Society for Technology in Anesthesia

STA 2022 Virtual Annual Meeting

January 13-15, 2022

Innovation for a Sustainable Future

THANK YOU CORPORATE MEMBERS
Welcome to the Society for Technology in Anesthesia’s (STA) 2022 Virtual Annual Meeting, Innovation for a Sustainable Future. I want to thank our Program Chairs, Drs. Olivia Nelson and John Pearson for putting together an exciting program that is sure to exceed everyone’s expectations.

The meeting will begin with a course for our Corporate Members on Challenges and Opportunities in Developing Anesthesia Products on Thursday, January 13, followed by a full-day program on Friday, January 14 and a half-day program on Saturday, January 15. This year's exciting lineup of speakers will feature presentations and discussions on emerging innovations and technology in anesthesia, with a particular emphasis on the value of innovation to address climate change and environmental impacts of perioperative care delivery. Our keynote address, given by Dr. Jodi Sherman, will speak on the role of anesthesiologists in slowing climate change.

Topics covered throughout the program include the latest advancements in Machine Learning and Artificial Intelligence, innovations to create resilient supply chains, environmental impacts of operating room anesthetic choices, circular economics for perioperative care, electronic anesthesia records and how corporate and hospital partnerships can advance sustainability through technological innovation.

I’d like to give special thanks to our Corporate Members who’s commitment to STA through our second year of virtual programming is not only appreciated, but vital to the future of STA.

Save the date for the 2023 Annual Meeting planned for January 11-14 at the Four Seasons Hotel in Las Vegas, Nevada. I will look forward to seeing everyone in person again.

Don’t forget to tag the STA in your Annual Meeting social media posts: @STAhq and #STA22AM.

Maxime Cannesson, MD, PhD
President, Society for Technology in Anesthesia

Invited Faculty

Justin Adams, BSEE, MBA
AlertWatch

Michael Burns, MD, PhD
University of Michigan

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

Brian Chesebro, MD
Providence Health & Services - Oregon Region

Gary Cohen, BA
Healthcare Without Harm

David Feinstein, MD, MS
Beth Israel Deaconess Medical Center

Jeffrey M. Feldman, MD, MSE
Children’s Hospital of Philadelphia, Perelman School of Medicine, University of Pennsylvania

Jorge Gálvez, MD, MBI
Children’s Hospital in Omaha

Seema Gandhi, MD
University of California, San Francisco

Diane Gordon, MD
University of Colorado

Nate Greenbaum, MD
SUNY Downstate Medical Center

Calvin Gruss, MD, MS
Vanderbilt University

Thomas Hemmerling, MD, MSc, DEAA
McGill University

Jan Hendrickx, MD, PhD
OLV Hospital

Harriet Hopf, MD
University of Utah Health

R. Ross Kennedy, MB, ChB, PhD, FANZCA
University of Otago Christchurch

Patrick Kolbay, PhD
University of Utah

Christos Koutentis, MBChB, MS
SUNY Downstate Medical Center

Samsun Lampotang, PhD, FSSH, FAIMBE
University of Florida

Christine Lee, PhD
Brightside Health

Hannah Lonsdale, MBChB, FRCA
Johns Hopkins University

Jeff E. Mandel, MD, MS
Mandel Anesthesia Innovations, LLC

Azad Mashari, MD, FRCPC
University Health Network, University of Toronto

Clyde Matava, MD
Hospital for Sick Children/University of Toronto

Richard Missett, DO
Children Hospital of Philadelphia

Shazia Mohammad, MD
Texas Children’s Hospital

Olivia Nelson, MD
Children’s Hospital of Philadelphia

John Pawlowski, MD, PhD
Beth Israel Deaconess Medical Center

Matthew Zapf, MD
Vanderbilt University Medical Center

Christopher Quartararo, MD
Winchester Anesthesia Associates

Priya Ramaswamy, MD, MEng
University of California, San Francisco

Nada Sabourdin, MD, PhD
Armand Trousseau University Hospital

Terri Scannell, MBA
Vizient

Jodi Sherman, MD
Yale School of Medicine

Jonathan Tan, MD, MPH, MBI, FASA
Children’s Hospital of Los Angeles

Ian Yuan, MD, MEng
Thomas Jefferson University

Seema Gandhi, MD
University of California, San Francisco
Meeting Accreditation Information

Activity Overview
The Society for Technology in Anesthesia (STA) 2022 Annual Meeting will provide a forum for discussion of emerging innovations and technology in anesthesia, with a particular emphasis on the value of innovation to address climate change and environmental impacts of perioperative care delivery. Topics covered throughout the program include the latest advancements in Machine Learning and Artificial Intelligence, innovations to create resilient supply chains, environmental impacts of operating room anesthetic choices, circular economics for perioperative care, electronic anesthesia records and how corporate and hospital partnerships can advance sustainability through technological innovation.

Educational Objectives
As a result of participation in this CME activity, learners should be able to:
1. Better understand how to leverage technology in a rapidly changing environment
2. Gain knowledge on best practices for the integration of technology and sustainability into clinical practice
3. Know about the barriers and opportunities for implementing technology to address patient needs as well as climate change into perioperative care

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.

CME Accreditation Statement
In support of improving patient care, this activity has been planned and implemented by Amedco LLC and the Society for Technology in Anesthesia (STA). 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.

Amedco LLC designates this live activity for a maximum of 9.50 AMA PRA Category 1 Credits™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.
## Schedule of Events (Time Zone Specific)

**Thursday, January 13, 2022** (Time Zones Listed)

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

- David Feinstein, MD, MS
- Jeffrey M. Feldman, MD, MSE
- John Pawlowski, MD, PhD
- Christopher Quartararo, MD
- Nate Greenbaum, MD
- Christos Koutentis, MBCAB, MS

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**Introduction and Welcome**
Olivia Nelson, MD & John Pearson, MD

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**KEYNOTE Address: Look Up: The Role of Anesthesiologists in Slowing Climate Change**
Jodi Sherman, MD

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**Sustainable Inhaled Anesthetic Delivery – Is it Possible?**
Moderator: Jeffrey M. Feldman, MD, MSE

- 8:00 – 8:15 AM
- 10:00 – 10:15 AM
- 11:00 – 11:15 AM

**Paying the Carbon Tax – Limitations of Anesthesia Delivery Systems for Low Flow Anesthesia**
Jeffrey M. Feldman, MD, MSE

- 8:15 – 8:30 AM
- 10:15 – 10:30 AM
- 11:15 – 11:30 AM

**Low Flows: One User’s Experience**
R. Ross Kennedy, MB, ChB, PhD, FANZCA

- 8:30 – 8:45 AM
- 10:30 – 10:45 AM
- 11:30 – 11:45 AM

**Closed Loop and Automated Inhalation Delivery – Is it the Answer and Why Don’t We Have It?**
Jan Hendrickx, MD, PhD

- 8:45 – 9:00 AM
- 10:45 – 11:00 AM
- 11:45 AM – 12:00 PM

**Panel Discussion**

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**Environmental Sustainability**
Moderator: John Pearson, MD

- 9:00 – 9:15 AM
- 11:00 – 11:15 AM
- 12:00 – 12:15 PM

**Moonshot Moment for Healthcare Sector**
Gary Cohen, BA

- 9:15 – 9:30 AM
- 11:15 – 11:30 AM
- 12:15 – 12:30 PM

**Climate, Health and Equity Across Our Value Chain**
Terri Scannell, MBA

- 9:30 – 9:45 AM
- 11:30 – 11:45 AM
- 12:30 – 12:45 PM

**How Institutions Can Make Decisions that Benefit the Environment and Their Budget**
Brian Chesbro, MD

- 9:45 – 10:00 AM
- 11:45 – 12:00 PM
- 12:45 PM – 1:00 PM

**Panel Discussion**

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**Friday, January 14, 2022** (Time Zones Listed)

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**Pediatric Anesthesia**
Moderator: Ian Yuan, MD, MEng

- 10:15 – 10:30 AM
- 12:15 – 12:30 PM
- 1:15 – 1:30 PM

**Machine Learning in Pediatric Anesthesia: The State of the Art**
Hannah Lonsdale, MBCAB, FRCA

- 10:30 – 10:45 AM
- 12:30 – 12:45 PM
- 1:30 – 1:45 PM

**Social, Economic, and Environmental Determinants of the Health in Pediatric Anesthesiology**
Jonathan M. Tan, MD, MPH, MBI, FASA

- 10:45 – 11:00 AM
- 12:45 PM – 1:00 PM
- 1:45 – 2:00 PM

**Panel Discussion**

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**STA Annual Business Meeting**
Moderator: Maxime Cannesson, MD, PhD

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**Corporate Member Networking Session**
Moderator: Jorge Galvez, MD, MBI

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**Corporate Member Networking Lunch**
Moderator: Justin Adams, BSEE, MBA

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**Abstract Award Presentations**
Moderators: Calvin Gruss, MD, MS & Patrick Kolbay, PhD

- 1:15 – 1:25 PM
- 3:15 – 3:25 PM
- 4:15 – 4:25 PM

**Best Clinical Application Award**
Carter Lybbert, BSc

- 1:25 – 1:35 PM
- 3:25 – 3:35 PM
- 4:25 – 4:35 PM

**Excellence in Technology Award**
Georgia Georgostathi, BS/BA Candidate

- 1:35 – 1:45 PM
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**Best in Show Award**
David Zarrin, MSE

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<td>2021 Neurowave Research Grant Recipient Presentation: Incentivizing Spirometry</td>
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**Friday, January 14, 2022 cont. (Time Zones Listed)**

- 3:00 – 3:15 PM PST • 5:00 – 5:15 PM CST • 6:00 – 6:15 PM EST
  Development of a Machine Learning Model to Predict Intraoperative Transfusion and Guide Type and Screen Ordering
  Matthew Zapf, MD
- 3:15 – 3:30 PM PST • 5:15 – 5:30 PM CST • 6:15 – 6:30 PM EST
  Panel Discussion

**Saturday, January 15, 2022 (Time Zones Listed)**

- 9:15 – 10:00 AM PST • 11:15 AM – 12:00 PM CST • 12:15 – 1:00 PM EST
  Posters in a Minute
  Moderators: Calvin Gruss, MD, MS; Patrick Kolbay, PhD; Olivia Nelson, MD; John Pearson, MD
- 10:00 – 11:00 AM PST • 12:00 – 1:00 PM CST • 1:00 – 2:00 PM EST
  Decreasing the Carbon Footprint of the Operating Room
  Moderator: Shazia Mohammad, MD
  - 10:00 – 10:15 AM PST • 12:00 – 12:15 PM CST • 1:00 – 1:15 PM EST
    Clinical Decision Support and Low Fresh Gas Flow Anesthesia
    Seema Gandhi, MD
  - 10:15 – 10:30 AM PST • 12:15 – 12:30 PM CST • 1:15 – 1:30 PM EST
    Greener Anesthetics - Implementing a Sustainable EEG-Guided TIVA Program in a Children's Hospital
    Richard Missett, DO
  - 10:30 – 10:45 AM PST • 12:30 – 12:45 PM CST • 1:30 – 1:45 PM EST
    Culture Change and Volatile Recapture Technology
    Diane Gordon, MD
  - 10:45 – 11:00 AM PST • 12:45 – 1:00 PM CST • 1:45 – 2:00 PM EST
    Panel Discussion

**Saturday, January 15, 2022 (Time Zones Listed)**

- 11:00 AM – 12:00 PM PST • 1:00 – 2:00 PM CST • 2:00 – 3:00 PM EST
  Panel Discussion

- 12:00 PM PST • 2:00 PM CST • 3:00 PM EST
  Closing Remarks
  Olivia Nelson, MD & John Pearson, MD
AlertWatch • www.alertwatch.com

AlertWatch develops integrated decision support software to help anesthesiologists improve quality, safety, and efficiency across the entire continuum of care. The software integrates device and medical record information to produce real-time alerts focused on improving outcomes and reducing length of stay. At the STA meeting, we will be demoing the following solutions:

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 application, pending FDA clearance, helps clinicians oversee all types of acute care patients in the ICU and lower acuity settings in the hospital. The solution has powerful clinical decision support built for ECMO and ventilated patients, and also helps clinicians improve their response to sepsis. 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: We have partnered with BioIntelliSense, makers of innovative wearable sensors, to enable continuous remote monitoring of patients in low acuity units, and after they leave the hospital. The combined solution will enable anesthesia to expand their services beyond the standard perioperative environments.

Becton Dickson • www.bd.com

BD is a global medical technology company that is advancing the world of health by improving medical discovery, diagnostics and the delivery of care. BD leads in patient and health care worker safety and the technologies that enable medical research and clinical laboratories. The company provides innovative solutions that help advance medical research and genomics, enhance the diagnosis of infectious disease and cancer, improve medication management, promote infection prevention, equip surgical and interventional procedures and support the management of diabetes.

The company partners with organizations around the world to address some of the most challenging global health issues.
Codonics • www.codonics.com

Codonics Safe Label System (SLS) helps to greatly improve medication safety, compliance and efficiency in the operating room. An award-winning FDA Class II medical device, SLS integrates with anesthesia dispensing carts to help safely identify and label medications during preparation. A quick scan of a vial or ampoule provides visual and audible verification of the drug in hand, acting as a second set of eyes. A full-color, easy-to-read, and ready-to-apply TJC-compliant label is presented as the syringe is drawn up. The label also includes a barcode that enables the anesthesia record to be populated with the drug, concentration and time stamp to be electronically documented in the Epic/Cerner patient record at administration. Using Codonics SLS-WAVE, a highly optimized scanner, prepared syringes are scanned 'hands-free' by the anesthetist, eliminating clicks and improving workflow. Advanced integration with Epic enables interoperable syringe and LVP pumps to be automatically programmed and documented, significantly improving the anesthesia workflow, safety and charge capture while reducing provider interaction with the EMR. Let us help you modernize your anesthesia workflow for improved safety, compliance and documentation.

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

Improving Critical Care is what drives everything we do. 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

Our company is driven by a passion to help patients. We partner with clinicians to develop innovative technologies in the areas of structural heart disease and critical care monitoring to help patients live longer, healthier and more productive lives.

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

- Fresenius Kabi is a global health care company that specializes in medicines and technologies for infusion, transfusion and clinical nutrition.
- The company's products and services are used to help care for critically and chronically ill patients. The company's U.S. headquarters is in Lake Zurich, Illinois. The company's global headquarters is in Bad Homburg, Germany.
- To learn how the company is doing More in America, please visit www.fresenius-kabi.com/us/company/more-in-america.

Gas Man® • www.gasmanweb.com

Gas Man® Professional Edition is free. In an effort to help anesthesia professionals around the world, the nonprofit organization Med Man Simulations Inc. and its President, James H. Philip MD, is offering Gas Man® Computer Simulation and Workbook free for download worldwide.

Med Man Simulations, Inc. (MMSI), is a nonprofit charitable organization (USA 501(C)(3) Educational Charity) providing education in the use of inhaled anesthetic agents.

Our mission is to advance medical care quality, safety, and planet sustainability worldwide by creating, distributing, and using educational tools that teach the anesthesia community to better understand and use inhaled anesthetic drugs and the equipment that delivers and measures them.

Gas Man® and MMSI support your interest in learning more about inhalation kinetics and how to apply kinetics to your clinical practice to speed induction and emergence, achieve tight control, and minimize waste and environmental impact. We also help you teach this subject to colleagues and students by providing the Gas Man® Workbook that is guide to the entire experience.

Our current additional products are live and virtual educational lectures, workshops, and courses for students and teachers. We are looking for experienced Gas Man® users to join us in disseminating Gas Man® and what it teaches, worldwide.

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A Physiological 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 are a rapidly advancing type of technology that can control the state of patients by using physiological feedback in a closed-loop manner. Unlike the standard of care, PCLC devices do not require constant human adjustment of parameters, and thus, assessing the performance of this type of devices is essential.

Assessment of PCLC medical devices through comprehensive clinical trials is often costly. In conjunction with smaller clinical trials, mathematical models can be leveraged to evaluate a device's performance under different physiological conditions [1]. These models give control over different parameters and enable the simulation of a virtual cohort of patients under a wide range of physiological states for testing medical devices [2], [3].

This abstract for the first time presents a physiological mathematical model of heart rate (HR) response to hemorrhagic shock and fluid infusion. The model can be ultimately used to create a virtual patient cohort, which in turn can be used to study the performance of PCLC devices for fluid resuscitation. Hemorrhage and fluid infusion were induced in 21 conscious sheep, the data from which was used to develop the model [4]. The model adequately maps the rate of hemorrhage and fluid infusion to the change in HR.

**Method:** To create the mathematical model of HR response to blood loss and fluid infusion, two types of responses need to be studied. The first is the transient response which describes the instantaneous change in HR due to fluid perturbation. The second is the long-term response, which is the change in the steady-state value of HR response due to the perturbation. Figure 1-A presents an overview of the overall effect of the transient and long-term HR response.

Hemorrhages cause tachycardia due to an increase in sympathetic nerve activity. A severe hemorrhage causes a transient increase in HR. Moreover, due to the loss in blood volume and arterial pressure, there is a long-term increase in HR within a few hours after the hemorrhage till it reaches a plateau [5]. Fluid infusion also transiently alleviates HR response, as reported in prior studies [6], [7]. To capture the long-term HR response due to the blood loss, a proportional-integral controller is implemented into the model, which enforces the change in HR to follow the expected long-term effect of blood loss. Figure 1-B to 1-E illustrate the individual components of the model, which includes 7 parameters.

**Result:** Maximum likelihood optimization was used to tune the parameters in all the subjects. To analyze the performance of the model, Normalized Root Mean Square Error (NRMSE) was extracted between the estimated and true HR values. Averaged between all 21 subjects, results from the model gave an NRMSE of 7.4+/-2.8%. This result indicates that the model can accurately predict the change in HR due to fluid perturbation. Results from 2 representative subjects are shown in Figure 1-F.

**Conclusion:** In this paper, a model to predict the change in HR due to hemorrhage and fluid infusion was presented. This system applies a control-oriented approach where the rate of hemorrhage greatly influences the change in HR. This model can be incorporated into existing hemodynamic models to create a virtual cohort of patients that can be used to test PCLC devices for hemorrhagic applications.
References:


Figure 1: The heart rate model structure with estimation results from two representative subjects
Title: Processed electroencephalogram normative values in neonates

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Introduction:
Electroencephalogram (EEG) monitors brain electrical activity that can reflect anesthetic depth. However, intraoperative proprietary EEG indices (e.g., BIS and PSI) originally developed from healthy adult volunteers are not reliable in infants and neonates, a population particularly sensitive to the effects of anesthesia. Whereas raw unprocessed EEG can reliably detect “excessive” anesthesia in neonates, interpreting raw EEG requires advanced training and practice. Besides proprietary EEG indices and raw EEG, there are other non-proprietary processed EEG (pEEG) parameters that can be used to determine anesthetic levels. However, there are no normative values for these non-proprietary pEEG parameters in unanesthetized infants that can be used for comparison to neonates under anesthesia. This study aims to address this knowledge gap by deriving normative values for pEEG parameters in unanesthetized neonates in awake and asleep states. The secondary aim is to determine the best pEEG parameters to discriminate between the different states of consciousness.

Methods:
This retrospective study included normal EEG recordings (14-channel neonatal bipolar montage) from healthy neonates, as interpreted by neurology and annotated into awake vs quiet asleep vs active sleep states. Since most intraoperative EEG monitoring use frontal channels, only frontal channels Fp1-C3 and Fp2-C4 were analyzed. EEG processing was performed using Matlab with NEURAL, a publicly available and validated library of Matlab functions. After band-filtering between 0.5-30hz and artifact removal using the built in-function, the pEEG parameters listed in table 1 were calculated across 5 frequency bands (δ1: 0.5-1hz; δ2: 1-4hz; θ: 4-8hz; α: 8-13hz; β: 13-30hz) for each EEG file. Mean and standard deviation (SD) were calculated for each channel and state (awake, quiet sleep, and active sleep) and paired 2-tailed Student’s t-test were used to compare pEEG between states.

Results:
EEG from 23 neonates (mean [stdev] adjusted age on day of recording: 40.9 [1.97] weeks) were analyzed. The mean [stdev] of SEF 50/90 are listed in table 2. SEF 50 but not SEF 90 was able to differentiate between Awake vs Quiet and Awake vs Active. The power ratio, entropy, and coherence for each frequency band are listed in table 3. Power ratio can best differentiate between Awake vs Quiet and Awake vs Active best in δ1 and θ bands. Conversely, entropy can best differentiate between the same states in β bands. Finally, left/right coherence can differentiate between Awake vs Active best in δ2 band. None of the pEEG were able to differentiate between Active vs Quiet sleep states.

Conclusion:
This retrospective study provides normative pEEG values in neonates that will allow future researchers to compare to pEEGs obtained in neonates under anesthesia or sedation and provide direction on selecting pEEG parameters and frequency bands to best differentiate different states of consciousness.

Table 1:
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<th>pEEG parameter</th>
<th>Definition</th>
<th>Changes with increased anesthetic depth</th>
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<td>Spectral Edge Frequency 50</td>
<td>Frequency where 50% of the EEG power lies under.</td>
<td>Decreases</td>
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<tr>
<td>Spectral Edge Frequency 90</td>
<td>Frequency where 90% of the EEG power lies under.</td>
<td>Decreases</td>
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<tr>
<td>Power ratio ($\delta_1,\delta_2,\theta,\alpha,\beta$)</td>
<td>% of power for each of 5 frequency band over total power</td>
<td>Increase in lower frequency bands</td>
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<tr>
<td>Coherence ($\delta_1,\delta_2,\theta,\alpha,\beta$)</td>
<td>Synchrony between Left vs Right channels (0: no synchrony; 1: total synchrony)</td>
<td>Increases</td>
</tr>
<tr>
<td>Entropy ($\delta_1,\delta_2,\theta,\alpha,\beta$)</td>
<td>Amount of randomness in EEG signals. (0: total order; 1: total randomness)</td>
<td>Decreases</td>
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Table 2:

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<th><strong>SEF 50 (hz)</strong></th>
<th><strong>SEF 90 (hz)</strong></th>
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<tr>
<td><strong>Fp1-C3</strong></td>
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<tr>
<td>Awake</td>
<td>Mean 0.92</td>
<td>Mean 3.99</td>
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<tr>
<td></td>
<td>Stdev 0.33</td>
<td>Stdev 3.22</td>
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<tr>
<td>Quiet Sleep</td>
<td>Mean 1.20</td>
<td>Mean 4.63</td>
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<tr>
<td></td>
<td>Stdev 0.32</td>
<td>Stdev 1.20</td>
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<tr>
<td>Active Sleep</td>
<td>Mean 1.14</td>
<td>Mean 4.11</td>
</tr>
<tr>
<td></td>
<td>Stdev 0.32</td>
<td>Stdev 1.09</td>
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<td>Awake vs Quiet</td>
<td>$&lt; 0.01$</td>
<td>0.38</td>
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<td>Awake vs Active</td>
<td><strong>0.03</strong></td>
<td>0.86</td>
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<td>Quiet vs Active</td>
<td>0.59</td>
<td>0.16</td>
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<tr>
<td><strong>Fp2-C4</strong></td>
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<tr>
<td>Awake</td>
<td>Mean 0.95</td>
<td>Mean 4.64</td>
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<tr>
<td></td>
<td>Stdev 0.29</td>
<td>Stdev 3.99</td>
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<tr>
<td>Quiet Sleep</td>
<td>Mean 1.21</td>
<td>Mean 5.39</td>
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<td></td>
<td>Stdev 0.27</td>
<td>Stdev 3.59</td>
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<tr>
<td>Active Sleep</td>
<td>Mean 1.11</td>
<td>Mean 4.21</td>
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<tr>
<td></td>
<td>Stdev 0.26</td>
<td>Stdev 1.29</td>
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<tr>
<td>Awake vs Quiet</td>
<td>$&lt; 0.01$</td>
<td>0.52</td>
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<tr>
<td>Awake vs Active</td>
<td><strong>0.05</strong></td>
<td>0.63</td>
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<tr>
<td>Quiet vs Active</td>
<td>0.25</td>
<td>0.17</td>
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Table 3:
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<th>Power ratio</th>
<th>( \delta 1 % )</th>
<th>( \delta 2 % )</th>
<th>( \theta % )</th>
<th>( \alpha % )</th>
<th>( \beta % )</th>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Mean</td>
<td>0.51</td>
<td>0.39</td>
<td>0.06</td>
<td>0.02</td>
<td>0.03</td>
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<td>Stdev</td>
<td>0.18</td>
<td>0.12</td>
<td>0.04</td>
<td>0.01</td>
<td>0.03</td>
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<td><strong>Quiet Sleep</strong></td>
<td>0.39</td>
<td>0.47</td>
<td>0.10</td>
<td>0.02</td>
<td>0.02</td>
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<tr>
<td>Stdev</td>
<td>0.10</td>
<td>0.08</td>
<td>0.04</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td><strong>Active Sleep</strong></td>
<td>0.39</td>
<td>0.49</td>
<td>0.08</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Stdev</td>
<td>0.15</td>
<td>0.13</td>
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<tr>
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<td>Mean</td>
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Abstract Title: Telemedicine improves Anesthesia Pre-operative Evaluation Appointment Adherence: A Retrospective Analysis

Presenting Author:
Danny Quy Le, BS, David Geffen School of Medicine at UCLA, Los Angeles, CA

Co-Authors:
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Zhi Dong, MD, MPH, Anesthesiology and Perioperative Medicine, Hospital for Special Surgery, New York, NY
Nirav Kamdar, MD, MPP, MBA, Anesthesiology and Perioperative Medicine, Ronald Reagan UCLA Medical Center, Los Angeles CA

Background/Introduction: Amidst the COVID-19 pandemic, the sudden demand for virtual medical visits drove the drastic expansion of telemedicine across all medical specialties. Current literature demonstrates limited knowledge on the impact of telehealth on appointment adherence particularly in preoperative anesthesia evaluations. We hypothesized that there would be increased completion of preoperative anesthesia appointments in patients who received telemedicine visits.

Methods: We performed a retrospective cohort study of adult patients at UCLA who received preoperative anesthesia evaluations by telemedicine or in-person within the Department of Anesthesiology and Perioperative Medicine from January to September 2021 and assessed appointment adherence. The primary outcome was incidence of appointment completion. The secondary outcomes included appointment no show and cancellations. Patient demographic characteristics including sex, age, ASA physical status class, race, ethnicity, primary language, interpreter service requested, patient travel distance to clinic, and insurance payor were also evaluated. Demographic characteristics, notably race and ethnicity, are presented as captured in the electronic health record and we recognize its limitations and inaccuracies in illustrating how people identify. Patient reported reasons for cancellations were also reviewed and categorized into thematic groups by two physicians. Statistical comparison was performed using independent samples t test, Pearson’s chi-square, and Fischer’s exact test.

Results: Of 1332 patients included in this study, 956 patients received telehealth visits while 376 patients received in-person preoperative anesthesia evaluations. Compared to the in-person group, the telemedicine group had more appointment completions (81.38% vs 76.60%, p = 0.0493). There were fewer cancellations (12.55% vs 19.41%, p = 0.0029) and no statistical difference in appointment no-shows (6.07% vs 3.99%, p = 0.1337) in the telemedicine group (Figure 1). Compared to the in-person group, patients who received telemedicine evaluations were younger (55.81 ± 18.38 vs 65.97 ± 15.19, p < 0.001), less likely American Indian and Alaska Native (0.31% vs 1.60%, p = 0.0102), more likely of Hispanic or Latino ethnicity (16.63% vs 12.23%, p = 0.0453), required less interpreter services (4.18% vs 9.31%, p = 0.0003), had more private insurance coverage (53.45% vs 37.50%, p < 0.0001) and less Medicare coverage (37.03% vs 50.53%, p < 0.0001). Main reasons for cancellation included
patient request, surgery rescheduled/cancelled/already completed, and change in method of appointment.

**Conclusions:** In 2021, preoperative anesthesia evaluation completion was greater in patients who received telemedicine appointments compared to those who received in-person evaluations at UCLA. We also demonstrate potential shortcomings of telemedicine in serving patients who are older, require interpreter services, or are non-privately insured. Knowledge of these factors can provide feedback to improve access and equity to telehealth for patients from all backgrounds, particularly during the COVID pandemic as virtual evaluations increase.

**Images:**

![Figure 1. Comparison of cancellation, no-show, and completion of appointments between patients who received telemedicine or in-person preoperative evaluation appointments. **P values < 0.05 were considered significant.](image-url)

Figure 1. Comparison of cancellation, no-show, and completion of appointments between patients who received telemedicine or in-person preoperative evaluation appointments. **P values < 0.05 were considered significant.

**References:**


Exploring the digital divide in telehealth adoption among pediatric pain patients in a children’s hospital

**Presenting Author:** Phillip A. Quiroz

**Co-Authors:** Eugene Kim MD, Grace Hsu MD, Jonathan M. Tan, MD MPH MBI FASA

1 MD/MPH Candidate, Keck School of Medicine at the University of Southern California, Los Angeles, CA
2 Chief, Division of Pain Medicine, Department of Anesthesiology Critical Care Medicine, Children’s Hospital Los Angeles; Assistant Professor of Anesthesiology, Keck School of Medicine at the University of Southern California, Los Angeles, CA
3 Assistant Professor of Anesthesiology, Department of Anesthesiology Critical Care Medicine, Children’s Hospital Los Angeles; Keck School of Medicine at the University of Southern California, Los Angeles, CA
4 Assistant Professor of Spatial Sciences, Spatial Sciences Institute, Dornsife School of Arts and Sciences at the University of Southern California, Los Angeles, CA

**Disclosures:** JMT receives grant funding from the Anesthesia Patient Safety Foundation and the Foundation for Anesthesia Education and Research.

**Introduction:** Telehealth provides an opportunity to deliver health care by reducing physical barriers. Although the adoption of telehealth has increased, the COVID-19 pandemic expedited the expansion and support for telehealth due to a need for social distancing and changes to reimbursement. While telehealth can bridge gaps in care, the rapid adoption of telehealth technology may lead to an increased digital divide, whereby technology can exacerbate existing health disparities. Understanding the impact of telehealth on health disparities is an important component toward achieving health equity. The goal of our study was to describe telehealth utilization among a pediatric pain clinic population and understand if patient demographic factors were associated with differences in telehealth utilization.

**Methods:** Following IRB approval, we conducted a retrospective study of all pediatric pain clinic patients seen by telehealth at the Children’s Hospital Los Angeles from 4/2020 to 5/2021. Patient demographic details and telehealth utilization data were abstracted from electronic health records. The primary outcome was telehealth appointment no-show or cancellation within 24 hours. Statistical analysis was conducted using SAS.

**Results:** Our study included 550 patients, with 241 (43.8%) patients seen as new patient visits and 309 (56.2%) having their follow-up visits during the study time period. The median age was 15-years old. The most frequent self-reported race was White (24.6%), followed by Black (6.4%), and Asian (2.8%), with reports of Other (51.8%) and Unknown (14.2%). Our cohort self-reported their ethnicity as Hispanic (38.3%), Non-Hispanic (29.3%), with a group of Unknown (32.4%). The most common self-reported language was English (85.8%), followed by Spanish (14.0%). Most patients had government insurance (61.6%) versus commercial (38.4%). For all appointments, 14.9% were cancelled <24 hours/no-show, whereas new appointments had 21.2% of patients cancelled/no-show and follow-up appointments were cancelled/no-show in 10.0% of appointments. Among new patient visits, ethnicity and government insurance status were statistically associated with being cancelled <24 hours from appointment, or no-shows (p<0.05). Among new patient visits, those who identified as “Other” were more than twice as likely to cancel/no-show than those who identify as White.

**Discussion:** In our study of pediatric pain clinic patients, ethnicity and insurance status were significantly associated with patients who had cancellations and no-shows for telehealth appointments. These factors may represent barriers related to the utilization of telehealth and are opportunities to further study how to reduce the digital divide and work toward health equity. We also found there were a large number of patients who self-identified their race as “Other” or “Unknown.” Improving the accurate collection of demographic data remains an important foundation toward identifying and reducing disparities in health and health care.

**References**
ABSTRACT TITLE: VIRTUAL COACH CAN BE EQUIVALENT TO A HUMAN INSTRUCTOR IN REBOA TRAINING: A PROSPECTIVE RANDOMIZED STUDY

Presenting Author: Yahya Acar, MD, University of Florida, Guluhan School of Medicine  
Co-Authors: Robert Smith, MD, University of Florida, George Sarosi, MD, University of Florida, David Lizdas, BSME, University of Florida, William Johnson, BS, University of Florida, Anthony DeStephens, MSME, University of Florida, Alex Koo, MD, Madigan Army Medical Center, Kyle Couperus, MD, Madigan Army Medical Center, Nikolaus Gravenstein, MD, University of Florida, Samsun Lampotang, PhD, University of Florida.

Background/Introduction: Engberg et al. described the need for an assessment tool for procedural competency supported by validity evidence to advance research in resuscitative endovascular balloon occlusion of the aorta (REBOA) training¹. To increase access to training, we developed a virtual coach for simulator-based REBOA mastery training and evaluated whether the virtual coach (VC) is equivalent to a human instructor (HI).

Methods: Using the System of Modular Mixed and Augmented Reality Tracking Simulators (SMMARTS) software development kit², we developed a REBOA simulator with electromagnetic tracking of the needle tip, catheter, and ultrasound probe³ allowing real-time tracking of ultrasound-guided femoral arterial access. We integrated a VC to autonomously teach and assess learners. We conducted a validation study in a university hospital. Consenting surgery residents with no experience placing REBOA were randomized into either HI (n=7) or VC (n=7) groups using a random number table and took the Guay Visualization of Views Test to assess spatial ability. After didactic training with a prerecorded video, the first two attempts at REBOA placement were recorded as the baseline measurement. Then, hands-on, curricular training was given by either HI or VC. Participants then did free practice until they felt ready for mastery assessment. Mastery standards⁴ were to complete consecutive successful REBOA insertions in Zone 1 then Zone 3 within 2 minutes, while scoring 14/14 on critical actions. Mastery assessment allowed unlimited attempts to reach mastery, and mean score at mastery evaluation. Secondary objectives included pre- and post-survey comparisons. Demographics were reported as frequency, median, and mean±SD, categorical data were compared using the χ² test, and the Mann-Whitney U test was used for pairwise comparisons of continuous data using SPSS.

Results: Fourteen participants completed all study-related interventions and achieved mastery. There was no statistically significant difference in demographic data between groups (Table 1). None passed the baseline evaluation for either time or critical actions (Table 1). VC and HI groups showed similar results based on the mastery evaluation (i.e., no difference between groups; Table 1). There was no statistically significant difference between VC and HI groups in the pre- and post-study survey results (p>0.05, χ² test), except for the simulated probe (p=0.02, χ² test). 97% of the participants commented positively about the training in the post-study survey.

Conclusion: This validation study showed that our mixed reality simulator was efficacious for the REBOA training. VC performed similarly to a HI in teaching participants in placing a REBOA catheter on the REBOA simulator.


Table 1. Human Instructor vs. Virtual Coach Group Comparisons

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Human Instructor (n=7)</th>
<th>Virtual Coaching (n=7)</th>
<th>Total (n=14)</th>
<th>p</th>
</tr>
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<tr>
<td>Age - Median (min-max)</td>
<td>31 (28-33)</td>
<td>33 (29-36)</td>
<td>31 (28-36)</td>
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<tr>
<td>Sex - (Female/Male)</td>
<td>5/2</td>
<td>3/4</td>
<td>8/6</td>
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<td>Guay Visualization of Views Test score</td>
<td>16 (13-23)</td>
<td>17 (10-24)</td>
<td>16 (10-24)</td>
<td>0.898*</td>
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<td>Number of attempts to reach mastery during mastery assessment Median - (min-max)</td>
<td>4 (2-9)</td>
<td>2 (2-6)</td>
<td>4 (2-9)</td>
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<td>Free practice attempts - Median (min-max)</td>
<td>1 (0-3)</td>
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<td>Baseline time (seconds) - (Mean±SD)</td>
<td>268.4±193.8</td>
<td>243.4±144.0</td>
<td>255.9±168.0</td>
<td>0.613*</td>
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<tr>
<td>Baseline success in allotted 2 minutes for each attempt</td>
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<td>0</td>
<td>0</td>
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<tr>
<td>Mastery times (seconds) - (Mean±SD)</td>
<td>99.6±10.7</td>
<td>104.6±9.9</td>
<td>102.1±10.4</td>
<td>0.223*</td>
</tr>
<tr>
<td>Total scores - (Mean±SD)</td>
<td>10.1±4.3</td>
<td>9.72±4.8</td>
<td>9.91±4.5</td>
<td>0.702*</td>
</tr>
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</table>

*: Mann-Whitney U test, **: χ² test, SD: Standard deviation
Monitoring Medical Device Data Quality for Safe Smart and Autonomous Medical Systems (SaAMS) – A Closed Loop Infusion System Study

Presenting Author: Yi Zhang, PhD (yzhang134@mgh.harvard.edu)

Co-Authors: Michael Jaffe, PhD; David Arney, PhD, MPH; Simon Kelly; Sandy Weininger*, PhD; Julian Goldman, MD

Affiliation: Medical Device Plug-and-Play Interoperability & Cybersecurity Program, Dept. of Anesthesia, Critical Care, and Pain Medicine, Massachusetts General Hospital, Boston, MA, *U.S. Food and Drug Administration/CDRH/OSEL

Introduction: Recent advances in medical device interoperability have shown that coordinating medical devices into Smart and Autonomous Medical Systems (SaAMS) – such as physiologic closed loop control (PCLC) TIVA systems - may improve efficiency, safety, and patient outcomes. SaAMS leverage interoperable sensors, actuators, and apps (Software as a Medical Device, or SaMD), on open health platforms such as OpenICE (www.openice.info). The quality of data produced by medical devices may vary due to sensor auto-calibration or drifting, device failure, and conditions like communication delays. Variation and degradation of data quality can cause data consumers, such as other devices and algorithms, to make unsafe clinical decisions if no mechanism is provided to proactively detect and address it. The lack of a consensus definition of medical device data quality, together with the limitations of existing devices to emit data-quality metadata, make it challenging for SaAMS to capture comprehensive system context that is critical for safe interoperability [1].

Method: We investigated the definition of medical device data quality and requirements for interoperable platforms to monitor and safeguard data quality degradation. In accord with ISO 25012 standard [2], we defined a preliminary data quality model to capture accuracy, completeness, consistency, credibility, and currentness quality attributes of medical device data. Based on this model, we extended medical device interfaces to augment each output data sample with Data Quality Index (DQI) metadata, which adds data quality attributes to that sample. Using our OpenICE research interoperability platform we established a mechanism to continuously monitor medical device data degradation by comparing DQIs from connected devices with predefined quality thresholds. The mechanism informs relevant data consumers of data quality degradation as it is detected in individual devices and permits the system to enter a safety fallback mode (if present) should system-wide data quality degradation be detected.

Result: We developed a prototype PCLC fluid resuscitation system on top of OpenICE to demonstrate and evaluate the proposed medical device data quality model and monitoring mechanism. The prototype system consists of AthenaGTX and Philips MX800 patient monitors, a Q Core Sapphire IV infusion pump, and a control algorithm that adjusts the fluid delivery rate based on BP measures from one of the two patient monitors, to maintain the target BP levels. Two additional apps were developed in OpenICE – one implementing the data quality monitoring (DQM) mechanism and the other implementing an example cardiac arrest monitoring (CAM) algorithm. The CAM app reports a cardiac arrest condition when vital signs meet pre-defined rules and no data quality degradation is reported. The control algorithm uses invasive BP data from the MX800 monitor, and switches to NIBP data from AthenaGTX should data quality degradation occur to the IBP signal, triggering BP cuff inflations at AthenaGTX when NIBP data is needed. This switch however is prohibited when the CAM app reports a cardiac arrest condition, as NIBP measurements in this situation are no longer trustworthy.

Our experiments confirmed that the DQM app could monitor and report synthetic data quality degradation conditions introduced to MX800 and AthenaGTX data or when network QoS was degrading across the system. The control algorithm could switch between different BP sources as expected upon notifications from the DQM and CAM apps.

Conclusion: The proposed concept of monitoring medical data quality for safer interoperability has been included in the JHU/APL medical device interoperability reference architecture [3]. We believe our data quality model suggests a possible direction for medical device manufacturers to enrich the metadata output from their products, e.g., in the form of Medical Device Interface Data Sheets (MDIDS) [4], to advance interoperability in a safer manner.

References:


This work was supported under the U.S. Army Medical Research Acquisition Activity Contract W81XWH-17-C-0251. 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 the Army position, policy or decision unless so designated by other documentation. The mention of commercial products, their sources, or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products by the Department of Health and Human Services.
Title: CREATION OF A VALIDATED INTENSIVE CARE UNIT DATA MART

Presenting Author: Christina S. Boncyk, MD; Department of Anesthesiology, Vanderbilt University Medical Center

Co-Authors: Karen Y. McCarthy, EdD; Pamela Butler, BS; Robert E. Freundlich, MD, MSCI; Department of Anesthesiology, Vanderbilt University Medical Center

Introduction: The acceptance and adoption of findings from observational studies based on data derived from the electronic health record (EHR) is frequently limited by the perception that these data are inadequately validated and inherently inferior to data collected through more traditional means. We sought to create a structured, rigorously validated intensive care unit (ICU) data mart based on data automatically and routinely derived from the EHR, inclusive of data elements commonly used for quality improvement and research purposes, including high-quality outcomes data.

Methods: Key variables were identified by study investigators and faculty critical care physicians. Physicians worked closely with analysts using a structured approach. First, the presence of data in routine clinical practice was confirmed using chart review. Next, algorithmic definitions were created for complex data elements, including most outcomes, leveraging existing literature, when available. Data analysts worked to identify the location of variables within the data architecture underlying the EHR. Test patients were extracted and algorithms were iteratively refined. Once shown to be reproducible in a broad cohort of patients, structured query language (SQL) was used to extract, transform, and load data from the EHR.
into a relational database housed on a departmental server. The sensitivity and specificity of algorithmic definitions was formally assessed.

**Results:** A total of 459,465 patient ICU encounters were identified and included within the ICU data mart. These patients include over 460,000,000 individual laboratory results and 4,610,776 vital signs (with q1 minute fidelity in the first 24-hours of admission). We currently have 26 validated outcomes, structured within 19 tables, all of which have a sensitivity and specificity of greater than 95%. These data can be joined to 215 validated variables included within 125 tables comprising an existing anesthesiology perioperative data warehouse (PDW) for perioperative patients.

**Conclusions:** We propose a methodology for building a robust and highly granular ICU data mart, leveraging the synergistic expertise of clinicians and data analysts. Work to further identify and validate additional patient variables remains a core component of future quality improvement and research processes.
Patient and Operative Factors Predict Risk of Discretionary Prolonged Postoperative Mechanical Ventilation in a Broad Surgical Cohort

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Background: Patients undergoing surgery with general anesthesia and endotracheal intubation are ideally extubated upon case completion, as Prolonged Postoperative Mechanical Ventilation (PPMV) has been associated with poor outcomes [1]. However, some patients require PPMV for surgical reasons, such as airway compromise, while others remain intubated at the discretion of the anesthesia provider. Incidence and risk factors for discretionary PPMV (DPPMV) have been described in individual surgical subspecialties [2, 3] and intensive care unit (ICU) populations [4], but are relatively understudied in a broad surgical cohort. The present study seeks to fill this gap and identify the perioperative risk factors that predict DPPMV.

Methods: After obtaining IRB exemption, existing electronic health record databases at our large referral center were retrospectively queried for adult surgeries performed between January 2018 and December 2020 with general anesthesia, endotracheal intubation, and by surgical services that do not routinely leave patients intubated for surgical reasons. Patients who arrived to the ICU intubated after surgery were identified as experiencing DPPMV. Candidate risk factors were screened for physiologic plausibility and clinical availability. Further variable selection was performed with LASSO-regularized logistic regression, and surviving variables were used to generate a multivariable logistic regression model of DPPMV risk.

Results: A total of 32,917 cases met inclusion criteria, of which 417 (1.27%) experienced DPPMV. Compared to extubated patients, those with DPPMV were more likely to have undergone emergency surgery (42.7% versus 3.4%, p < 0.001), surgery during an existing ICU stay (30.7% versus 2.8%, p < 0.001), and have 20 of the 31 Elixhauser comorbidities (p < 0.05), amongst other differences. A risk model (Table 1) with thirteen variables yielded an area under the receiver operating characteristic curve of 0.97 (95% Confidence Interval [CI], 0.96-0.97), sensitivity of 0.92 (95% CI, 0.89-0.96), and specificity of 0.90 (95% CI, 0.87-0.93) for prediction of DPPMV.

Conclusions: DPPMV was uncommon in this broad surgical cohort but could be accurately predicted using readily available patient-specific and operative factors. These results may be useful for preoperative risk stratification, postoperative resource allocation, and clinical trial planning.

References:

Unsupervised Machine Learning Models for Characterization of Risk for Pediatric Severe Critical Events from Anesthesia Using the Wake-Up Safe Registry

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Introduction: Despite improvements in anesthesia safety, patients continue to experience unintended harm related to anesthesia and surgical care. Characterization of these serious adverse events in children remains an ongoing challenge due to their relative infrequency. Wake Up Safe (WUS), a national pediatric anesthesia collaborative supported by the Society of Pediatric Anesthesia launched in 2008, with the goal to make anesthesia safer for children. The registry represents one effort to better understand and reduce the incidence of serious adverse event. This study applies unsupervised machine learning methods to characterize risks for severe critical events from anesthesia and provide useful tools for clinical decision making and risk stratification. These tools help facilitate better use of the WUS registry in the clinical setting.

Methods: Two datasets are made available from WUS, one for billing data and one for critical events data. The billing dataset has relatively few features collected (Age, ASA Score, ICD, CPT, ASA Emergency Status), while the events dataset contains detailed information on each critical event. The absence of a direct link between the events dataset and the billing dataset, as well as the substantial discrepancy in the features contained in each dataset, prohibit directly combining them into a single dataset for predictive modeling. To overcome this issue, a novel strategy to indirectly link the two together is devised. The approach is as follows: first the billing dataset is clustered using the k-prototypes algorithm. A fuzzy record matching algorithm is then applied to match the entries from the events dataset to clusters in the billing dataset. Then, the probability of different events is calculated for each cluster. This can be used to predict patient risk given diagnosis, procedure and demographics.

Results: Table 1 shows cluster statistics. Four clusters were identified as optimal (data not shown). Cluster 1 had young, complex patients (ASA IV/V majority), with majority male. Cluster 2 contained older, moderately complex patients (ASA III majority). Cluster 2 contained the highest number of ASA emergency designations. Cluster 3 was composed of preschoolers who were medically stable (ASA I majority), predominantly nonemergency ASA status and female. Cluster 4 was composed of grade-schoolers who were moderately stable (ASA II majority).

Table 1. Cluster Statistics.

<table>
<thead>
<tr>
<th>Cluster</th>
<th>Age</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>Non.</th>
<th>Emerg.</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.26 (0.89)</td>
<td>24.71</td>
<td>39.20</td>
<td>26.61</td>
<td>9.15</td>
<td>0.32</td>
<td>95.02</td>
<td>4.98</td>
<td>64.91</td>
<td>35.09</td>
</tr>
<tr>
<td>2</td>
<td>14.79 (1.90)</td>
<td>22.56</td>
<td>45.02</td>
<td>29.27</td>
<td>3.02</td>
<td>0.13</td>
<td>93.15</td>
<td>6.85</td>
<td>53.07</td>
<td>46.93</td>
</tr>
<tr>
<td>3</td>
<td>4.85 (1.17)</td>
<td>25.74</td>
<td>45.20</td>
<td>26.46</td>
<td>2.54</td>
<td>0.07</td>
<td>95.43</td>
<td>4.57</td>
<td>43.66</td>
<td>56.34</td>
</tr>
<tr>
<td>4</td>
<td>9.07 (1.35)</td>
<td>23.00</td>
<td>46.65</td>
<td>27.83</td>
<td>2.43</td>
<td>0.09</td>
<td>93.21</td>
<td>6.79</td>
<td>62.18</td>
<td>37.82</td>
</tr>
</tbody>
</table>

The largest number of critical events occurred in Cluster 1 (N=1645), with Airway complications (N=135), Cardiac Arrest (N=396), Cardiovascular Support (N=195), Malignant Hyperthermia (N=5), Perioperative death (N=111) and Respiratory events (N=455) found most frequently in this group out of all groups. Cluster 2 had the second highest number of events (N=1308), with the highest number of Airway Injury (N=39), Cutaneous/Musculoskeletal (N=37), Eye Injury (N=19), Medication Event (N=197), Nervous System Injury (N=71), Other Injuries (N=52), Under General Anesthesia (N=8) and Wrong Side Sites (N=11) occurring in this group. Cluster 3 had the second lowest number of events (N=1289), with Blood Transfusion complications (N=16) occurring with the highest frequency in this cluster. Cluster 4 had the lowest number of events (N=914). Respiratory events (N=1477) represented the most commonly occurring critical events, while Malignant Hyperthermia (N=10) was the least common.

Conclusion: Application of unsupervised ML techniques along with matching facilitated development of a model with clinical utility from a dataset not amicable to advanced data use. Patient characteristics were identified from the clusters, while the type and frequency of several critical events was determined using matching. Young, medically complex patients were most likely to suffer from Respiratory events. Older, moderately complex patients undergoing emergency procedures were most likely to suffer from medication events when compared to all patient groups. This work provides insight into leveraging a complex dataset for better characterization of patient groups suffering from severe critical adverse events.

References

Title: UNDERSTANDING THE ACCURACY OF CLINICIAN PROVIDED ESTIMATED DISCHARGE DATES FOR SURGICAL VS NON-SURGICAL HOSPITAL ADMISSIONS

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Introduction: Discharge planning can improve the safety and timeliness of discharge from the hospital. It is a vital tool in managing hospital capacity and can have a positive impact on length of stay and efficiency in the hospital, which can be essential for maintaining hospital throughput for surgical postoperative admissions. The decision to discharge a patient from the hospital is governed by many complex factors including patient characteristics, insurance, follow-up, and hospital factors. ¹ Early discharge planning, beginning at the time of admission, has been effective in reducing hospital length of stay and readmissions.²–⁴ Between 2014 and 2017, Vanderbilt University Medical Center implemented a tool in the electronic medical record (EMR) requiring providers to input the patient’s estimated discharge date on each hospital day. We hypothesized that estimated discharge dates would be more accurate for surgical patients compared to medical patients and analyzed the data to identify factors associated with more accurate discharge estimates.

Methods: In this retrospective observational study, we identified admitted adult patients on both surgical and non-surgical services at VUMC between March 2014 and November 2017. Via an analysis of covariance (ANCOVA) approach, we identified the potential factors for more accurate estimates of discharge dates. The primary outcome was the difference between estimated discharge date and actual discharge date, and the primary exposures of interest were the clinical team the patient was admitted to and whether the patient underwent surgery while admitted to the hospital.

Results: A total of 304,802 entries from 68,587 inpatient encounters met inclusion criteria. After controlling for measured confounding, we found that discharge estimates got more accurate as the difference between estimated and actual discharge date narrowed; for each additional day closer to discharge, prediction accuracy improved by .67 days (95% confident interval [CI], 0.66 to 0.67; p<0.001), on average. No difference was observed on the primary outcome of patients receiving surgical procedures, in comparison to non-surgical treatment (0.02; p=0.1106). Faculty members performed best among all clinicians in predicting estimated discharge date with a 0.44-day better accuracy (95% CI, 0.40 to 0.48; p<0.001), on average, than trainees and a 0.24-day better accuracy (95% CI, 0.20 to 0.27; p<0.001), on average, than other staff. Specific clinical care teams, staff types, and discharge dispositions were associated with the variability in estimated discharge date versus actual discharge date (p<0.0001).

Discussion: Prior studies have demonstrated that failure to assign and communicate an estimated discharge date is one barrier to timely discharge planning.³–⁵ Given the widespread variation in current efforts to improve discharge planning and the recommended approach of assigning a discharge date early in the hospital stay, understanding provider estimated discharge dates is vital to hospital bed management. We anticipated surgical patients would have higher accuracy in discharge estimates because many surgeries are planned and follow predictable recovery paths. Unlike surgery, most medical patients are not electively admitted for a distinct problem. However, we found no different in discharge prediction accuracy between surgical and non-surgical patients. It is possible that patients were admitted to a medical service, then underwent unplanned surgeries, which may have added variability to discharge estimations. The higher than anticipated variability in discharge estimates for surgical patients may also be attributable to complications associated with surgery. Assessing factors that impact the variability in discharge accuracy can allow hospitals to design targeted interventions to improve discharge planning and reduce unnecessary hospital days.

Conclusion
By understanding the performance of clinicians in estimated discharge dates, we can inform operational decisions around discharge planning, identify specific hospital services and patient factors that are vulnerable to discharge delay, and optimize efficient discharge planning.
References:


An Audit of Patterns of Inhalational Anesthetic Use During Pediatric Anesthesia.

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The significant environmental impact of healthcare is now well recognised. The global warming potential of inhalational anesthetic agents is a small but significant part of this footprint. Our department has a long interest in rationalising inhalational anaesthetic agent use. We have previously observed that short pediatric cases with inhalational induction can use more than 2.5 times the amount of sevoflurane used in long complex adult cases utilising intravenous induction (1). In 2019 we collected data on volatile anesthetic use in paediatric practice in our hospital (2). The aims of the current audit were to look at agent use, including N\textsubscript{2}O, during induction and maintenance and explore the effect on consumption of using a separate machine in the anesthetic bay for induction.

Methods: Study approved by the New Zealand Ethics Committee. We recorded patient demographics, and the consumption of inhaled anaesthetics from anesthetic machine logs, during induction and maintenance in patients aged under 13 yr. This was an opportunistic sample based on the days one of us (AM) was available for this task during Jan-Mar 2021. Christchurch Hospital is a 600 bed tertiary hospital with 3 (of 30) OR dedicated to pediatric procedures. All our OR machines are GE Aysis with end-tidal control. Anesthetic bays of the paediatric OR have GE Avance machines.

Results: 205 cases were available for analysis. 167 (81%) had inhalational inductions, 130 (63% of the total) of these were maintained on sevoflurane while 37 (18%) were transitioned onto TIVA for maintenance which was used for 55 (27%) patients. Volatile anaesthetics used a median of 20mLs sevoflurane (IQR 16-29.25) and 12.41 L of N\textsubscript{2}O (IQR 8.3-19.9). If the patient was transitioned onto IV maintenance after inhalational induction, sevoflurane consumption was 10mLs (IQR 8-13). There was no difference between the amount of sevoflurane or N\textsubscript{2}O used when the patient was induced in the anaesthetic room, compared to induction in theatre. N\textsubscript{2}O was not used for maintenance in any cases.

Conclusions: This study reiterates that about half of agent consumption occurs during induction. Induction and maintenance each account for an average of about 10ml of sevoflurane, similar to our data from 2019. Surprisingly we found that use of a separate machine for induction in the anesthetic bay did not increase total consumption. We speculate that automated low flow anesthesia was initiated as soon as the patient was connected to the OR Aysis. At the time of this audit our TIVA rate across all patient groups was 50% compared to 27% TIVA maintenance in this group. Our data further quantifies sevoflurane and N\textsubscript{2}O use during paediatric anaesthesia in our hospital and has helped identify strategies for decreasing inhalational use in this group.

REFERENCES:
1. van der Griend, B. F. & Kennedy, R. R. Time to stop the go slow on the low flow. Paediatr Anaesth 2019; 29:300-1

Abstract Title: Phenotyping patients undergoing colectomy to anticipate clinical trajectory

Presenting Author: Pascal Laferrière-Langlois, MD, Department of Anaesthesiology and Perioperative Medicine, David Geffen School of Medicine at UCLA, Los Angeles, CA, USA

Co-Authors: Fergus Imrie, PhD, Department of Computer Science, University of California, Los Angeles, CA, USA; Maxime Canneson, MD, PhD, Department of Anaesthesiology and Perioperative Medicine, David Geffen School of Medicine at UCLA, Los Angeles, CA, USA

Background High-risk surgeries account for 12% of the cases performed but represent 80% of the postoperative mortality [1]. The ASA (American Society of Anesthesiology) score, used since 1941, categorizes risk based on patient’s comorbidities [2]. Such stratification is of utmost importance, enabling therapeutic decision making, distribution of resources, decision sharing with patients, and billing. By exploiting clinical databases, risk scores could become automatically extracted from medical records, personalized for different populations, and quickly provide insights on several outcomes. By clustering a population with unsupervised artificial intelligence (AI) algorithms, we can create subgroups without specifying how to subdivide them. By identifying discriminative features, the AI creates subgroups from which we extract the typical profile, or phenotype, before describing the associated outcomes [3]. This recent approach identified subgroups among covid-19 and septic patients [3, 4]. The objective of this project is to export this concept for the first time to a surgical population and, considering the democratization of “Enhanced Recovery after Surgery” protocol, to identify phenotypes and associated outcomes in a population undergoing colectomy [5].

Methods Using the patient data warehouse (PDW) from University of California in Los Angeles (UCLA), we retrospectively extracted all surgical cases containing “colectomy” in the procedure name, which occurred between 2013, inception of the database, and November 2021 [6]. Institutional Review Board of UCLA waived the need for patient’s consent. We selected 56 relevant variables, including demographic data, comorbidities, and medication. Unsupervised K-means clustering was applied to the data, and the optimal number of phenotypes was determined based on discrimination of significant binary outcomes, including mortality, intensive care unit (ICU) length of stay (LOS) over 10 days, and hospital LOS over 20 days. Continuous data, including age and preoperative vitals were normalized with a min-max algorithm before clustering. A random forest plot algorithm was used to identify the 15 most relevant features linked to mortality and compare the clustering results in a restricted set.

Results We identified three major phenotypes in the population (N=2273) based on the major characteristics described in Table 1, with an overall mortality of 0.08%. Despite being younger (average age: 52), phenotype 1 had the highest in-hospital mortality risk with 3.4% (15/437) and had longer ICU LOS (10.1% stayed > 10d), and hospital LOS (26.7% stayed >20d). This subgroup mostly contained patients undergoing urgent surgery (90%) with intestine obstruction (26%). While phenotypes 2 and 3 both were elective and included most cancer cases, mortality and LOS varied significantly between groups (mortality: 0.06% vs 2.1%; ICU>10d: 0.5% vs 7.2%; hospital LOS>20d: 2.4% vs 11.3% ). Phenotype 2 was generally younger (57 vs 62 years old) and presented less comorbidities (see Figure 1). Cases lengths were similar across all groups, and phenotype 3 received more intravenous fluids. In this cohort, phenotype 1 (19.5% of procedures) accounted for 83.3% of deaths, 74.5% of prolonged ICU LOS, and 68.4% of prolonged hospital LOS. Clustering on the restricted feature built after random forest plot algorithm provided similar results.

Discussion and conclusion By identifying 3 phenotypes in the colectomy population, we could discriminate patients’ outcome and trajectory of care. We confirmed that despite having few comorbidities, the highest risk of complication and prolonged ICU/hospital LOS correlates with urgent surgeries. In other words, urgency seems more correlated to adverse outcomes than comorbidities or ASA score. These results confirm the effectiveness of clustering the surgical population for risk stratification. While these analyses were limited by the low number of deaths, LOS insights were of great interest. Accumulating more data will be interesting to further phenotype patients undergoing urgent colectomy, or to personalize risk stratification for other surgeries.
Table 1. Summary statistics for the key covariates and clinical outcomes across phenotypes.

<table>
<thead>
<tr>
<th></th>
<th>Phenotype 1 N= 437</th>
<th>Phenotype 2 N= 1739</th>
<th>Phenotype 3 N= 97</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital Mortality</td>
<td>15 (3.4%)</td>
<td>1 (0.1%)</td>
<td>2 (2.1%)</td>
</tr>
<tr>
<td>ICU LOS &gt; 10 d</td>
<td>44 (10.1%)</td>
<td>8 (0.05%)</td>
<td>7 (7.2%)</td>
</tr>
<tr>
<td>Hospital LOS &gt; 30d</td>
<td>117</td>
<td>43</td>
<td>11</td>
</tr>
<tr>
<td>Age (mean)</td>
<td>53.7</td>
<td>57.5</td>
<td>62.2</td>
</tr>
<tr>
<td>Sex (Male)</td>
<td>49.9%</td>
<td>51.1%</td>
<td>50.5%</td>
</tr>
<tr>
<td>Weight (mean)</td>
<td>68.5 kg</td>
<td>74.8 kg</td>
<td>75.5 kg</td>
</tr>
<tr>
<td>Elective case</td>
<td>10.1%</td>
<td>98.4%</td>
<td>77.3%</td>
</tr>
<tr>
<td>Abdominal Obstruction</td>
<td>26.1%</td>
<td>0.8%</td>
<td>0.8%</td>
</tr>
<tr>
<td>Malignant intestine neoplasia</td>
<td>8.9%</td>
<td>27.2%</td>
<td>26.8%</td>
</tr>
<tr>
<td>Obesity (IMC &gt;30)</td>
<td>0.1%</td>
<td>2.9%</td>
<td>13.4%</td>
</tr>
<tr>
<td>Hypertension</td>
<td>1.8%</td>
<td>0.9%</td>
<td>38.1%</td>
</tr>
<tr>
<td>Diabetes</td>
<td>3.6%</td>
<td>5.8%</td>
<td>10.3%</td>
</tr>
<tr>
<td>Smoking</td>
<td>0.7%</td>
<td>5.4%</td>
<td>8.2%</td>
</tr>
<tr>
<td>Ischemic heart disease</td>
<td>2.1%</td>
<td>2.9%</td>
<td>20.6%</td>
</tr>
<tr>
<td>Length of case</td>
<td>296 min</td>
<td>307 min</td>
<td>299 min</td>
</tr>
<tr>
<td>Crystalloid received</td>
<td>657 mL</td>
<td>739 mL</td>
<td>916 mL</td>
</tr>
<tr>
<td>Colloid received</td>
<td>169 mL</td>
<td>120 mL</td>
<td>156 mL</td>
</tr>
</tbody>
</table>

References

Accuracy of Masimo SET pulse oximetry in black and white volunteer subjects: a retrospective review

Co-Authors:
Steven J Barker, PhD, MD; Chief Science Officer, Masimo Corporation
William C Wilson, MD, MA; Chief Medical Officer, Masimo Corporation

Introduction: A recent letter to the editor¹ and more recent paper² purported to find a “racial bias” in pulse oximeter measurements based upon a comparison of data obtained from black and white patients. We questioned the validity of these reports, which were compiled from previously collected health record data using unspecified pulse oximeters and controls. Therefore, we performed a retrospective review of laboratory data obtained from black and white volunteer subjects undergoing induced hypoxia studies using Masimo SET pulse oximeters to identify any differences in pulse oximeter accuracy and bias between these ethnic groups.

Methods: Volunteer desaturation data collected between October 2015 and July 2021 was retrospectively evaluated. The data included 7,183 paired samples (3,201 black and 3,982 white) obtained from 75 subjects (39 black and 36 white). \( \text{SpO}_2 \) values obtained from Masimo SET pulse oximeters with RD SET sensors (Masimo, Irvine, California) were time-matched (within 5 seconds) with arterial blood gas (ABG) samples obtained from a radial arterial line and analyzed on ABL-835 Flex CO-oximeter blood gas analyzers (Radiometer, Brea, California). The ABG samples were collected and handled in accordance with the guidelines provided by the blood gas analyzer manufacturer.³,⁴ Subjects from each ethnic group were screened using the same criteria to remove potentially biasing health conditions. These subjects were exposed to the same hypoxia protocol that varied the arterial saturation of hemoglobin (\( \text{SaO}_2 \)) between 70% and 100% while non-invasive pulse oximeter (\( \text{SpO}_2 \)) values were obtained for comparison using a standard protocol aligned with the ISO 80601-2-61 standard.

Statistical calculations include bias (mean difference of \( \text{SpO}_2 - \text{SaO}_2 \)), precision (standard deviation [SD] of the difference), and accuracy (root mean square error [\( A_{\text{RMS}} \)]).

Results: The bias for black subjects was -0.20, compared to -0.05 for white. The precision for black subjects was 1.40, compared to 1.35 for white subjects. The accuracy (\( A_{\text{RMS}} \)) for black subjects was 1.42, compared to 1.35 for white. The bias difference between the white and black subgroups was found to be 0.15 (p-value < 0.001). This difference is not clinically significant because the \( \text{SpO}_2 \) display resolution on pulse oximeters is 1%.

<table>
<thead>
<tr>
<th>Masimo SET</th>
<th>Bias</th>
<th>Precision</th>
<th>( A_{\text{RMS}} )</th>
<th>( N_{\text{Pairs}} )</th>
<th>( N_{\text{Subj}} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>-0.20</td>
<td>1.40</td>
<td>1.42</td>
<td>3,201</td>
<td>39</td>
</tr>
<tr>
<td>White</td>
<td>-0.05</td>
<td>1.35</td>
<td>1.35</td>
<td>3,982</td>
<td>36</td>
</tr>
<tr>
<td>All</td>
<td>-0.12</td>
<td>1.37</td>
<td>1.38</td>
<td>7,183</td>
<td>75</td>
</tr>
</tbody>
</table>

Conclusion: There was no clinically significant difference in the accuracy or bias between black and white subjects monitored with Masimo SET pulse oximetry and RD SET sensors.

References:


AMBIENT AIR QUALITY EXPOSURE AMONG PEDIATRIC ANESTHESIA PATIENTS IN A CHILDREN’S HOSPITAL: AN APPLICATION OF SPATIAL ANALYTICS AND POPULATION DATA LINKAGE

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Introduction: Exposure to poor air quality has been associated with the development of asthma, increases in the severity of asthma exacerbations, and increases in the utilization of health care resources in children. Traffic-related air pollution and nitrogen dioxide represent significant risk factors for pediatric asthma development. Pollutants that are considered the greatest impact on human health are particulate matter (PM). PM can be measured as PM$_{2.5}$ and PM$_{10}$, where 2.5 or 10 represents the diameter size of particles in microns. The smaller the PM the more likely particles penetrate to the lower respiratory system, exacerbating bronchitis and other lung disease. Both long-term and short-term exposure to levels of air pollution can impact respiratory health in children. Although studies have recently examined the ambient air quality exposure on children in primary care settings, to our knowledge there is no research on the epidemiology of air quality exposure among pediatric patients undergoing anesthesia and surgery care. Understanding the long- and short-term exposure variation in air quality over space and time will enable future studies on the subsequent impact on perioperative outcomes such as respiratory adverse events.

Methods: Following IRB approval, we conducted a retrospective study of all pediatric patients receiving elective urologic surgery ≤5 years of age at a freestanding quaternary care children’s hospital from 1/2019 to 11/2021. Patient demographic data, including street level address were abstracted from electronic health records at the time of procedure and from the enterprise data lake. Patient EHR addresses were geocoded to the street address level, and spatial data linkage methods were used with various air quality metrics from the year 2019. Air quality exposures of interest included PM$_{2.5}$ and PM$_{10}$ modeled to small areas of geography. Data was obtained from a collaboration with Plume Labs. Analysis was conducted utilizing R, SAS, and ArcGIS Pro. Interactive maps were created to visualize geographic variation of air quality exposure across space in the greater Los Angeles region.

Results: Our study included 2,503 unique pediatric patients that represented at total of 3,454 unique anesthetic cases. The mean age was 1.9 years with a median age of 1.5 years. The most common self-reported race was White (19.5%), followed by Black (7.5%), Latino/a/x (7.4%), and Asian (6%). However, as a self-reported race, the “Other” (37.3%) and “Unknown” (13.3%) categories represented the largest number of responses. There was a similar reported number of Hispanic (21%) and non-Hispanic (21.5%) patients in our cohort with the rest an ethnicity of “Unknown” (57.6%). The mean PM$_{2.5}$ exposure for all patients was 10.4 microns with a standard deviation of 0.82 microns. The mean PM$_{10}$ annual ambient exposure at the residential address was 29 microns with a standard deviation of 2.9 microns. Large variation in other measures of ambient air quality were also found across our pediatric anesthesia patient cohort. Figure 1 is a spatial representation of the patients and their annual exposure to PM$_{2.5}$ by quintile in the year 2019.

Discussion: We successfully linked a large population of pediatric patients receiving anesthesia for elective surgery and their annual exposure to ambient air quality at small areas of geography. Leveraging EHR data with geospatial analytics can augment our understanding of the environmental exposures that may impact the delivery of perioperative care. We found that large variation of annual ambient air quality exposure exists in our pediatric patients undergoing general anesthesia within our city. Our study represents an application of geospatial analysis and population data linkage techniques to understand the epidemiology of air quality exposure in children undergoing general anesthesia.

Figure 1. Annual ambient air quality exposure (PM$_{2.5}$) for a cohort of pediatric anesthesia patients in the Los Angeles (n=2,503)

References
SPATIAL ANALYSIS OF TELEHEALTH UTILIZATION IN A PEDIATRIC PAIN CLINIC

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Introduction: Social determinants of health (SDOH) have a significant impact on access to health. Low socioeconomic status (SES) has been associated with delayed care and missed appointments. Telehealth services provides an opportunity to deliver health care by reducing physical barriers. During the COVID-19 pandemic, telehealth services were expanded by many health systems to continue providing socially distant care. While telehealth has the potential to bridge physical gaps in care, technology can be an additional barrier to accessing care and exacerbate existing health disparities. Understanding the impact of telehealth in the context of SDOH risk factors may be an important component toward studying and achieving health equity. Unfortunately, there is a limited amount of SES factors available to study in the electronic health record (EHR). The goal of our study was to use an innovative method to better understand the SES and location risk factors that are associated with the utilization of telehealth services in a pediatric pain clinic.

Methods: Following IRB approval, we conducted a retrospective study of all pediatric pain clinic patients seen by telehealth at a free-standing academic children’s hospital from 4/2020 to 5/2021. Patient demographic details and telehealth utilization data were abstracted from the EHR and the enterprise data lake. Administrative outcomes of interest were telehealth appointment no-show or cancellations within 24 hours. Patient EHR addresses were geocoded and geospatial analytic techniques, including spatial linkage of EHR data with US Census-American Community Survey 2019 Data (5-Year) was conducted. Analysis was at the patient-level and neighborhood block-group level for SDOH measures. Specific neighborhood level measures used included the percent of households that have no computer. Analysis was conducted utilizing SAS, R, and ArcGIS Pro.

Results: Our study included 550 pediatric pain patients, and all were successfully geocoded at the street level address. There were 309 patients (56.2%) who had their initial follow-up appointment using telehealth and 241 (43.8%) who were seen as a new patient visit. Most patients had government insurance (61.6%) as compared to commercial (38.4%). Overall, 14.9% of appointments were cancelled <24 hours or did not show up for their telehealth appointment. New appointments were more likely to be cancelled <24 hours or not show up (21.2%) as compared to follow-up appointments where 10% were cancelled/no show. A large percentage of patients self-reported their race as “Other” (51.8%) or were unknown (14.2%). Patient residential addresses came from a variety of locations in the state of California with a small number of patients from Nevada and Arizona. Patients who cancelled <24 hours or did not show up were more likely to come from neighborhoods (defined as Census Block Groups) of lower socioeconomic status. In addition, census block groups that had more “households with no computers” were more likely to cancel/no show for their telehealth appointment. Digital maps demonstrating geographic variation and disparities in access to telehealth utilization were created for exploration and descriptive purposes.

Discussion: We successfully identified patient level and neighborhood level socioeconomic risk factors that are associated with cancelling (<24 hours) or not showing up for their telehealth appointment. Leveraging EHR data with geospatial analytics can augment our understanding of the SDOH that may impact the delivery of telehealth services in a pediatric population. Future steps include using these spatial risk factors to risk stratify and improve care delivery pathways to reduce disparities in telehealth utilization.

Figure 1. Percent of households that have no computer by Census Block Group in the Greater Los Angeles Region

References
Is a change in end-tidal carbon dioxide concentration associated with hypotension during periods of general anesthesia with stable mechanical ventilation? Analysis of a large cohort.

**Presenting author:** Rama Sreepada PhD 1,2

**Co-authors:** Vanessa Giesbrecht MD 1, Matthias Görges PhD 1,2, Perseus I. Missirlis MSc, MD, FRCPC 1,3,4

**Affiliations:** 1. Dept of Anesthesiology, Pharmacology & Therapeutics, University of British Columbia, Vancouver, BC, Canada. 2. Research Institute, BC Children’s Hospital, Vancouver. 3. Royal Columbian Hospital, Fraser Health Authority, New Westminster, BC, Canada. 4. Fraser Health Authority, Surrey, BC

**Introduction:** Detection of intraoperative hypotension relies on measuring non-invasive blood pressure (NIBP) or invasive arterial blood pressure. However, significant decreases in end-tidal carbon dioxide concentration (etCO$_2$) can also indicate decreased cardiac output [1]. During most general anesthetics, NIBP is sampled infrequently, typically every 5 minutes as per the Canadian Anesthesiologists’ Society guidelines [2], while etCO$_2$ is monitored on a breath-by-breath basis, i.e. every 3-9 sec. This mismatch in sampling frequencies suggests an opportunity to anticipate acute hypotensive events using capnography before the next NIBP measurement becomes available. The aim of this study is to determine if acute decreases in etCO$_2$ predict hypotension in patients undergoing general anesthesia during otherwise stable mechanical ventilation.

**Methods:** With Research Ethics Board approval (H20-01248) and waiver of patient consent, we conducted a retrospective study of patients undergoing general anesthesia for non-cardiac surgery at any of eight hospitals within the Fraser Health Authority between Jan’14 and Jun’20. NIBP artifacts were removed [3], and cases without etCO$_2$ data or < 75% case coverage for mean arterial pressure (MAP) were excluded. Periods of stable mechanical ventilation were identified as episodes with average variability in positive end-expiratory pressure < 5% and in minute ventilation < 2.5%. Our primary outcome was the occurrence of significant intraoperative hypotension with MAP < 65 mmHg and MAP decrease of ≥ 20 mmHg from a baseline measurement 10-min prior to the hypotensive observation. For each hypotensive episode, the change in etCO$_2$ was calculated as the difference between etCO$_2$ reading at the time of the hypotensive event and 10-min prior to the event. Magnitude of etCO$_2$ change was examined as an individual cut-off value, and analyzed for its predictive value. The area under the receiver operating characteristic curve (AUROC) was obtained, with the Youden index identifying the optimal threshold. The analysis was repeated using a hypotension definition of MAP < 50 mmHg.

**Results:** Data from 66,683 procedures were available for analysis, of which 39,581 had at least one episode of intraoperative hypotension with a MAP < 65 mmHg. Data from 63,343 hypotensive episodes with stable ventilation from 12,951 procedures were used in our model; of these 7,456 were labeled as significant (i.e. MAP decrease ≥ 20 mmHg). A maximum Youden index of 0.43 was observed for a decrease of 2 mmHg (Figure 1a & b). The model’s AUROC was 0.776 (95% CI 0.77 to 0.782). Using the definition of MAP < 50 mmHg, hypotension was observed in 7,903 procedures from which only 1,331 hypotensive episodes with stable ventilation could be used; of these 980 were labeled as significant. Here, the optimal change in etCO$_2$ was also ≤ -2 mmHg (Figure 1c & d). This model’s AUROC was 0.747 (95% CI of 0.727 to 0.767). Interestingly, acute etCO$_2$ change of ≤ -5 mmHg did not indicate hypotension (Fig 1a & c).

**Conclusion:** These data suggest that acute changes in etCO$_2$ were not a reliable predictor for intraoperative hypotensive events, yet more sophisticated analysis approaches should be explored before ruling out this potentially useful clinical warning sign. Data show that an etCO$_2$ decrease ≤ -2 mmHg had a true positive rate of 59%, and false negative rate of 41% for predicting hypotensive MAP < 65 mmHg, implying that hypotensive cases could not be accurately predicted from etCO$_2$ drops.

Title: A Retrospective Analysis Using Algorithmic Software To Determine the Missing Rate for ICD and DRG Codes Used to Identify Patient Co-Morbidities.

Presenting Author: Eilon Gabel MD
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1UCLA David Geffen School of Medicine, Department of Anesthesiology and Perioperative Medicine
Introduction:

The mechanism for recording International Classification of Diseases (ICD) and diagnosis related groups (DRG) codes in a patient’s chart is through a certified medical coder who reviews the entire medical record at the completion of an admission. If high-acuity ICD codes are included, coders can add DRG modifiers (CC or MCC), indicating that a patient required escalated hospital resources due to existing comorbidities. We hypothesize that administrative codes are incomplete and we evaluated the incidence of missed ICD codes for the diseases in a cohort of hospital admissions. Secondarily, we evaluate the extent to which missing ICD codes led to an incorrect DRG assignment for the admission, as well as the potential financial impact of these omissions.

Materials and Methods:

This study (IRB# 15-000518) qualified for IRB exception status. All study data were acquired via a previously published Department of Anesthesiology and Perioperative Medicine at UCLA’s Perioperative Data Warehouse.¹

Eighteen diseases were selected from the CMS list of disease that met criteria for DRG modifiers, seen in Table 1. Each admission was flagged as having/not having the diseases by algorithm and by billed ICD code. Billed DRG comorbidity level was evaluated in algorithm-positive admissions and flagged when inappropriate. A single relative weighted factor (RWF) point was estimated at $20,000 for private payors, $10,000 for Medicare, and $7,500 for Medicaid. The difference RWF between the actual billed DRG value the algorithm-corrected DRG modifier value was the projected loss.

Results:

Data were analyzed from January 1, 2019 to December 31, 2019. In total, 34,982 hospitalization met inclusion criteria for having at least one DRG assigned to the admission with 34,104 (97.5%) of the admissions had a primary DRG designated. 13,313 (34%) hospital admissions with were flagged as having no corresponding ICD code. 1,035 (3%) admissions were flagged for upgrade from the base DRG to CC modifier, 194 (0.6%) admission were flagged for upgrade from the base DRG to MCC modifier, and 785 (2.2%) admission were flagged from upgrade from the CC modifier to MCC modifier. Accounting for the difference RWF points between the DRG codes originally assigned to admissions and the DRG codes assigned by the algorithm, then multiplying by the payor-dependent dollar estimated per point, we calculated a loss of $22,448,800.
Table 1: Results of individual disease algorithms

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Total Admission Flagged by Algorithm</th>
<th>Algorithm-Verified Proper ICD Coding</th>
<th>Algorithm-Verified Proper DRG Modifiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acidemia</td>
<td>2453</td>
<td>36.8% (34.9%-38.7%)</td>
<td>97% (96.3%-97.6%)</td>
</tr>
<tr>
<td>Acute MI</td>
<td>32</td>
<td>87.5% (71.9%-95%)</td>
<td>75% (57.9%-86.7%)</td>
</tr>
<tr>
<td>Acute Trop Leak</td>
<td>2631</td>
<td>66.3% (64.5%-68.1%)</td>
<td>96.5% (95.7%-97.1%)</td>
</tr>
<tr>
<td>Bacteremia</td>
<td>774</td>
<td>96.4% (94.8%-97.5%)</td>
<td>98.6% (97.5%-99.2%)</td>
</tr>
<tr>
<td>Chronic CHF</td>
<td>1363</td>
<td>78.5% (76.2%-80.6%)</td>
<td>97.6% (96.6%-98.3%)</td>
</tr>
<tr>
<td>CKD</td>
<td>4325</td>
<td>99.2% (98.9%-99.5%)</td>
<td>97.9% (97.4%-99.3%)</td>
</tr>
<tr>
<td>Death</td>
<td>946</td>
<td>97.6% (96.4%-98.4%)</td>
<td>98% (96.7%-98.8%)</td>
</tr>
<tr>
<td>Delirium</td>
<td>710</td>
<td>71.4% (68%-74.6%)</td>
<td>89.8% (88.9%-90.8%)</td>
</tr>
<tr>
<td>Extreme BMI</td>
<td>3931</td>
<td>59.5% (58%-61.1%)</td>
<td>81.7% (80.4%-82.9%)</td>
</tr>
<tr>
<td>GCS &lt;= 8</td>
<td>3457</td>
<td>50.4% (48.7%-52.1%)</td>
<td>97.2% (95.5%-98.3%)</td>
</tr>
<tr>
<td>Hemodialysis</td>
<td>539</td>
<td>87.4% (84.3%-89.9%)</td>
<td>59.5% (53.9%-64.9%)</td>
</tr>
<tr>
<td>HIV</td>
<td>299</td>
<td>95% (91.9%-96.9%)</td>
<td>95.6% (95.2%-96%)</td>
</tr>
<tr>
<td>Hyponatremia</td>
<td>9772</td>
<td>39.9% (38.9%-40.9%)</td>
<td>69.3% (63%-75%)</td>
</tr>
<tr>
<td>Pancreatitis</td>
<td>225</td>
<td>80% (74.3%-84.7%)</td>
<td>94.8% (93.3%-95.9%)</td>
</tr>
<tr>
<td>Post-op anemia</td>
<td>1149</td>
<td>78.7% (76.2%-80.9%)</td>
<td>95.6% (94%-96.7%)</td>
</tr>
<tr>
<td>Respiratory Arrest</td>
<td>854</td>
<td>96.1% (94.6%-97.2%)</td>
<td>80.4% (77.4%-83%)</td>
</tr>
<tr>
<td>TPN</td>
<td>794</td>
<td>86.9% (84.4%-89.1%)</td>
<td>98.2% (97.7%-98.6%)</td>
</tr>
<tr>
<td>Transplant</td>
<td>2801</td>
<td>96% (95.2%-96.7%)</td>
<td>97.5% (96.7%-98.1%)</td>
</tr>
<tr>
<td>UTI</td>
<td>2065</td>
<td>74.1% (72.2%-75.9%)</td>
<td>97% (96.7%-98.1%)</td>
</tr>
</tbody>
</table>
Conclusion:

In this manuscript, we demonstrate that value of using computer algorithms to identify ICD codes that were not documented in patients’ medical records for completed hospitalizations. These missing ICD codes question the validity of using administrative databases and, in many cases, had downstream effects such as incorrect DRG modifiers. Embedding artificial intelligence into this problematic workflow has the potential for improving administrative data, but more importantly, advancing patient care.

Works Cited

TITLE: Impact of Virtual-Reality-Guided Mindfulness on Focus Prior to High-Fidelity Simulation Debrief

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CO-AUTHORS: Brett Weingart, B.A. (Medical Student; Department of Anesthesiology, Perioperative & Pain Medicine; Icahn School of Medicine at Mount Sinai), Daniel Katz M.D. (Associate Professor; Department of Anesthesiology, Perioperative & Pain Medicine; Icahn School of Medicine at Mount Sinai)

ABSTRACT BODY:
BACKGROUND: High-fidelity simulation (HFS) is commonly used to train anesthesiology learners in how to perform in high-stress situations. Previous studies have shown physiologic stress responses during HFS may enhance performance during subsequent high-intensity scenarios, however this level of stress may hinder focus and knowledge retention during a post-HFS debrief session. Currently, the optimal mindset to maximize learning during the debrief is unknown and the ideal modality to create this mindset after a stressful learning session has not been determined. Virtual reality(VR)-based mindfulness exercises has previously been demonstrated to increase focus and reduce anxiety. This study aims to examine changes in focus, anxiety, and EEG patterns in anesthesia residents immediately after a guided meditation session, either with or without VR supplementation. We hypothesized that meditating with VR would lead to a more successful meditation and a larger increase in focus than meditating without VR.

METHODS: 26 anesthesiology PGY-2 residents completed twice-weekly HFS sessions. Immediately after the HFS session and before a standardized debrief, subjects completed a 5-minute guided mindfulness exercise. Half of the subjects wore a VR headset and meditated in a virtual forest environment, while the other half meditated with their eyes closed. Immediately before and after meditating, they completed a brief anxiety and focus questionnaire, then participated in a standardized debrief on the HFS session. All subjects wore a consumer-grade EEG headband to monitor frontal EEG waveforms. Changes in focus and anxiety after meditating (self-reported) were compared between the two groups, as well as a composite EEG scores (relating to calm or neutral states) between the two groups.

RESULTS: Analysis showed no significant differences between two groups regarding baseline anxiety levels or composite EEG scores. There were no significant differences in the amount focus and anxiety levels changed after meditating between the two groups. The only significant results were that, across all participants and regardless of VR supplementation, meditation reduced anxiety levels by about 19% (p < 0.0001). Focus levels remained constant after meditation.

CONCLUSION: The addition of VR had no effect on the quality of meditation or on changing the student’s mental state. Meditation led to reduced anxiety levels across all groups, suggesting
that meditation of any form is useful before HFS debrief in reducing stress, but the addition of VR is not a necessity.

REFERENCES:
**Abstract Title:** Intraoperative Management of Deep Neuromuscular Blockade: The Case for Quantitative Electromyographic Monitoring of Single Twitch Recovery (T1/T1 control)

**Presenting Author:** Richard H. Epstein, MD, University of Miami, Miami, FL,
**Co-Authors:** Réka Nemes, MD, PhD, University of Debrecen, Hungary; J. Ross Renew, MD, Mayo Clinic, Jacksonville, FL; Sorin J. Brull, MD, Mayo Clinic, Jacksonville, FL.

**Introduction:** Numerous studies have demonstrated the unreliability of clinical assessment of adequate recovery from neuromuscular blockade (NMB) (train of four ratio [TOFR] ≥90% before extubation). However, the TOFR has minimal intraoperative utility because surgical levels of NMB eliminate the 4th twitch (TOFR=0). Clinical assessment of NMB is typically performed using the number of twitches present following train of four (TOF) stimulation (the train of four count, TOFC), with redosing of relaxant to maintain the TOFC=1 or 2. Quantitative assessment of NMB most commonly utilizes acceleromyography (AMG). However, AMG is often unsuitable intraoperatively because patient positioning interferes with free thumb motion, and inverse fade (i.e., baseline and/or recovery TOFR >1.0) is common. Furthermore, single twitch recovery, defined as the ratio of the first twitch (T1) in the TOF to the control T1 value (Tc), is often unreliable with AMG. The T1/Tc ratio is what has been used for pharmacodynamic assessment of NMB drugs. In contrast, assessment of NMB by electromyography (EMG) is not subject to inverse fade, the T1/Tc is reliable, and free thumb motion is not required for accurate measurement. We postulated that the EMG measurement of the T1/Tc is a more precise and consistent indicator of the depth of intraoperative block than the TOFC at the adductor pollicis following TOF stimulation of the ulnar nerve.

**Methods:** We obtained raw monitor output files for N=19 patients receiving rocuronium from a recent intraoperative study comparing the TOFR from an EMG device (TetraGraph, Senzime AB, Sweden) to an AMG device (TOF-Watch SX, Organon Teknika BV, The Netherlands). Full spontaneous recovery of the TOFR was intended by protocol, resulting in a wide range of values. The control T1 (Tc) was obtained just before rocuronium administration; the T1 and T4 amplitudes were determined at 15-sec intervals along with the corresponding TOFC. The T1/Tc and TOFR were calculated for each TOF stimulation, and noise was filtered by fitting to an order-15 polynomial. Smoothed values were used for comparisons at each TOF time. We determined the T1/Tc corresponding to the return of each successive twitch (T1, T2, T3, T4) in the TOF. We calculated the mean, median, and interquartile range of the T1/Tc among patients. Data are presented as the mean and standard error (SE) or the median and interquartile range (IQR).

**Results:** Recovery of NMB in a sample patient is shown in the Figure. In all patients, responses were abolished (TOFC=0) following the intubating dose. The T1/Tc returned to 25% in a mean of 27.6 min (standard error [SE] 2.7 min, median 27.0 minutes (IQR 21.5 to 36.6 min). Values of the T1/Tc at the time of TOFC recovery are shown in the table.

<table>
<thead>
<tr>
<th>T1/T1c</th>
<th>1st Twitch</th>
<th>2nd Twitch</th>
<th>3rd Twitch</th>
<th>4th Twitch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SE)</td>
<td>9.2% (1.6%)</td>
<td>21.0% (3.0%)</td>
<td>34.7% (4.2%)</td>
<td>36.8% (4.3%)</td>
</tr>
<tr>
<td>Median (IQR)</td>
<td>8.2% (4.3%–13.0%)</td>
<td>17.7% (11.3%–29.7%)</td>
<td>34.6% (18.8%–48.1%)</td>
<td>35.2% (21.8%–52.4%)</td>
</tr>
</tbody>
</table>

**Conclusions:** Re-dosing muscle relaxants based on the TOFC will result in substantial variation among patients in the T1/Tc during surgery. Thus, relying on the TOFC to guide redosing of relaxants may lead to suboptimal surgical conditions when deep levels of NMB are needed. Titration to maintain the T1/Tc at a surgical level of NMB would avoid this problem. Given the lack of reliability of AMG during many surgical procedures and the improved performance of EMG vs. AMG when assessing baseline values and recovery of the TOFR, quantitative monitoring of NMB using EMG rather than AMG provides advantages.

**Reference**

**Figure:** Recovery from NMB in a typical patient. The arrows of the green dotted lines indicate the T1/Tc at the time of sustained recovery of the indicated TOFC Count (green circles).
Artificial intelligence and the future of anesthesiology: Qualitative findings from a national survey of physician anesthesiologists
Carlos Estrada Alamo, MD, MBA, Fortunay Diatta and Meghan Lane-Fall, MD, MSHP, FCCM

Context
Thanks to recent advancements in computer processing power and cloud computing, artificial intelligence (AI) is poised to have a major effect on healthcare delivery and access. (Karras et al., 2019) The acceptance and adoption of AI applications in clinical practice, particularly in specialties that have traditionally supported innovation such as anesthesiology, is of significant academic interest. (CL & CJ, 2012) Despite the multiple studies in literature discussing physicians’ beliefs and attitudes about the use of technologies such as AI in medicine, the perspectives of physician anesthesiologists have been overlooked. (Jungmann et al., 2020; Scheetz et al., 2021; Truong et al., 2019; Wadhwa et al., 2020) The purpose of this study was to explore whether physician anesthesiologists’ attitudes, motivators and perceived barriers towards using AI in clinical practice were associated with physician-level and practice characteristics.

Methods
In this cross-sectional study, we surveyed physician anesthesiologists of the American Society of Anesthesiology (ASA) using a web-based survey distributed via e-mail. Associations between physician level of training and experience, practice characteristics and physician attitudes, motivators and perceived barriers to using AI in clinical practice were estimated.

Results
Survey invitations were emailed to 27,056 physician anesthesiologists practicing in the United States. Between May 2021 and June 2021, 1,086 physicians (4%) completed the survey. Only 7% of respondents indicated they were well educated on AI. Thirty-seven percent of respondents reported they had heard of but didn’t know much about AI and less than 2% reported they didn’t know and hadn’t heard about AI. In total, 47% of physicians describe their feelings regarding using AI in clinical practice as positive or very positive (4-5 on a 5-step Likert-type scale). As benefits of AI, anesthesiologists collectively identified enhanced efficiency (79%), timeliness (75%) and effectiveness of health-care delivery (69%). The pre-hospital (69%), continued quality improvement (61%) and intra-operative (58%) domains of anesthetic care were selected as most likely to benefit from AI in the next 10 years. When it comes to anticipating the future role of AI in the field, anesthesiologists anticipate that AI will likely outperform them in predicting adverse peri-op events (83%), formulating pain management plans (67%) and performing airway examinations (45%). A majority of respondents doubt AI will ever outperform them in providing empathetic care to patients (81%), performing endotracheal intubation (65%) and performing regional anesthetic blocks (64%). The primary motivators of using AI in clinical practice were improving healthcare outcomes (81%), remaining in charge of final clinical decision-making (55%) and reducing healthcare costs (54%). Leading barriers to using AI in clinical practice were a lack of algorithmic transparency (60%), malpractice and legal liability concerns (47%) and the potential for medical errors (41%). Concerns about job replacement (46%) and income loss (45%) where also identified.

Conclusions
Overall, physician anesthesiologists' attitudes toward using artificial intelligence in clinical practice were positive. Though nearly half of respondents were pessimistic about how AI will impact both patient safety and labor market dynamics, respondents nonetheless identified motivating factors that, if true, would encourage them to use AI in practice. It remains unclear whether these motivating factors would, overall, outweigh the negative impact of perceived risks and barriers of using AI in anesthesiology. Despite the limitations of a cross-sectional survey design and the possibility of non-response bias, our results have implications for perioperative leaders charged with integrating AI into modern anesthetic practice. Given the scope and complexity of the subject, further discussions and research are required.
A postoperative patient outcome dashboard for individualized and team performance feedback

Presenting author: Ai Ching Chang MEng 1,2
Co-authors: Rama Sreepada PhD 2,3, Andrew Poznikoff BSc 3,4, James Chen MD 3,4, Norbert Froese MD 2,3,4, Rebecca Munk MBBS 4,5, Matthias Görges PhD 2,3

1. School of Biomedical Engineering, University of British Columbia (UBC), Vancouver, Canada; 2. Research Institute, BC Children’s Hospital (BCCH), Vancouver; 3. Dept. of Anesthesiology, Pharmacology & Therapeutics, UBC; 4. Dept. of Pediatric Anesthesia, BCCH 5. Dept. of Anaesthesia, Flinders Medical Centre, Adelaide, SA, Australia

Background: The perioperative period is a data-rich environment, with the potential for improving personal and population-level postoperative outcomes through digital health innovations. Yet much of the data collected remains inaccessible to clinicians; anesthesiologists often lack the information needed to assess their performance or know their patients’ outcomes beyond discharge from the operating room. Professional anesthetic practice and outcomes can be improved with data-driven performance feedback [1,2]; e.g., individualized feedback improves anesthesiologists’ temperature monitoring compliance during spine surgery [3]. Feedback is most effective when it is individualized rather than unit-wide, locally relevant, and from a credible source [4]. A recently established BC Children’s Hospital Post-Operative Follow Up (POFU) registry presents an opportunity to develop a dashboard for anesthesiologists to reflect on their patients’ postoperative outcomes and hypothesize that this feedback will motivate potential personal and population-level improvements in anesthetic care.

Methods: This quality improvement (QI) project was exempt from research ethics approval. The POFU registry captures outcomes from all outpatient procedures at our tertiary pediatric center and obtains age, sex, and scheduled procedure, from the operating room scheduling system. Nurses record rescue opioids and antiemetic medications given in the Post Anesthesia Care Unit (PACU). Within 24 hours of discharge, the PACU nurses telephone the parent for a follow-up report on post-discharge nausea, vomiting, pain, bleeding, return to normal behavior, eating and drinking, urination, and seeking urgent care. Exploratory data analysis removed data artifacts and estimated data distribution. An interactive dashboard was created using Microsoft’s Power BI, co-developed with feedback from five anesthesiologists over four rounds of iteration. De-identified patient outcomes are visualized at anesthesiologist and department levels.

Results: The dashboard prototype (Figure 1) contains three pages: 1) anesthesiologist’s PACU pain and nausea summary; 2) 24-hour postoperative outcomes summary; and 3) practice profile. Anesthesiologists highlighted the importance of allowing an individual provider to compare performance with their peers anonymously, which required additional de-identification and security. We added the ability to filter and drill down into results based on the patient demographic and procedure type, as anesthesiologists valued the ability to interpret and compare postoperative outcomes using known risk factors. Follow-up phone call data from 5,976 cases between Sep/2020 and Sep/2021, and PACU data from 2,610 cases between Apr/2021 and Sep/2021, were captured for pilot analysis; 3,891 (65%) follow-up calls were completed successfully. Cases with missing data were excluded from the analysis of that outcome, but not from other analyses. Prevalence of undesirable postoperative outcomes was generally low: pain or nausea in PACU requiring opioid (7.6%) or anti-emetic (1.3%) rescue medications, and moderate to severe 24-hour postoperative nausea (0.9%), vomiting (1.1%), pain (4.0%), or bleeding (1.0%).

Conclusion: Preliminary results established design requirements for the outcome dashboard, which is being deployed by the anesthesia department, allowing additional usability testing and feedback into the effectiveness of the visualization approach. Long-term clinical impact on group performance and outcome variability will be evaluated in 6 months.


Figure 1: Example of the dashboard’s PACU pain and nausea rescue summary page. The page displays (from left to right) the individual’s overall pain and nausea rescue rate, monthly average of individual vs. department rescue rates, and the individual’s ranking among their peers. The page can be filtered by demographics and surgical procedure group. The page provides navigational buttons to view detailed reports of PACU pain rescue and PACU nausea rescue.
Title: Virtual reality-based cognitive exercises to enhance attention and focus  
Presenting Author: Peter Lin¹  
Wesley Lim, Peter Lin, Antara Dattagupta, Rohan Gupta, Hina Faisal²  
¹. Texas A&M University, EnMed program, Houston, TX.  
². Division of Critical Care, Anesthesiology, Department of Surgery, Houston Methodist Hospital, Houston, TX.

Introduction: Attention is the most crucial cognitive domain required to complete mentally challenging tasks by healthy individuals effectively. Healthy subjects may not be able to complete higher executive function tasks due to lack of focus or attention, leading to poor performance at work and home. Generally, mild attention deficits are not identified, and errors are incorrectly attributed to life stresses. Computerized cognitive training programs have been shown to improve attention deficit disorder and mild cognitive impairment. [¹, ²] Virtual Reality (VR) is an emerging technology that can improve brain functions, including attention, focus, and reorientation. Studies are emerging where VR is being used to improve cognitive function and daily activities in older patients with mild cognitive impairments. [³, ⁴] VR engages multiple learning systems, making it a more effective natural environment for cognitive training. Based on this idea, our team developed a 3D simulated software platform prototype called "ReCognition" VR with incorporated exercise in the forms of games which can improve attention, focus, and executive functions.

Methods: Virtual Reality (VR) provides sensory inputs and interactions to users by providing an artificial three-dimensional (3D) environment using computing technology or software. ReCognition VR software in Unity creates this artificial 3-D environment through the Oculus Quest 2 VR headset. The virtual environment (VE) created cognitively stimulates the user's brain to think they are in an artificial world. This VE allows flexibility and measurement of different types of stimuli while recording the various responses created by users in the controlled VE. Next, the generated VE relaxes users by playing calming beach water sound effects in the background, which helps the patient acclimate to his/her surroundings. After the user is acclimated to the environment, the nurse avatar will orient the patient to the situation, location, and time once the patient feels relaxed. Then, the patient will be instructed to use the controllers to perform mini-games with minimal physical movements to promote early mobility. These exercise "games," e.g., balloon popping, allow the patient to focus and pay attention to the game while helping reorient and cognitively stimulate the patient. The games are built with levels of increasing difficulty and complexity of user demand and output. The cognitive interventions are described in a stepwise fashion in the photographic presentation in figure -1.
**Conclusion:** ReCognition VR is a pilot software developed explicitly to enhance cognition's attention and reorientation domains, which are usually involved in mentally challenging tasks. The short-term goal of this project is to test the feasibility and acceptability of virtual reality-based cognitive exercises in enhancing attention and focus in healthy subjects. Contingent on promising results from healthy subject trials, the software can be expanded to be used on post-operative patients. The long-term goal of this project is to use a VR-based cognitive exercise program in clinical trials for neurological disorders involving attention and orientation domains of cognition such as delirium. It is hypothesized that early reorientation and cognitive stimulation of attention and focus can help improve prognosis and reduce the likelihood of these disorders.
References:


A Novel Dosing Algorithm for High-Dose Propofol Administration for the Treatment of Depression

Presenting Author: Carter Lybbert, B.Sc., University of Utah
Co-Authors: Brian J. Mickey, MD, Ph.D, Kai Kuck, Ph.D., Scott C. Tadler, MD, Jason Huang, M.S., University of Utah

Introduction: Recent evidence suggests that high doses of anesthetics produce significant and durable antidepressant effects in those with drug-resistant depression, comparable to the positive effects of electroconvulsive therapy (ECT) [1][2]. Maintaining a 70-90% EEG burst suppression ratio (BSR) for ~15 minutes seems to yield the strongest antidepressant effects [2]. To date, no dosing guidelines or algorithms have been published by any group to aid anesthesiologists in achieving 15 minutes of 70-90% burst suppression with the administration of these drugs in human subjects.

We have developed a novel dosing recommendation algorithm that gives anesthesiologists an estimate of the levels of Propofol that they will need to administer to a patient to achieve 70-90% BSR for 12-15 minutes. This algorithm is based upon the Eleveld pharmacokinetic/pharmacodynamic (PK/PD) model of Propofol [3], with some adjustments. The objective of this study was to assess how well these dosing algorithms perform in giving recommendations that achieve the desired BSR in participants.

Methods: Following IRB approval and informed consent, each of 13 participants (69% female, 29-51 years old, 52-119 kg) underwent 3-6 treatments of high doses of Propofol. This analysis represents a retrospective look at these treatments. Two separate algorithms were used for dosing the first treatment and all subsequent treatments. For the first treatment of every participant, mean values for Ke0, Hill and EC50 from all treatments, except for those of the particular subject for whom the dosing recommendation was being made, were used to estimate the PK/PD behavior of the drug. For subsequent treatments, Ke0, Hill and EC50 parameters were estimated based on a log-log linear regression of the second-by-second observed BSR of the most recent past treatment to the effect site concentration predicted by the Eleveld model for that treatment. Based on these model parameters, an iterative approach was then used to find an estimated bolus and infusion rate for Propofol that would achieve a 70-90% BSR target range for 12-15 minutes for that participant.

To assess the effectiveness of these a priori dosing recommendations, they were compared to retrospectively determined ideal dosing levels. These ideal dosing levels considered were the actual administered bolus size and mean infusion rate that the anesthesiologist administered during the treatment.

Results: We found that there was a MdAPE of 21.6% with an interquartile range of 38.8% between the recommended prospective and the retrospective ideal infusion rate and a MdAPE of 18.2% with a 35.1% interquartile range between the recommended and ideal bolus.

Discussion: The error of prospective dosing recommendations before treatments when compared to ideal dosing levels made based on retrospective data collected after the treatment is considerable. However, the error lies well within the 20% to 30% range that is considered acceptable for MdAPE of PK models alone [4]. Limitations of our findings include that the findings result from a relatively small sample size of participants and represent a secondary analysis of data from a study that was not primarily designed as a PK/PD modeling study.

Conclusion: This dosing model represents an imperfect but useful first prototype for dosing Propofol during high-dose anesthetic treatments for depression.

References:
CO-Oximetric Measurement of Left Innominate Vein Oxygen Saturation During Hypoxemia in Volunteers

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Background/Introduction: We previously used a noninvasive optoacoustic (OA) technique in volunteers to measure oxygen saturation (SO\textsubscript{2}) in the left innominate vein (LIV), which joins the right innominate vein to form the superior vena cava (1). OA monitoring of SO\textsubscript{2} in the LIV (SLIVO\textsubscript{2}) may represent a rapid, convenient method for assessing central venous SO\textsubscript{2} in patients in shock. In that study, progressive lower body negative pressure (LBNP) was associated with relatively well maintained SLIVO\textsubscript{2} until abrupt hypotension occurred, necessitating immediate termination of LBNP before measurements could be obtained. We hypothesized that graded hypoxemia, used by others to evaluate pulse oximeters (2), would produce stable reductions in SLIVO\textsubscript{2} measured by CO-Oximetry.

Methods: In a protocol approved by the institutional review board, LIV catheters were placed in 12 healthy volunteers. Pulse oximetry (SpO\textsubscript{2}), noninvasive blood pressure and ECG monitoring were monitored. Through a snug face mask, FiO\textsubscript{2} was changed in the following sequence: 0.21, 0.08, 0.18, 0.09, 0.17, 0.10, 0.16, 0.11, 0.15, 0.12, 0.21. After SpO\textsubscript{2} had stabilized at each FiO\textsubscript{2}, two blood samples were drawn at one-minute intervals and SLIVO\textsubscript{2} was immediately measured using a clinical CO-Oximeter. At study conclusion the LIV catheter was withdrawn. Two of 12 subjects became sufficiently uncomfortable that they did not complete the study sequence. SLIVO\textsubscript{2} and SpO\textsubscript{2} were correlated using the coefficient of determination (R\textsuperscript{2}).

Results: Because two subjects could not complete the protocol, the total number of measurements of SLIVO\textsubscript{2} and SpO\textsubscript{2} was 237. Decreases in SLIVO\textsubscript{2} correlated well with decreases in SpO\textsubscript{2} (R\textsuperscript{2} = 0.65) (Figure).

Conclusion: In volunteers, graded hypoxemia produces stable, highly correlated decreases in SLIVO\textsubscript{2}. Graded hypoxemia represents a suitable protocol for comparing hemoximetric measurements to optoacoustic measurements of SLIVO\textsubscript{2}.

Introduction: Inspired oxygen concentration analysis is a cornerstone of safe anesthesia delivery. Anesthesia machines use O2 sensors that convert current flow to a proportional O2 concentration readout. At our institution we use Dräeger Apollo and Perseus anesthesia machines (Lübeck, Germany) which have a baseline +/- 2.5% error margin for O2 measurement.

Methods: Each machine had a full checkout test performed prior to testing. A MaxO2 ME oxygen analyzer device (Maxtec, Salt Lake City, UT) was calibrated with 100% O2 in the same room as the machines immediately prior to testing. All three analyzers use galvanic cell technology. The machine’s adjustable pressure limiting valve was fully closed and the oxygen analyzer was attached via a tee-piece adaptor to the Y-piece of the anesthesia circuit. Testing was performed with the end-piece of the analyzer open to room air unless otherwise noted. A minimum of 3-minute equilibration time was allowed to elapse or until O2 analyzer readout was no longer changing prior to measurement.

Results: Table 1 summarizes the differences in O2 concentrations measured by each anesthesia machine’s built-in analyzer vs the external analyzer. Neither machine reported an O2 concentration of higher than 98%, regardless of flow rate of 100% O2. At lower flows, both machine’s built-in analyzers and external analyzer O2 readings began to decrease.

Discussion: As our empirical testing demonstrates, the anesthesia machine’s built-in oxygen analyzer reported oxygen concentration has a flow dependent difference compared to measurements made by an independently calibrated oxygen analyzer at the Y-piece. Accurate measurement of inspired oxygen concentration is important in a variety of clinical scenarios: lower FiO2 may be desired when risk of airway fire is high (e.g., use of electrocautery or laser), avoidance of oxidative stress (e.g., to avoid retinopathy of prematurity in neonates), and an accurate measure of FiO2 is critical for safe use of low flow anesthesia. Higher FiO2 may be desired in patients with poor oxygenation (e.g., ARDS) or requiring additional reserve (preoxygenation). Clinicians should be aware that there is a margin of error measurement in the anesthesia machine’s built-in oxygen analyzer and titrate flows appropriately based on desired clinical effect. Additionally, the measured oxygen concentration is flow dependent and can be influenced by dilutional effects. It may be of value to compare other makes and models of anesthesia machines in their range of accuracy to monitor FiO2 at different clinically relevant flow rates.

Table 1: Comparison of anesthesia machine’s built-in O2 concentration measurements vs external oxygen analyzer measurements with 100% O2 at varying flows

<table>
<thead>
<tr>
<th>O2 Flow (L/min)</th>
<th>Dräeger Apollo O2 (%)</th>
<th>O2 at Y-Piece (%)</th>
<th>Dräeger Perseus O2 (%)</th>
<th>O2 at Y-Piece (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15, circuit fully occluded</td>
<td>-</td>
<td>-</td>
<td>98</td>
<td>100</td>
</tr>
<tr>
<td>8</td>
<td>98</td>
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<tr>
<td>0.5</td>
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<td>95</td>
</tr>
<tr>
<td>0.2</td>
<td>96</td>
<td>96</td>
<td>92</td>
<td>82</td>
</tr>
<tr>
<td>0.2, circuit fully occluded</td>
<td>-</td>
<td>-</td>
<td>93</td>
<td>96</td>
</tr>
</tbody>
</table>

References:
3. Instructions for use Apollo. Anesthesia Workstation Software 4.5n. p297. https://www.draeger.com/Products/Content/IFU_Apollo_SW_4.5n_9055395.pdf  
Abstract Title: Validity of Non-Contact technology for Diagnosis of Sleep-Disordered Breathing: A Systematic Review & Meta-Analysis

Presenting Author: Sahar Zarabi BHSc, MD Candidate (2022)

Co-Authors: Khalil C (BHSc, MD Candidate ‘23), Soni V (BHSc Candidate ‘23), Li Q (BSc, MSc), Yadollahi A (PhD), Taati B (PhD, PEng), Kirkham K (MD, FRCPC), Singh M (MBBS, MD, MSc, FRCPC).

Affiliations: 1. University of Toronto; 2. McMaster University; 3. Biostatistics Research Unit, University Health Network; 4. Department of Computer Science and Institute of Biomedical Engineering, UT; and KITE-Toronto Rehabilitation Institute (TRI), University Health Network; 5. Department of Anesthesiology and Pain Medicine, WCH, and TWH, University Health Network

BACKGROUND Obstructive Sleep Apnea (OSA) is a known perioperative risk factor impacting many body systems including cardiac, respiratory and neurological functions. OSA is highly prevalent yet significantly under-diagnosed with roughly 82-93% of surgical patients with OSA not having a formal diagnosis. This can lead to adverse patient outcomes in a perioperative setting. Polysomnography (PSG, gold standard test) is costly, and resource intensive. Pre-operative OSA diagnosis is currently utilized by way of screening questionnaires (high sensitivity, but poor specificity), and more accurate screening tools are needed that are portable, and can provide non-contact assessment of OSA severity, more objectively. The objective of this systematic review and meta-analysis is to evaluate the utility of non-contact methods used in the diagnosis of obstructive sleep apnea, and their diagnostic accuracy as compared with the gold standard PSG.

METHODS A systematic search of MEDLINE, EMBASE CENTRAL, and Cochrane Central Register of Controlled Trials (CENTRAL) was conducted from database inception to March 2021. Both published and unpublished trials were searched. Inclusion criteria were observational cohort and randomized controlled trials of adult patients undergoing OSA diagnosis concurrently with both PSG and a non-contact method. Only English language literature was searched. Two independent reviewers completed the article screening, data extraction, and summarization. Conflicts were resolved by consulting the senior author. Diagnostic properties and association between non-contact methods (index test) and OSA diagnosis using apnea-hypopnea index (AHI) determined by a PSG (reference standard) were evaluated. Summary receiver operative curves were generated wherever applicable. Risk of bias assessment was done using the QUADAS tool.

RESULTS Our search yielded 4929 studies, of which 23 cross-sectional cohort studies were included in the meta-analysis. Overall, a total sample size of 1232 participants were included, with the vast majority being patients referred to sleep clinics (79%). The average age of participants was 50.7 years, female sex (35%), average BMI of 30.25, average AHI of 23.54 events per hour, and pooled OSA prevalence of 69%. The pooled sensitivity and specificity of non-contact methods in diagnosing OSA (AHI > 5 events per hour) was found to be 0.846 (95% CI 0.771-0.900) and 0.829 (95% CI 0.764-0.878). Overall heterogeneity was low ($I^2$ 15.39%). The majority of the devices used 1) video analysis, 2) sound analysis, 3) biomotion sensors. Risk of bias assessment showed an overall low risk of bias for reference standard, flow and timing and low-moderate risk for index test, applicability concerns, and patient selection.

CONCLUSION The results of this study show that contactless methods have the potential to revolutionize the field of sleep medicine through a convenient, affordable, and accessible approach in diagnosing sleep disordered breathing. This is highly relevant in a perioperative setting where patients can be readily assessed for OSA prior to their elective surgery, leading to safer planning and management of their anesthetic care. Further subgroup analysis of the various types of technology including video, sound, and biomotion sensor is warranted.
Table. Pooled results of overall sensitivity and specificity

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<table>
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<tr>
<td>Sensitivity</td>
<td>0.846 (0.771,0.9)</td>
<td></td>
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<tr>
<td>Specificity</td>
<td>0.829 (0.764,0.878)</td>
<td></td>
</tr>
<tr>
<td>Prevalence</td>
<td>0.688 (0.583,0.776)</td>
<td></td>
</tr>
<tr>
<td>AUC</td>
<td>0.898</td>
<td></td>
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<tr>
<td>Higgins’ I²</td>
<td>15.39%</td>
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Figure. Summary receiver operative curve (SROC) for OSA diagnosis (AHI>5 events per hour), and contactless methods used.

References


Abstract Title: A RANDOM FOREST CLASSIFIER FOR PREDICTING CEREBRAL VASOSPASM FOLLOWING SUBARACHNOID HEMORRHAGE

Presenting Author: David Zarrin, MSE¹
Co-authors: Bayard Wilson, MD², Bilwaj Gaonkar, PhD², Luke Macyszyn, MD², Eilon Gabel, MD, MHA³
Affiliations: David Geffen School of Medicine at UCLA¹, Department of Neurological Surgery at UCLA². Department of Anesthesia and Perioperative Medicine at UCLA³.

Background: Cerebral vasospasm (CV) is a life-threatening phenomenon in patients with subarachnoid hemorrhage (SAH), and is of critical importance since it contributes to delayed cerebral ischemia (DCI) and concomitant morbidity and mortality in this population¹. It is standard clinical practice to admit patients post-SAH to an intensive care unit (ICU) for 14-21 days following SAH for close monitoring and potential intervention for clinically significant CV. Since current monitoring capabilities cannot determine which patients with SAH ultimately develop CV, considerable hospital resources are consumed supporting and observing many patients with SAH who never develop CV². In this context, our group was motivated to explore the feasibility of using machine learning to predict CV in patients following SAH using routinely measured clinical values, with the end goal of guiding clinicians to monitor patients with a level of vigilance commensurate to their actual risk for complication. Herein, we train and validate a random forest classifier for the prediction of CV warranting angiographic intervention using several clinical measures from the electronic medical record (EMR).

Methods: Using the Perioperative Data Warehouse³, we extracted EMR data from ICU patients who were admitted for SAH at our institution between 2013 and 2021. Time-series of blood pressure (BP), laboratory sera (sodium, albumin, hemoglobin, glucose, creatinine, potassium, and chloride), and intracranial pressure (ICP) were extracted for the entire hospital admission for qualifying patients. CV was defined as angiographic vasospasm warranting intra-arterial verapamil infusion. All datapoints proceeding verapamil administration, unavailable datapoints, and datapoints within time-series with fewer than 100 datapoints at the time-of-prediction were excluded. Each time-series was condensed to a 21-dimensional feature vector by extracting measurements at various percentiles. A random forest classifier was subsequently trained to predict CV based on the described distributions and its predictive power was validated using a five-fold cross validation within the study cohort at 240, 720, 1440, 2160, 2880, and 3600, 4320 minutes prior to verapamil injection. Receiver operator characteristic (ROC) curves and the associated areas under each curve (AUC) were computed to assess predictive power.

Results: A total of 1,534 SAH patients (average age 51.3 years, 45% female) were identified; 1,027 contained complete datasets and were included. Sample sizes at times-of-prediction ranged from 82 to 72 patients based on the count of patients with at least 100 datapoints available. Sample sizes and AUCs for each predictive model at each time interval prior to verapamil injection are shown in Table 1.

Conclusion: Our findings indicate that a random forest classifier trained on ICP following SAH is a strong predictor of cerebral vasospasm necessitating verapamil injection up to three days prior to injection (average AUC=0.81). Furthermore, the same classifier trained on BP and laboratory sera achieved less predictive power than when trained on ICP. This report details, to our knowledge, the first machine learning-based approach to strongly predict severe cerebral vasospasm requiring verapamil administration based on routine clinical measurements in the literature.

References
Characterizing Precordial Doppler Audio in Patients Receiving Agitated Saline Injection During Echocardiography
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Department of Anesthesiology, University of Florida College of Medicine, Gainesville, Florida

Introduction
Precordial doppler ultrasound is one of the many tools anesthesiologists can use to monitor patients that are undergoing a variety of intracranial procedures in the sitting semi-setting or reverse Trendelenburg positions, which carry risk for venous air embolism (VAE). Incorporation of a software component that could independently monitor the precordial doppler ultrasound and alert the anesthesiologist of possible air entrainment via doppler signal interrogation would provide an excellent opportunity for earlier detection and treatment of a VAE. Generation of such a piece of software necessitates the collection of data to characterize the various potential sound qualities of VAE. Therefore, the goal of this study is to record and characterize precordial doppler ultrasound audio in patients who undergo echocardiogram with agitated saline microbubble test, which is a small VAE.

Methods
With IRB approval, patients undergoing elective bubble studies at UF Health Gainesville for other indications were consented and enrolled in the study. A precordial doppler ultrasound was placed over the right atrium/ventricle of the study participant’s during the echocardiography exam. The doppler audio was continuously recorded before, during and after the injection of agitated saline. The recordings were analyzed using Audacity (Muse Group) to measure transient changes in doppler intensity and frequency before, during and after the microbubble study.

Results
14 patients were recruited for the study. Data was evaluated for normality and met assumptions. A paired t-test was used to compare pre and post injection doppler intensity. Mean normalized standard deviation of post injection sound intensity (0.0311) was significantly higher than that of pre injection (0.0059) (p-value 0.0065) (SE: 0.00831) (Table 1). A matched pairs t-test was used to compare mean pre-injection doppler frequency per heartbeat with mean post-injection doppler frequency per heartbeat at the maximum doppler intensity. Results shows that mean post-injection frequency (859 Hz) was found to be significantly higher than mean pre-injection frequency (417 Hz) (p< 0.0001) (Table 1).

Discussion
Standard deviation of the mean was chosen as the method to compare changes in doppler intensity due to the symmetry the data had with the x axis (the average intensity over time would have been near 0). The standard deviation of the doppler data between patients was high, which we suspect is a result of a combination of probe placement, patient variability and potential variability of agitated saline quality, which is a limitation in our study. We also noted that despite clear heart sounds pre injection of agitated saline, doppler probe placement on the patient’s right sternal border sometimes failed to produce significant changes in doppler audio intensity. Additionally, when attempted, probe placement on the patient’s left sternal border was able to consistently pick up significant changes in doppler audio, even
when placement on the right side on the previous attempt had failed to. Despite a high standard deviation, the results show a clear and quantifiable distinction between absent vs present bubbles with a transient fivefold increase in doppler intensity and a twofold increase in doppler frequency at peak intensities (Figures 1 and 2). This data could be used to drive alarm parameters in monitoring software for VAE. Future work will look at integrating these doppler parameters into software detect and alert for early VAE.

<table>
<thead>
<tr>
<th>Sound Quality Analyzed</th>
<th>Trials</th>
<th>Average Normalized Standard Deviation ± Standard Deviation</th>
<th>P-value (Paired t-test)</th>
<th>Sound Quality Analyzed</th>
<th>Trials</th>
<th>Mean ± Standard Deviation (Hz)</th>
<th>P-value (Paired t-test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensity</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Pre-Injection (n = 14)</td>
<td></td>
<td>0.0059 ± 0.0071</td>
<td>0.019</td>
<td>Frequency</td>
<td></td>
<td>417 ± 123</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Post-Injection (n = 14)</td>
<td></td>
<td>0.0311 ± 0.0252</td>
<td></td>
<td></td>
<td></td>
<td>859 ± 51</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1.** Intensity and frequency analyzed before versus after microbubble saline injection
Figure 1. Intensity and frequency plots of trial 4. (A) Plot of normalized intensity vs. time (sec) and (B) plot of frequency (Hz) vs. time (sec). Transient increases in doppler intensity and frequency can be clearly distinguished post-agitated saline administration.
Figure 2. Doppler Frequency vs Intensity for Trial 4. Clear shifts in doppler frequency and intensity can be noticed during the presence of microbubbles after administration of agitated saline.
Development of a Risk Communication Tool for Postoperative Pain – Design Requirements Indicated by Clinicians, Families & Patient Partners

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Affiliation. 1. Dept. of Anesthesiology, Pharmacology, & Therapeutics, University of British Columbia (UBC); 2. BC Children’s Hospital Research Institute; 3. School of Information, UBC; 4. Dept. of Psychology, UBC; 5. Patient Partner; 6. Dept. of Pediatrics, UBC

BACKGROUND. Approximately 1 in 5 children have persistent postoperative pain at 12 months following surgery [1], which can substantially affect their quality of life, frequency of hospital visits, opioid consumption, and overall trust in the healthcare system [2]. Pain management has been identified as a key area for improvement at BC Children’s Hospital (BCCH) [3]. Although some risk factors for postoperative pain are known, there is limited evidence of the use of personalized risk calculation and communication [4], suggesting an opportunity for substantial improvement.

OBJECTIVES. As part of a larger project to develop individualized pediatric pain risk prediction, we aim to design an easy-to-use communication tool, for use by clinicians and families, to present a child’s risk of developing postoperative pain. In this study, we aimed to identify the requirements of our expected end-users for this tool and establish a means to visualize the inherent uncertainties resulting from the use of risk prediction models.

METHODS. We conducted focus groups with families (parents of children who had recently undergone surgery or a diagnostic procedure at BCCH), patient partners (with lived pediatric surgical experience), and clinicians (with expertise in postoperative pain), to gain insights into current risk communication practices and obtain feedback on example risk communication tool designs found in the literature. Focus group sessions were held virtually using Zoom videoconferencing, were conducted separately by participant type (clinicians or families/patient partners) in groups of 3-4 participants, and lasted approximately 1-hour. Data were analyzed thematically using NVivo (QSR International, Melbourne, Australia) to create design requirements. A prototype was created using Figma (Figma Inc, San Francisco, CA) to enable rapid co-design of future iterations.

RESULTS. Nineteen participants attended six focus groups: 10 clinicians, 2 patient partners, and 7 family members. Most participants (15/19, 79%) were female, with 13/19 (68%) aged under 49 years. Participants indicated that risk is typically communicated verbally to patients and their families using severity descriptions and/or a numerical representation, which may be contextualized, and that risk communication tools were seldomly used in practice. Participants believed that families should be provided with risk information and subsequently allowed time to reflect and follow up with questions or concerns. Participants identified five key design requirements 1) present risk in a non-threatening and non-frightening manner using human-centered design principles (e.g. color coding that accounts for color vision impairment); 2) provide risk information in a multimodal format to ensure user comprehension (e.g. visual representation of risk, clear and concise text to contextualize and explain the risk score, and a severity index); 3) include the top variables in the model that contribute to the patient’s risk to increase transparency; 4) provide a checklist to guide the clinical conversation around risk comprehension; 5) include educational resources and risk mitigation strategies to empower families and provide a sense of agency over their care. A prototype was designed based on these preliminary requirements (Figure 1).

CONCLUSIONS. Co-design workshops will soon be held to gather and apply participant design ideas, get feedback regarding the current prototype and re-design, followed by tool usability evaluations. Although further work is needed, designing and implementing risk communication tools into clinical practice may help to alleviate the discrepancy between the accessibility, utilization, and comprehension of personalized risk information by patients, families, and healthcare professionals.

THE DEVELOPMENT OF NON-CONTACT ‘TOUCHLESS’ MONITORING OF RESPIRATORY RATE

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Introduction: The measurement of respiratory physiological parameters is ubiquitous in the hospital setting. Of these, respiratory rate (RR) is the most prevalent and often forms an essential component of many early warning clinical scoring systems [1]. Changes in RR are often one of the earliest and more important indicators that precedes major complications such as respiratory tract infections, respiratory depression associated with opioid consumption, anesthesia and/or sedation, as well as respiratory failure [2–4]. Here, we report on the performance of a depth-sensing camera system [5] for the continuous non-contact ‘touchless’ monitoring of Respiratory Rate (RR).

Method: Six 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, 265 separate rates were captured across a range of conditions including posture (prone, supine, lateral), position (center and edge of bed) and coverings (no sheets, sheets, duvet). An Intel D415 depth camera was used to acquire depth information from a field of view centered on the subject torso. This data was processed to extract the localized depth-changes within the torso region of the subject corresponding to respiratory activity. This was further processed to produce a respiratory rate RR\text{depth} output once-per-second from the device. RR\text{depth} was compared to a capnograph reference, RR\text{capno}.

Results: Figure 1 contains a bubble plot of RR\text{depth} versus RR\text{capno} for all subjects and tests. An RMSD of 1.74 BrPM (mean bias of -0.13 BrPM) was achieved across the target RR range of 4-40 BrPM.

Conclusions: These early-stage results are encouraging and exhibit similar accuracies to earlier studies we have conducted [6,7]. However, the current results extend over a much wider range than those previous studies. We believe that “non-contact”, or “touchless”, monitoring has great potential for the future. We continue to iterate on our algorithm to improve its performance and robustness.

References

The Role of Point of Care Viscoelastic Testing in Hemorrhaging Obstetric Patients

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**Background:** Post-partum hemorrhage (PPH) is a major cause of maternal morbidity and mortality. Worldwide PPH accounts for at least 30% of all maternal deaths. PPH is defined as blood loss of more than 1000 mL within 24h after vaginal delivery or cesarean delivery. Fibrinogen is a critical factor of hemostasis during PPH and it is recognized as the most sensitive and earliest predictor of severe hemorrhage. Whereas the gold standard laboratory testing for obtaining fibrinogen level (Clauss Fibrinogen) can take up to one hour whereas Point of Care Viscoelastic Testing (POCVT), provides fibrinogen function within 10 min. The aim of this study is to determine the correlation between Clauss Fibrinogen and fibrinogen function measured by; FIBTEM A10 (Fibrinogen ThromboElastoMestery amplitude at 10 min) and the CFF-MA (Citrated Functional Fibrinogen – Maximum Amplitude) from the Rotational thromboelastometry (ROTEM) and the thromboelastography (TEG6) devices, respectively as shown in figure 1-A. The secondary aim was to compare FIBTEM A10 to CFF-MA.

**Methods:** We obtained 2 blood samples from 48 pregnant women without comorbidities for the coagulopathy assays: ROTEM, TEG6s, and the lab coagulation test. Each fibrinogen equivalent (FIBTEM A10, CFF-MA, and Clauss fibrinogen as gold standard) was compared with each other through Pearson’s correlation coefficients. The cutoffs for the coefficients were determined as 0.30 to 0.50 as low, 0.50 to 0.70 as moderate, 0.70 to 0.90 as high, and 0.90 to 1.00 as very high.

**Results:** The Clauss fibrinogen and FIBTEM A10 had a Pearson’s 2-sided t-test of r = 0.76; Clauss fibrinogen to CFF-MA was r=0.72. The fibrinogen values of the POCVT devices had a correlation of r = 0.88, P <.0001 (as shown in figure 1-B, C, D)

**Discussion:** The high correlation between CFF-MA and FIBTEM-A10, and the Clauss Fibrinogen, makes these devices ideal for the early recognition and management of hypofibrinogenemia. The main advantage of POCVT is that it allows for goal directed blood product management instead of formulaic blood product management (the traditional 1:1:1). Recent reports demonstrated a rising trend in severe maternal morbidity during US delivery hospitalizations that was attributable largely to the increased use of blood transfusions. Furthermore, decreased blood product transfusion related to utilization of POCVT has been shown to decrease both morbidity and hospital costs by decreasing blood transfusion complications (e.g. transfusion circulatory overload) and intensive care unit admissions.

**Conclusion:** The use of POCVT will not only provide patients with personalized care, but it will also save hospital resources and ease the financial burden of PPH on the healthcare system. Furthermore, TTEG-6s is simple, self-contained cartridge system, thus decreases operator variability. This study is still under collection, the goal is to delineate the baseline parameters for pregnant women to create an algorithm for management of PPH based on goal directed blood product transfusion.

**References:**

1.*Khan KS, et al. The lancet.* 2006; 367(9516):1066-74  
Figure 1: (A): Picture of devices TEG-B (left) and ROTEM (right) (B): FIBTEM A10 vs fibrinogen level (C) CFF MA vs fibrinogen level (D) CFF- MA vs. FIBTEM-A10
Introduction: The COVID-19 pandemic has advanced market awareness of the benefits of remote-controlled ventilators to reduce the exposure of healthcare workers to patients with COVID-19, enable more rapid and frequent ventilator setting adjustment, and preserve limited personal protective equipment. The US FDA permitted manufacturers to add remote monitoring and control capabilities to ventilators and infusion pumps through immediate in effect guidance [1,2]. When integrated with tele-critical care systems, remote control of medical devices allows distant clinical experts to collaborate with local clinicians to “virtually” manage the therapy of patients at hotspots. Core remote control capabilities can also be used by software applications to implement medical device control algorithms for Software as a Medical Device (SaMD).

The US Army /TATRC launched the National Tele-Critical Care Network (NETCCN) to rapidly develop and deploy a platform to support COVID-19 disaster response [3]. We are investigating technical solutions, communication protocols, and safety assurance measures for integrating remote control of medical devices to the NETCCN systems.

Methods: We developed an architecture and a prototype system (Figure 1) to investigate safety, security, and interoperability requirements for integration of remote control of medical devices with tele-critical care systems. The prototype system is based on OpenICE [4], an open-source interoperability platform developed by our program to transmit data and control medical devices at the patient’s bedside. Customized interfaces (hardware and software) translate device proprietary protocols to ISO/IEEE 11073-10101 terminology over DDS middleware.

Remote control applications of devices connected to OpenICE are implemented as either stand-alone OpenICE apps, which can be deployed inside or immediately outside the patient’s room, or as web-based apps, which can be launched from any location to communicate with the OpenICE system. We refer to the former as “near-patient remote control”, which may be at the bedside or co-located outside the room, and the latter as “far remote” control where the operator does not have physical access to the patient or medical equipment. Our prototype system uses the RTI Web Integration Service [5] to enable web-based control applications to communicate with the connected devices.

Results: The generic architecture in Figure 1 is device agnostic: it can be used with critical care ventilators, IV infusion pumps, and other devices, provided that the device interfaces support remote control. As a proof of concept, we applied this architecture to a Q Core Sapphire IV infusion pump using a non-clinical control interface, and confirmed that the infusion rate could be adjusted by both near-patient and far remote (web) control applications with generally acceptable delays (3–8 seconds from remote control action until the pump executes the change). This prototype system allows the exploration and validation of risks associated with medical device remote control in the tele-critical care context. An example of a risk identified in our study relates contention between near and far “lo ci of control”. Unexpected device behavior can occur if there is no mechanism to 1) explicitly prioritize loci of control that may occur simultaneously (e.g., always prioritize local control over far control to enable the local provider to regain control or prevent remote control); and 2) clearly indicate where the locus of control resides.

Other risks may arise due to issues related to cybersecurity, network QoS, permission for remote control, and usability (e.g., use errors associated with far remote control due to the lack of a real-time view of the patient). We are collaborating with the AAMI InterOperability Working Group (IOWG) to share the experience and lessons learned in this effort to develop a safety standard for medical device remote control, and with other performers in the NETCCN portfolio.

References:

4. Arney, D, Plourde, J, Goldman, JM. OpenICE medical device interoperability platform overview and requirement analysis. Biomedical Engineering / Biomedizinische Technik 2017,0040

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Acute Lung Injury in Trauma and Critical Illness - Reducing Unsafe Manual Ventilation Practices with a Mechanical Flow Limiter

Authors

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Ventilating with a BVM is considered a basic skill that the most inexperienced provider is expected to perform proficiently. (2) However, there is no feedback mechanism or method of control for the volume, pressure, or frequency of ventilation. (1) During positive pressure ventilation, peak inspiratory pressure (PIP) and Tidal Volume (TV) must be kept at optimal levels to achieve appropriate ventilation without causing complications, such as trauma to the lung parenchyma (3,8), aspiration (9), or stomach insufflation. (4,6,7) In the first component of this 2-part study we aim to quantify the ventilation parameters of each breath delivered by EMS personnel in a simulated model. Volunteers were requested to manually ventilate a simulated manikin using a BVM while observing chest rise. Ventilation parameters including respiratory rate, tidal volume, and peak pressure were gathered every 10 milliseconds. We found that the majority of providers delivered inadequate breaths that were outside of desired TV and PIP levels. The second leg of this study used a lung simulator and volunteer medical students, medics, and nurses to assess whether the pressure and flow limiting Sotair™ safety accessory (5) resulted in more appropriate TVs and PIPs during manual ventilation. Using mechanical ventilation as a base line, we compared BVM only ventilation in both normal and abnormal compliance settings to simulate healthy and diseased lung states. We found that the Sotair™ safety accessory helped maintain PIP and TV closer to mechanical ventilator baseline levels than BVM only ventilation across lung compliance settings. The Sotair™ safety accessory also helped providers maintain PIP levels below the threshold of pressures known to cause gastric insufflation and barotrauma. Together this data indicates the need for a BVM ventilation mitigating device as well the efficacy of the Sotair™ device as a safer option than unmitigated BVM only ventilation in both normal and decreased lung compliance conditions.
Figure 1: Peak Inspiratory Pressure (PIP) and Tidal Volume (TV) delivered at normal and decreased lung compliance conditions, both with and without the Sotair™ device. Each dot represents an individual breath delivered. PIP and TV with the Sotair™ device (Green dots) more closely resemble mechanical ventilator baseline data (blue lines) than bag only ventilation (Red dots).
References


5. *safeBVM | Technology*. 2019


A Secure Interoperability Platform to Facilitate Anesthesia Technology Innovation

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Introduction: With the improvement of data integration capabilities, medical devices connected to “software as a medical device” apps can accelerate the development and deployment of anesthesia technology innovations. For example, a closed-loop control algorithm to maintain a target depth of anesthesia or blood pressure can be rapidly prototyped and evaluated (either in-silico or hardware-in-the-loop) if implemented on an open health platform (OHP) where the interaction of algorithms and candidate infusion pump and monitors is managed.

OHPs need to demonstrate acceptable safety, security, and reliability when they are used to compose medical systems, especially when algorithms, devices, and sensors are from different vendors. As cybersecurity concerns have grown in healthcare, securing these platforms has become one of the deciding factors for their adoption.

We developed an OHP complying with the Integrated Clinical Environment (ICE) architecture defined in the AAMI 2700-1 standard [1]. It incorporates a rich library of device interfaces, simulated devices, example clinical algorithms, and utility apps to support R&D of interoperable medical systems [2]. Within OpenICE, medical devices, clinical and utility apps and other supporting equipment (such as a database for data logging) communicate with each other using the RTI Connext DDS network middleware [3] in which entities in the system communicate in a publish-subscribe paradigm - entities publish their data to pre-specified topics while consumers of such data subscribe to these topics to receive the published data.

Methods: Even though RTI’s latest Connext DDS middleware (version 6.0.1) provides a collection of security capabilities at the network layer, such as encryption of data communication, we have established a holistic approach to security controls at the platform level for authentication, authorization, and access control of entities (i.e., devices, apps, users, and equipment) with the intention of generalizing this knowledge to assess other OHPs.

Our approach implements security controls for the following entities:

- **User Security**. A mechanism has been added to lock the screen after user inactivity for a configurable period and re-authenticate when the user logs back in, including requirements accommodating multiple caregivers and handoffs.
- **Device Security**. Devices with security credentials issued by trusted Certification Authorities are allowed to connect to the system. Medical devices need to present permission files issued by CAs that prescribe the security keys to decrypt the DDS network communication and the topics to which the devices can publish or subscribe. Attempts to communicate data beyond the permission files will be rejected by the DDS middleware. This achieves topic-level, fine-grained access control of connected devices.
- **App Security**. We implemented an anti-compromise check of apps during system startup, where the Message Authorization Code (MAC) of each app is checked for potential compromise. A mismatch between an app’s JAR file and its MAC will prevent the app from being launched.

Conclusion: We were able to use secure OpenICE as the basis of a DDS reference implementation of JHU APL Medical Device Interoperability Reference Architecture [4] and we will be using it to pilot remote ventilator control and closed-loop sedation systems. The secured OpenICE platform is freely available for public use [5].

References:

1. AAMI, AAMI 2700-1 Medical Devices and Medical Systems - Essential safety and performance requirements for equipment comprising the patient-centric integrated clinical environment (ICE) - Part 1: General requirements and conceptual model, 2019.
4. [https://secwww.jhuapl.edu/mdira](https://secwww.jhuapl.edu/mdira)
5. [https://github.com/mdpnp/mdpnp/releases/tag/SecureOpenICE](https://github.com/mdpnp/mdpnp/releases/tag/SecureOpenICE)

This work was supported under the U.S. Army Medical Research Acquisition Activity Contract W81XWH-17-C-0251. 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 the Army position, policy or decision unless so designated by other documentation.
RESPIRO: THE WASTE ANESTHETIC SCAVENGING DEVICE

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Co-Authors: Alice Karp, B.S. Biological Sciences. Corey Jameson, M.F.A Printmaking, M.S. Industrial Design. Delara Kiani, B.S. Bioengineering, M.S. Industrial Design

Introduction: My team’s project focus was on mitigating the exposure of medical personnel to waste anesthetic gases. Inadequate mask fit, patient anatomy, and other factors are all sources that may cause providers to be exposed to waste anesthetic.¹ Short term exposure to hospital staff may cause headaches and cognitive impairment, while the long term exposure may be more serious. Staff exposed over a long period of time may be more likely to suffer from a miscarriage, congenital defects in their children, liver damage, and kidney damage.²,³

Methods: In order to find a solution to this problem, we utilized the design thinking process of empathize, define, ideate, prototype, and test. My team empathized with providers exposed to waste anesthetic and defined the problem as waste anesthetic escaping from the mask during induction. We believed this problem to be a major contributing factor to waste anesthetic and one where we could design a product to solve this. Utilizing rapid 3D printing, multiple designs were created to determine the ideal size and shape in order to trap waste anesthetic and scavenge it away. The design also had to not interfere with the providers hand placement and grip.

Results: Our project, titled Remora, is a transparent, flexible, and disposable outer shell which attaches to existing anesthesia masks. Remora consists of a soft outer frame that is designed to trap any waste anesthetic gas for the inner more ridged frame that scavenges the gas. To attach the device, simply remove the paper tab to expose the adhesive and press Respiro onto the brim of the anesthesia mask. It is then able to be attached to an existing suction port on the anesthesia machine to scavenge waste anesthetic away from the breathing zone of the provider.

Conclusion: Remora is a valuable addition to any basic anesthesia circuit kit and can easily be added to existing products. The design is made to not infer with the provider while also protecting them from potential long term effects. While our device is designed for adult sized anesthesia mask, my team and I wish to continue research and develop to create a version for pediatric masks, where gas induction is used more frequently. My team and I currently have a provisional patent for Respiro and with the help of Thomas Jefferson University have filed for a full U.S. patent.

References
Abstract Title: DESIGN AND IMPLEMENTATION OF AN EHR-BASED PROPOFOL DECISION SUPPORT TOOL FOR TOTAL INTRAVENOUS ANESTHESIA

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Introduction: Propofol-based total intravenous anesthesia (TIVA) is used increasingly due to its smaller carbon footprint compared to inhalational anesthesia and association with decreased incidence of post-anesthesia nausea and emergence delirium. Propofol must be drawn up into syringes from vials for each patient and large volumes of propofol are often wasted for short procedures because only 10 mL and 50 mL vials are available. Clinicians also often use a “set-and-forget” approach to propofol dosing, resulting in over-dosing and delayed anesthesia emergence. Thus, we designed and implemented a propofol dosing calculator in our electronic health record (EHR) system to display anticipated propofol volume to draw up for each case and guide dosing changes to maintain a target effect site concentration of 3 mcg/mL. We calculated the potential propofol savings that would have occurred if this tool had been used.

Methods: A team of EHR analysts and clinical champions designed and implemented a propofol dosing tool in the EHR (Epic™, Verona, WI). Patient weight and age are used to generate a table of total anticipated propofol volume based on expected infusion duration. An age-appropriate dosing table based on pharmacokinetics and electroencephalography was generated. Estimated propofol saved using the dosing tool was calculated for microlaryngoscopy and bronchoscopy (MLB), a common short procedure usually performed with TIVA, from January 1 to June 17, 2021.

Results: The tool was built and added to the EHR pre-procedure navigator (Figure 1). During the study period, 117 MLBs were conducted in patients with mean age 3.8 years, mean weight 16 kg, and mean procedure duration 44 minutes. The standard approach consists of drawing up 50mL propofol; the tool recommends 25 mL of propofol. Given a hypothetical (nonsensical) scenario of 100% adherence and all patients with the mean characteristics, a total of 2.9 L of propofol could have been saved using the tool for MLBs.

Conclusion: An EHR-based propofol decision support tool is feasible and can potentially optimize propofol dosing, infusion management, and drug usage. Future plans include measuring the use of the tool, collecting user feedback, and comparing propofol use and dosing with and without the tool.
# Propofol Dosing

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Adoption of Mobile Technology in Anesthesia Workflows: A Quantitative and Qualitative Analysis

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Introduction: Healthcare providers have access to new technologies to assist in improving efficiency and effectiveness of care. Electronic medical records (EMRs) as accessed through desktop-based applications are widely available in major academic medical centers, while mobile-based applications are a more recent development. Mobile-based EMRs offer providers convenient access to information regarding patient investigation status and conditions¹. Within anesthesiology, EMRs can serve as anesthesia information management systems and patient handoff guides. The usage of and barriers for mobile EMRs within the anesthesia workflow have not been well explored previously and is the focus of this present study.

Methods: We performed a qualitative and quantitative analysis of mobile EMR usage by clinical providers within the Department of Anesthesiology at Vanderbilt University Medical Center (VUMC). VUMC utilizes Epic as its EMR, and Haiku is Epic’s mobile application for providers. Data collected for this study include user role, National Provider Identifier (NPI), SmartTool usage, and recent Epic Haiku application usage for the department. Provider NPIs were used to query the NPPES NPI Registry for provider gender and NPI enumeration date, which was used to estimate years in practice. Provider usage of personalized SmartTools, including SmartPhrases, SmartTexts, and SmartSets, was extracted from the EMR and used to generate a score from 0 to 4 to serve as a proxy for technology savviness. A multivariate logistic regression was fitted to the data. A 16 item questionnaire was adapted from an existing, validated instrument, using a modified Delphi method². The questionnaire was distributed to Haiku non-adopters, defined as providers who had not logged into Haiku within the past 30 days. The questionnaires were completed between April and May 2021 and the frequency distribution of questionnaire responses were analyzed.

Results: 490 clinical providers were identified in the Department of Anesthesiology. 107 Student Registered Nurse Anesthetists were excluded due to lack of NPIs. Of the remaining 362, there were 88 physicians (24%), 72 residents (20%), and 202 Certified Registered Nurse Anesthetists (CRNA; 56%). 266 providers (73.5%) had recently used Haiku, 55 (15.2%) had not recently used Haiku, and 41 (11.3%) had never used Haiku. Using a multivariate logistic regression, only provider role of resident (odds ratio, 3.55; 95% CI, 1.30 - 9.71; P < 0.05) and CRNA (odds ratio, 2.06; 95% CI, 1.10 - 3.85; P < 0.05) increased the likelihood of recent Haiku use. Logistic regression fit parameters are shown in Table 1. 27 questionnaires were completed out of 107 sent with a response rate of 25.2%. Among non-adopters, 16 (59%) disagreed that Haiku would improve job performance, 15 (56%) were worried about draining phone battery and having VUMC applications on their personal phone. 17 providers (63%) would use Haiku if provided a smartphone for that purpose.

Conclusion: Provider characteristics including resident or CRNA role increase the likelihood of mobile EMR use. Non-adopters do not believe that mobile EMR use would increase job performance. Institutionally provisioned devices are likely to increase use of mobile EMR within anesthesia workflow.

Abstract Title: Urine oxygen tension monitoring as a measure of systemic perfusion

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Introduction
Acute kidney injury (AKI) is a common complication of cardiac surgery. There are currently no effective treatments for AKI, outside of expensive and complex clinical support options such as renal replacement therapy. Thus, injury prevention is the primary clinical goal. However, there are no validated tools or tests with robust prognostic value. Current diagnostic methods, which are based on changes in urine output or serum creatinine concentration, lead to a delayed diagnosis. Therefore, researchers have focused on identifying biomarkers to predict post-operative AKI earlier. However, these biomarkers change in response to renal injury, thus are not useful in preventing injury. Recent research has shown that urine oxygen partial pressure (PuO$_2$) can differentiate AKI from non-AKI patients during surgery [1]. It is essential for any monitor to be effective, to be tied to a proven clinical treatment. It is well understood that renal hypoxia contributes to AKI and that maintaining oxygen delivery above a critical threshold can prevent AKI [2], [3]. Thus, any potential interventions should focus on improving renal oxygenation. One possible method to improve renal oxygenation is increasing or maintaining systemic perfusion, as measured by mean arterial pressure (MAP). However, little research has been done connecting MAP and PuO$_2$ to measure perfusion of the renal medulla. The purpose of this preliminary work was to explore the relationship between PuO$_2$ and MAP. Understanding this relationship will help guide future studies focused on validating clinical interventions to prevent AKI.

Methods
Four pigs were anesthetized and instrumented. A novel device which measures PuO$_2$ in real-time was placed in line with a urinary catheter inserted into the bladder. MAP was monitored throughout each experiment. At time 0, hemorrhagic shock was induced by removing an estimated 25% of expected blood volume over 30 min through an arterial line. The subject then remained in a hypotensive state for 30 min. Following the hypotensive period, all animals underwent 45 minutes of resuscitative endovascular balloon occlusion of the aorta (REBOA). Animals received either a placebo or a novel drug. Before and during balloon deflation, the shed blood was transfused. 115 min after the start of the experiment, the animals entered the critical care phase. During this time, animals received a combination of balanced isotonic crystalloids (Plasmalyte 148) and norepinephrine according to a resuscitation algorithm to target a MAP > 65 mmHg. The relationships between the MAP and PuO$_2$ were qualitatively compared.

Results
During the hemorrhage and the following hypotensive period, the subjects did not produce enough urine to measure PuO$_2$ accurately. However, during the critical care period, urine output was sufficiently large to monitor PuO$_2$ reliably. Figure 1 shows the PuO$_2$ and MAP during the resuscitation period of the 4 separate experiments. In pig 1, at approximately 155 min, there is a large increase in MAP, followed by a large increase in PuO$_2$. This delayed relationship
seems to be similar in pig 2. For example, at approximately 300 min, there is a drop in MAP, and shortly after, there is a drop in PuO₂. The relationship between PuO₂ and MAP is less clear for pig 3. However, it appears that there is a sharp increase in MAP followed by a gradual increase in PuO₂. In pig 4, it seems that changes in MAP are reflected by changes in PuO₂ with a slight delay similar to the prior studies.

**Conclusion**
Qualitatively, changes in MAP are reflected by changes in PuO₂ with a slight delay. Therefore, future work will focus on quantifying the delay between the two variables as well as the biological relevance of PuO₂ in diagnosing renal hypoxia early and as a potential goal-directed resuscitation tool.

**References**

**Figure 1**

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Blood Pressure (mmHg)  
PuO₂ (mmHg)
Abstract Title: Automated Transducer Leveling System for Pressure Measurements

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Background: Accurate invasive pressure measurements depend on the alignment of the pressure transducer with the patient’s phlebostatic axis (level of the right heart) which is typically done by visually estimating the phlebostatic axis and manually moving the transducer which is on an IV pole near the patient. When the patient’s position changes, the provider must remember to correspondingly move the transducer. There is currently no warning system or way to remind a provider to make this adjustment. Failure to align the pressure transducer with the patient’s phlebostatic axis can lead to inaccurate pressure measurements, initiation of inappropriate treatment, and can cause patient harm. We compared invasive blood pressure measurement estimates obtained with our novel automated height tracking system to blood pressure measurements obtained by the clinical monitor.

Methods: We created a novel automated height tracking system consisting of a wireless sensor that attaches to the patient’s chest and a detector device with a wireless speaker that can determine the sensor’s height using inaudible sound waves. The automated height tracking system maintains the pressure transducer in a stationary position, estimating the blood pressure with hydrostatic force adjustments based on continuous height measurements. We obtained paired height measurements in the intensive care unit (ICU) using a laser distance meter (laser level height) and the automated height tracking system (estimated height) while changing the patient’s bed height to 10 random heights over the range of 50 cm. We also obtained paired invasive blood pressure measurements using the clinical monitor with the transducer taped to the patient’s chest (clinical blood pressure) and a second research monitor with a stationary transducer (research blood pressure). We then compared the clinical blood pressure and research blood pressure measurements by adjusting for the height difference to account for hydrostatic forces between the stationary transducer and the sensor (multiplied by a 0.77 conversion factor for cmH2O to mmHg).

Results: A total of 120 paired height and blood pressure measurements were collected from 9 post-cardiac surgery patients in the ICU. Each session consisted of 10 paired height measurements. The mean ± SD for the height difference between the heights measured by the laser distance meter (laser level height) and the automated transducer leveling system (estimated height) was 0.7 cm ± 1.0 cm. The mean ± SD for the mean arterial pressure difference between the clinical and calculated blood pressure measurements based on the laser level height measurements was 0 mmHg ± 3.0 mmHg. The mean ± SD for the mean arterial pressure difference between the clinical and calculated blood pressure measurements based on the estimated height measurements was 0.6 mmHg ± 3.3 mmHg.

Discussion: Our novel automated height tracking system is able to detect changes in the patient’s position and determine the height difference between the transducer and the patient’s chest obviating the need for the provider to remember to manually adjust the transducer height. This new system demonstrates high accuracy and precision and could be incorporated into clinical care pending integration into existing monitors. This innovation has the potential to improve patient care and safety as well as decreasing provider workload, limiting the potential for human error.
Assessing Agreement Between Clinical MAP and Calculated MAP

- Mean: 0.32
- +1.96 SD: +4.91
- -1.96 SD: -4.28
Title: EVALUATION OF PULSED OPEN OXYGEN DELIVERY IN PREVENTING OPERATING ROOM FIRES DURING MONITORED ANESTHESIA CARE

Presenting Author: Christian W. Orr MSII, University of Utah School of Medicine
Co-Authors: Kyle M. Burk, Ph.D., Dynasthetics LLC, and Barak Spittle

Background/Introduction: Operating room fires represent major risks for patients and clinicians. The risk is especially high for chest and neck procedures in monitored anesthesia care with open oxygen delivery via nasal cannula. In these procedures oxygen accumulates under drapes and may ignite when electrocautery is applied. Burk et. al developed a pulsed nasal cannula oxygen delivery system that limits delivery to inhalation and demonstrated that this system significantly reduces the risk of oxygen under drapes. The purpose of this study was to evaluate whether residual oxygen left in the cannula between pulses still represents a fire hazard using a pulsed, open oxygen delivery system.

Methods: We attempted to ignite nasal cannulas when flowing 100% oxygen at 2L/min, with static 100% oxygen, with 100% oxygen delivered in 44mL pulses every 3 seconds, with pulsed oxygen that is paused upon initial ignition, and with 30% oxygen flowing at 2L/min.

Results: Even with 100% oxygen concentration, cannulas would not ignite static oxygen. Cannulas burnt most rapidly and completely with 100% oxygen flowing at 2L/min. When 100% oxygen was delivered in 44mL pulses the tubing would not ignite until the second pulse. Once ignited, flames continued to travel up cannulas at a much slower rate if pulses continued to be delivered. When pulses stopped flames were not sustained for more than a few seconds.

Conclusion: Our tests demonstrated that 100% open continuous oxygen delivery is a major hazard in the OR. We found that pulsed 100% open oxygen delivery is a safe alternative to 100% continuous oxygen for patients who cannot be managed on 30% oxygen as recommended by the joint Commission and the American Society of Anesthesiologists.

References:


Abstract Title: Augmented Reality as Sole Anxiolytic for Pediatric Inhalational Induction of General Anesthesia

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Introduction:

Preoperative anxiety is common in pediatric surgical patients and increases the risk of emergence agitation and maladaptive behavior weeks after surgery.1-5 Children requiring multiple procedures are particularly susceptible, often demonstrating exaggerated fear and distress during subsequent hospital visits.

Immersive technologies show promise as effective anxiolytics. However, most head-mounted displays (HMD) block the eyes and obscure appropriate face mask placement over the nasal bridge. The purpose of this abstract is to present the feasibility and effectiveness of a unique holographic HMD that provides distractive anxiolysis while minimizing typical limitations of HMDs during mask induction.

Methods:

This feasibility pilot implementation occurred at a quaternary care children’s hospital in northern California. The DreamGlass AR 4K is a head-worn apparatus that allows viewers to see 2D or 3D images superimposed onto the real environment, projected onto the equivalent of a 200-inch screen with 90-degree field of vision optics. The headset utilizes a native, embedded platform to access commercial entertainment applications. Unlike virtual reality HMDs, a glass
visor sits approximately 2 inches away from the patient’s face, allowing the provider to visualize the patient’s eyes and provide a face mask seal during induction. Media release was obtained prior to enrollment. The primary outcome was acceptability and effectiveness as determined by patient and family interviews.

**Results:**

A 12 year-old female with trisomy 21 and a complex neuropsychiatric history including anxiety and needle-phobia was recruited to pilot this device. She was scheduled for a diagnostic lumbar puncture followed by MRI under general anesthesia (GA) for diagnostic workup in the context of an acute developmental regression attributed to Down Syndrome Disintegrative Disorder.

Although initially planning to administer preoperative oral midazolam, the patient’s mother expressed concerns around prolonged sedation following the patient’s prior anesthetics. In discussing distraction techniques, the patient’s mother identified “Moana” (Walt Disney Animation Studios™) as the patient’s favorite movie. The patient was then fitted with a DreamGlass HMD.

With “Moana” playing on the headset, separation from the patient’s mother was achieved in the preoperative area. Uninterrupted by changes in position or perioperative location, the patient continued to be aware of her surroundings while simultaneously enjoying her projected movie. As the patient watched the movie in the operating room, she was compliant with monitor placement and introduction of the anesthesia mask. A mixture of 30% oxygen with 70% nitrous oxide was administered through the patient’s mask as she continued to use the headset (Image 1). Sevoflurane was titrated to induction of GA. The headset was then removed for the remainder of the patient’s perioperative course and cleaned with hydrogen peroxide wipes. In the post-operative care unit, the patient emerged without issue and was ready for discharge within 41 minutes after arrival (in comparison to 102 minutes with her prior anesthetic 5 months earlier). Video of the induction was shared with the patient’s mother, who expressed gratitude and high satisfaction for how calm her daughter appeared during mask induction of anesthesia.

**Conclusion:**

The DreamGlass headset offers a practical, cost-effective tool for addressing preoperative anxiety, and may be an alternative to pharmacological anxiolysis for appropriate patients. A previous report has described the use of parent present induction of anesthesia with augmented reality as a tool for employing distraction techniques with interactive games. However, this headset is 75% more affordable, allows for provider control with a tethered mobile device, and offers mixed media including commercially available videos in addition to gaming applications. With wireless internet connectivity and online streaming services, we are now able to provide our patients with semi-immersive experiences during mask induction while overcoming the typical barriers associated with immersive technologies.
Image 1:

Patient wearing augmented reality headset during mask induction of anesthesia
References:


Panoramic, screen-based simulator of neuromuscular blockade administration, monitoring and reversal

Lampotang S, Lizdas DE, Tumino J, Gravenstein N

Introduction:
There is renewed interest in neuromuscular blockade (NMB) monitoring and reversal with the continued significant incidence of residual postoperative NMB and the fairly recent availability of sugammadex. We developed the Simulated Anesthesia App (SAA), an interactive screen-based simulator to practice NMB administration, NMB monitoring, and NMB reversal including with sugammadex.

Methods:
We implemented in Adobe Director an interactive screen-based simulator of the operating room (OR) and anesthesia activities. To have only one main screen represent the entire OR, we developed a dynamic panoramic representation of the OR that allows the entire OR to “fit” within one screen as a scrolling panoramic photograph, Fig. 1. We simulated activities and equipment like intubation (video clips), laparoscopy (video clips), a NMB monitor, an anesthesia machine with user-adjustable flowmeters and vaporizers, gas analysis (by modeling breathing circuit dynamics like wash-in and washout) and physiological monitoring. We used PK/PD parameters from official package inserts to simulate, via compartmental models, drugs like oxygen, sevoflurane, isoflurane, glycopyrrolate, neostigmine, succinylcholine, fentanyl, propofol, rocuronium and sugammadex. Scrolling time plots of drug concentrations and circuit gas concentrations respond to user actions like drug administration and provide line of sight of future concentrations, Fig. 2. We included the package inserts used for our PK/PD models into the SAA as searchable PDF files. An event log captures all user actions and is a tool to go back in time and undo mid-case events, e.g., taking a different decision without re-starting the scenario. For each new user interaction, the models forecast all parameters up to three hours. A scrolling timeline allows users to jump forward and backward in time, e.g., to skip periods of no activity or to undo a prior action.

Results:
During verification of the SAA, the output of each model of the SAA was compared to the source like the package insert. Drug concentrations, clinical durations and recovery times matched source materials. Anesthesiologists who used the SAA deemed that its output matched what they observe in their clinical practice. A short (6 minute) video of the SAA is at https://simulation.health.ufl.edu/technology-development/#PanoramicSimulations

Discussion:
The SAA has a “taximeter” option that allows setting a dollar value for a minute of OR time and the cost of materials used and displays a running sum of the total cost. We are exploring re-purposing the SAA to include the carbon footprint of each item or consumable used during an anesthetic.
Figure 1. The panoramic user interface, facing the patient. The scrolling timeline and clock are at the top. Tools and options are selectable within the photograph-based scene and in two columns on the right and left sides of the screen. The user is selecting the mathematical models viewer (enlarged icon, upper right)
Figure 2. Three superimposed graphs of neuromuscular function recovery from the mathematical models viewer. The triangular caret at the timeline indicates the current time during the simulation.
DEVELOPMENT OF A CLINICAL APPLICATION FOR PAIN MEDICINE IN PEDIATRICS

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Introduction:
Clinical dashboards and applications have extensively been described for use in quality improvement, administrative optimization and clinical decision making. Pain specific applications has also been utilized to help clinicians improve pain management. However, the development and adoption of these tools have been lacking in pediatrics. At our institution, a quaternary free-standing pediatric hospital, pain medicine physicians and clinical staff have been relying on simple text-based reporting documents from the electronic health record to care for patients. Clinicians then manually interpret the data and develop a clinical picture of each patient. As the clinical practice increased in size, the efficiency of team-based practice needed to be improved while increasing the quality of care delivered. We sought to develop an interactive web-based pain application to augment the ability for pediatric pain medicine clinicians to visualize, understand, and care for children more efficiently.

Methods:
A multidisciplinary team was formed with content expertise to develop the interactive web-based pain application. Initial meetings were held to detail current clinical workflow and processes for clinicians rounding on the inpatient pain service at a free-standing pediatric hospital. Priorities were outlined to define clinical content from our electronic health record (Cerner, North Kansas City, MO) and several iterations of mock designs of the user-interface were created with clinician feedback. A hand-drawn mockup was developed using feedback from team members. Based on this, the informatics team then created an application using Tableau (Seattle, WA). An iterative process followed with the clinical and technical team members collaborating to refine the displays of clinical information while enhancing user interface.

Results:
A continuously updated rounding list consisting of pediatric pain patients that are actively being following by the inpatient pain team was used as a defined population. Their current location and primary diagnosis were including in the opening page to help the team plan for rounding efficiency. Pain scores based on the FLACC, FACES or Verbal Numerical Rating Scale were divided into mild (0-3), moderate (4-7) and severe (8-10) which were coded green, yellow, and red, respectively. These pain scores based on time were displayed with each patient for the last 24 hours. Figure 1, is an example of the opening page that provides a visual analysis of pain scores and the pain experience for clinicians to use.

Discussion:
The development of this pain application allows for quick and efficient visualization of pediatric patients admitted to our institution. Based on color coding, clinicians can use visual analytics to triage and more efficiently address pain concerns in a timely manner as our practice continues to grow and scale across the enterprise. We will continue to improve the applications user interface and content to help pain clinicians with their workflow and support decision making. Further studies are needed to assess whether a visual analytic web-based pain application results in improved patient outcomes, patient experience, and clinician satisfaction.
Figure 1. Color coded visual analytic dashboard of the opening page for pain clinicians to use when rounding in a children’s hospital.

References:
Analysis of postoperative patient outcomes following the intervention of clinician-centered dashboards

Presenting Author: Rama Sreepada PhD 1,2

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Introduction: The perioperative period is a data-rich environment, with potential for improving personal and population-level postoperative outcomes through digital health interventions. Data-driven performance feedback can improve professional anesthetic practice and patient-relevant outcomes [1,2]. A postoperative follow-up (POFU) registry was established at BC Children’s Hospital (BCCH) to collect postoperative outcomes from ambulatory patients, which was augmented with anesthesiologist-centered dashboards to visualize performance on an individual and team level [3]. The goal of this work is to present pilot data comparing baseline and short-term implementation changes in patient-relevant outcomes.

Methods: This quality improvement project was exempt from research ethics board approval. The POFU registry contains day-surgery patient information, including age, sex, procedure (from the operating room scheduling system), post-anesthetic care unit (PACU) opioid and/or antiemetic administration (collected by PACU nurses), as well as pain, nausea, and vomiting within 24-hours post-discharge (collected from parents by a single nurse phone call). The PACU and 24-hr outcome rates are presented to the anesthesiologists using Power BI (Microsoft, Richmond, WA) run charts, and bar charts. Pre-intervention data were available for a 3/9-month baseline: April/2021 to June/2021 for PACU outcome data, and September/2020 to June/2021 for 24-hr postoperative outcome data. Post-intervention data were available for a 3-month period: September/2021 to November/2021. Baseline and post-intervention data were graphed and overall prevalence compared using Fisher’s exact test. As dashboard co-design was carried out in July/2021 and August/2021, this period was plotted, but not considered for comparison to reduce bias.

Results: For the baseline period, data available for analysis included PACU data from 1,203 cases and 24-hr postoperative data from 2,966 cases (65.5% call success rate). For the post-intervention period, available data included PACU data from 1,359 cases and 24-hr postoperative data from 880 cases (64.8% successful calls). The mean baseline vs. post-intervention PACU opioid administration rates were 8.5% vs. 7.1% (p=0.18; Figure 1a) and PACU nausea rescue rates were 1.7% vs. 1.1% (p=0.24; Figure 1c). Baseline vs. post-intervention prevalence of moderate/severe outcomes in the 24-hr postoperative period were 4.4% vs. 3.2% (p=0.15; Figure 1d) for pain, 1.0% vs. 0.6% (p=0.31; Figure 1e) for nausea, and 1.1% vs. 0.7% (p=0.34; Figure 1f) for vomiting.

Conclusion: From the preliminary analyses, no significant differences were found for any outcome; this is possibly an effect of the low prevalence, small sample size, latency in practice change, or limitations in provider access to the data. The low incidence of PACU nausea intervention may result from total intravenous anesthesia being the predominant mode of anesthesia at BCCH [4][5]. We plan to conduct usability surveys, gather an additional 6-months of post-intervention data to enable exploration of seasonal trends in the outcome and repeat the analysis before considering any further interventions.

Figure 1: Variability in monthly outcome rates (in %) are plotted in subplots: for rescue rates in the post-operative care unit (PACU) including (a) opioid rescue, (b) opioid rescue needing ≥4 doses, and (c) antiemetic rescue; and for 24-hr postoperative outcome prevalence rates, including (d) pain, (e) nausea, and (f) vomiting. The department’s aggregate outcome rates are plotted as black lines. Anesthesiologist’s monthly data are superimposed as box plots; outliers <3 times the standard deviation are plotted as gray dots; others are censured for presentation.
**Title:** The use of handheld ultrasound device for neuraxial placements in obstetric patients.

**Presenting Author:** Pedro Acevedo Rodriguez, MD, OB Anesthesiology Fellow, Yale School of Medicine  
**Co-Authors:** Nayema Salimi MD, Ahmed Abdelfattah, MS; David, Yanez, PhD; Antonio Gonzalez, MD; Aymen Alian, MD

**Background:** Although the use of ultrasound (US) guided neuraxial anesthesia was described over two decades ago, its use remains scarce. The lack of adoption of this non-invasive technique persists despite its known benefits of better identification of the lumbar interspace level, optimal needle insertion site, diagnosis of associated scoliosis and estimated depth of epidural space. The causes for its limited use may relate to cost, technical expertise, difficulty interpreting images, access to, and space for storage of ultrasound equipment.(1,2)

**Methods:** After institutional review board approval, we have started this prospective observational study for epidural placement utilizing handheld US (Butterfly iQ+) guidance and landmark technique. We evaluated time to perform epidural placement (the time from needle insertion till loss of resistance), number of insertion attempts (needle in and out of skin), number of needle redirections (needle adjustments without removal of needle from insertion point), and -for cases in which US was utilized we compared the estimated depth by US and actual depth of epidural space. Intergroup differences were assessed for significance using Mann-Whitney test. Values are presented as mean and standard deviation (SD)

**Results:** A total of 139 of epidural placement were evaluated, 84 of which were placed with US guidance. The average number of needle insertion attempts [US 1.0 (0.6) versus landmark 2(1.3); p = 0.29] and number of needle redirection [US 1.0 (0.8) versus landmark 3.0 (1.3); p < 0.001] was lower in the US group. The duration of the procedure was also lower in the US groups versus the landmark groups with average duration of 3.1 min (3.2) versus 6.3 (7.5); p = 0.009, respectively. In terms of accuracy, our handheld US underestimated measurements by -0.15 (0.37) 95% confidence interval [-0.07, -0.23].

**Conclusion:** In a cohort of patients with a mean (SD) body mass of 33.3 (6.9), the use of US helped reducing the number of needle insertion attempts and adjustments in a statistically significant manner when compared to landmark-guided technique. Our results are in agreement with previously reported accuracy, with some authors reporting an accuracy within 0.8 cm. The use of the portable Butterfly iQ+, obviates some of the limitations related to cost and real state. More importantly, the use of this device resulted in procedure performance in half the time when compared to a landmark technique. the authors think that the additional information obtained improves patient satisfaction and may potentially decrease the risk of complications, such as accidental dural puncture.

**References:**  