require specialized endotracheal tubes (ETT) with unique characteristics. Anatomic variations in patients as well as oropharyngeal and laryngeal lesions may make placement of a normal sized ETT challenging or impossible. Clinicians may provide solutions to the problems experienced during intubation, but need collaboration with engineers. In order to develop medical devices to solve unique clinical challenges, the development of a program with access and assistance of technical and business expertise is required. We present our experience and the pathway used by the Dartmouth Health Innovation Development and Entrepreneurship in Anesthesia (IDEA) Lab in the development of an expandable ETT.

Methods: In the spring of 2021, we identified a clinical problem experienced by many anesthesiologists when placing a normal sized ETT in patients undergoing dental and ENT surgeries: placement can be very difficult. The idea to develop an expandable ETT was formalized into a written proposal and presented to engineers (ENGS 89/90) at the Thayer School of Engineering at Dartmouth College. Clinicians, the IDEA Lab program developer and engineers collaborated (Fall 2021-Spring 2022) on the device's mechanical and structural feasibility and developed a crude prototype. IDEA Lab members enrolled in medical innovation courses at The University of Michigan (Fast Forward Medical Innovation) and at Dartmouth College (I-Corps program). Both were focused on product development, commercialization and regulatory pathways. We filed a United States provisional patent via the Technology Transfer Office at Dartmouth College.

Results: The IDEA Lab developed a device development pathway, from ideation and to a provisional patent (Figure 1). On October 18, 2022 we successfully filed a provisional patent for "An expandable endotracheal tube and method for use of same". Our expandable ETT's reduced outer diameter has the potential to be used for all intubations.

Conclusion: We highlight the pathway used by the Dartmouth Health IDEA Lab in the development of the idea for an expandable ETT to a provisional patent. Technical challenges were solved in collaboration with engineers, and business challenges were discussed and learned from national and NSF based medical innovation courses and programs. The IDEA Lab pathway is currently being used for numerous other projects, with the goal of future commercialization of such devices.

Figure 1. Device development pathway for an expandable endotracheal tube.



References:

1. Grand View Research. Endotracheal Tube Market Size, Share & Trend Analysis Report by Product Type (Regular Endotracheal Tube, Reinforced Endotracheal Tube), By Route, By Application, By End-use, By Region, And Segment Forecasts, 2021-2028. 2022.

Updating the Christchurch Fresh Gas Flow Data

Presenting Author: R Ross Kennedy. MB., ChB., PhD.
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Background
At Christchurch Hospital in Aotearoa New Zealand we have been tracking fresh gas flows (FGF) during volatile anesthesia since we first installed machines with electronic flow control, nearly 22 years ago. Among the unique features of our data series is that we have always included the entire case. We recently demostrated that high FGF during the early, induction, phase of anesthesia can account for a significant proportion of the total vapor consumption during a case. (1). This time period is excluded from many published datasets.
With increasing use of TIVA (as TCI) there is some concern that trainees may not be profiucent in low-flow voaltile anesthesia.

Aims
In this poster we update our data series, include data on the use of TIVA, briefly discuss the FGF changes we saw with the introduction of automated end-tidal vapor control when we replaced Datex-ADU with GE Aysis in 2011 and explore differences between in and out of hours as a marker for trainee use of FGF during volatile anesthesia.

Methods
Since 2018 we have used GE Insights to collect this data. Between 2001 and 2017 we used a variety methods, described elsewhere. (1). Our current data incorporates data from 20 OR used for a wide variety of surgery, and includes cardiac, neurosurgical, and dedicated pediatric rooms.

Results
The Figure shows our mean FGF at intervals since 2001. TIVA (TCI) is used in 60% of cases.
For 2022, to the end of October, our overall mean FGF was 780ml/min with a mean sevoflurane consumption of 13.1ml [median 11.2, IQR 7.1-17.1ml] representing a mean CO2 equiv footprint of 2.6kg per case.
Aysis with ET-control was introduced in 2011 and was followed by an increase in mean FGF to 1.5 l/min in June 2011. At that time automated control was used for 30% of the time vapor was in use. By Nov 2013 use of automated control had increased to 85% of case time and mean FGF had decreased to 1.1 l/min.
From two OR used for upper and lower G/I non-elective proceedures, there were 394 volatile cases during the “working week” and 315 “out of hours” with similar mean duration (83 v 84min). The mean FGF was significantly lower out-of-hours (747ml/min v 822ml/min, p=0.03)

Comments and Conclusions
Our overall FGF remains low despite the increasing use of TIVA. Our data that suggests that trainees use slightly lower FGF than more senior staff despite the increasing use of TIVA.
Our experience of the effect of the proportion of time automated vapor control is used on overall FGF may be useful in guiding the introduction of this technology into markets, such as the US, that are new to this technology.

Reference
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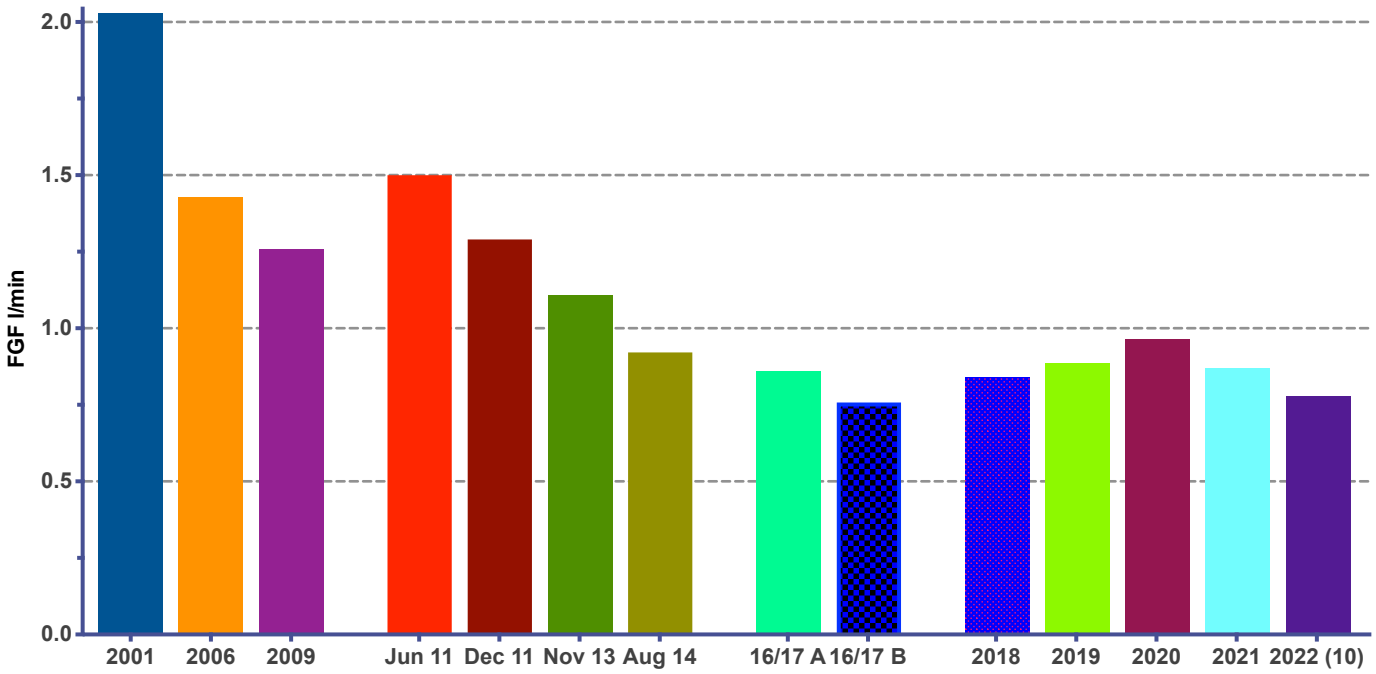

Figure: Mean time weighted FGF 2001 – 2022. Data prior to 2010 from Datex ADU. GE Aisys introduced 2010. Data for 2016 from Insights devolvement project. 2018 onwards commercial version of Insights (GE Healthcare).

Title: Demonstration of Remote Control of Critical Care Ventilators and the Integrated Clinical Environment

Presenting Author: Steven Dain MD, FRCPC[1,2]
Authors: Tracy Rausch MS, CCE[2], Julian Goldman MD[3], Yi Zhang PhD[3], Hong-Lin Du MD, MBA[4]
Affiliations: [1]Systems Design Engineering University of Waterloo, Waterloo Ontario Canada, [2]DocBox Inc, Waltham, MA, [3]MDPNP Program, Massachusetts General Hospital, Harvard University, [4]Nihon Kohden OrangeMed, Santa Ana, CA.

Introduction: The COVID-19 pandemic posed numerous challenges to patient care, including extensive PPE use, patient care in isolation rooms, inadequate numbers of intensivists particularly in rural communities, use of unfamiliar ventilators that would be partially remedied by the ability to remotely control lung ventilation. The goals of the project were to study the intended use, risk management, usability, cybersecurity for remote control of ventilators and demonstrate the use of a single interface for several different ventilators.

Methods: Clinical scenarios were developed including remote control of the ventilator from an antechamber of an isolation room, nursing station within the same ICU, and remote control from across the country. A risk analysis and was performed and a risk management plan established using the AAMI Consensus Report--Emergency Use Guidance for Remote Control of Medical Devices. A cybersecurity plan is in progress. Testing was done at the MDPNP laboratory.

We worked with Nihon Kohden OrangeMed NKV-550, Santa Ana, CA, and Thornhill Medical MOVES SLC, Toronto, Canada. Both companies modified their devices to allow remote control by and application operating on DocBox's Apiary platform. Apiary is a commercially available ICE solution, DocBox Inc, Waltham, MA. An expert panel was created to provide guidance on the design of a single common, simple to use graphical user interface (GUI) for both ventilators. Manufacturers' ventilation modes were mapped to ISO 19223 vocabulary, data was logged using ISO/IEEE 11073-10101 terminology using AAMI 2700-2-1, Medical Devices and Medical Systems — Essential safety and performance requirements for equipment comprising the patient-centric integrated clinical environment (ICE): Part 2-1: Requirements for forensic data logging.

Results: We demonstrated that both ventilators can be controlled and monitored using common user interface within an institution and across the country. Pressure and flow waveforms were available for the NKV-550 ventilator, and usual ventilator measurements were displayed in near-real time. The interface allowed changing FiO2, ventilation mode, respiratory rate, tidal volume, inspiratory pressure, and alarm settings. At times, increased network latency negatively affected the transmission of waveforms.

Conclusions: We were able to demonstrate remote control of 2 ventilators with a common user interface. Further work needs to be done on cybersecurity, effects of network perturbations, safety of ventilator remote control, usability implications of having a common UI for different devices needs to be investigated.

Figure: Browser based remote view for both the NKV-550 Ventilator and the MOVES SLC life support system.

Work was completed via funding for the National Emergency Telemedicine Effort and Virtual Hospital Programs funding by DHA TATRC

Title: Feasibility and gap analysis of using Controlled Vocabularies for coding ICU Flowsheets

Presenting Author: Steven Dain MD, FRCPC[1,2]
Authors: Rizwan Shareef[2,3]
Affiliations: [1]Systems Design Engineering University of Waterloo, Waterloo Ontario Canada, [2]DocBox Inc, Waltham, MA, [3]Student, University of Ottawa, Ottawa, ON Canada

Introduction: In order to improve the care of critically ill patients and assisting the development of machine learning algorithms and predictive analytics, large, standardized multinational and multi-institutional data sets are required.

Methods: Paper based ICU flowsheets from several hospitals in Canada, US and India were examined as well as the electronic ICU flowsheet. Flowsheet Data fields were transferred to an Excel spreadsheet and mapped where possible using the SNOMED CT browser, (https://browser.ihtsdotools.org/), LOINC (Logical Observation Identifiers Names and Codes) browser (https://loinc.org/search/?) or ISO/IEEE 11073-10101 (https://rtm.prometheuscomputing.com) as of the August 2022. Attempts to map data fields were done using both precoordinated and post coordinated terms. For pre-coordinated, multiple concepts are brought together in one term, for example, "69833005 |Structure of right femoral artery (body structure)|". Post coordination, would describe it as IntersectionOf(62175007 |Structure of right lower limb (body structure)|:7657000 |Structure of femoral artery (body structure):272741003 |Laterality (attribute)|:24028007 |Right (qualifier value)| using SNOMED CT.

Results: Clinical Laboratory test terms were easily mapped to LOINC, although some terms required knowledge of the method and specimen type. Although the name of several scores were available in SNOMED CT, the individual items that make up the scores, such as the Glasgow Coma Scale (GCS), Braden Scale and Visual Infusion Phlebitis score were impossible to code. Terms related to vital signs were easily coded. Recently, common ventilation modes and terms from ISO 19223 Lung Ventilators vocabulary and semantics were added to SNOMED CT. Gaps were discussed with the SNOMED Anesthesia clinical reference group, and physical finding terms were submitted to SNOMED CT to code the GCS findings. SNOMED terminologists suggested that an ICU flowsheet project be initiated with interested parties to fill further identified gaps. The Society of Critical Care Medicine and other professional organizations will be contacted because of this work.

Conclusions: Although terms in currently available controlled vocabularies can be used to code many of the fields that are in an ICU flowsheet, further work is required to identify and fill the gaps. Cooperation between ICU professional and the controlled vocabulary organizations would be of value.

Abstract Title: A Medical Device Information Data Sheet (MDIDS) to Support the Interoperability of Externally Controllable Infusion Pumps for Tele-Critical Care[1]

Presenting Author: Julian M. Goldman MD
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Problem and Motivation. Medical device remote control technologies can enable remote experts to contribute to patient care during tele-critical care during public health emergencies like COVID-19 to address the shortage of local clinical expertise. The benefit of such technologies may be further amplified if one remote-control application can operate multiple interoperable medical devices (e.g. multiple types of ventilators or IV pumps) to support the typical diversity of deployed medical devices in one institution. However, due to the variation in capabilities of different makes/models of the same device type, this unified remote control capability requires the standardization of the data interfaces of similar devices to provide sufficient information about these devices to enable safe remote control.

Methods: Medical Device Interface Data Sheets (MDIDS) [1] can provide a useful tool for documenting current and future device interface requirements and capabilities. We examined several clinical use scenarios where externally controllable infusion pumps are used to support tele-critical care, based on which we generalized an MDIDS for remotely controllable infusion pumps. To validate this generic MDIDS, we cross-checked it with the capabilities of several externally controllable infusion pumps: the NeuroWave Accupump, Eitan Medical Sapphire, and the BD Alaris GH.

Results: During the development of the generic remotely controllerable infusion pump MDIDS, we were able to identify the common and specific data elements that different infusion pumps need to provide at their data interfaces, considering the great diversity in these devices related to infusion mechanism, infusion programming methods, device alarms and alerts, and system settings. The resulting MDIDS includes over 100 data elements, many of which are essential for safety, including those common across different pump types (e.g., maximum settable infusion rate, occlusion alarm) and those specific to certain pump types (e.g., syringe size for syringe pumps).

We developed the generic MDIDS as the theoretical basis and developed an application in our OpenICE open-source interoperability research platform [2] to remotely control the above three infusion pumps either via serial communication (representing controlling the infusion pump at a distance limited by a physical wired connection inside or outside the patient room) or across the Internet using the web extension service of OpenICE (representing situations where remote experts have no physical access to the patient).

Conclusion. MDIDS for externally controllable medical devices can provide a solid basis to improve the safety and interoperability of medical device remote control technologies in the tele-critical care context. They can also benefit the research, development, and testing of physiological closed-loop control systems. We applied the MDIDS methodology to infusion pumps and ventilators to support the integration of these devices to the U.S. Army Telemedicine & Advanced Technology Research Center (TATRC) National Emergency Tele-Critical Care System.

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Abstract Title: Endotracheal Tube Innovation: Embedded Flexible Mesh

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Background/Introduction: Endotracheal intubation is a fundamental anesthetic procedure in which a tube is inserted through the mouth or nose to maintain an airway. Once firmly in place, the endotracheal tube (ETT) normally retains its rigid curvilinear shape. One form of an ETT known as oral RAE tubes used commonly for otolaryngology procedures has a pre-formed bend at the distal end of the tube for clearance of the surgical site and reduction of kinking and obstruction. However, oral RAE tubes are limited since the depth of insertion is pre-determined and the pre-formed kink is unadjustable. There also exists reinforced tubes, standard ETT embedded with concentric steel rings meant for flexibility and resistance to kinking[1]. However, these are limited by their incomplete kink resistance, and inability to retain shape after bending unless through taping or tying. For facial and intra-oral surgeries, the anatomy significantly varies between patients, leading to a need to improve existing endotracheal tubes and combine the best features of reinforced ETT and oral RAE. Furthermore, similar constraints can be seen in the pediatric population; given that the surgical field and oral airways are much smaller, decreasing the room for error and increasing the possibility of total airway occlusion, in addition to the inconsistent lengths and distances of the pre-formed kink among brands and manufacturers[2].

Methods: The general approach was guided through the biodesign process, clearly defining the problem and implementing the solution while keeping the core needs of the patient and practitioner in focus. Market landscape, financial, cost-estimate, and stakeholder analyses were performed. The current standard of care ETT, oral RAE tubes, and reinforced ETT adult and pediatric versions were broken down into vital points, shortcomings, and inefficiencies. Design criteria were then established to lead our concept generation. Materials include nitinol and stainless-steel wire.

Results: The concept selection process yielded the idea of incorporating a stent-like metallic mesh framework embedded within the ETT plastic wall, ideally allowing the lumen to remain fully patent and fully adjustable. The degree and direction of the kink were essential parameters to be adjustable. Additional design elements are optical transparency to be able to view the “misting” of the ET tube for confirmation of intubation, and incorporation of modularity to be able to add and remove the flexible mesh section as needed with other attachments, brands, and tube types. The optimal mesh geometry, length, and material are currently being tested.

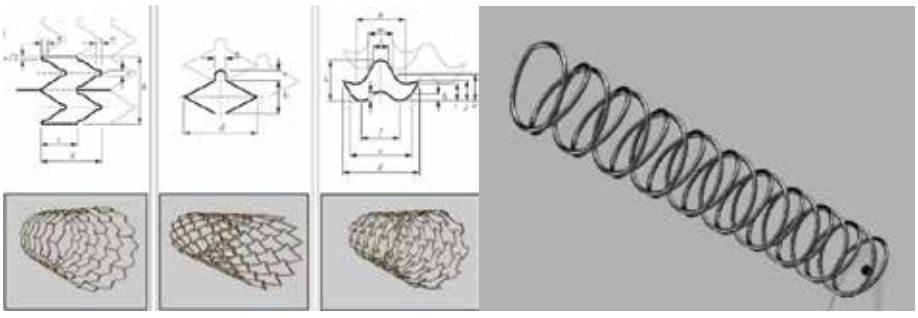

Figure 1: Mesh geometry variations of intricate patterns (left) and simple loop coil (right)

Conclusion: Our work demonstrates the need for an improvement in oral RAE tube design. Patient anatomy, limited otolaryngology operating space, and pediatric populations pose problems. The luxury of a fully adjustable distal component has major value in the operating room for the surgeon and the anesthesiologist. Future direction resides in optimizing the design and testing with in-vitro models.

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Abstract Title: The Effect of Suction on Passive Oxygenation for a novel, 3D-printed Laryngoscopy Sleeve

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Introduction: Suction and oxygen administration are commonly used during emergent intubations[1]. We created a novel 3D-printed laryngoscopy sleeve combining these two elements, but it is unknown what extent does suction limit the creation of a passive, oxygen-rich environment. We examined the end-tidal oxygen concentration (et-O2) at various points along the respiratory tract during an intubation of an airway manikin with the IVOS BOSS G4 video laryngoscope sleeve.

Methods: An airway manikin was intubated with our IVOS BOSS G4 sleeve to achieve a grade 1 Cormack-Lehane view. Average et-O2 was measured using mass spectrometry at the carina. Under constant suction (-200 mmHg), the oxygen flow was increased from 6, 10, to 15 L/min. Measurements were also repeated with suction off. The manikin's airway was washed out with air in between each trial.

Results: Without suction, et-O2 was greatest at 6 L/min at the carina (100%) and least with 15 L/min. However, it remained at 21% when maximum suction was applied, regardless of oxygen flow rate.

Conclusion: Maximum suction on the IVOS BOSS G4 appears to prevent the passive increase in end-tidal oxygen at the carina, despite maximal oxygen flow rate. 6 L/min appears to be the best flow rate to achieve 100% et-O2. Further studies are required to determine which suction pressure is optimal for maintaining 100% et-O2 while providing simultaneous suction to remove bodily fluids.

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Title: Deep Neural Network employing Transfer Learning to Improve Racial Bias in Pulse Oximetry Accuracy

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Background and Aims:

Pulse oximetry has become the medical standard for continuous and noninvasive monitoring for peripheral arterial oxygen saturation (SpO2, %). However, the inaccuracy of pulse oximetry has been reported in certain racial groups. In addition, the high-fidelity dataset including race and oxygen saturation are limited. Therefore, we proposed a framework employing Deep Neural Networks (DNN) based transfer learning to reduce the inter-group bias in pulse oximeter accuracy and applyed our framework in high fidelity dataset.

Methods:

Machine Learning of Physiological Waveforms and Electronic Health Record Data to Predict, Diagnose, and Treat Hemodynamic Instability in Surgical Patients (MLORD) dataset, collected at University of California Los Angeles (UCLA), was analyzed in this study. A total of 19,525 patients underwent surgeries at UCLA between 2019 and 2022 were included. All data was collected during surgery, which increased fidelity of dataset compared to other clinical data collected outside operating room. We defined SdO2 (%), non-invasive peripheral oxygen saturation predicted by DNN, as an estimation of arterial oxygen saturation (SaO2, %). First, in Caucasian group (n=10,068), we trained the DNN. Second, using Black group (n=1,273), we applied transfer learning into the “pretrained DNN” to generate “transferred DNN”. The input of DNN was composed of non-invasive features including values of SpO2, heart rate, age, gender, body mass index, and blood pressure. The accuracy of SdO2 was evaluated by assessing the mean ± standard deviation of root mean square error (RMS) between SdO2 and SaO2, and then compared to RMS between SpO2 and SaO2 using t-test.

Results:

In each patient, we selected the first measurement of SaO2 and then selected input features in the closest time with selected SaO2. Timing difference of measurement between SaO2 and periodic features was within 5 minutes in 99.8% of observations. Each racial group split into training set and test set. DNN was trained only by the training set while the accuracy of SdO2 was evaluated in the test set. In Caucasian group, the accuracy of SdO2 (2.15 ± 2.62) using the pretrained DNN outperformed the accuracy of SpO2 (2.51 ± 3.37) with statistical significance ($p<0.001$). Similarly, in African American group, the accuracy of SdO2 (2.42±2.99) using the transferred DNN still outperformed the accuracy of SpO2 (2.81±3.84) with statistical significance ($p<0.001$).

Conclusions:

Despite a smaller number of African American group compared to Caucasian group, the accuracy of SdO2 using the transferred DNN still outperformed the accuracy of SpO2. This finding suggests that DNN employing Transfer Learning may be applicable to increase pulse oximetry accuracy in African American group.

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Title: Machine learning predicting hypotension in operating room: application of deep neural networks on continuous physiologic waveforms for early prediction of intraoperative hypotension

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Background and Aims:

Intraoperative hypotension (IOH), defined as mean arterial pressure (MAP) less than 65 mmHg during operation, is associated with increased rates of postoperative organ damages which may be fatal. [1,2] Our previous work reported that Machine learning can predict hypotension using feature extractions upon physiologic waveforms in limited numbers of patients [3]. In this research, we proposed a framework employing Deep Neural Networks (DNN) on continuous physiologic waveforms for early prediction of intraoperative hypotension without no feature extraction and applied our framework in high fidelity dataset.

Methods:

Machine Learning of Physiological Waveforms and Electronic Health Record Data to Predict, Diagnose, and Treat Hemodynamic Instability in Surgical Patients (MLORD) dataset, collected at University of California Los Angeles (UCLA), was analyzed in this study. A total of 7062 patients' physiologic waveforms over 17,655 hours was collected at UCLA between 2019 and 2022 during operations, which increased fidelity of dataset compared to other clinical data collected outside operating room. Each waveform, arterial blood pressure (ABP), photoplethysmography (PPG), and electrocardiography (ECG), was preprocessed into 30 seconds of windows as inputs into DNN predicting IOH, defined as mean arterial pressure less than 65 mmHg during operation. Receiver-operating characteristic curve (ROC) analysis with mean [standard deviation] evaluated performance of our framework in predicting IOH. The patients were split into two groups; (1) training set (n=5,021) for training of DNN; and (2) test set (n=2,041) for the performance evaluation.

Results:

Among 7062 surgery cases, 1038 episodes (14.7%) of IOH occurred. In the test set, DNN predicted IOH (1) 10 mins before with ROC of 0.93 [0.90 to 0.96], (2) 5 mins before with ROC of 0.96 [0.95 to 0.97]; (3) 1 min before with ROC of 0.99 [0.98 to 0.99].

Conclusions:

DNN achieved excellent performance in early prediction of IOH using physiologic waveforms including ABP, PPG, and ECG during operations.

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Title: **Utilization of Electronic Medical Record Clinical Tools to Improve Antibiotic Re-dose Rate in Pediatric Cardiopulmonary Bypass Surgeries**

Presenting Author: Shazia Mohammad, MD; Texas Children's Hospital, Baylor College of Medicine
Co-Authors: Jennifer Chien, MD; Ali Hassanpour, MD; Matthew James, MD; Texas Children's Hospital, Baylor College of Medicine

Background: Post-operative wound infections occur in 2.3–8% of pediatric patients undergoing cardiothoracic surgery, with a financial burden over $1.6 billion annually in hospital costs.[1,2] During cardiopulmonary bypass (CPB) surgery, the priming volume may be particularly high in proportion to the circulating volume in the pediatric population resulting in subtherapeutic perioperative antibiotic levels if the re-dose does not occur.[3] At our institution, a clinical challenge was identified in 2019 when the number one source of fallouts for the Surgical Site Infection (SSI) Bundle Compliance monitoring was due to missed re-dosing of antibiotics after CPB. The aim of this study is to improve antibiotic re-administration compliance upon CPB initiation.

Methods: The Plan Do Study Act method of quality improvement was utilized. Each month, we recorded the number of CPB cases and the percentage in which antibiotics were successfully re-administered shortly after CPB initiation. After identifying the problem and the stakeholders involved, multiple interventions were instituted via repeated reminder emails, operating room (OR) discussions, involvement of cardiovascular (CVA) division chiefs, and attendance of CVA division meetings. Lastly, we implemented an electronic medical record (EMR) automatic reminder, which triggers a pop-up antibiotic re-dosing message on the electronic intraoperative record when CBP is charted.

Results: Before November 2020, the monthly re-dose rate was as low as 83.3%, and various interventions had sub-optimal and even reduction of re-dosing rates. However, since the EMR reminder was implemented in December 2020, the re-dose rate had increased to and remained at 100%.

Discussion: We demonstrated a significant improvement of antibiotic re-dose rate upon CPB initiation with implementation of an EMR tool, which was found to be superior to many traditional methods. This clinical tool increases antibiotic compliance which may reduce surgical site infections and associated healthcare costs. By providing a system change, it also reduces the provider's burden during CPB initiation.

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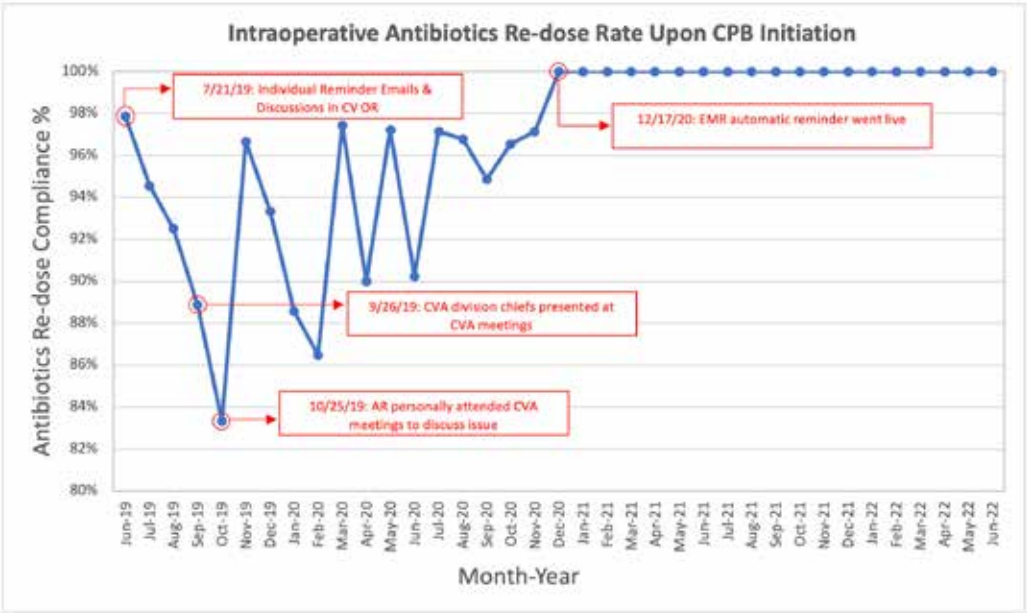

Fig. 1 Intraoperative Antibiotics Re-dose Rate with Interventions