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

FAER

STA

Society for Technology in Anesthesia

2012
Annual Meeting Syllabus

January 18-21, 2012
Four Seasons Resort & Spa
Palm Beach, Florida


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Palm Beach


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Society for Technology in Anesthesia

Society for Technology in Anesthesia Annual Meeting

Dear STA Annual Meeting Attendee,

On behalf of the Society for Technology in Anesthesia (STA) Board of Directors, we would like to welcome to this year's STA Annual Meeting. We are very excited to be partnering with the Foundation for Anesthesia Education and Research (FAER) to present a special session on, "Translational Medical Research." We would like to thank Dr. Maxime Cannesson, Dr. Donn Dennis and Dr. Jesse Ehrenfeld for organizing this event and securing the outstanding faculty, who have generously given their time to prepare and present their lectures and demonstrations.

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

With the increasing fiscal and political challenges that face healthcare and industry, STA in partnership with FAER. We hope you find the meeting topics and discussions timely and informative.

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

Kirk Shelley, MD, PhD
President
Society for Technology in Anesthesia

Denham Ward, MD
President
Foundation for Anesthesia Education & Research

Society for Technology in Anesthesia

Mission Statement

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

MEETING ACCREDITATION INFORMATION

Target Audience

This program is designed for physicians, engineers or other practitioners in the field of anesthesia seeking an update on the current state of anesthesia technology.

Overall Goal Statement

The goal of this program is to provide theoretical and practical information on various technological aspects within the field of clinical anesthesia.

Program Objectives

1. Examine and identify problems and solutions in the anesthesia workspaces with a special emphasis on exploring new developments in drug delivery, information management and patient monitoring.
2. Identify and explore key factors required for effective translation medical research, including management of conflict of interest issues and implementation of successful strategies to develop technologies.
3. Examine potential barriers and subsequent solutions in order to bring new and safe technologies to the clinical practice with an emphasis on patient safety.
4. Explore opportunities to advance and enhance environmentally responsible practices within anesthesia care.
5. Explore opportunities to advance automated anesthesia delivery with the goal over improving patient safety.

Practice Gaps

This STA Annual Meeting will address the use and implementation in considerations of bringing research to market, technology and safety, closed loop anesthesia management, non-invasive hemodynamic monitoring and Anesthesia Information Management Systems. The program is designed to address gaps in knowledge and techniques by exposing physicians to challenges and complications when using and implementing various technologies into ones practice.

Accreditation Statement for Jointly Sponsored Activities & Designation of Credit

This activity has been planned and implemented with the Essential Areas of the Accreditation Council for Continuing Medical Education (ACCME) through the joint sponsorship of the Society for Technology in Anesthesia (STA) and the International Anesthesia Research Society (IARS.) The IARS is an accredited by the ACCME to provide continuing medical education for physicians.

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MEETING ACCREDITATION INFORMATION (cont.)

Designation of Credit

The IARS designates this continuing medical educational meeting for a maximum ***18.25 AMA PRA Category 1 Credit(s)™.*** Physicians should claim only those hours of credit that he/she actually spent in the educational activity.

Disclosure

It is the policy of the International Anesthesia Research Society (IARS) to comply with the ACCMEs standards for commercial support for CME. Planning Committee members and related staff disclosures must be on file annually with disclosures made available on program materials. Faculties participating in sponsored or jointly sponsored programs by IARS are required to disclose to the program audience any real or apparent financial relationships with commercial interests related to the content of their presentations. Faculty members are also responsible for disclosing any discussion of off-label or investigational use of a product.

Planning Committee Disclosures

This program is designed for physicians, engineers or other practitioners in the field of anesthesia seeking an update on the current state of anesthesia technology.

Corporate Support & Exhibitor Disclosures

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STA 2012 Annual Meeting Speaker Disclosures

Mark Ansermino, MBBCh
* *Dräger Research Grant*
* *Intends to Discuss Investigational Products*

Steven Barker, MD, PhD
* *Consultant Masimo*

Charlotte Bell, MD
**No Disclosure*

Anthony Doufas, MD, PhD
**No Disclosure*

Richard Dutton, MD
**No Disclosure*

Maxime Cannesson, MD, PhD
**Masimo & Edwards Life Sciences Consultant*

Bruce Gingles, AB
**Cook Medical Salaried Employee*

Thomas Hemmerling, MD
**NSERC Research Grant*
**Intends to Discuss Investigational Products*

Kate Hunke, MD
**No Disclosure*

Dean Kurth, MD
**No Disclosure*

Ngai Liu, MD, PhD
**No Disclosure*

Jürgen Manigel, MD
* *Dräger Salaried Employee*
* *Intends to Discuss Unlabeled Uses for Products*

Richard Melker, MD, PhD
* *No Disclosure*

Joseph Rinehart, MD
**Shareholder Sironis Inc.*
**Intends to Discuss Investigational Products*

Debra Schwinn, MD, PhD
**No Disclosure*

Jos Settels, MSc
**BMEYE BV Shareholder & Honorarium*

Theodore Stanley, MD
**No Disclosure*

Mohamed Rehman, MD
**No Disclosure*

David Reich, MD
**No Disclosure*

Brian Rothman, MD
**No Disclosure*

Patrick Tighe, MD
**No Disclosure*

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STA Annual Meeting Moderator Disclosures

George Blike, MD
**No Disclosure*

Julian Goldman, MD
**No Disclosure*

Dwayne Westenskow, PhD
** Dräger Consultant*

D. John Doyle, MD, PhD
**No Disclosure*

Kirk Shelley, MD, PhD
**No Disclosure*

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STA Annual Meeting 2012: Daily Program Schedule

Wednesday, January 18, 2012

07:00 – 08:00	Mizner Foyer	**Anesthesia Essentials Course Registration**
08:00 – 12:00	Mizner Room	**Anesthesia Essentials Course 101** Norma Sandrock, MD
08:00 – 17:00	Royal Poinciana I/II	**Exhibitor Registration & Set-Up**
12:00 – 13:15	Banyan Room	**Essentials Course & STA Board of Directors Lunch**
13:00 – 19:30	Mizner Foyer	**Attendee Registration**
13:15 – 17:00	Royal Poinciana III	**A.I.M.S. Workshop** David Reich, MD
18:00 – 19:30	Royal Poinciana I/II	**Opening Reception with Exhibitors**

Thursday, January 19, 2012

07:00 – 08:00	Royal Poinciana I/II	**Registration & Continental Breakfast**
08:00 – 09:30	**Royal Poinciana III**	**Session 1: Technology & Safety**
08:00 – 08:15		**Opening Remarks** *Kirk Shelley, MD, PhD, Maxime Cannesson, MD, PhD & Donn Dennis, MD*
08:15 – 09:30		**Keynote Address: Anesthesia Quality Institute** *Richard Dutton, MD*
09:30 – 10:00	Royal Poinciana I/II	**Break with Exhibits and Posters**
10:00 – 12:00	**Royal Poinciana III**	**Session 2: Close Loop Anesthesia Management: Here, There & Everywhere** *Dwayne Westenskow, MD – Moderator*
10:00 – 10:30		**Closed Loop System for Depth of Anesthesia** *Ngai Liu, MD, PhD*

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Thursday, January 19, 2012 (cont.)

10:30 – 11:00		**Closed Loop Ventilation** *Jürgen Manigel, PhD*
11:00 - 11:30		**Closed Hemodynamic Management** *Joseph Rinehart, MD*
11:30 – 12:00		**Reinforced Learning** *Anthony Doufas, MD, PhD*
12:00 – 12:15		**Panel Discussion**
12:00 – 13:30	**Flagler I/II**	**Lunch** *Presentation By: Arthur Taft, MD*

Joint Education Session with

FAER FOUNDATION FOR ANESTHESIA EDUCATION AND RESEARCH

13:30 – 16:00	Royal Poinciana III	**Session 3: Translational Medical Research** *George Blike, MD- Moderator*
13:30 – 14:00		**Translational Medical Research and Scientific Integrity: Positive & Negative Academic/Industry Relations** *Debra Schwinn, MD, PhD*
14:00 – 14:30		**Translational Medical Research: Why Industry Needs Physicians** *Bruce Gingles, AB*
14:30 – 15:00		**Case Study in Successful TMR: Technology Development of University Intellectual Property via New Company Formation** *Theodore Stanley, MD*
15:00 – 15:30		**Case Study in Successful TMR: Technology Development of University Intellectual Property via Licensing** Richard Melker, MD, PhD
15:30 – 16:00		**Panel Discussion**
16:00 - 16:15	Royal Poinciana I/II	**Break with Exhibits and Posters**
16:15 – 18:00	Royal Poinciana III	**Session 4: Research Awards & Presentation**

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Thursday, January 19, 2012 (cont.)

16:15 - 17:15		**Research Awards & Presentation**
17:15 – 18:00		**Guided Poster Viewing with Q&A**

Friday, January 20, 2012

07:15 – 08:15	Royal Poinciana I/II	**Registration & Continental Breakfast**
08:15 – 10:00	Royal Poinciana III	**Session 5: Non-Invasive Hemodynamic Monitoring** Steven Barker, MD, PhD– *Moderator*
08:15 – 08:45		**Non-Invasive Arterial Pressure Monitoring** *Jos Settels, MSc*
08:45 – 09:15		**Non-Invasive Cardiac Output Monitoring** *Steven Barker, MD, PhD*
09:15 – 09:45		**Non- Invasive Fluid Responsiveness Evaluation** *Maxime Cannesson, MD, PhD*
09:45-1000		**Panel Discussion**
1000– 1030	Royal Poinciana I/II	**Break with Exhibitors**
10:30 – 12:15	Royal Poinciana III	**Session 6: New Challenges Facing Technologies in Healthcare** *Charlotte Bell, MD– Moderator*
10:30 – 11:00		**Institutional and System Barriers to Improving Sustainability in the Perioperative Area: How to Address & Overcome Them?** *Kate Huncke, MD*
11:00 – 11:30		**Facilities: How to Address Environmental Issues in Facility Planning, Patient and Provider Health & Safety** *Charlotte Bell, MD*
11:30 – 12:00		**How to Decide What New Technologies Are Needed That Will Address the All-Important Triumvirate of Patient Safety, Environmental Sustainability & Cost Effectiveness** *Brian Rothman, MD*
12:00 – 12:15		**Panel Discussion**

Friday, January 20, 2012 (cont.)

12:15 – 13:30	Flagler I/II	**STA Business Luncheon & Awards** *Kirk Shelley, MD, PhD & Denham Ward, MD* **Gravenstein Award Presentation** *Lecture Presented By: Kevin Tremper, MD*
13:30 – 15:30		**Session 7: Concurrent Workshops**
	Room: Flagler A&B	**Blood Pressure Measurement: How Old is Too Old?** An audience participation experience to design the ideal approach to display non-invasive blood pressure information *David Feinstein, MD*
	Room: Flagler E&F	**Hemodynamic Monitoring Workshop** *Kirk Shelley, MD, PhD & Maxime Cannesson, MD, PhD*
	Room: Mizner	**Anesthesia Machine Workshop** *Julian Goldman, MD*
15:30 – 17:00		**Session 8: Concurrent Workshops**
	Royal Poincianna III	**Engineering Contest** *Jeff Mandel, MD*
	Banyan Room	**MPOG Technical Architecture Workshop** *Sachin Kheterpal, MD, MBA*
18:30 – 21:30		**Beach Party & Dinner** **Four Seasons Pool Deck** (Included with the Attendee Registration Fee)

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Saturday, January 21, 2012

07:30 – 08:30	Royal Poinciana I/II	Registration & Continental Breakfast
08:00 –09:45	Royal Poinciana III	**Session 9: Anesthesia Information Management Systems (A.I.M.S.)** *Mohamed Rehman, MD- Moderator*
08:00 – 08:30		**Data Driven Quality Improvement in an Anesthesia Department** *David Reich, MD*
08:30 – 09:00		**Data Driven Quality Improvement in a Hospital** *Dean Kurth, MD*
09:00 – 09:30		**Using Aggregated AIMS Data to Generate Benchmarks: Results from the National Anesthesia Clinical Outcomes Registry** *Richard Dutton, MD*
10:00 – 10:15		**Panel Discussion**
10:15 – 10:30		Coffee Break
10:30 – 12:15	Royal Poinciana III	**Session 10: Cutting Edge Technologies in Healthcare** *D. John Doyle, MD, PhD & Kirk Shelley, MD, PhD- Moderator*
10:30 – 11:00		**Robotics in Anesthesia & Airway Management: What Does the Future Hold?** *Patrick Tighe, MD*
11:00 – 11:30		**Information Overload at the Clinical Interface: Can We Design Our Way Out of This One?** *Mark Ansermino, MBBCh*
11:30 – 12:00		**Path Towards Automated Anesthesia: Exploring the Future** *Thomas Hemmerling, MD*
12:00 – 12:15		**Panel Discussion**
12:15		**STA Meeting Adjourns**

Society for Technology in Anesthesia

Annual Meeting Presentations will post on the
STA Website
by
February 15, 2012
Please visit www.stahq.org

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Society for Technology in Anesthesia 2012 Corporate Supporters & Exhibitors

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2012 Corporate Supporters & Exhibitor Profiles

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Abbott is a broad-based health care company devoted to bringing better medicines, trusted nutritional products, innovative medical devices and advanced diagnostics to patients and health care professionals around the world.

Baxter International, Inc.

Baxter International Inc., through its subsidiaries, develops, manufactures and markets products that save and sustain the lives of people with hemophilia, immune disorders, infectious diseases, kidney disease, trauma, and other chronic and acute medical conditions. As a global, diversified healthcare company, Baxter applies a unique combination of expertise in medical devices, pharmaceuticals and biotechnology to create products that advance patient care worldwide. Baxter is a leading manufacturer of products for general anesthesia. These include anesthetic gases, or inhaled anesthetics, and anesthesia-related critical care drugs.

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CASMED, a leader in vital signs monitoring systems, presents the innovative FORE-SIGHT® Absolute Tissue Oximeter for non-invasive, continuous monitoring of absolute tissue oxygen saturation. This intelligent device enables tailored patient management and a reduction in catastrophic desaturation events. Tel: (800)227-4414 www.CASMED.com/FORE-SIGHT

Codonics

Headquartered in Middleburg Heights, Ohio, Codonics is an international supplier of dry, diagnostic medical imagers, medical disc import solutions, medical image servers and solutions for compliant labeling of syringes in hospital facilities. Codonics SLS Safe Label System is a complete solution for safe, compliant, fast labeling of medication in the operating room, or anywhere syringes are prepared. SLS improves the syringe preparation workflow by automatically printing American Society of Anesthesiologists (ASA) compliant full-color labels containing all The Joint Commission required elements while the syringe is being filled. Each label includes a configurable data-rich barcode that can be used to integrate into the Anesthesiology Information Management System (AIMS) or a broader hospital information system.

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Cook Medical

Cook Medical offers advanced solutions to meet anesthesia needs and advance patient care worldwide. Cook provides a comprehensive offering of difficult airway solutions, including Cook Airway Exchange Catheters and the Melker Emergency Cricothyrotomy Set. Cook also manufactures the Arndt and Cohen Endobronchial Blockers and Spectrum® minocycline+rifampin impregnated CVCs.

Covidien

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

Dräger Medical

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

Edwards Lifesciences

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

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GE Healthcare

GE is making a new commitment to health. Healthymagination will change the way we approach healthcare, with more than 100 innovations all focused on addressing three critical needs: lowering costs, touching more lives and improving quality.
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iMDsoft is a leading provider of clinical information systems dedicated to automating the critical care and perioperative continuum. The Meta Vision™ suite is fully integrated, customizable solution for data collection and presentation, order management, clinical analysis and decision support. Major medical centers across the United States and Europe and Asia use iMDsoft technology to improve quality care, promote patient safety, enhance financial performance, support research and compliance while achieving sustainable market leadership.

Masimo

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

Kair Medical

Kair Medical is uniquely positioned to be a partner with health care facilities to assist them in meeting the new challenges facing the industry. By providing high quality yet cost-effective Wound Care Support Surfaces, Bariatric Patient Management Equipment and Negative Pressure Wound Therapy, Kair Medical allows you to maintain high quality patient care while controlling costs

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Mindray North America

Mindray is a global medical device company focusing on the needs of the Anesthesia Delivery, Patient Monitoring, In-Vitro Diagnostic Products, and Medical Imaging health care professional. With advanced research and development taking place on three continents and with more than 4,500 employees world wide, Mindray offers the healthcare community a range of innovative solutions designed to manage costs while ensuring the highest quality of patient care. Mindray measures our success by our customer's satisfaction. Our clinical education specialists provide the hospital staff with comprehensive, on-site training and in-service on demand 24-hours a day, 7-days a week. Our dedicated field service and in-house technical support organization are one of the largest direct service teams in the industry. Individually and collectively they are committed to enhancing patient care while protecting your investment.

NeuroWave Systems

NeuroWave Systems Inc is an ISO 13485 medical device company, dedicated to developing innovative, state-of-the-art signal processing technologies for the next generation of brain monitors for improved and safer patient care.

Oridion Capnography, Inc

Oridion develops medical devices and patient interfaces, based on its patented Microstream® capnography technology, for the enhancement of patient safety through etCO2 monitoring. These products provide 'real ventilation monitoring' in various clinical environments -- including post-operative, procedural sedation, emergency department, and critical care -- where a patient's ventilation may be compromised or at risk.

PharMEDium Services, LLC

PharMEDium is the national leading outsourced pharmacy provider, rigorously ensuring the accuracy and sterility of all your customized IV and epidural preparations. PharMEDium is a nationwide network of state-licensed and federally registered pharmacy outsourced compounding centers, providing trusted solutions to more than 2,000 hospitals throughout the United States.

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Philips Healthcare

Philips Healthcare is a worldwide provider of Diagnostic Imaging Products, Cardiac and Physiological Monitoring Systems and Information Management applications. Philips provides clinical informatics and patient care solutions that simplify clinician workflow, improve financial outcomes, and help improve and save lives. With focused technologies that acquire, integrate, and present information as it's required throughout the perioperative process, Philips is delivering on a commitment to address the clinical, business, and technical requirements of anesthesia care teams.

SensorMed, Inc.

SensorMed is a progressive innovator, designer, and developer of medical devices. Our products offer substantial benefits to both physicians and patients in areas ranging from minimally invasive surgical procedures to simple IV starts. Our primary objective is to design and develop instruments that assist physicians and other medical professionals in their efforts to provide the highest quality healthcare possible to their patients. By providing solutions to real and expressed needs in the medical industry, SensorMed is working to improve the standard of quality in healthcare today.

Surgical Information Systems

Surgical Information Systems ("SIS") provides software solutions that are uniquely designed to add value at every point of the perioperative process. Developed specifically for the complex surgical environment, all SIS solutions – including anesthesia – are architected on a single database and integrate easily with other hospital systems. SIS offers the only surgical scheduling system and the only anesthesia information management system endorsed by the American Hospital Association (AHA), and a rules-based charging system that has been granted Peer Reviewed status by the Healthcare Financial Management Association (HFMA). SIS is also the first AIMS provider to be designated as an AQI Preferred Vendor by the Anesthesia Quality Institute (AQI).state-licensed and federally registered pharmacy outsourced compounding centers, providing trusted solutions to more than 2,000 hospitals throughout the United States.

SECTION EDITOR,
TECHNOLOGY, COMPUTING AND SIMULATION

APPLICATION DEADLINE
SEPTEMBER 1, 2012

The *Society for Technology in Anesthesia* is pleased to accept applications for Section Editor, Technology, Computing and Simulation, of the society's official scientific journal, *Anesthesia & Analgesia*. Candidates should be leaders in academic anesthesiology, particularly in the many technologies applicable to the field of anesthesiology: perioperative medicine, critical care, and pain management. Candidates should have an international reputation for research excellence in anesthesia technology, computing, and simulation. Candidates should also have experience in medical editing, and proven administrative and organizational skills.

The duties of the Section Editor for Technology, Computing, and Simulation include:

1. Handling approximately 100 manuscripts a year
2. Serving as an *ex-officio* member of the STA Board
3. Providing an annual report to the STA Board
4. Attending the STA Annual Meeting held in January
5. Attending the annual Editorial Board Meeting at the IARS Congress, and
6. Commissioning review articles, updates, commentaries, annual reports, and other articles related to anesthetic technology

Anesthesia & Analgesia, the first scientific publication in the field of anesthesiology, is the Journal of the International Anesthetic Research Society, the Society of Cardiovascular Anesthesiologists, the Society for Pediatric Anesthesia, the Society for Ambulatory Anesthesia, the International Society for Anaesthetic Pharmacology, the Society for Technology in Anesthesia, and the Society for Obstetric Anesthesia and Perinatology. Additional, information is available from the Committee Chair. Interested candidates should submit their curriculum vitae to:

Society for Technology in Anesthesia
6737 W. Washington St.
Suite #1300
Milwaukee, WI 53214

STA 2012 Annual Meeting Abstracts

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3	*The Methodology in Creating a Stewardship System of Pharmaceutical Costs for Anesthesia Providers*	No Disclosure	Jesse Ehrenfeld, MD, MPH	3
4	*Closed Loop vs. Anesthesiologist Fluid Administration during Simulated Massive Hemorrhage Using Stroke Volume, Heart Rate, and Mean Arterial Pressure*	Sironis, Inc.	Joseph Rinehart, MD	4
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MEDICAL DEVICE CLOCK ERRORS IN THE HOSPITAL

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[1]Medical Device Plug-and-Play Interoperability Program at CIMIT, Cambridge, MA; [2]Dept. of Biomedical Engineering, Partner's Healthcare, Boston, MA; [3]Dept. of Anaesthesia, Mass. General Hosp, Boston, MA

Many have observed that medical device clocks are not set to the correct time. This is due to a number of causes. Most medical devices lack automatic clock-setting capabilities and cannot set their clocks using a network time reference. Also, there is no adopted standard for medical device time management. Consequently, clocks are typically set manually twice yearly for DST.

Most electronic medical devices contain an internal clock that is used to timestamp data. Depending on the configuration of the EMR and the data source, the EMR may insert the incorrectly time-stamped data into the wrong time slot, or reject the data altogether. Therefore, asynchronous time stamps may undermine the integrity of EMR data and the accurate reconstruction of clinical events or device failures.

To explore the problem, a sample of medical device clocks from the operating rooms, ICUs, and equipment storage facilities at Massachusetts General Hospital (Boston, MA) were recorded. Device clocks were compared to the NIST Internet Time Service to compare clock consistency and evaluate the deviance of the device clocks. Of 337 device clock-times that were recorded, 53% had an offset of > 1 min, 17% had an offset of > 30 minutes, and 11% had an offset of > 1 hour.

This pilot study supports anecdotal data and first principles that erroneous clock times are pervasive. Given the absence of automatic clock setting capabilities in most medical devices, and typical clock drift, these finding are not surprising. We are working on extending the study to other institutions and care areas.

ICE STORM: A PROTOTYPE VIRTUAL INTEGRATED CLINICAL ENVIRONMENT

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It is challenging to plan clinical environments of the future without first developing a means to try "what if" scenarios with innovative clinical workflow and system integration. To address this need, the MD PnP research group collaborated with Lockheed Martin Corporation and DocBox, Inc. in developing ICE STORM, a prototype virtual reality environment for simulating workflows in an advanced and fully integrated clinical environment. This system, implemented in the MD PnP Lab, used five computer-driven plasma displays, the largest (85") showing a first-person view of an ICU, and the others showing clinical context: alarm settings, event log, close-up of vital signs monitor, and floor map. Lockheed built the hardware and software infrastructure and implemented the ICU, device design, and workflows to the requirements developed by DocBox and MD PnP.

Workflows in the ICE STORM environment demonstrated the potential patient safety benefits of integrating data from all devices in the ICU and providing advanced bedside clinical decision support. One scenario showed that EKG electrical interference triggered an arrythmia alarm. The alarm was supressed by using data from the within-normal-limits arterial BP and SpO2 pleth. Another scenario detected a vasodilator drug-infusion error, and an invasive BP measurement error which could otherwise mask the drug infusion error.

The technology we explored is promising, and further development, if closely coupled with clinical expertise, will lead to a simulation tool that may be useful in domains as diverse as prototyping medical devices and electronic device interfaces, training clinicians, and adverse event analysis.

THE METHODOLOGY IN CREATING A STEWARDSHIP SYSTEM OF PHARMACEUTICAL COSTS FOR ANESTHESIA PROVIDERS

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Introduction: Healthcare expenditures have increased over the last decade, including anesthetic-related costs. The same time period has seen the advent of more advanced intra-operative electronic records and automated data collection systems. These improved technologies provide the ability for accurate and timely communication of anesthetic-related costs to anesthesia providers.

As part of a multi-center effort with the ultimate goal of decreasing the average cost of anesthesia for surgery, we are creating an automated cost display within a specific AIMS system. Here we describe the methodology for using AIMS data and pharmacy cost information from two large academic medical centers to facilitate this effort.

Methods: The projects received IRB approval from both institutions. We began by obtaining acquisition costs of all intra-operative medications from the institutions' pharmacy. Next, a spreadsheet was manually created to demonstrate a cost calculation for a small sample of patients. We manually entered patient weight, totals of medications given by bolus, rates and durations of medications given by infusion, and expired concentration of inhalation agents for fifteen-minute epochs along with fresh gas flow rates for each epoch. Costs were then determined as a total for each case and a cost-per-minute for each case.

Next, our programming team used the sample patient set to create a set of SQL queries program to automatically obtain and calculate cost per case using the institution's AIMS databases. Specific parameters allowed extraction of data regarding amount of drug given by bolus, infusion, or inhalation. These drug amounts were then indexed with the drug-acquisition cost, providing automated total cost-per-case and cost-per-minute data.

Results: We have now developed at two centers a methodology for automatically determining the drug cost per case.

Discussion: The next phase will be implementation of a real-time display of ongoing cost during a case. We anticipate better stewardship as providers realize what effect their practice patterns have on cost. We also will use selected CPT codes to determine the institution's average cost-per-case for a given CPT, and then provide practitioners with their own average cost-per-case data. .

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CLOSED LOOP VS. ANESTHESIOLOGIST FLUID ADMINISTRATION DURING SIMULATED MASSIVE HEMORRHAGE USING STROKE VOLUME, HEART RATE, AND MEAN ARTERIAL PRESSURE

E. Chung, M. Cannesson, J. Rinehart

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Background: In a previous publication (1) closed-loop fluid management was studied in-silico using pulse-pressure variation (PPV) as a monitored system output. One limitation of this work was the fact that both the simulator and controller utilized the same PPV dataset, creating a possible bias. Additionally, PPV cannot be used in all patients, so a system dependent on PPV would be limited in scope. In this study, we compared the performance of a group of anesthesia providers in managing a simulated hemorrhage to closed-loop (LIRTM) fluid-management using stroke volume (SV), heart rate (HR), and mean-arterial pressure (MAP) alone.

Methods: Using a simulator previously described elsewhere (1), a 90-minute simulated hemorrhage protocol was run which included a 1200mL blood loss over 30 minutes. Twenty practicing anesthesiology providers (residents and faculty) were asked to manage this scenario by providing fluids and vasopressor medication at their discretion (group 1). The simulation program was also run twenty times with the closed-loop algorithm managing fluids (group 2) and an additional twenty times with no intervention (group 3).

Results: Simulated patient weight, height, HR, MAP, and CO were similar at baseline. The closed-loop group received slightly more fluid than the anesthesiologist group. The mean SV, MAP, CO, and final CO was higher in the closed-loop group than in the practitioners group, and the variance was lower

Discussion: Despite the roughly similar volumes of fluid given, the closed-loop outperformed the practioners primarily because the fluid was given earlier in the protocol and SV optimized before the hemorrhage began, whereas practioners tended to resuscitate well but only after significant hemodynamic change indicated the need. Overall, these data support the usability of this algorithm in clinical settings where PPV is not available or applicable.

Table 1: Fluid Management: Practitioners vs. Closed-Loop (LIR™)

	Group		
	(1) Anesthesiologist Managed	**(2) Closed-loop Managed**	**(3) No Management**
Total Fluid Given (mL)	1907 ± 366	2172 ± 323*	0 ± 0**
Mean arterial pressure (mmHg)	77.3 ± 7.9	86.2 ± 1.1*	57.0± 25.8**
Heart rate (beats per minute)	86.2 ± 15.6	75.6 ± 3.8*	141.4 ± 53.2**
Mean SV (mL)	47.9 ± 17.2	76.2 ± 5.6*	31.4 ± 26.9**
Mean CO (L/min)	3.9 ± 1.2	5.7 ± 0.2*	3.1 ± 2.1**
Final CO (L/min)	4.3 ± 1.1	5.8 ± 0.8*	0.8 ± 0.1**

Data are reported as mean ± standard deviation. * P< 0.05 compared to group 1; **P<0.05 compared to groups 1&2.

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CLOSED-LOOP FLUID MANAGEMENT DURING HEMORRHAGE IN ADULT PIGS: LIR™ VERSUS ANESTHESIOLOGISTS

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Many have observed that medical device clocks are not set to the correct time. This is due to a number of causes. Most medical devices lack automatic clock-setting capabilities and cannot set their clocks using a network time reference. Also, there is no adopted standard for medical device time management. Consequently, clocks are typically set manually twice yearly for DST.

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This pilot study supports anecdotal data and first principles that erroneous clock times are pervasive. Given the absence of automatic clock setting capabilities in most medical devices, and typical clock drift, these finding are not surprising. We are working on extending the study to other institutions and care areas.

Fluid Management During Hemorrhage in Adult Pigs: Closed-Loop (LIR™) vs. Anesthesiologists

	Blood Loss (ml)	Volume Given, ml/Kg	HR	MAP	Average CO	Min CO	Average SV	Min SV	Urine Output (ml/min)
Anes 1	1340	80.0	77 ± 4	63 ± 21	4.5 ± 0.5	3.5	60 ± 7	41	4.6 ± 3.5
Anes 2	1200	72.7	103 ± 6	69 ± 9	5.1 ± 0.4	4.5	50 ± 5	39	1.1 ± 2.7
Lir 1	1125	72.0	111 ± 3	76 ± 5	6.8 ± 0.9	5.2	61 ± 7	48	11.8 ± 4.2
Lir 2	1650	72.5	87 ± 10	77 ± 9	4.7 ± 0.7	3.8	54 ± 8	35	8.4 ± 5.9
Lir 3	1200	75.8	82 ± 2	63 ± 9	5.5 ± 0.6	4.7	67 ± 7	56	8.3 ± 6.0

HR - Heart Rate; MAP - Mean Arterial Pressure; CO - Cardiac Output; SV - Stroke Volume; Min - Minimum

A CO2 WAVEFORM GENERATOR USE IN EVALUATING CAPNOMETER PERFORMANCE USING PREVIOUSLY RECORDED CLINICAL DATA

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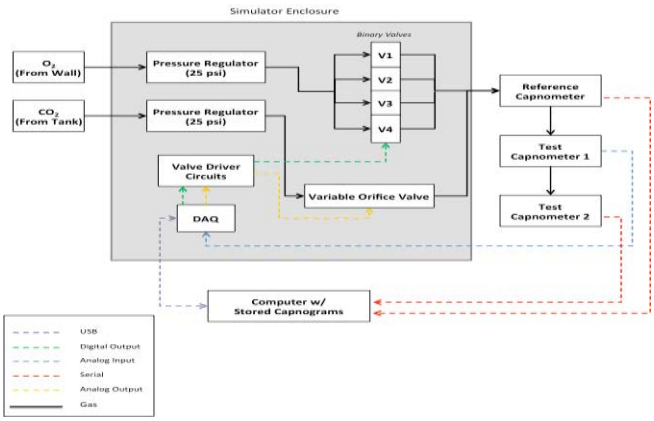
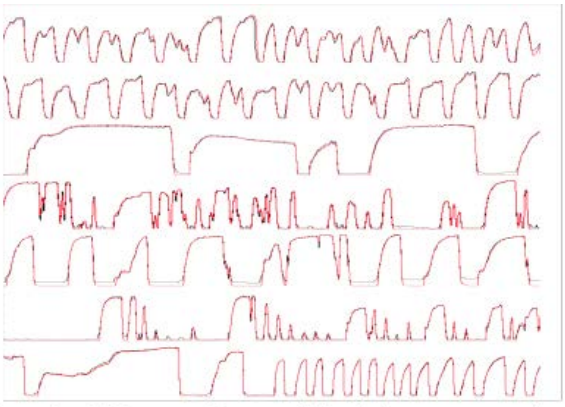
Introduction: Capnometry is becoming a standard for monitoring of spontaneously breathing patients during procedural sedation, during PCA and in the PACU. Because of the variable nature of spontaneous breathing in these conditions, identification of the start and end of each breath within the CO_2 signal can be difficult. Extraction of an accurate breath rate measurement from the capnogram signal becomes more difficult as the breathing becomes less mechanically controlled and as the sampling site moves away from the airway. Identifying breaths from the capnogram for a patient that is intubated and mechanically ventilated is trivial. On the other hand, if a patient is a sedated and breathing spontaneously and CO_2 is sampled via a split-lumen nasal cannula which is also being used to deliver oxygen, accurate detection of the start and end of each breath is much more difficult. Present performance standards for capnometers only require accurate measurement of the concentration of CO_2. There are no performance standards for the algorithms used tocalculate breath rate or end-tidal CO_2 from the CO_2 waveform. We have developed a system that physically re-creates clinically recorded CO_2 signals so that breath detection algorithms, as implemented in multiplecapnometers, can be compared using identical input data.



Methods: Our capnogram waveform generator consists of: 1) 100% CO_2 and O_2 gas sources, 2) a simulator enclosure, 3) a reference capnometer, and 4) a computer with stored capnograms. The concept of the simulator is to continuously change the flow rate of CO_2 being injected into a constant flow of O_2, in order to create varying CO_2 partial pressures over time that mimic capnograms. The CO_2 flow rate is computer controlled through a variable orifice solenoid valve that outputs higher flow rates or higher solenoid currents. Its response is non-linear and requires calibration before use. Once the CO_2 is injected into the O_2 stream, the mixed gas is diverted to the reference capnometer, which is used to calibrate the CO_2 valve and measure the performance of the simulator. The reference capnometer used in this study was the on-airway Capnostat analyzer (Phillips Respironics, Wallingford, CT). Five capnogram data files were used to simulate different CO_2 levels, respiratory rates, and waveform shapes and trends. These files include waveforms from intensive care unit (ICU), operating room (OR), new born, pediatric, and sedated adult patients.

Results: The average statistics for five minute simulations were root mean squared error (RMSE) = 1.99 mmHg, normalized root mean squared error (NRMSE) = 3.77%, mean absolute error (MAE) = 1.40 mmHg, and $R^2 = 0.989$.

Discussion: Using a CO2 waveform generator, it is possible to directly evaluate the performance of capnometer algorithms using a library of clinical data. This waveform generator facilitates the standardization of capnometry algorithm performance so that clinicians can be assured that the parameters reported by their capnometers are consistent for a given type of CO2 waveform regardless of the make or manufacturer of monitor. Furthermore, use of a physical simulation ensures that the capnometer algorithm accounts for the limitations of the analyzer and sampling system.



Sample CO_2 waveforms. Black line represents clinically collected capnogram waveform, red line represents output of waveform simulator

MODEL IDENTIFICATION FOR CLOSED-LOOP CONTROL OF PROPOFOL IN CHILDREN

Sara Khosravi, Klaske Van Heusden, Jonathan Stinson, Guy A. Dumont, J. Mark Ansermino

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Background: The effect of intravenous anesthetic drugs is traditionally modeled using pharmacokinetic (PK) and pharmacodynamic (PD) models. However, a physiological meaningful set of PD parameters is not required for controller design and is not essential for prediction of closed-loop performance provided that the experimental conditions for identification and closed-loop control are similar[1]. In this study, a set of models describing the effect of propofol in children is identified specifically for the design of a robust linear closed-loop controller.

Methods: Following approval of the institutional ethics board, data was analyzed for thirty children, ASA category I/II undergoing elective general surgery using total intravenous anesthesia (TIVA). The WAVcns index[2] as measure of the depth of hypnosis (DOH) was recorded during induction and maintenance of anesthesia. Corresponding propofol infusion rates were recorded manually. Sixteen recordings were discarded due to corrupted data (6), missing data (8) or a strong reaction to tracheal intubation (2) as reflected in the measure of DOH. Data for the first 8 min following the start of the propofol infusion were used for model identification. The Paedfusor[2] PK model was used to predict the propofol plasma concentration. Three different methods were employed for patient model identification: i). Single-step PD model[4]: The PD model was identified using an extensive search of k_{e0} and time-delay combined with constrained least-squares estimation of γ and EC_{50}; ii) Two-step PD model: In the first step, the linear part of the PD model plus time-delay was identified. In the next step, a search algorithm determined the hill parameter that minimizes the root mean squared of the residual; iii). Black-box model: Parameters of a first-order time-delayed model, directly relating the infusion profile to clinical effect were identified. Closed-loop performance of a robust linear controller, designed based on the Black-box model, was verified for the three model sets.

Results: Similar modeling errors can be obtained with the three different sets of parameters. The predicted mean (SD) EC_{50} and γ were 4.5(1.4) and 5.5(1.8) μg/ml and 2.1(0.8) and 1.7(0.2) for the Single-Step PD model and the Two-Step PD model, respectively. The Two-step PD model contained a significantly larger delay 31(24) seconds, compared with the Single-Step PD model 14(20) seconds. Predicted closed-loop performance with a robust linear controller was similar for all three model sets, despite the parametric or structural differences. Clinical evaluation of the controllers in a pilot study[5] confirms the reliability of the models for the design of linear controllers.

Conclusions: Data from induction of anesthesia is not sufficiently rich to independently identify all PD model parameters but is adequately exciting to identify a linear first-order time delay model. Although the identified PD models do not necessarily provide physiologically relevant parameters, the identified models are appropriate for model-based controller design.

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MEASURING ADEQUACY OF ANALGESIA WITH CARDIORESPIRATORY COHERENCE

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Introduction: An automated nociception monitor would be very useful in general anesthesia, providing anesthesiologists with real-time feedback about the adequacy of analgesia. We have developed an algorithm to measure nociception using respiratory sinus arrhythmia (RSA) in heart rate variability (HRV). We have previously shown that this algorithm can detect patient movement (strongly nociceptive events) during general anesthesia [1]. We will now attempt to determine if the algorithm responds to boluses of anesthetic drugs (strongly anti-nociceptive events).

Method: *Algorithm:* The algorithm estimates cardiorespiratory coherence, which is the strength of linear coupling between HR and respiration (one measure of RSA). It measures and combines the spectral power in both signals using wavelet analysis. Coherence is dimensionless, and ranges from 0 (no coherence, strong nociception) to 1 (perfect coherence, no nociception).

Data Analysis: Following ethics approval and informed consent, 60 drug bolus events (excluding induction of anesthesia) were recorded in 47 pediatric patients receiving general anesthesia during dental surgery. In post hoc analysis, coherence was averaged over the 60s immediately preceding the bolus dose of drug (nociceptive period). The bolus was given 30s to take effect, after which the coherence was averaged over the following 60s (anti-nociceptive period). The change in average coherence between the two periods was calculated. The change in average HR was also calculated, for comparison.

Results: Coherence increased by an average of 0.14 (32%) in response to the bolus dose of anesthetic drug. HR decreased by an average of 4.1 beats/min (3.9%).

Discussion: Cardiorespiratory coherence responded much more strongly to the anesthetic boluses than did HR alone. This result, combined with previous work showing that coherence is low during periods of nociception [1], demonstrates that cardiorespiratory coherence can be used to measure the adequacy of analgesia during general anesthesia. We are currently adapting the algorithm so that it can be used in real-time.

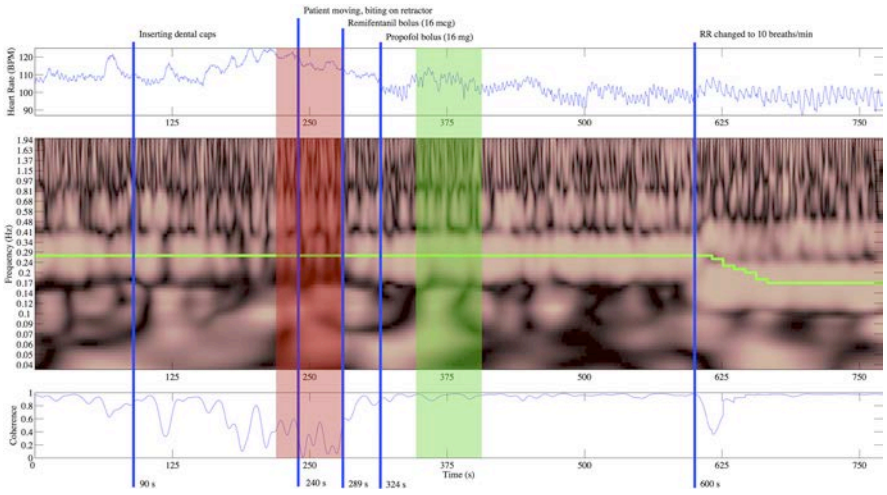

Figure 1: Example coherence analysis. Top plot: heart rate. Middle plot: coherence map in time/frequency. Bright areas indicate high coherence. Horizontal green line indicates the respiratory frequency. Bottom plot: coherence at the respiratory frequency. Vertical blue lines denote clinical events. Red box denotes nociceptive period, green box denotes anti-nociceptive period.

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COMPUTERIZED STANDARDIZED PREOPERATIVE PATIENT INTERVIEW SIMULATOR

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Background: Performing a preoperative evaluation is a critical skill for anesthesiologists [1]. Training and assessing the performance of preoperative evaluations with standardized patients is expensive, time consuming, resource intensive. In certain cases, virtual humans may provide more fidelity than standardized patients for certain kinds of pathophysiology [2]. Residents are increasingly familiar and comfortable with virtual reality and this technology has the potential to offer a scalable, portable solution to such a problem.

We created a virtual human preoperative patient interview simulator (Avatar) as a joint project with LogicJunction, Inc. (Cleveland, Ohio). The Avatar presents an immersive environment to match the sensory experience of interviewing a patient in the holding area of our hospital. Users may ask free text questions of the patient as well as perform physical examination and order relevant laboratory studies. The AI model for the Avatar was created through an iterative test-build process. At the conclusion of the interview, the participant entered their assessment and anesthetic plan and was given performance-based feedback based on a 23-item checklist generated by a panel of anesthesia experts via a modified delphi process.

Methods: All 24 CA-1 residents in our program were recruited to participate in this study at four months into their training. As part of a standard performance assessment, residents were asked to perform a preoperative interview on an ASA 2 female patient presenting for emergent appendectomy. The residents were randomly assigned to interview the Avatar or a standardized patient. Interviews with a standardized patient were observed and adherence to feedback criteria was recorded. Performance of residents interviewing the Avatar was assessed by reviewing system logs.

Results: Group makeup as determined by characteristics and self-reported confidence in performing resident duties was comparable. Residents interviewing the Avatar spent 1.75 minutes longer asking questions (7.33 +/- 0.9 min vs 4.48 +/- 0.5 min; p=0.002) however total number of questions asked was comparable (26.92 +/- 2.3 vs 29.00 +/- 1.5; p=0.09). Residents interviewing the Avatar were more likely to perform physical examination (83% vs 33%) and check vital signs (83% vs 8%). Overall performance as measured by total scores on feedback criteria was similar (16.25 +/- 0.6 vs 16.58 +/- 0.5; p=0.26).

Conclusions: Resident performance of preoperative interview on a virtual reality simulated patient and a standardized patient was comparable. While average interview time was increased, total number of questions, and performance on objective feedback criteria was similar between the two groups.

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ANESTHESIA ATTITUDES REGARDING METHODS OF MONITORING ADEQUACY OF VENTILATION

Greg Spratt, BS, RRT, CPFT, David Lain, PhD, JD, RRT

Oridion Capnography, Needham, MA

Introduction: Multiple clinical organizational standards and recommendations recognize the importance of monitoring quality or 'adequacy' of ventilation during procedural sedation and when monitoring patients receiving post-operative opioids.[i, ii, iii, iv, v, vi] The American Society of Anesthesiologists (ASA) states, "All patients receiving neuraxial opioids should be monitored for adequacy of ventilation (e.g., RR, depth of respiration, oxygenation, and level of consciousness)." [i] The Joint Commission on the Accreditation of Healthcare Organizations recommends "respiratory frequency and adequacy of pulmonary ventilation should be continually monitored in patients undergoing conscious sedation." [vi]

Multiple methods of measuring ventilation have been developed by healthcare manufacturers. The purpose of this work was to survey anesthesia attitudes toward various methods' ability to actually measure 'adequacy of ventilation'.

Methods: A survey of attendees was performed at the 2011 ASA Conference in Chicago. Surveys were self-administered using Apple iPads to access SurveyMonkey.com. Attendees responded to the question, "In your opinion, please rate each of the following in their ability to measure adequacy of ventilation" and given three choices as outlined below. Results were downloaded and assessed in Microsoft Excel.

Results: Primary country of practice for the survey was 85% US and 15% listed as 'outside the US'. In all, 77% of respondents were anesthesiologists, 14% medical students or in residency, 5% respiratory therapists, 3% nurses, and 1% PhD or other doctoral degree.

Measure of Adequacy of Ventilation?

Answer Options	Provides measure of adequacy of ventilation	Provides indication of ventilation but not a measure of adequacy	Not a measure of ventilation	Response Count
Capnography	37 (64%)	21 (36%)	0 (0%)	58
Bioacoustic Respiratory Rate	5 (9%)	33 (61%)	16 (30%)	54
Impedance Respiratory Rate	8 (15%)	27 (49%)	20 (36%)	55
SpO2	12 (21%)	17 (30%)	28 (49%)	57

Conclusions: Of the 4 technologies surveyed, ASA attendees chose capnography as 'provides a measure of adequacy of ventilation' by a margin of more than 3 to 1 over SpO_2, more than 4 to 1 over impedance RR, and more than 9 to 1 over bioacoustic RR.

In choosing which methods are 'not a measure of ventilation':

- Nearly half (49%) chose that SpO2 is not a measure of ventilation
- 36% chose that impedance RR is not a measure of ventilation
- 30% chose that bioacoustic RR is not a measure of ventilation
- 0% chose that capnography is not a measure of ventilation.

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DEVELOPMENT AND IMPLEMENTATION OF A VISUAL INTERFACE TO ACCESS THE COMPURECORD DATA REPOSITORY FOR DATABASE NAIVE END-USERS

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Introduction: Anesthesia Information Management Systems (A.I.M.S.) have been in use for two decades. Their role has been expanded to include patient tracking, perioperative documentation, billing, quality assurance, and research. One common complaint is that it's difficult to obtain specific information within their complex data structures. This project was undertaken to design a visual front-end interface for departmental members without extensive knowledge of database structure or sql language to query our clinical data repository.

Methods: Historical A.I.M.S. data was extracted from an archived repository using the Philips CompuRecord (CR) (Build E01) application and Microsoft Access (MSA). These data were aggregated into five tables, then mapped to 71 visual interface fields. A user-friendly interface was developed using Microsoft Visual Basic allowing users to easily navigate buttons and drop-down menus to compile data of interest. Based on the user's clinical question, an algorithm developed by our group creates a "Select" query statement. The results are then visually represented in a MSDataGrid. The data can be exported to either MSA or MS Excel from within the interface.

Results: The interface was created during a two-month period by self-taught physician programmers and has been implemented to assist with retrospective departmental administrative and quality assurance inquiries. This interface was developed with minimal overhead, and without the outlay of large infrastructure support.

Implications: Creating an easily navigable visual interface permits database naive users to easily gain access to archived anesthetic data.

DEVELOPMENT OF A RESOURCE-CONSERVATIVE AND COST-LIMITED "BACK-END" DATA REPOSITORY OF COMPURECORD INFORMATION

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[2]Department of Anesthesia, Mount Sinai Medical Center, New York, NY

Introduction: Anesthesia Information Management Systems (AIMS) have been in use for two decades. Their role has been expanded to include patient tracking, perioperative documentation management, billing, quality assurance, and research. Data collected from our institution's A.I.M.S. has been archived, yet largely inaccessible for analysis since implementation 13 years ago. We herein demonstrate the method used to transform this historical data into an accessible repository.

Methods: The architecture of Phillips CompuRecord (CR) (Build E01) tables was decrypted from the operative reports of 100 patients via Microsoft Access. Using known field inclusions, the data was mapped to ListL table and divided into patient- and case-specific data to complete the charting of CR Native Data Reports. A module was designed in Visual Basic (VB) to automate data extraction from the research module not archived to CR tables. Using a second VB utility this data was aggregated and placed in re-normalized tables.

Results: An aggregated data table consisting of greater than 220,000 cases was created containing a comprehensive archive of anesthetic and patient information since inception of the A.I.M.S. at our institution. Self-taught physician programmers created the repository during a two-month period without the outlay of large infrastructure support.

Implications: An A.I.M.S. data repository can be developed inexpensively, and be employed for retrospective analysis of large data sets.

EVALUATION OF AN EXPERT SYSTEM FOR DETECTING VENTILATORY EVENTS DURING ANESTHESIA IN A HUMAN PATIENT SIMULATOR

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The University of British Columbia, Vancouver, Canada

Background: Current perioperative monitoring systems produce a huge amount of largely un-interpreted data, employ threshold alarms prone to artifacts and rely on the clinician to continuously visually track changes in multiple sources of physiological data over time. A prototype expert system "eVent" was developed to make full use of this data and provide real-time clinical decision support. It uses a validated set of limits and rules for the identification of selected critical events during anesthesia [1]. The purpose of this study was to evaluate the efficacy of the expert system in enhancing the anesthesiologist's ability to detect critical events in a simulated operating room environment.

Methods: A high fidelity human patient simulator was used to simulate an operating room. Study participants were randomized to experience four scenarios: Anesthetic vapor overdose, tension pneumothorax, anaphylaxis, and endotracheal tube cuff leak. The expert system was placed on top of the usual anesthesia displays and in half of the scenarios the expert system provided trend-based alerts and differential diagnoses. Time to diagnosis (detection) and time to treatment (clinical intervention) were measured. Workload questionnaires [2] and structured debriefings were administered after each scenario. A usability questionnaire [3] was completed at the conclusion of the simulation session.

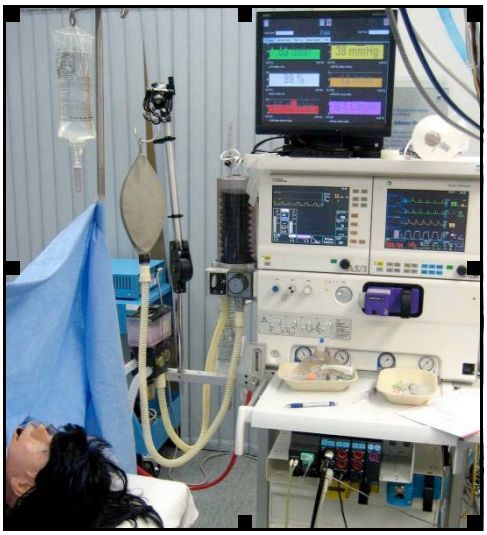

Figure 1: Anesthetic setup for the anaphylaxis scenario. The decision support system (black monitor) is seen at

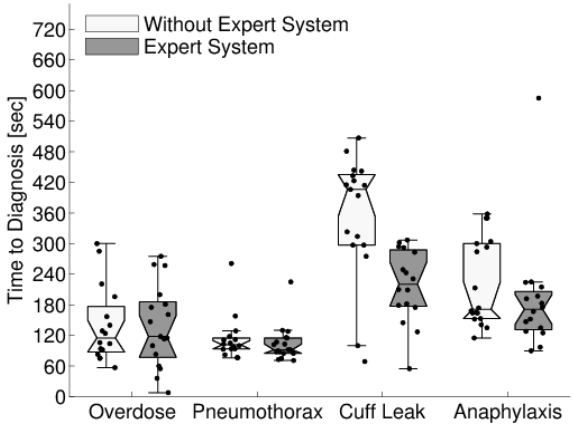

Figure 2: Time to Diagnosis, Grouped by Scenario. Each icon shows the lowest value, the lower quartile, the median value, the upper quartile, and the uppermost value. A dot denotes each datum.

Results: Fifteen anesthesiology residents, 5 anesthesiology fellow physicians, and 15 staff anesthesiologists participated in this study; 24 were male. The median age (range) was 36 (29-66) years with a median (range) of 6 (1-38) years of anesthesia experience. A significant improvement in both time to detection and time to treatment was observed in the ETT cuff leak scenario; a median reduction by 185.5 and 128.5 seconds respectively. No reduction in times to detection and treatment were found for any of the other three scenarios. Participants were highly satisfied (median of 2 on a scale of 1-7) with the expert system. Three areas critical to safety: Avoidance of task fixation, reassurance to initiate invasive treatment, and confirmation of a suspected diagnosis, were identified from the debriefings.

Conclusions: Participants appreciated the system's support in making their diagnosis and encouragement to perform invasive treatments. Many participants noted that the system prevented them from falling victim to task fixation and expressed their desire to have access to such a system during their routine clinical activities. We had hoped to show an improvement in all scenarios but only found an improvement in one scenario. Nevertheless, we were encouraged by the skill and performance of the study participants both with and without the expert system. The study highlights the difficulty in simulating the clinical environment in a situation when participants are aware that something is very likely to happen within a short space of time.

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A ROBOT TO REDUCE THE TIME AND NUMBER OF STEPS TO DELIVER INTRAVENOUS MEDICATION DURING ANESTHESIA

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Background: Conventional method of delivering intravenous medication during anesthesia is timeconsuming, requiring 45 seconds and 41 steps to administer one medication. We introduce a robot to reduce the time and number of steps.

Method: The robot consists of eight syringe pumps controlled by an app running on an Android tablet (Google, Mountain View, CA). In the first study, thirty trials are conducted with the robot, which requires 3 steps: inspecting cartridge, placing cartridge into device, and selecting medication. The timing of medication administration begins when a syringe is selected and ends when the pump is activated. Another thirty trials are performed in another study with medications prepared in advanced, reducing the step to 1: selecting medication. The time starts when a button is selected from the tablet to control the pump and ends at the same point as the first study.

Results: In the first study, medication is prepared and administered in 5.0 seconds +/- 1.2 seconds (mean +/- standard deviation). This represents a savings of 89% for time and 93% for steps compared to conventional methods. The second study shows that medication can be delivered in 2.8 seconds +/- 0.4 seconds, a reduction of 94% for time and 98% for steps.

Discussion/Conclusion: The use of an anesthesia robot speeds the delivery of medication by reducing the 41 required steps to as few as 1. The delivery of intravenous medications can be performed faster by pressing electronic buttons on a touch screen with an anesthesia robot than by conventional methods.

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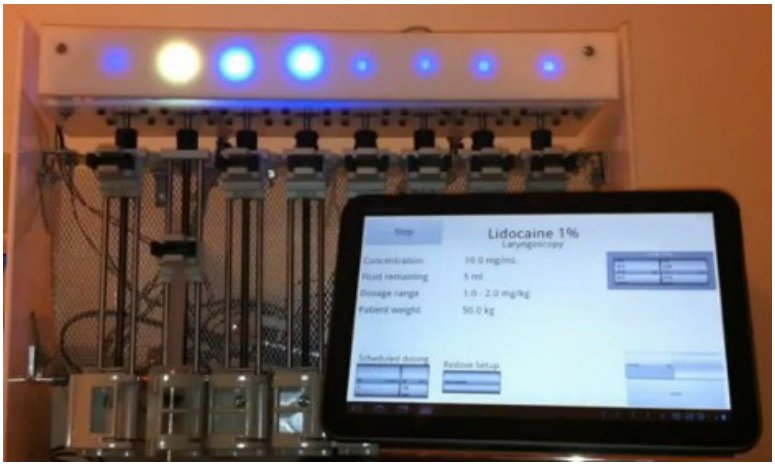

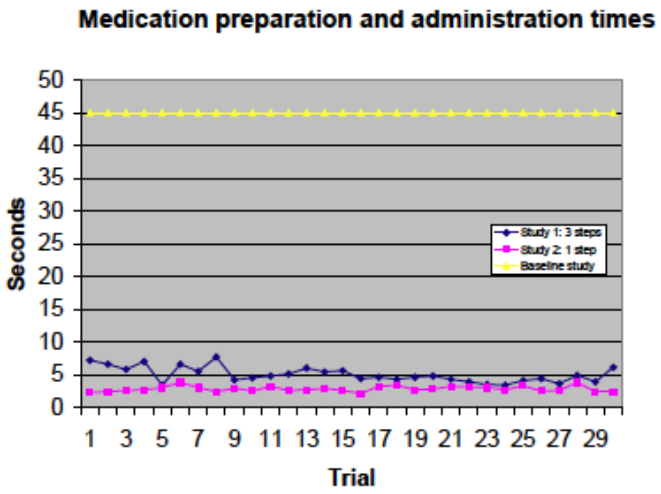

DEVELOPMENT OF AN IOS APPLICATION FOR TEACHING PHARMACOKINETICS OF COMMON ANESTHETIC DRUGS

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Jefferson Medical College, Atlantic City, NJ

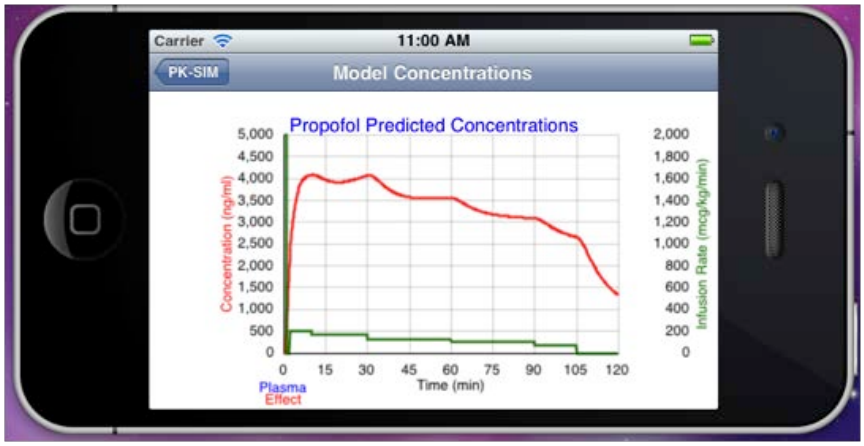
Introduction: Computer simulation is a powerful tool that allows one to model intravenous drug concentrations, including such concepts as plasma and effect site target control, and context-sensitive half-times. We describe our experiences developing and publishing a pharmacokinetic modeling program (PK-SIM) for iPhone or iPAD devices.

Methods: A Macbook Pro and an Apple Developer license were purchased to allow software development and deployment, and placement in the App Store, respectively. The original PK-SIM program (Medical Data Applications, Ltd), written in Delphi (Borland) for the Windows operating system (Microsoft), was rewritten in Objective C (Apple), with inclusion of the following drugs: alfentanil, atracurium, dexmedetomidine, diazepam, etomidate, letamine, methohexital, midazolam, pancuronium, propofol, remifentanil, rocuronium, sufentanil, thiopental, and vecuronium. Accuracy of the new code was confirmed by numerical comparison of sample simulations with the original PK-SIM program, previously validated against STANPUMP (http://anesthesia.stanford.edu/pkpd). The original PK-SIM manual and pharmacokinetics tutorial was updated and made available at no cost on the Jefferson Department of Anesthesiology web site (http://www.jefferson.edu/jmc/anesthesiology/education/PK-SIM.cfm)

Results: Considerable difficulty was experienced is securing the developer license due to business documentation requirements not relevant to an academic anesthesia department. Implementation in the Objective C development environment (Xcode) was complicated due to poorly documented public libraries and code limitations imposed by Apple. Testing and deployment was complex due to requirements for registering test devices, multiple provisioning codes, and confusing documentation. Program behavior on the Xcode simulators did not always mirror behavior on actual devices. The Apple review process was prolonged (> 2months) with no means to determine the cause of the delay. Replies from the Apple development support group to questions were often delayed by a week or longer. Apple rejected the initial build based on their demand for a 17+ rating ("Frequent/Intense Alcohol, Tobacco, or Drug Use or References") despite explanations that this was a medical simulation product and complaints that similar simulation programs carried an unrestricted 4+ rating. Application rating is important, as the 17+ rating preludes distribution in some countries. Instructions supplied by Apple to modify the rating were incorrect and resulted in having to resubmit the application, with a return to the back of the review queue. The application was eventually published in the App Store, and subsequent versions have been reviewed and approved more quickly than the original build.

Conclusion: Development and deployment of this iOS application was difficult and time consuming, contrasting with the comparable process for Android devices. For Android applications there are no vendor-imposed code restrictions, no arbitrary review process, no limitations on distribution for testing, and a greatly simplified deployment process. Those seeking to do iOS development of anesthesia-related software should expect frustration and a large initial expenditure of time and effort and. However, subsequent development cycles should be considerably less onerous as the development team learns to deal with the rigid Apple process.

Main Screen	Sample Model Plot	PK Parameter Screen



PERFORMANCE OF THREE NASAL CANNULAS AND TWO ORAL BITE BLOCK DEVICES FOR END TIDAL CO2 MONITORING DURING SEDATION FOR UPPER GI ENDOSCOPY, A COMPARATIVE BENCH STUDY

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Background: Upper GI endoscopy are typically performed using conscious sedation.[1] Drug-induced respiratory depression is a major cause of serious adverse effects during sedation. Recently, many manufacturers have introduced new models of monitoring bite blocks and sampling nasal cannulas that facilitate CO2 monitoring to assess breathing during sedation. However, the utility of these devices for CO2 monitoring has not been evaluated. This bench study was designed to compare the performance of three nasal cannulas and two oral bite block which are commonly used in conscious sedation especially during the EGD.

Methods: We connected a mannequin head to one side of a two-compartment test lung model by a 7.0mm endo-tracheal tube with its opening in the nasopharyngeal position. (Fig 1) The other lung compartment was driven by a ventilator to mimic "patient" inspiratory effort. In this spontaneously breathing lung model, we evaluated the YX GE nasal mask (Yong-Xu medical instrument Co., Ltd. Taiwan), The Hauge airway bite block (Penlon, UK), CO25 Bite Block (Encompas Unlimited, Inc., FL), a conventional nasal canula (Adult Nasal Cannula 032-10-020, Flexicare Medical Limited, UK), Flexicare dual nare nasal cannula (Flexicare Medical Limited, UK), a CO2 sampling nasal cannula (Adult Divided cannula 4707-7-7-25, Salter Labs, CA), and an Oral-Trac nasal cannula (Adult Divided Oral/Nasal Cannula 4797, Salter Labs, CA) at various oxygen flow rates and over a range of mouth opening apertures. Note that a Flexicare dual mask (Flexicare Medical Limited, UK) was also tested in an upside down configuration to allow insertion of an upper GI scope. Test lung compliance was set to 50 ml/cm H2O with a simulated airway resistance of 8.2 cm H2O/ (L*s). Simulated rate and volumes were12 /minute with 500 ml and 8 /minute with 300 ml. Pneumatic resistors in different sizes were applied in the mouth of Manikin head to simulate different levels of mouth opening. CO2 measurements from two locations (at the sampling device and from a sampling gas port connected between the from the endotracheal tube and test lung) were compared. CO2 was measured using an anesthesia gas analyzer (CapnoMAC, Datex, Helsinki, Finland).

Results: With all devices, supplemental oxygen flow was increased from 1 L/min to 10 L/min. We observed a substantial decrease in EtCO2 values from tested devices when oxygen flow was increased while the measured decrease in EtCO2 was less when measured at the endo-tracheal tube. All observed etCO2 sampled from the test devices were lower than the corresponding measurement sampled at the endo-tracheal tube Different sizes of mouth opening played an important role in theetCO2 measured at both locations (see figure below).

Conclusion: Specially designed CO2 Monitoring oxygen delivery devices provide a good and acceptable method of monitoring etCO2 and respiratory rate for patients under conscious sedation for upper GI endoscopy. Oxygen flow to the device highly influences the etCO2 value measured from the side stream sampling either from devices in this bench manikin head study. In the sampling cannula, CO2 cannot be monitored if oxygen flow is high and the mouth is open.

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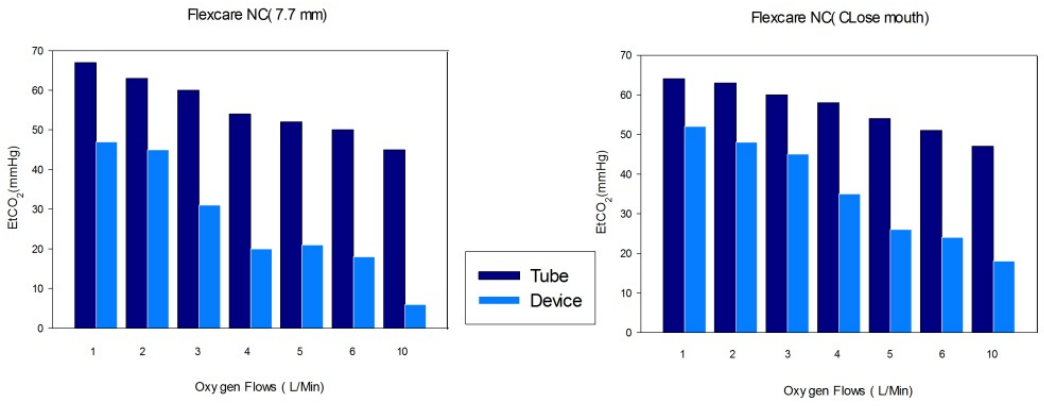


COMPARISON OF FIO2 OF NASAL CANNULAS, MASKS, AND MOUTH BITE BLOCK USING IN SEDATION PATIENTS DURING ESOPHAGOGASTRODUODENOSCOPY- A BENCH STUDY

Chien-Kun Ting, MD, PhD,[1,2] Joseph A. Orr, PhD,[2] Lu Yu, MS,[2,3] Dwayne Westenskow PhD[2]

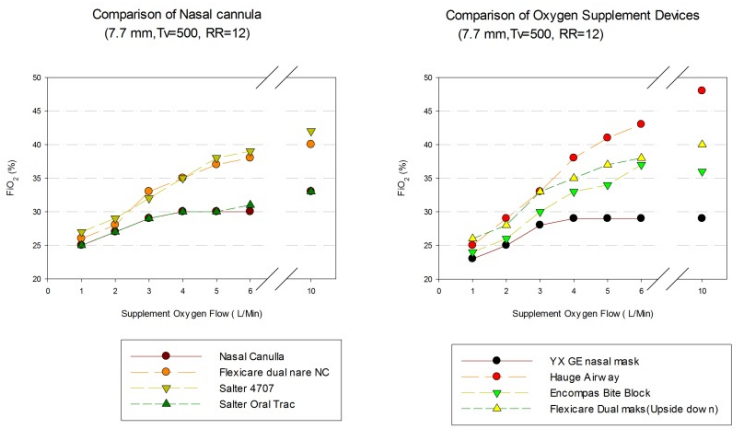
[1]Department of Anesthesiology, Taipei Veterans General Hospital and National Yang-Ming University, Taipei, Taiwan; [2]Department of Anesthesiology, University of Utah, Salt Lake City, Utah; [3]Department of Biomedical Engineering, China Medical University, Shenyang, P.R.China

Background: Esophagogastroduodenoscopy (EGD) and colonoscopy procedures are usually performed using conscious sedation [1, 2]. Drug-induced respiratory depression is a major cause of serious adverse effects.Adequate oxygen saturation is very important for patient safety [2]. Keeping the patient at higher oxygen saturation can reduce the severe complications.[2, 3] The oxygen saturation level is affected not only by patient's breathing, but whether supplemental oxygen is being supplied. Supplying the supplemental oxygen to a sedative patient is a common and standard practice[3]. The higher of oxygen saturation before apnea, the longer the patient can tolerate hypoventilation. During the past few years, manufacturers have introduced new models of bite block and nasal cannula that include CO2 sampling ports along with supplemental oxygen delivery. However, the oxygenation ability of these devices has not been evaluated. The current bench test study was designed to compare the FiO2 performance of these new nasal cannulas, masks, and bite block devices which are commonly used during sedation for EGD, colonoscopy and other procedures.

Methods: We connected a mannequin head to one side of a two-compartment test lung model by a 7.0mm endo-tracheal tube with its opening in the nasopharyngeal position. The other lung compartment was driven by a ventilator to mimic "patient" inspiratory effort. In this spontaneously breathing lung model, we evaluated the YX nasal mask (Yong-Xu medical instrument Co., Ltd. Taiwan), The Hauge airway bite block (Penlon, UK), CO25 Bite Block (Encompas Unlimited, Inc., FL), a conventional nasal canula (Adult Nasal Cannula 032-10-020, Flexicare Medical Limited, UK), Flexicare dual nare nasal cannula (Flexicare Medical Limited, UK), a CO2 sampling nasal cannula (Adult Divided cannula 4707-7-7-25, Salter Labs, CA), and an Oral-Trac nasal cannula (Adult Divided Oral/Nasal Cannula 4797, Salter Labs, CA) at various oxygen flow rates and over a range of mouth opening apertures. Note that a Flexicare dual mask (Flexicare Medical Limited, UK) was also tested in an upside down configuration to allow insertion of an upper GI scope. Test lung compliance was set to 50 ml/cm H_2O with a simulated airway resistance of 8.2 cm H_2O/(L*s). Simulated rate and volumes were set at 12 /minute with 500 ml and 8 /minute with 300 ml. Pneuflo resistors in different sizes were applied in the mouth of Manikin head to simulate different levels of mouth opening. FiO_2 was evaluated continually by sampling gas port connected between the from the endotracheal tube and test lung. FiO_2 was measured using an anesthesia gas analyzer (CapnoMAC, Datex, Helsinki, Finland).

Results: FiO_2 was measured using each device with supplemental oxygen flow rates increased from 1 to 6 L/min and at 10 L/min. The amount of FiO_2 increase for each device, oxygen flow rate and breath rate are shown in the figure below. Although the Flexicare dual mask was tested in an upside down method, the results show acceptable performance relative to the other tested devices.

Conclusion: Orifice size of the mouth opening, supplement oxygen flow, tidal volume and respiratory rate all influence the FiO2 in most of the tested devices. Flexicare dual mask in the upside down method has a similar result with other devices that are specially designed for oxygenation during upper GI procedures. This implies that we can use any conventional oxygen delivery mask in this simple method to get the similar effect of supplemental oxygen.



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AUDIO PHONE OXIMETER

Christian L Petersen, J Mark Ansermino, Guy Dumont

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Introduction: Pulse oximetry is critically important in anesthesia as an early indicator of hypoxemia. Conventional pulse oximetry is widely used in the developed world, but many developing regions do not have access to this life saving technology due to lack of infrastructure (such as electricity) and the prohibitive cost of devices. The use of the ubiquitous cell phone as a vehicle for pulse oximetry may be a way to address these issues [1]. We describe a method for connecting an oximeter finger sensor directly to the generic audio port of a cell phone, thereby bringing cost to a minimum.

Method: We connected a standard NellcorTM oximeter finger sensor directly to the audio port of a second generation iPod TouchTM. The light emitting diodes in the sensor were lit by the headphone output signal and the photodiode signal detected directly by the microphone input. All signal processing, including signal quality estimation and heart rate and oxygen saturation extraction, was performed onboard the phone in a custom software application.

Results: The sensor was activated through the audio interface, and the sensor light appeared visually as bright as when operated by commercial oximeter hardware. The extracted red and infrared waveforms from the sensor were processed in real time using conventional algorithms adjusted for the AC coupled nature of the audio interface (see Fig 1). The application calculated heart rate and oxygen saturation (currently uncalibrated) in real time. Sufficient signal levels are obtainable with adequate sensor placement.

Conclusion: We have demonstrated the feasibility of a pulse oximeter consisting of a sensor cable connected to a cell phone through the audio interface. The manufacturing cost of such audio sensor cables is several orders of magnitude less than conventional hardware solutions, thus potentially allowing wider dissemination of pulse oximetry to remote regions of the world.

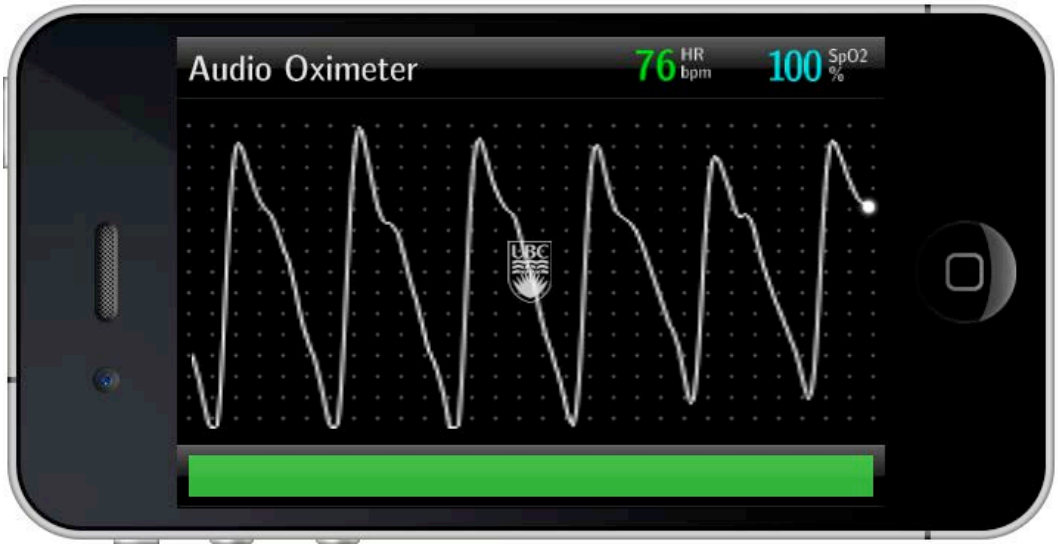

Figure 1: Audio Oximeter showing plethysmogram, trends and signal quality (bottom bar).

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HIGH-SPEED ALGORITHM FOR PLETHYSMOGRAPH PEAK DETECTION IN REAL-TIME APPLICATIONS

Christian L Petersen, J Mark Ansermino, Guy Dumont

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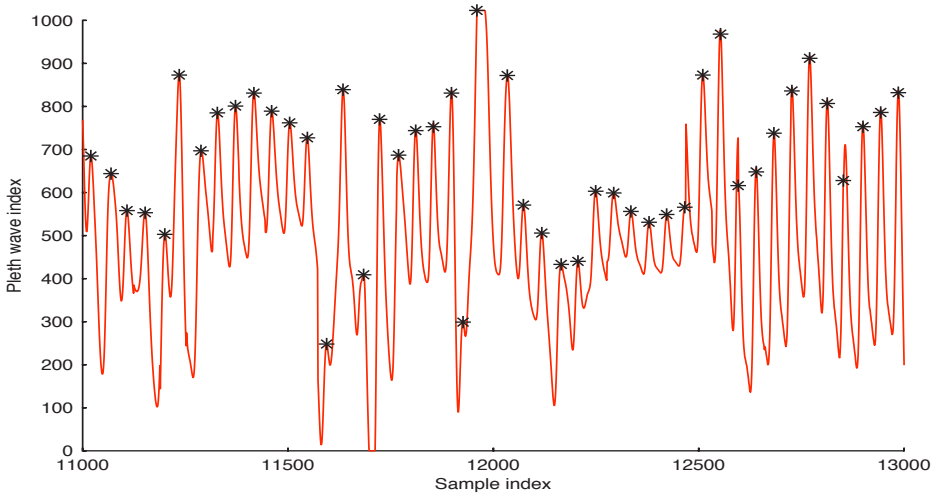
Introduction: Conventional methods for peak detection involve complicated filter banks and/or frequency domain analysis. We present a much simpler and computationally efficient method using an iterative function fractal. The simple nature of such functions and their ability to operate on complex unfiltered data could potentially provide a useful trade-off between speed and complexity for real-time applications in systems with limited resources, such as mobile phones.

Method: We considered a one-dimensional iterative function fractal $f_n = \{ (P_n - P_{n-1} > 0 \ ? \ 1 : 0) + f_{n-1} \} / 2$ with peak detection logic $f_n<0.6 \ \wedge \ f_{n-1}>0.999$, P_n being the unfiltered plethysmogram data. This algorithm was implemented in a few lines of C language and applied to two publicly available expert annotated plethysmogram benchmark data sets with a total of >15,000 annotated peaks and a sampling rate of 125Hz [1]. No tuning was performed against the benchmark data, and no checks applied to validate the calculated peak positions. Only the $f_{n-1}>0.999$ threshold has significance to the detection and was selected independently by processing 75Hz plethysmogram data collected with a Nonin™ Xpod™ oximeter module.

Results: The algorithm displayed good resistance to changes in signal offset and amplitude, as shown in figure 1(a). Statistical analysis against the benchmark data further revealed a positive predictive median value of 98.8% (98.6-99.8%) and a sensitivity of median 97.7% (97.3-98.1%) (figure 1(b)). The PPV is about 1% less than results achieved with a much more elaborate conventional algorithm [2], but does provide a clinically acceptable tradeoff between speed and accuracy. The algorithm is fully implemented by three lines of C code, and has virtually no computational overhead.

Conclusion: A fractal method to analyze plethysmographic signal waveforms has been developed, and we have shown good correlation with benchmark data. The method provides a new method for detecting the heart rate with extremely low computational requirements, ideal for embedded real time systems and mobile applications.



A

SET 1		Expert	
		Positive	Negative
Algorithm	Positive	9450 (P)	182 (FP)
	Negative	17 (FN)	- (N)

Positive Predictive Value: 99.8 %
Sensitivity: 98.1 %

SET 2		Expert	
		Positive	Negative
Algorithm	Positive	6317 (P)	174 (FP)
	Negative	87 (FN)	- (N)

Positive Predictive Value: 98.6 %
Sensitivity: 97.3 %

B

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EVALUATION OF OXYGEN DELIVERY VIA A NOVEL SMART CAPNOLINE DELIVERY SYSTEM DURING SIMULTANEOUS OXYGEN THERAPY AND CARBON DIOXIDE MONITORING

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Oridion Capnography, Jerusalem, Israel

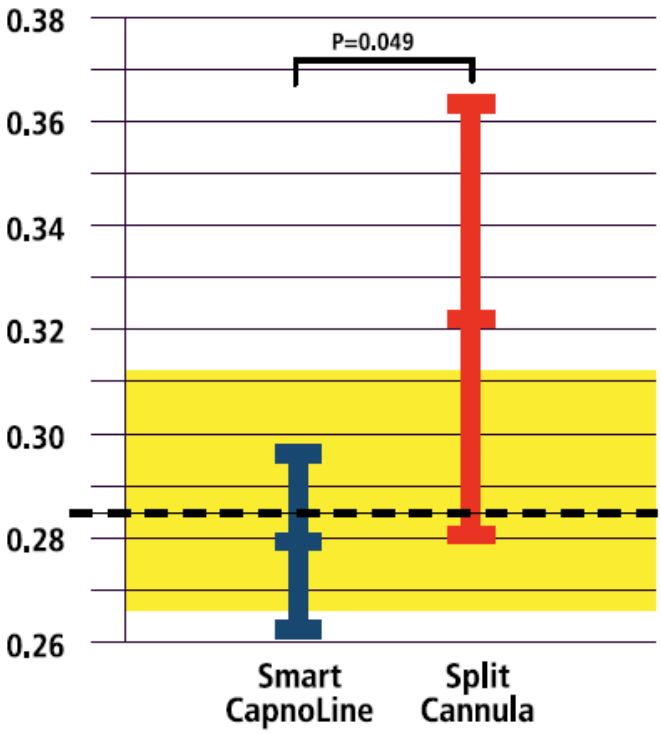
Introduction: Split cannula monitoring of CO2 during oxygen delivery is an incomplete solution to this clinical need. Oxygen is often required during non-invasive capnography. The titration of oxygen is important in many pathologies. Nasal cannula is the standard for low flow oxygen delivery during simultaneous CO2 monitoring. This study evaluated a novel method for oxygen delivery during CO2 monitoring, employing a nasal diffuser to create a pre-nasal cloud of oxygen enriched gas.

Materials & Methods: Subjects were studiedusing oxygen delivery at 2.5 and 5lpm of either split delivery (split) nasal cannula (Salter Labs, Arvin, CA) or a Smart CapnoLine (SC) oxygen cloud-delivery monitoring line (Oridion, Jerusalem, Israel), or both. Gas in the posterior pharynx was monitored using a continuous oxygen monitor (Mini-OX 3000/406931-CAG13, MSA, PA USA) sampled through a feeding tube inserted nasally under direct observation. Pharyngeal oxygen concentration was measured using each sampling system and under both oxygen flow rates after values stabilized.

Results: 10 subjects were measured using the SC, 16 using the traditional split cannula. Pharyngeal oxygen concentrations were significantly different between the two methodologies at 2.5lpm ($p<0.05$); the pharyngeal oxygen concentration was SC 27.9±2.4% v. split 32.2±7.6%. FiO2 was not significantly different at 5lpm; SC 36.4±4.2% v. split 41.7±10.7% . These data also suggest a clinically-significant difference in the consistency of the FiO2 delivered to the pharyngeal airway at 2.5 LPM (Figure 1). The standard clinical rubric of 0.21 + (LPM*3) lies in the centre of the 95%CI for the Smart CapnoLine results. The use of the traditional cannula delivered a highly variable and generally elevated FiO2 as compared to the value expected for both oxygen flow rates.

	Smart CapnoLine		Split Cannula	
	2.5 LPM	5.0 LPM	2.5 LP	5.0 LPM
Mean	27.9	36.4	32.2	41.7
SD	2.4	4.2	7.6	10.7
95%CI	26.2-29.6	3 3 . 5 - 39.4	28.2-36.2	35.9-47.4
Range	25.2-31.3	31.2-44	24.6-49.6	31.3-73.9

Pharyngeal FiO_2 at 2.5 LPM Flow (shown Mean ± 95%CI). Blue = Smart Capnoline, Red = Split Cannula, Dashed = "Expected 0.285" value from calculation, Yellow = Range Mean ± 95% CI derived from Schacter et al, Crit Care Med 1980 – as used in Egan, Fundamentals of Respiratory Care 6th Ed.



Conclusions: The pharyngeal FiO2 of the Smart Capnoline is not different from the anticipated FiO2 predicted from standard references and from the common FiO2 calculation. Smart Capnoline oxygen delivery provided a more consistent FiO2 and was significantly different, as compared to a traditional split cannula design at 2.5 LPM. FiO2 was not significantly different between the two methods at 5.0 LPM. Larger trials in clinical environments are now required to extend these findings.

THE PHONE OXIMETER FOR MOBILE SPOT-CHECK

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Introduction: The Phone Oximeter is an inexpensive and portable pulse oximeter that uses a finger sensor connected to a mobile phone. This innovative device is targeted at users in developing countries with little or no availability of pulse oximetry equipment. The Phone Oximeter was initially developed by the Electrical and Computer Engineering in Medicine (ECEM) group for continuous monitoring of oxygen saturation (SpO2) in the operating room (OR) . A low SpO2 is also a good predictor of disease severity and treatment response in a wide range of diseases such as pneumonia in children . We aim to make SpO2 more widely usable outside the OR through quick spot-checks of SpO2 in combination with clinical predictive models of disease states. For this, we have started by designing a mobile phone research application (PhoneOxR) to record and store accurate spot-checks of a patient's SpO2 using the Phone Oximeter.

Methods: To develop the PhoneOxR (Figure 1), we used an iterative process of design and informal testing. PhoneOxR is comprised of:

a) The display and recording of the i) plethysmogram and ii) heart rate (HR) and SpO2 trends.

b) A Signal Quality Index (SQI) algorithm computes the quality of the incoming measurements as a percentage (where 100 is a perfect SQI). The SQI is reduced below 100 by the presence of warning flags from the sensor's module, low plethysmogram amplitude (low perfusion) and high trend variability. Algorithm thresholds can be adjusted within the application. The SQI value is mapped to a colour: red (0), orange (0-89), or green (90-100), which is displayed as the current colour of the graph background. Changes in data quality result in prominent colour changes.

c) A horizontal progress bar shows the SQI colour over time. The recording length can be set and the recording is complete once the bar fills. The percent of the recording that was good quality, as well as the median HR and SpO2 trend values calculated from only green (SQI > 90) sections of the recording are displayed at the end of the recording.

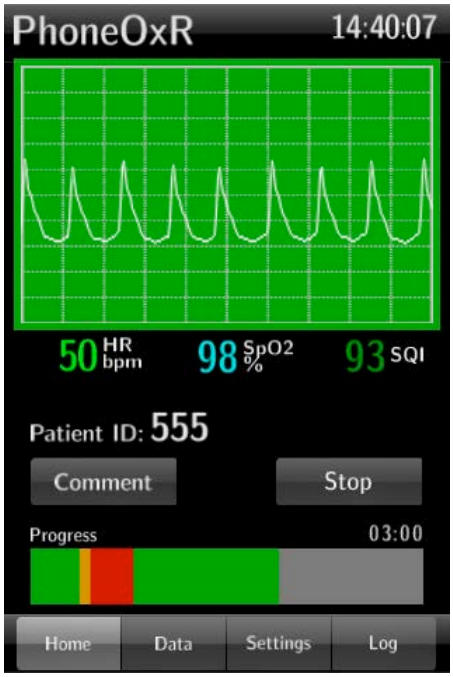

Figure 1: The PhoneOxR application's 'Home' tab displaying (a) the plethysmogram with trend values and (b) SQI below , and (c) a recording progress bar indicating SQI over time.

d) A survey component for the entry of patient details such as demographics, which are stored with all the patient's SpO2 recordings. In the future this information can be combined to produce a predictive score of how likely the patient is to have a given disease.

Results: The PhoneOxR application provides a means of quickly obtaining a spot check recording of a patient's SpO2 along with an indication of the quality of the recording. The final percent of data quality and colours of the progress bar may prompt the user to redo the recording, promoting the collection of good data. The PhoneOxR application is currently in use in Uganda for a clinical study on childhood sepsis.

Conclusions: The PhoneOxR is a simple application for quick and high quality spot-check recordings of SpO2 and HR for research purposes. In the future, its utility will be greatly expanded by the use of the phone's camera and GPS to more accurately keep track of patients, and the storage of data to a secure server, which will synchronize data between multiple mobile devices in the field.

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EMPLOYING BUOYANCY TO EXTRACT MICROEMBOLUS-SIZE MICROBUBBLES FROM FLOWING FLUID: QUANTIFICATION WITH A UNIQUE MATLAB ALGORITHM

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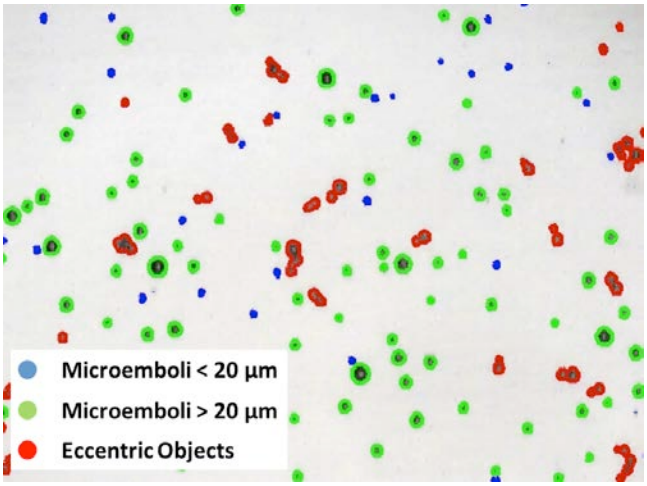
Summary: A Matlab script to characterize microembolus-size bubbles in flowing fluid was created to assess efficacy of a prototype device designed to model removal of microbubbles from extra-corporeal blood flow for heart-lung bypass. Microembolus size and shape characteristics are superimposed on video images for visual assessment.

Hypothesis: Microbubbles of sizes thought to contribute to cognitive deficits after cardiopulmonary bypass can be quantitated and attrition demonstrated in rapidly flowing fluids.

Introduction: Cardiopulmonary bypass machines are known to introduce microemboli into circulatory tubing and thus into the patient. Current generation arterial filters serve as a barrier to microemboli, preventing the circulation of microemboli larger than about 40 microns in diameter. However, microemboli of less than 40 microns have been shown to be detrimental to patient health. Pore or lattice barrier filters with smaller passages have excessive resistance to flow and produce excessive shearing damage to blood cells. Therefore, a device employing a different mechanism capable of preventing circulation of microemboli less than 40 microns could be beneficial. Microemboli less than 20 microns in diameter are thought to be inconsequential to human health and thus do not need to be removed during extra-corporeal circulation. Proof that a device is capable of preventing the circulation of hazardous microbubble emboli requires verification that microemboli are reduced. This study presents an innovative method for the quantification of microemboli in flowing fluid. This novel quantification method was employed to assess design changes to a novel microemboli extraction device.

Methods: Experimental Setup: A flow loop was constructed in which water was pumped at 400 mL/min through 3/8 inch rigid square acrylic tubing. Stable 10-40 micron microemboli were created in an albumin solution by hand agitation. These microemboli were then introduced into the flow loop. Optical microscopes with video recording capability were set at 40x magnification. Video of the albumin-stabilized microemboli within the flow channel were recorded at positions before and after the extraction device.

Microemboli Quantification: Recorded videos were post-processed with a novel Matlab script. The script accurately records the number and size of microemboli within video frames. Additionally the script recreates the processed video and color codes objects detected (Image), allowing for the rapid verification of the detection algorithm. Diameter, area, and eccentricity of the labeled microemboli are saved for future processing.



Bubble size (microns)	P-value for one-tailed t test
20-25	0.2475
25-30	0.0811
30-35	0.0059
35-40	0.0004

Results: Preliminary confirmation of the efficacy of this novel extraction device was obtained using this detection technique for a variety of experimental conditions. Extraction was statistically significant for microemboli larger than 30 microns, but not significant for extraction of microemboli smaller than 25 microns (Table). Extensive additional development and testing are needed.

PRELIMINARY ASSESSMENT OF NOISE IN THE OPERATING ROOM

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Sound levels affect communication, perception of clinical situations, and patient care in the operating room (OR). Noise in this context refers to the aggregate of all sounds present in the operating room environment. The OR is typically an undamped environment that resonates sound. While noise is a suspected contributor to some adverse events, attention to patient care details, and impairment of timely communication, its contribution is qualitative, unstructured, and difficult to document.

Methods: Sound levels were measured in a convenience sample of 39 general anesthesia cases attended by the author. Most cases involved tracheal intubation, though one involved LMA insertion. Some cases involved Rapid Sequence Inductions, difficult intubations, and intubated ICU transfers. Patient ages ranged from infant to nearly a century. ASA class ranged from 1 to 4. Eight surgical services were represented. No adverse induction-related events occurred during collection of this data sample.

Acoustic decibels (dB) are logarithmic (ratio) units sound intensity. Minimum (dBmin), maximum (dBmax) and average (dBavg) sound levels were recorded using an uncalibrated Radio Shack Digital Sound Level Meter (catalog no. 33-2055) for an indefinite period starting just before pharmacological induction of anesthesia until after satisfactory control of the airway. Concurrent observations of circumstances that might affect ambient noise were noted. Additional variables were identified when perceived to be either a consequence of noise, or a potential contributing factor. Thus there are many gaps and inconsistencies in this data sample. The Radio Shack meter is only capable of holding measurements within a preset 20 dB range, usually set for 60-80 dB. Fast response (0.2 second samples) and "C weighting" (flat, 32-10,000 Hz) were used. Under-range ("LO") values were recorded as the range minimum.

Results: Whenever the sound meter was noticed by OR staff there was an associated decrement in sound level. As such, reported measurements probably underestimate what would have occurred without observation bias. 39 cases were collected. The sample size is small and there is much missing data, so statistical assessment has little basis for validity. The mean of averages (dBavg) was 65 dB and the mean of maxima (dBmax) was 70 dB overall. By service, average and maximum decibels each differed by about 5 dB from least to most.

There is no firm relationship between recorded sound pressure levels in decibels (dB) and qualitative perception of noise that might affect communication at the head of the OR table. Depending on the character and source of ambient sound, differences of 5-10 dB could be perceived as qualitatively similar. That is, 65-70 dB conversation seems less intrusive than a low-pitched musical beat measuring the same intensity. In general, less than 60 dB characterizes a quiet office environment and soft speech. 65 dB is typical for normal conversation, while 70 dB characterizes moderately loud music or animated conversation. By 80 dB definitely raised voice and repetition are required for communication. Shouting is sometimes required for communication over 90 dB background noise. One loud, spurious monitor alarm registered 74 dB right at the head of the bed due to "high pressure" for an arterial line that had not yet been inserted. The highest sound levels recorded in this series of observations was 95 dB. On another occasion the author has recorded 105 dB in an operating room (loud music and correspondingly loud conversation). Pneumatic devices when used can be louder.

Future Plans: This preliminary quality assessment (QA) study was undertaken without IRB approval. No patient or staff identities were recorded. This study identified variables that may be incorporated in a formal prospective study of OR sound and provides preliminary data for estimation of statistical power. Qualitative observations will be used to define nominal scales for assessment of ambient conditions and potential impact on quality of patient care. A formal study assessing noise in the OR is anticipated.

CLINICAL PERFORMANCE OF ELECTRONIC CONTROL FOR AISYS™, TO AUTOMATICALLY ADJUST FRESH GAS, AGENT AND OXYGEN

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Traditionally, anesthesiologists administer oxygen and agent (AA) by manually adjusting vaporizer and FGF settings. However, it is technically possible to design a feedback system to automate manual adjustment. We did evaluate the end-tidal control (EtC) prototype designed for Aisys™ (GE Healthcare) on the human subjects. Our aim was to access clinical performance vs. expectations of anesthesiologist, plus to compare behavior of the control system vs. technical specs.

Methods: After approvals of ethical committee and authorities, and with written informed consent, we enrolled 20 ASA 1-3 patients undergoing standard gynecological procedures. Anesthesiologist responsible of patient care stayed in the O.R. observing the control system, and there was a technical observer to record time marked notes. At induction, anesthesiologist dialed targets for Et-AA and Et-O2 to the controller, enabling software algorithm to control FGF and vaporizer. Non-invasive monitoring included ECG, SpO2, NIBP, Entropy, NMT, spirometry, and airway gas concentrations of O2, N2O, CO2 and AA. Clinical data and control system's data flow were collected in real time. Clinical quality indicators (e.g. hemodynamic variability) had been defined a priori. After the case, anesthesiologist estimated whether any monitored variability was due to technical or clinical reasons.

Results: Enrolled 20 patients met all inclusions criteria; none had to exit during study. There were no adverse effects. HR and BP remained stable (±25% from control) in 16/20 patients, (clinical reason in 4 patients). In 18/20 cases SpO2 was above 90% all the time, (clinical reason in 2 patients).

Five anesthesiologists used the system in sevoflurane anesthesia: three were consultants and two were junior staff. Nobody stopped using controller during the cases. Neither did EtC system exit unexpectedly. Technical assessment of control performance parameters included response and setting times, command overshoot and steady state deviations of both Et-O2 and Et-AA.

Conclusion: This open observational study was the first systematic comparison on human subjects, with the prototype end-tidal control system designed for Aisys™ . Both clinical findings and technical data were according to pre-set specifications.

QR CODES IN ANESTHESIA PRESENTATIONS

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Introduction: We highlight our integration of QR (Quick Read) codes into anesthesia publications. QR codes increase the ability to disseminate information accurately and rapidly. The user needs a smartphone and an application to access the encoded information.

Method: Denso Wave, a subsidiary of Toyota developed a matrix barcode for fast readability and compactness with a built-in error correction resource and the ability to encode up to 4,296 alphanumeric characters. QR code1 is a registered trademark of Denso Wave who owns the patent rights (US 5726435) but chooses not to exercise them.

Over 85% of resident physicians in ACGME programs used a smartphone in 20112. By incorporating QR codes into our scientific submissions, a pathway is automated for accessing the information presented AND cited, thereby enhancing the reader's experience. Furthermore, the codes can link to websites with video and audio capacity thereby improving the reader's experience beyond words on paper.

Results: We present this poster with QR codes displayed on the publication. With the codes, the reader can access information about the authors, the authors' institution, the references cited, a digital copy of the presentation, further figures not included in the presentation, and video files that could not be presented otherwise.

We believe that utilization of QR codes in academic submissions enhances the product by offering more immediacy and raising the level of participation for the reader.

Conclusion: We feature the adoption of QR code technology into anesthesiology presentations by demonstrating some of the possibilities through this interactive poster.

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COMPARISON OF DIDACTIC BASED TO SIMULATION/MODEL BASED TEACHING OF A PERIOPERATIVE ULTRASOUND EXAMINATION TO ANESTHESIOLOGY RESIDENTS

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UCI Medical Center, Orange, CA

Introduction: Recent advances in ultrasonography has allowed the general anesthesiologists to explore point-of-care assessment of: cardiopulmonary function, volume status, and evaluate for severe thoracic/abdominal injuries. The focus of this study was two-fold: 1) to introduce the concept of a perioperative ultrasound exam that focuses on the concepts listed above 2) to evaluate if a simulation/live-model based lecture would be a more effective method of teaching this topic to anesthesiology residents than a traditional didactic lecture.

Methods: The subjects consisted of current anesthesiology residents at UCI medical center. Residents received either a ninety-minute one-on-one didactic lecture or a ninety-minute lecture at the simulation center during which they were able to practice on a live model and a simulation module (SimMan) throughout the lecture. Data points included a pre-lecture multiple choice test, post-lecture multiple choice test, and post-lecture live-model based examination. Post- lecture tests were performed within three weeks of the lecture. The model based examination was graded by an experienced sonographer who was blinded to the education modality.

Results: A total of 20 residents completed the study. Nonparametric Wilcoxon Tests (Table 1/Figure 2) showed statistically significant higher scores for the simulation group on both the post-lecture multiple choice written (p=0.038) and post-lecture model (p= 0.041) examinations. There were no differences between the two groups on pre-lecture test scores (p=0.97) (Figure2).

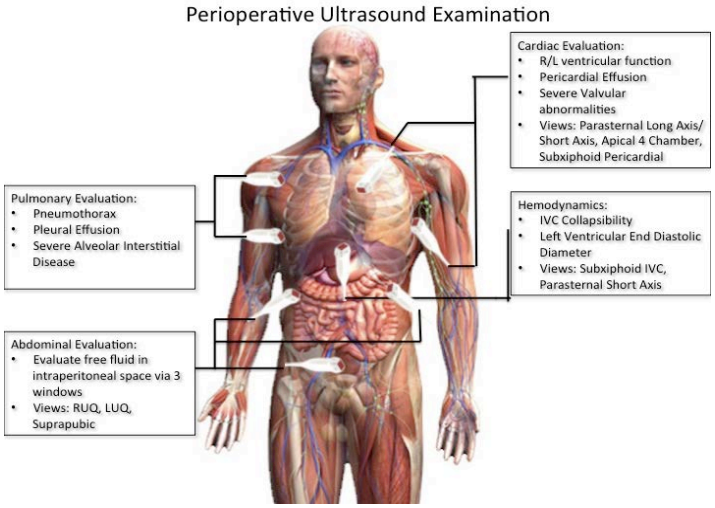

Figure 1: Perioperative Ultrasound Examination

Conclusions: This study introduces the concept of a perioperative ultrasound examination that focuses on basic interpretation of cardiopulmonary function, volume status, and evaluation for severe thoracic/abdominal injuries and suggests that a model/simulation based lecture series may be more significantly more effective in teaching these concepts to anesthesiology residents then traditional didactic lectures.

	Total # Residents	CA-1s	CA-2s	CA-3s
Didactic Group	10	3	4	3
Model/Simulation Group	10	3	3	4
Pre-Instructional Written Examination Scores (max=18)				
	Median	Mean	Percentage Correct	
Didactic Group	7 + 0.82	7.1 + 2.6	39.4 + 14.5	
Model/Simulation Group	6.5 + 0.99	7.2 + 3.12	40 + 17.3	
Nonparametric analysis	p=0.97			
Post-Instructional Written Examination Scores (max=28)				
	Median	Mean	Percentage Correct	
Didactic Group	15.5 + 1.32	16.1 + 4.18	57.5 + 14.9	
Model/Simulation Group	19.5 + 1.32	20.1 + 4.2	71.8 + 14.9	
Nonparametric analysis	p=0.038			
Post-Instructional Model Examination Scores (max=33)				
	Median	Mean	Percentage Correct	
Didactic Group	11.5 + 1.75	12.3 + 5.54	37.3 + 16.8	
Model/Simulation Group	18 + 1.84	17.8 + 5.81	53.9 + 17.6	
Nonparametric analysis	p=0.041			

Table 1: Didactic vs. Model/Simulation Test Score Comparison

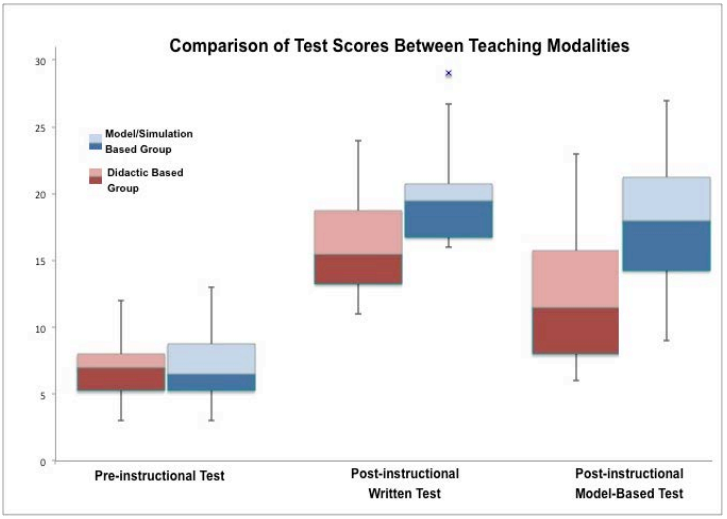

Figure 2: Comparison of Test Scores Between Teaching Modalities

APNEA DETECTION DURING SEDATION USING TRACHEAL SOUNDS ENTROPY

Lu Yu, MS[1,2], Bryce Hill, PhD[2], Ken Johnson, MD[2], Talmage Egan, MD[2], Chien-Kun Ting, MD[3], Joseph Orr, PhD[2], Dwayne Westenskow, PhD[2]

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Introduction: Undetected apnea can lead to hypoxic encephalopathy, bradycardia and even cardiac arrest. Tracheal sounds entropy has been proved to be a robust method for estimating respiratory flow,(1) thus maybe a more reliable way to detect apnea. Our study hypothesis is that changes in the entropy of tracheal sounds will provide an early warning of the onset of apnea in sedated patients, especially when the patients receive supplemental oxygen.

Method: After obtaining IRB approval, 24 volunteers received propofol and remifentinal in graded steps until they became unresponsive to the insertion of a bougie into the trachea (simulating an endoscope). At each step, respiratory flow rate and tracheal sounds were recorded using a pneumotachometer (CO2SMO, Novametrix, Louisville, KY) and a microphone (WM-56A103 Panasonic) placed in a precordial stethoscope. The logarithm of the tracheal sound Shannon entropy (Log-E) was calculated to estimate flow rate. An adaptive Log-E threshold was used to distinguish between the presence of normal breath sounds and apnea. Apnea detected from breath sounds was compared to the apnea detected from respiratory flow rate, Fig 1.

Result: Apnea occurred 322 times during the 12.9 hr study. Table 1 shows that the volunteers did not breathing for 15 sec or longer (apnea) for a total of 148 min, as detected from both the tracheal sounds and the respiratory flow meter. Periods of apnea were not detected by the tracheal sounds for a total of 7 min. Tracheal sounds misclassified periods of normal breathing as apnea for a total of 54 min. The acoustic method detected apnea in sedated volunteers with a sensitivity of 95% and a specificity of 91%.

Discussion: We found the entropy of the acoustic signal from a microphone placed over the trachea may reliably provide an early warning of the onset of apnea in volunteers receiving propofol and remifentanil.

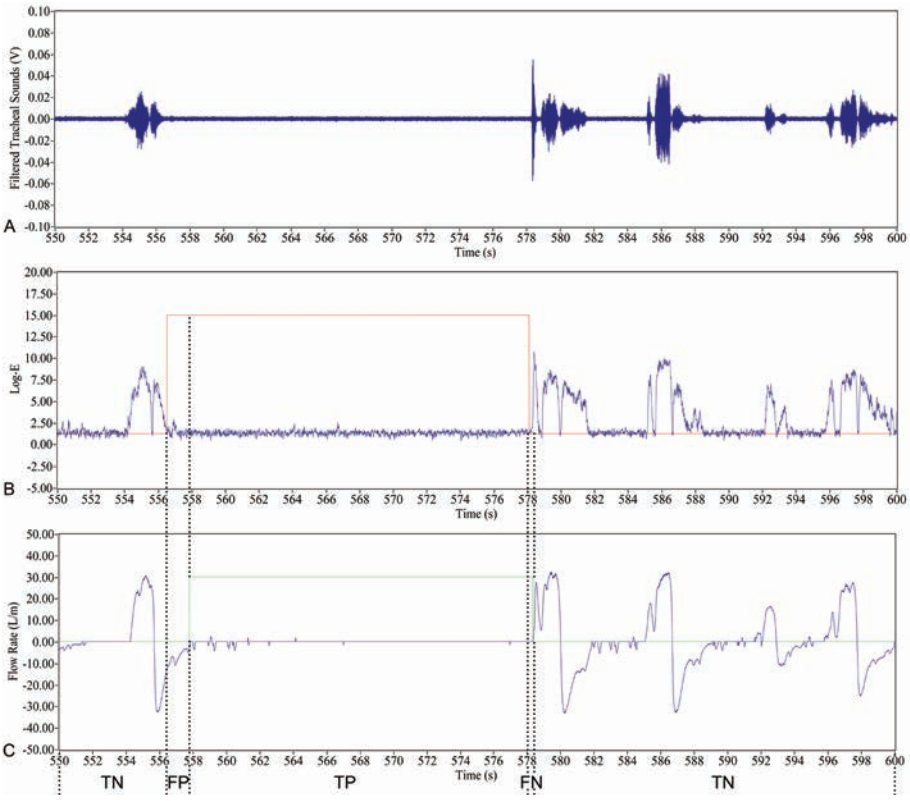

Fig 1. Tracheal sounds before and after a period of apnea (A), Log-E signal where the period of apnea is shown by the red line (B) and respiratory flow rate where the period of apnea is shown by the green line (C).

	Flow Meter	
Tracheal sounds	Apnea	Normal
Apnea	148 min (TP)	54 min (FP)
Normal	7 min (FN)	565 min (TN)

Table 1. The total sum of the length of all apneic periods, as detected from tracheal sounds and respiratory flow.

References

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LUNCH! A WEB APPLICATION TO COORDINATE ANESTHESIA PROVIDER LUNCH RELIEF

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Background: Everyone needs LUNCH! At a medical center with few anesthetizing locations, it should not be difficult to coordinate lunch relief to providers (i.e. residents, CRNA's, direct-providers). At a large tertiary care center with dozens of anesthetizing locations spread throughout multiple buildings, coordinating lunch relief is challenging. To address this, the LUNCH! application was created.

Methods: LUNCH! is an HTML based web application that functions both as a smartphone app (Figure 1) and a traditional desktop website (Figure 2). LUNCH! lists all of the anesthetizing locations in a two column layout, contains a call button for each location which rings the anesthesia providers line, and most importantly a button which toggles from HUNGRY to Fed when pressed. This information is relayed to the webserver and all LUNCH! application clients display the updated status. All locations are automatically reset to 'HUNGRY' daily at midnight.

Discussion: Prior to implementing this application at our institution, the team of residents (usually 4) responsible for providing lunch relief to anesthesia providers would need to repeatedly call or visit one-another in an operating room (OR) to cross-check and update their paper checklists throughout the afternoon. This was a very inefficient and distracting process. Additionally, a provider would often be asked multiple times by different lunch relief team members, with an interrupting phone call or visit to the OR, if they 'ate?' These redundant inquiries are distracting to the anesthesia provider and the surgical team, as well as unnecessarily increasing traffic into the OR's.

After deploying LUNCH! as a tool for the lunch relief team, the process is now streamlined and efficient. Redundant calls to anesthesia providers and multiple visits to OR's have been minimized. The need to call and track down other lunch relief team members to cross-check and update paper checklists is no longer necessary – everyone can see the real-time 'lunch' status of all anesthesia locations and act accordingly.

Conclusion: The LUNCH! application has provided practical benefits for coordinating lunch relief and a study is currently underway to quantify the improvements in efficiency and reduction in OR interference the application provides.

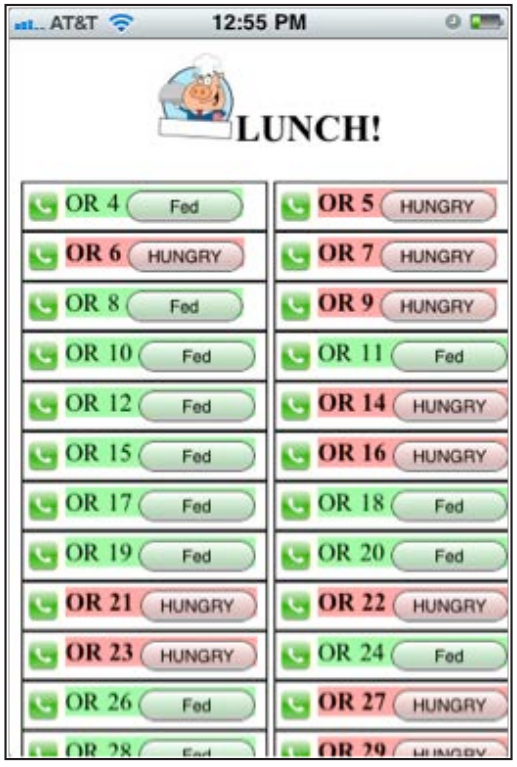

Figure 1

Figure 2

ANESTHESIA TECH MANAGER: WEB-BASED STAFF COMMUNICATION SOFTWARE SOLUTION

Frank Gencorelli, MD

University of Pennsylvania, Philadelphia, PA

Background: Anesthesia technicians (tech) help ensure anesthesia providers have the necessary means to deliver safe and efficient patient care. It is vital for the anesthesia provider to be able to quickly contact their assigned tech at any time and from any location within the hospital. To improve the anesthesia provider's ability to quickly and efficiently contact their currently assigned tech, the AnesthesiaTechManager and AnesthesiaTechFinder programs were created.

Methods: AnesthesiaTechManager and AnesthesiaTechFinder comprise a software suite of three parts:

1. AnesthesiaTechManager: a desktop web-browser application where administrators make staff 'assignments' via drag-and-drop in the 'AssignmentMaker' section (Figure 1), and in the 'Administration' section the staff roster and anesthetizing locations are managed with simple 'add' and 'remove' functions.
2. AnesthesiaTechFinder (desktop version): a desktop web-browser application displaying anesthetizing locations with assigned techs name and contact number, as well as an ordered list of techs with their current assigned locations. (Figure 2)
3. AnesthesiaTechFinder (mobile version): a mobile web-app with two views: the 'byLocation' view displaying all anesthetizing locations with their assigned techs (Figure 3) and the 'byTech' view which lists techs with their current assignments. Simply tapping on a 'location' in the 'byLocation' view initiates a phone call to that locations assigned tech.

Discussion: The current system of communicating with the anesthesia techs is often inaccurate and inefficient. During tech change-of-shift and case turnover, multiple phone calls are often required to contact the correct tech, which wastes time and potentially compromises patient safety. Efficient and accurate communication with the anesthesia techs may be achieved with the AnesthesiaTechManager and AnesthesiaTechFinder programs.

Conclusion: A study is currently underway to collect data on communication inefficiencies pertaining to anesthesia technicians at our hospital and we expect to reduce these inefficiencies when the AnesthesiaTechManager and AnesthesiaTechFinder programs are deployed for all end users.

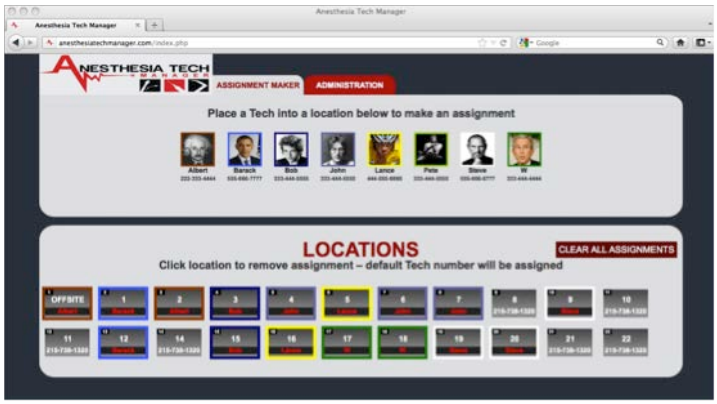

Figure 1

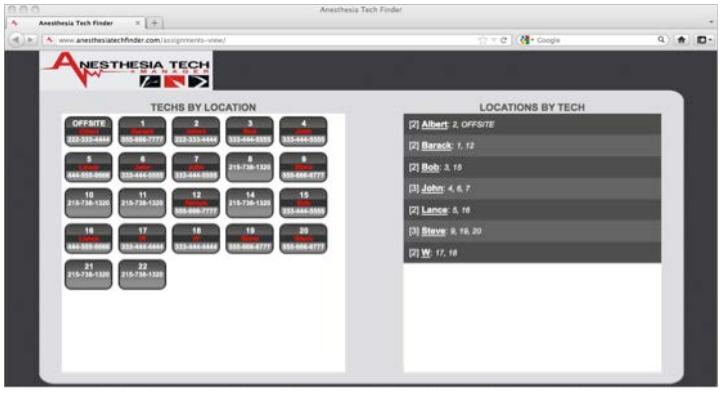

Figure 2

Figure 3

FEASIBILITY OF SMARTPHONES AS A TOOL TO VERIFY ANESTHETIC MEDICATIONS

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Background: Medication errors remain a major patient safety issue in anesthesia, occurring in 1:131 to 1:5475 anesthetics. Work from the Institute for Healthcare Improvement has demonstrated that the most effective changes are ones that "attempt to change processes, not people" (1). Two process changes that have emerged are 'double-checking' and barcode labeling of medications. The practice of 'double-checking' has been estimated to detect 58% of anesthetic medication errors (2). Barcoding has been demonstrated to reduce errors and improve charge capture (3). The implications of wide implementation of these schemes have been studied in the British NHS (4), and several limitations noted. Two person identification requires the availability of two providers who are able to focus on the task, and barcode systems require significant changes in infrastructure. Both systems are subject to involuntary automaticity, in which the drug passes from drawer to patient without passing through the mind of the person administering it.

Smart phones have become ubiquitous amongst healthcare providers, and provide the capacity, in a single device, to encompass all features of double-checking and barcode identification. We sought to identify the elements required for such a solution and the capacity of current devices to meet these needs.

Requirements:

1. The system should use multiple communication modalities to confirm drug choice. The user should speak the name of the drug and scan the barcode.
2. The device should make a connection between the communication modalities – the spoken drug name and a scanned barcode must agree.
3. The system should incorporate geographic context – medications should ideally be checked in proximity to the patient, or at least in the location in which the patient will be.
4. Implementation of the system should be feasible with currently available technology

Assessment:

1. Speech input – While natural language processing is beyond the capacity of current devices, identification of one word from a fixed vocabulary is achievable. The open source package OpenEars was evaluated for this purpose and found to perform acceptably.
2. Barcode recognition – Numerous packages are available for consumer barcode dictionaries, however, pharmaceutical labels are encoded in GS-1 DataBar Limited. Modification of the open source package ZBar to support this standard is under evaluation.
3. Image recognition – While reliable OCR of medication labels is beyond the capability of current devices, 2D correlation of a limited dictionary of containers is possible. The open source package OpenCV was evaluated and found to be feasible.
4. Identification of geographic context by WiFi SSID is feasible, but not ideal. RFID solutions such as NFC and DASH7 are available as external readers currently, and will be incorporated into devices in the near future.

Conclusion: Software is available for current iOS and Android devices to perform double-checking of medications with barcode labeling, and perhaps with recognition of a limited set of medication containers. Validation of this technology in high fidelity simulation will be the next step in the process.

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TOWARD MEANINGFUL USE OF THE EMR: DEVELOPMENT OF AN ANESTHESIA DATA WAREHOUSE FOR QUALITY IMPROVEMENT, ADMINISTRATIVE REPORT AND RESEARCH – THE OPERATION ROOM (OR) DATAMART

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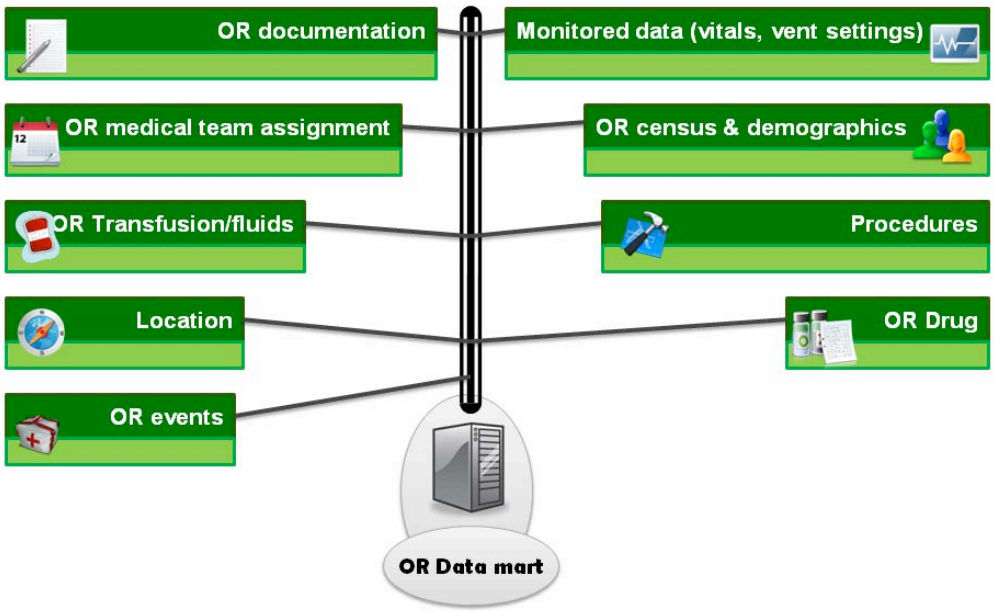
Introduction: Electronic medical records (EMR) have been increasingly integrated into the perioperative health care environment. In 2008, 44% of the 140 US academic anesthesia departments reported using an anesthesia information management system (AIMS). However most of these systems are proprietary and not particularly well suited for quality improvement initiatives or clinical research. Moreover, most exist as "silos" which do not communicate well with other information technology systems within the health care environment. To overcome these barriers, we have developed an anesthesia data warehouse - "OR Datamart." The datamart is a highly integrated, near-real time database that contains nearly all pertinent perioperative health care information. More importantly, the datamart is queryable, which is greatly facilitating quality improvement, administrative, and research initiatives.

Methods: The OR Datamart is a Microsoft SQL based database storing pertinent data from source electronic systems in a near-real time fashion. All relevant perioperative data for a single tertiary care academic medical center are captured and stored without pre-processing.

Results : In phase 1 of OR Datamart development, we obtained all relevant data from the perioperative environment from the year 2003 (limited data in 1999-2003) to present. For the year 2010, we captured clinical data from 648 anesthetizing locations including 103 full operation rooms which have average approximately 50,000 surgical cases per year. For each included year, the datamart contains information on approximately 300,000 unique procedures, 20,000,000 documented events, 1,900,000 data points related to fluid

Conclusions : We have developed a near-real time integrated OR Datamart that contains clinical and administrative data on all patients who received anesthetic care at a single academic medical center. This system utilizes EMR data to facilitate quality improvement initiatives, administrative and clinical reporting as well as clinical research.



IMPLEMENTATION OF PROBABILITY RAMP CONTROL SEDATION IN A HANDHELD DEVICE

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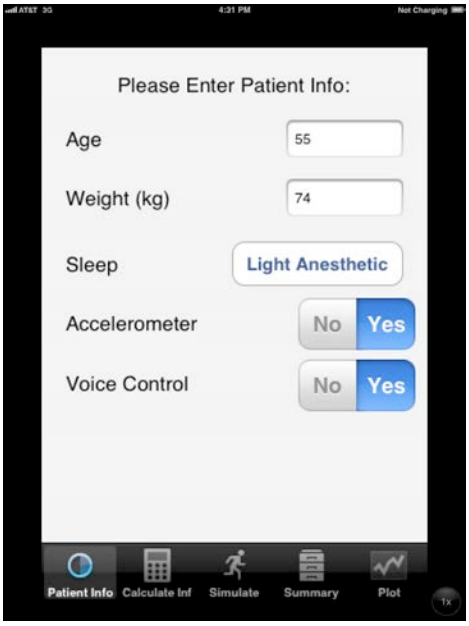
Introduction: Probability ramp control (PRC) employs pharmacokinetic/pharmacodynamics modeling to devise an infusion sequence that identifies, during a slow increment in the probability of loss of responsiveness (LOR), the effect site concentration associated with this endpoint (1). The system requires minimization of a nonlinear function to determine a bolus and two infusion rates that will track a target trajectory, and when LOR is observed, a second minimization to determine the subsequent infusion sequence. The system was originally implemented in MATLAB; the current effort describes implementation on the iPhone to permit distribution for a multicenter trial.

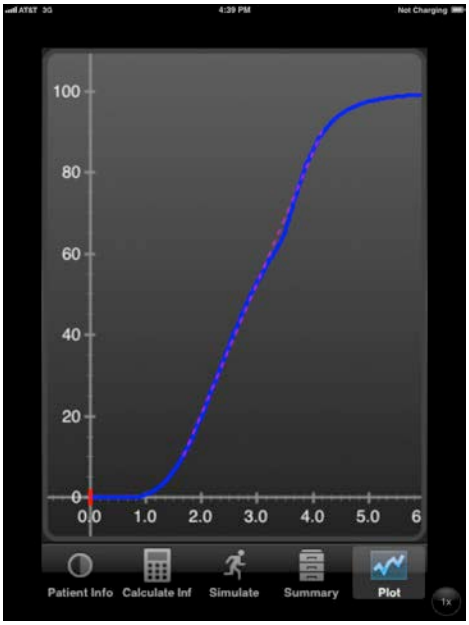
Methods: The mathematical core of the algorithm employs minimization of an error function derived from application of an infusion sequence to a state space model. In MATLAB, this is accomplished with built in functions; to implement in C, the GNU Scientific Library (GSL) was employed.

Two additions were made to exploit features of the iPhone – the accelerometer and voice command input/output. The accelerometer allows the iPhone to be secured in the patient's hand and loss of consciousness detected by sudden drop. Voice input/output was implemented using the OpenEars library to permit operator interaction when the device is in the patient's hand.

Results: The mathematical core calculations are performed in less than ten seconds on a first generation iPad. Voice commands are typically recognized on the first attempt for most speakers. Accuracy of detection of loss of motor tone is high under simulated conditions, but has not been evaluated in clinical conditions.

Discussion: Implementation of PRC in clinical practice with accurate identification of the pharmacodynamic endpoint seems feasible, but will require clinical validation.





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QUANTIFICATION OF ABDOMINAL EXPIRATORY MOTION VIA CORRELATION OF RESPIRATORY INDUCTANCE PLETHYSMOGRAPHY AND SPIROMETRY

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Introduction: Spontaneous ventilation (SV) during general anesthesia is associated with phasic contraction of expiratory muscles; this activity is decreased by pressure support ventilation (PSV) [1], and can be measured via EMG, intraabdominal pressure, and optical scanning of the abdominal wall [2], but this is not always practical. We describe a method that employs correlation of spirometry and respiratory inductance plethysmography (RIP), and demonstrate its application during transitions in PSV.

Methods: With IRB approval and informed consent, 12 patients undergoing cystoscopy under inhalational anesthesia with LMA were enrolled. Transitions from PSV to SV were performed during maintenance anesthesia. RIP and spirometry were recorded at 120 Hz. Spirometry signals were analyzed to determine breath boundaries, and trapezoidal integration used to determine tidal volume. RIP signals were differentiated and correlated with spirometry data, as suggested by [3] and depicted graphically in figure 1.

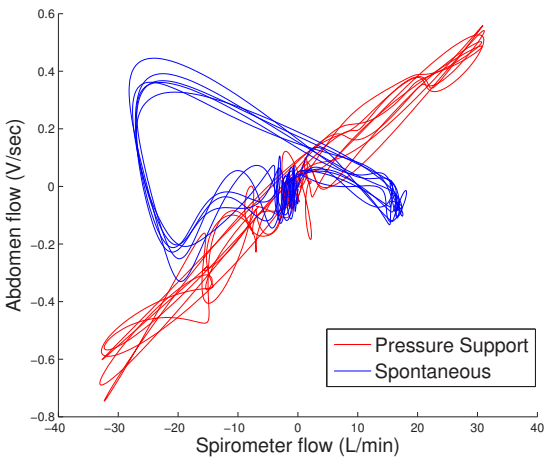

Figure 1

Results: Tidal volume (TV), respiratory period, and correlation from a typical patient are presented in figure 2. A clear drop in TV is seen following discontinuation of PSV, accompanied by a drop in correlation coefficient. While TV recovers to near baseline, the lack of correlation persists, but is restored by resuming PSV. This pattern was seen in 9 of 12 patients.

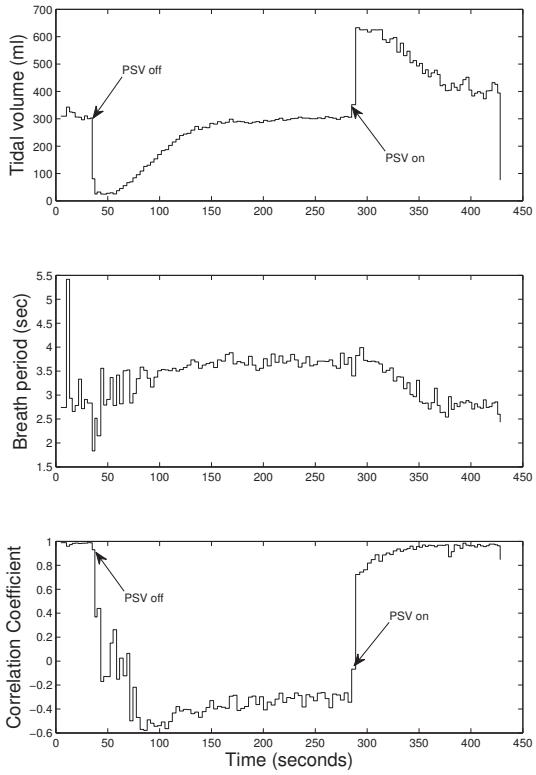

Figure 2

Discussion: The role of abdominal expiratory activity during anesthesia is not well understood, but may decrease FRC with attendant atelectasis. Rapid assessment of this effect has been lacking. Correlation of RIP and spirometry may provide such a tool.

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COMPARISON OF TONOMETRY-DERIVED VERSUS INTRA-ARTERIAL CATHETER-DERIVED ARTERIAL BLOOD PRESSURE AND RESPIRATORY VARIATION IN NEUROSURGICAL PATIENTS

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Introduction: Intraarterial catheters allow for continuous beat-to-beat monitoring of arterial blood pressure, as well as an estimation of fluid responsiveness, as determined by arterial respiratory variation. However, intraarterial catheter placement may be complicated by infection and thrombosis, and may be technically challenging in some patients. The T-line® Tensymeter is a potential non-invasive alternative to intraarterial blood pressure monitoring. We compared estimates of mean arterial pressure (MAP) and pulse pressure variability (PPV) from the T-line® with measurements of MAP and PPV taken from a radial artery.

Methods: Twenty-two patients undergoing major spinal surgery were recruited for the study. Intraoperative blood pressure was monitored by radial artery catheter in one arm and T-line on the contralateral arm. Mean arterial pressure and pulse pressure variation were calculated every minute and compared using Bland-Altman analysis, with adjustments for repeated measures.

Results: 4676 minutes of data were available for analysis from twenty-one patients. Analysis of MAP showed a mean bias of 6.3 mm Hg, and limits of agreement of -29 and 42 mm Hg, respectively (Figure 1, left). Analysis of PPV showed a mean bias of 7.7%, and limits of agreement of -12 and 28%, respectively (Figure 1, right). Trend analysis suggested that changes in MAP and PPV were concordant in 93 and 55% of non-excluded minutes, respectively.

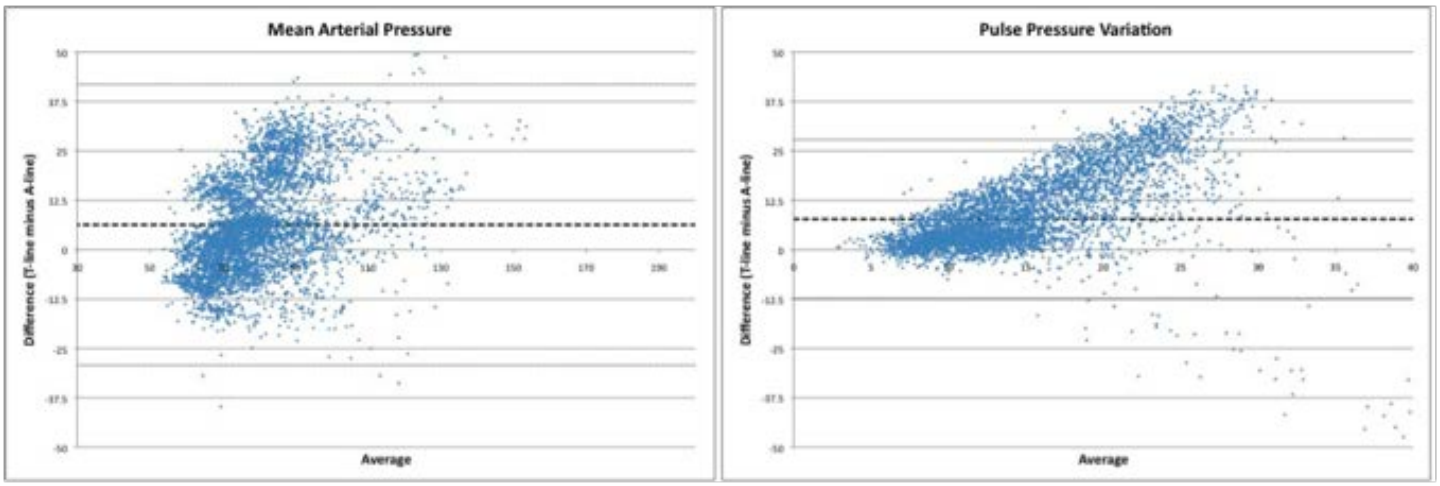

Figure 1: Bland-Altman analysis of mean arterial pressure (left) and pulse pressure variation (right)

Conclusions: The T-line® Tensymeter is an acceptable blood pressure trend monitor, but the limits of agreement between invasive and tonometrically derived absolute values are wide.

EFFICIENCIES GAINED UTILIZING A DEDICATED LINKED IPAD DEVICE VS DESKTOP AND LAPTOP ENTRY AND A COMPREHENSIVE ENTERPRISE-WIDE EMR AND THE ANESTHESIOLOGIST

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Objectives: We focused this study on the potential improved "time gains" produced during routine patient care for each physician as they functioned in our operating room environment. Each physician today must interface with the the Enterprise EMR and Surgical Systems for Preoperative Assessment, Intraoperative documentation, and Perioperative Order Entry as well as a Post operative Assessment. The Combined total time required to complete these tasks becomes significant when the Anesthesiologist is responsible for multiple patients. We therefore asked the question would a portable entry device (IPAD2) allow for improved "time gains" and reduce wasted nonproductive times over our standard desktop computers as well as possibly demonstrate other improvements in daily workload. This study focused one part of this computer Physician interaction that is the nonproductive logging in and out times using several different entry devices.

Methods: This study utilized our Comprehensive Enterprise-Wide Electronic Medical Record System for patient care (Cerner Millenium,) through a Citrix thin Client Platform. This EMR could be accessed through hard-wired desktop portals throughout the Surgical areas(Dell Corp Intel core2duo 2 GHz machine Desktops), or Laptop (Dell 2GHz machines) or wirelessly through dedicated IPAD2 devices connected to dedicated secured desktop computer via a Remote Desktop Connection(RDP). The Surgical Suite Desktop and laptop devices required an additional layer of security (Privacy Curtain) to access the Cerner Applications to maintain HIPPA compliance. This step was bypassed by the dedicated IPAD2 access since the remote computer (RDP) was not accessible by others. Time was calculated up to "ready to perform the same functions (CPOE, Signatures, Preop, Postop Notes) through these portals during daily management of patients. These times were then analyzed for nonproductive times (signing in, logging in, logging out) per patient, per day, etc The data was then tabulated by Full Time Equivalent(FTE), assuming the worst case scenario for example working in a busy OSC with rapid turnover with multiple rooms and cases of short duration. These data were calculated for maximum case load/day (16 cases/day) at OSC and multiplied by a minimum of (3 encounters with the devices/case).

Results: The IPAD2(dedicated to one physician at all times) vs the Desktop (nondedicated) and Laptop (nondedicated) allowed for shorter non-productive times (waiting to get logged on and ready to complete documentation (11.4sec vs 39.85 vs 29.86 sec respectively). The IPAD2 added secondary gains in that mobility was easily allowed. Relative to the Desktop the IPAD2 was 3.5 times faster to log-on, and the laptop was 1.3 times faster. Comparison of the Laptop to the Desktop demonstrated 1.3 times increase in speed to log-on. Unproductive time per day for the Physician amounted to (11.4min IPAD2 : 31.9min Desktop : 23.7 Laptop) and (2288min: 7979min: 5929min) per Avg. working year.

Conclusions: Dedicated entry devices provide a higher level of efficiency for the user with regards to nonproductive time waiting for logons and screen security measures. The additional benefit is mobility which allows for a higher level of productivity within the enterprise-wide system and the dynamic environment of the Surgical areas. The iPAD2 was superior to the Desktop and the Laptop in speed of log-on and calculated non productive time for this environment. Further experience is needed to improve efficiencies in the large enterprise-wide EMR systems.

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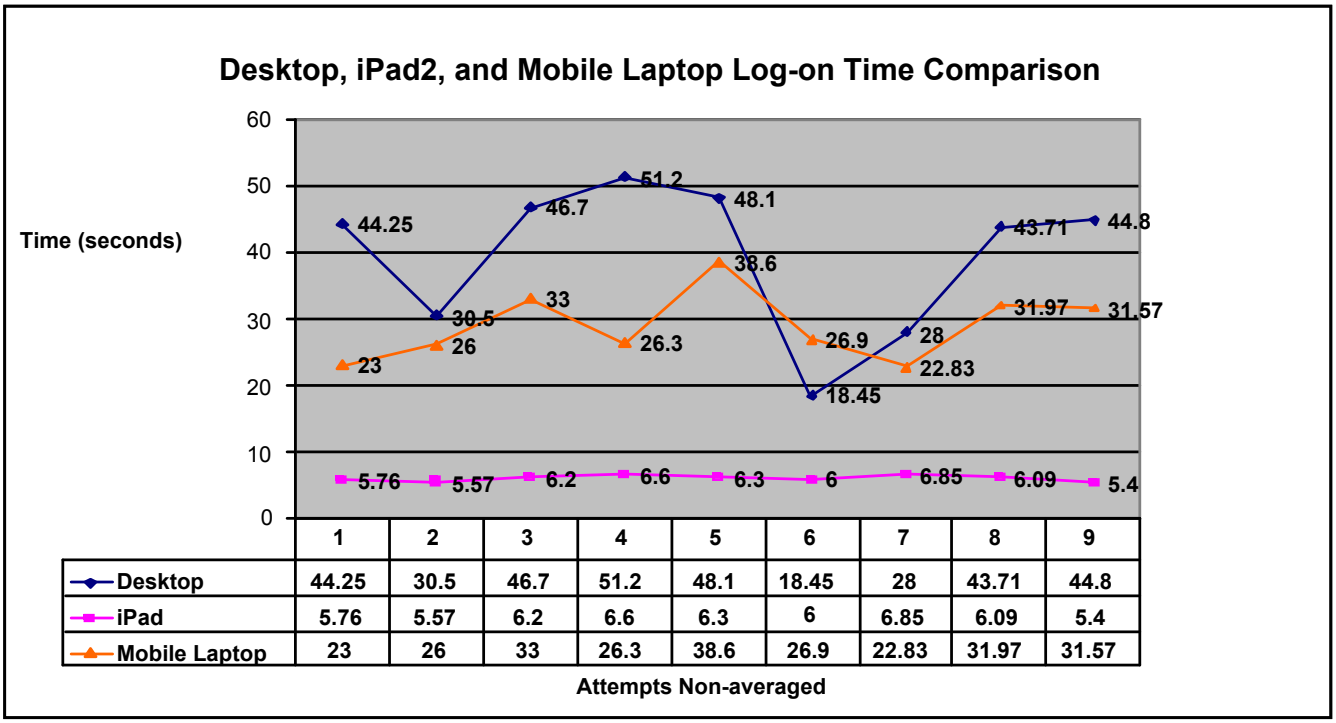
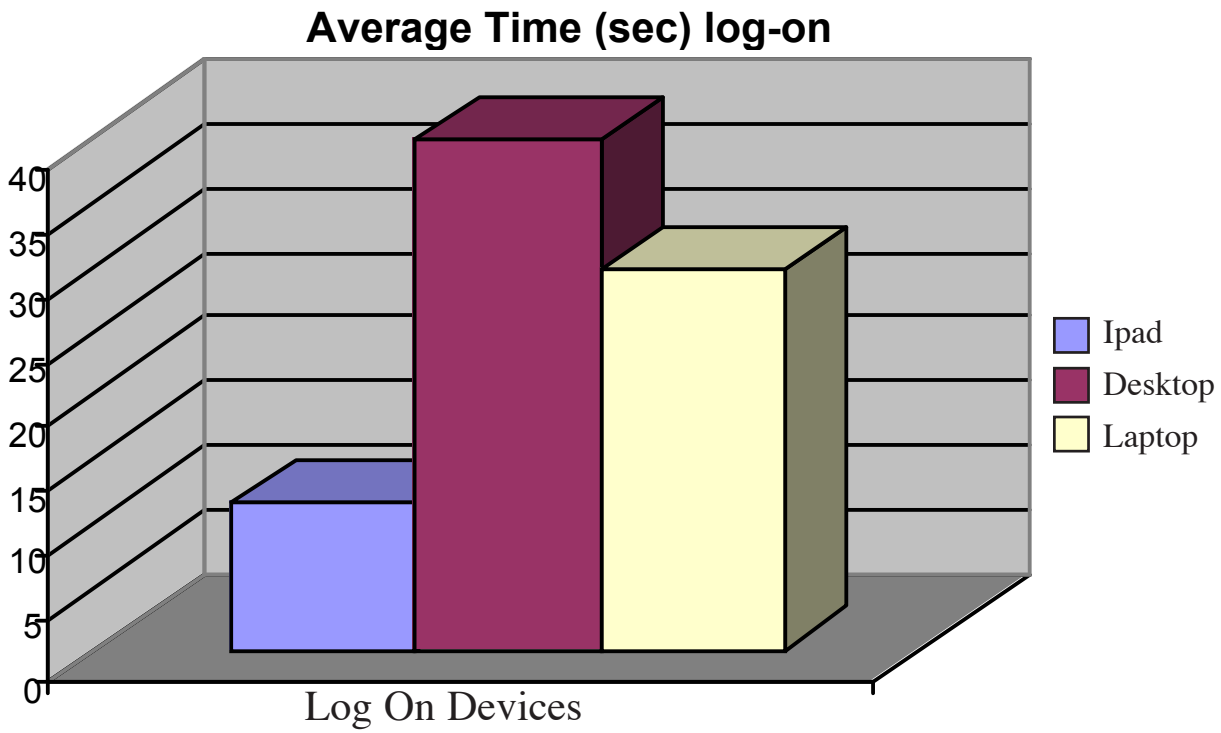
Graph information on next page


Desktop, iPad2, and Mobile Laptop Log-on Time Comparison
Time (seconds)
60
50
40
30
20
10
0
44.25
30.5
46.7
51.2
48.1
18.45
28
43.71
44.8
23
26
33
26.3
38.6
26.9
22.83
31.97
31.57
5.76
5.57
6.2
6.6
6.3
6
6.85
6.09
5.4
1 2 3 4 5 6 7 8 9
Desktop 44.25 30.5 46.7 51.2 48.1 18.45 28 43.71 44.8
iPad 5.76 5.57 6.2 6.6 6.3 6 6.85 6.09 5.4
Mobile Laptop 23 26 33 26.3 38.6 26.9 22.83 31.97 31.57
Attempts Non-averaged


Average Time (sec) log-on
40
35
30
25
20
15
10
5
0
Log On Devices
Ipad
Desktop
Laptop

Manipulation of Hyperbaric Lidocaine Using Magnetism: A Pilot Study

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Introduction:
Spinal anesthesia relies on placement of local anesthetic and adjuvant agents in the subarachnoid space. If the anesthetic agents reach the T_1-T_4 cardioaccelerator fibers, bradycardia and hypotension may result. The incidence of a "high spinal" is less than 1% but the results may be fatal. Anesthesiologists currently manipulate block height by modifying the dose of anesthetic agents, as well as by changing the angle between the patient's back and the surface of the earth. An additional means of controlling block height would be useful.

Methods:
A model of the spine was constructed using polyvinyl-chloride tubing and 0.9% sodium chloride. A non-magnetic solution of equal parts hyperbaric lidocaine (5% lidocaine in 7.5% dextrose) and methylene blue and a magnetic solution of equal parts hyperbaric lidocaine (5% lidocaine in 7.5% dextrose), methylene blue, and a water-based ferrofluid (EMG 304, Ferrotec Corporation, Santa Clara, CA) were developed. A 16-gauge needle was placed into the inner curvature of the model spine, and a permanent magnet was placed underneath the needle. One mL of each agent was injected over approximately one minute.

Results:

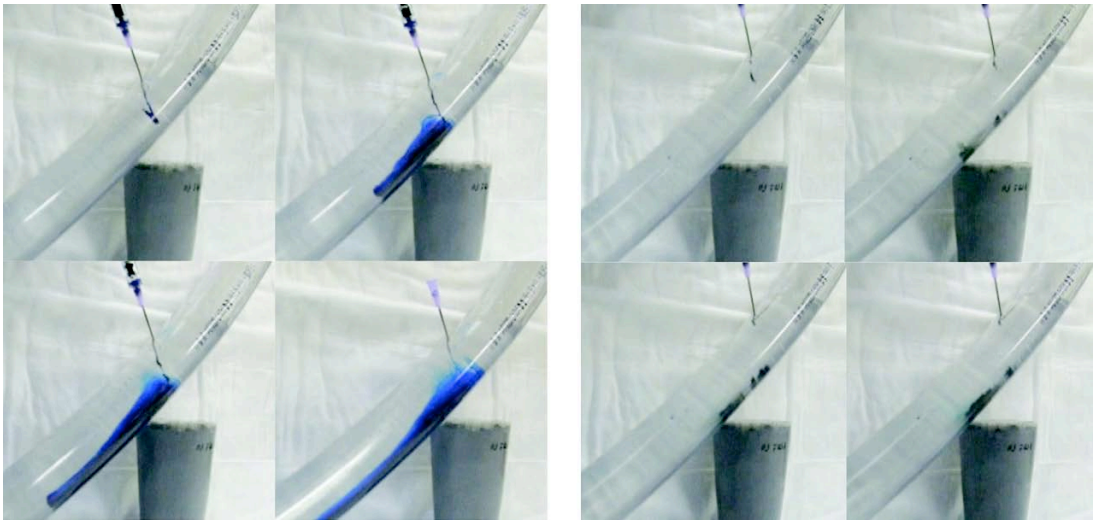

Figure 1: non-magnetic solution (left) ; magnetic solution (right)

Conclusions:
Application of an external magnetic field may provide anesthesiologists with an additional means of manipulating block height during neuraxial anesthesia. Additional, in vivo studies are warranted.

RESIDENTS HELPING IN NAVIGATING OR SCHEDULING (RHINOS): FACILITATING SELF-DIRECTED LEARNING

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Introduction: Few mechanisms exist for matching available clinical opportunities to trainee's individual interests. We created and deployed Rhinos, a web-based tool that facilitates self-directed learning by permitting residents to rank order preferences for specific assignments. The application was piloted on two core anesthesia residency rotations over six weeks. The impact on the residency experience was assessed with an ad hoc survey.

Methods: Success was determined by comparing the frequency with which resident requests matched the actual cases done. Residents were asked to complete an on-line survey which included the System Usability Scale to assess usability.

Results: 165 requests were entered. Residents received a requested assignment 76% of the time (1st choice 54%, 2nd choice 17%, 3rd choice 5%, no match 24%). 21 of the 26 residents who used Rhinos completed the survey (80% response rate). On a Likert scale (1="Much improved", 7="Much worse"), Rhinos improved satisfaction with the case assignment process (2.05 ± 0.97), increased feeling of case ownership (2.05 ± 1.20), improved daily satisfaction (2.29 ± 1.15), improved overall satisfaction (2.29 ± 1.23), self-assessed learning (2.38 ± 1.16) and morale (2.1 ± 1.13). Usability ratings were high (91.15 ± 12.04; maximum score 100).

Discussion: Rhinos integrates multiple peri-operative information systems with resident input to create a highly usable scheduling tool that improves the resident experience. Resident preferences varied sufficiently on a day-to-day basis to permit the majority of 1st choice assignment requests to be met. Scheduling workflow can be improved by replacing manual processes with drag-and-drop solutions.

INTEGRATION OF THE SOCIAL SECURITY ADMINISTRATION DEATH MASTER FILE INTO AN ANESTHESIA DATA WAREHOUSE

Matthew A. Levin, MD

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Introduction: A growing body of anesthesia research has begun to focus on the long-term effects of anesthetic exposure. Mortality is a key "hard" measure for such outcomes research. For studies involving tens of thousands of patients, individually determining mortality is infeasible. Instead, researchers typically purchase and use the Social Security Administration (SSA) Death Master File (DMF). Integration of this large dataset and automation of the monthly updates is a non-trivial exercise.

Methods: A perl program was written that handles loading both the base DMF from local files as well as monthly updates downloaded from the web. Data is stored locally in a transactional MySQL database. The local table is partitioned and indexed to maximize load and search speed. For base file loads, the supplied files are split and loaded in parallel. For monthly updates, the index file is downloaded and parsed to determine the current monthly file name and MD5 checksum. The update file is then downloaded, the checksum verified, and the updates are applied to the database. A monthly cron job automates the process.

Results: The full file contains ~90 million records, 8.6GB uncompressed. Parallel load using 9 processes takes ~3.4 hours - ~7,472/records second. The resulting table plus indexes are 25GB on disk. Load of a monthly update (~132,000 records) takes ~27 minutes. A typical research query to identify deaths in a 50,000 patient cohort takes ~1 minute.

ROBUST PID CONTROL FOR CLOSED-LOOP PROPOFOL INFUSION IN CHILDREN

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Background: Individual responses to propofol infusion in children are highly variable [1]. A closed-loop controlled system for anesthesia can reduce the effect of this variability, by automatically adjusting the drug infusion using feedback from a measure of the clinical effect. A robust controller design takes the interpatient variability into account, and is expected to provide adequate and safe closed-loop control of depth of hypnosis (DOH) regardless of the variability. In this study, a robust proportional-integral-derivative (PID) controller [2] is designed that automates both induction and maintenance of anesthesia. The designed system is clinically evaluated in a pilot study.

Methods: The WAVcns index [3] was used as measure of DOH. A PID controller was tuned to provide adequate robustness margins for a set of 14 identified models of the effect of propofol infusion on the DOH [4]. Following REB approval, and informed consent/assent, 23 children aged 6-15 (12y±3, 46kg±13, 154cm±15), ASA I-II, requiring anesthesia for elective upper or lower gastrointestinal endoscopic investigations were enrolled for clinical evaluation. Remifentanil was administered as a bolus (0.5 μg/kg) prior to propofol administration followed by continuous infusion (0.03 μg/kg/min).

Results: Automated induction of anesthesia was completed in an average (SD) of 4min10s (±80s) and the WAVcns index decreased to mean (SD) 39 (±5).During maintenance of anesthesia, the WAVcns index was stable and within 10 units of the setpoint for median (range) 90% (22-100%) of the time. Spontaneous breathing was maintained in all subjects. The limited overshoot during induction of anesthesia indicates sufficient robustness margins for all 23 subjects. One patient showed a strong response to stimulation (change of WAVcns index > 40).

Conclusion: Automated induction of anesthesia in children using a robust PID controller provides a stable level of anesthesia, maintains spontaneous breathing and limits overshoot in measured WAVcns. Maintenance of anesthesia during moderately painful procedures was adequate. In future work, the controller will be optimized to improve the speed of induction and the response to stimulation.

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STRUCTURED DEVELOPMENT PROCESS FOR AN AIMS-BASED PRACTICE TO CONTRIBUTE TO THE NATIONAL ANESTHESIA CLINICAL OUTCOMES REGISTRY

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Introduction: The Anesthesia Quality Institute (AQI) case registry, the National Anesthesia Clinical Outcomes Registry (NACOR) currently has over 2 million anesthetics recorded. While the AQI will accept simple billing data, the true value of the registry can only be realized with details about preoperative risk, perioperative events, and postoperative outcomes. Our institution developed a process to identify the location of each requested data point and develop a data harmonization and export process to NACOR.

Method: An anesthesiologist familiar with our institution's electronic medical record systems reviewed the AQI data dictionary and determined the source for each data item. We met with our hospital data warehouse team to export administrative and outcome data not available in our anesthesia data warehouse.

A list of outstanding issues was collected to discuss with AQI. Our list centered on patient and visit identification, preoperative risk factor details, and aligning our outcome list with that used by AQI.

Results: Of 113 elements in the AQI Data Dictionary, we identified 81 that could be extracted from our Anesthesiology Data Warehouse, 26 from the hospital Data Warehouse, and elected to ignore 6 elements. We mapped our department's 14 postoperative outcomes to the ASA Committee on Performance and Outcome Management's 26 outcomes. Once implementation of the hospital Data Warehouse feed is complete, we will begin sending complete anesthesia case data to AQI.

Conclusion: A structured development process improves the quality and breadth of data that can be provided to the AQI case registry.

THE INFLUENCE OF POSITIVE PRESSURE VENTILATION ON ELECTROCARDIOGRAM AMPLITUDE: A CONFIRMATORY STUDY

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Cleveland Clinic, Cleveland, Ohio

It is well-known that arterial pulse pressure variation can be induced by positive pressure ventilation. Arguing that positive pressure ventilation would likely also influence the electrocardiogram (ECG) through variations in thoracic blood volume and thus thoracic electrical conductivity, like Cannesson's team [1], we hypothesized that a similar effect might be obtained with the electrocardiogram. We set about to test this hypothesis using a custom data acquisition system to collect intraoperatve data at 600 samples per second per channel in patients with an arterial line in situ undergoing general anesthesia and positive pressure ventilation. Airway pressure was obtained by connecting a clinical pressure transducer to the patient breathing circuit. The figure below shows a sample result including a period of apnea.

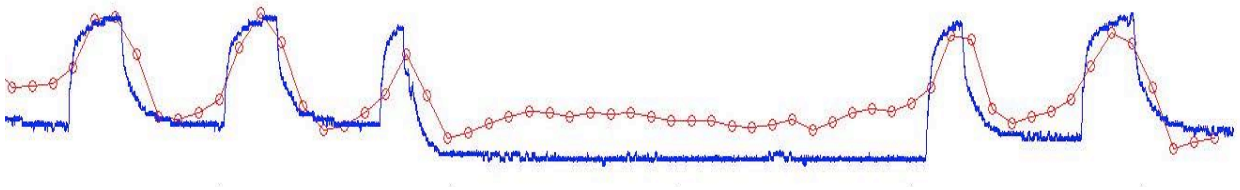

Figure: A plot of electrocardiogram (ECG) amplitude and airway pressure against time. Note how the regular respiratory variation in ECG amplitude vanishes with apnea.

The presented data clearly confirms the findings of Cannesson et al. that the amplitude of the electrocardiogram does vary with positive pressure variation. We hypothesize that the amplitude of the electrocardiogram increases as the volume of blood in the thorax decreases as a result of positive pressure ventilation. Note also how this variation vanishes under apneic conditions.

This hypothesis is also supported by the work of Madias and Guglin [2], who investigated the effect of fluid removal by ultrafiltration (UF) pump on the on the ECG amplitude in patients in heart failure (CHF). They concluded that "augmentation of the amplitude of QRS complexes correlates well with net fluid loss in response to UF in patients with CHF, and can be employed as an index of effectiveness of therapy."

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PSEUDO-NORMAL MITRAL VALVE DOPPLER DIASTOLIC FLOW PATTERN DERIVATION

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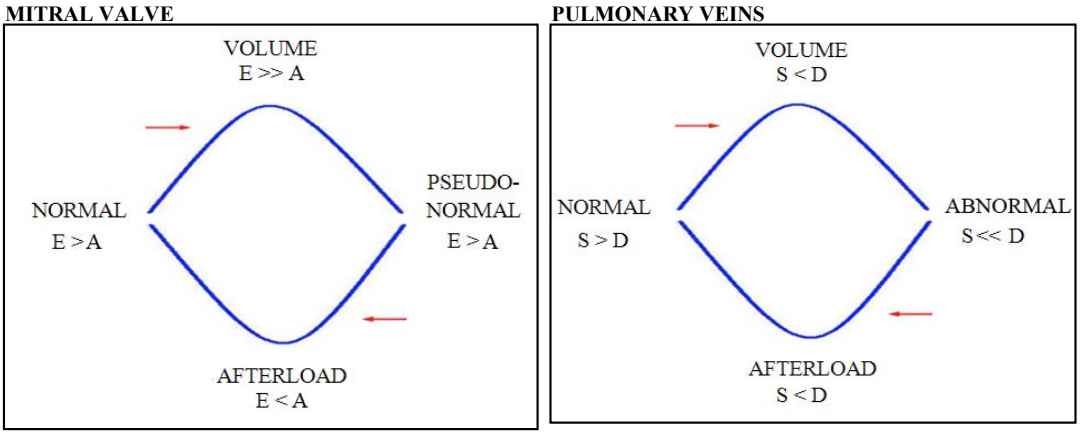
Yale University School of Medicine

Mitral valve and pulmonary vein Doppler flow velocity tracings represent left atrial afterload and volume hemodynamic loading conditions. Traces consist of normal, maximal volume, maximal afterload and supra-maximal load tracings. For the mitral valve, this last tracing is termed pseudo-normal because it resembles a normal tracing. This resemblance can cause confusion in data interpretation. Misinterpretation can be obviated by considering the genesis of the pseudo-normal tracing.

Tracings: Normal mitral valve diastolic flow traces feature a large initial wave (E), corresponding with passive flow from the left atrium into the left ventricle. This is followed by a smaller wave (A) which represents left atrial contraction. Increased left atrial afterload (left ventricular filling constraints) causes the left atrium to contract more vigorously. This causes the A wave peak to exceed the E wave peak. By contrast, volume loading causes the E wave peak to greatly exceed the A wave peak. Normal pulmonary vein flow traces feature a large initial wave (S), corresponding with systolic filling of the left atrium. This is followed by a smaller wave (D), corresponding with diastolic filling of the atrium. With increased left atrial afterload, the D wave peak increases. With volume loading, the D wave peak continues to increase.

Ratios: The relationship between the E and A wave peak velocities can be expressed as ratios. When E wave peak velocity exceeds A wave peak velocity, the ratio exceeds unity and vice versa. The relationship between S and D wave peak velocities can also be expressed as ratios. When S wave peak velocity exceeds D wave peak velocity, the ratio will, again, be greater than unity and vice versa.

Parabolas : The expression of E/A wave relationships as ratios facilitates graphic representation of the impact of volume and afterload. Directional changes in E/A ratios for volume and afterload are oppositely directed. When the left atrium is faced with excessive volume/afterload combinations, left atrial pump failure supervenes. Aggregate summation of mitral valve ratio values will result in a normally appearing trace (E >> A + E < A = E > A). Corresponding S/D ratios are uniformly directed. (S < D + S < D = S << D). These changes can be represented as mirror image parabolas.



Summary : Parabolic representation of mitral valve and pulmonary vein Doppler flow tracing values is an original concept. With this concept, it becomes self-evident that the summation of left atrial volume and afterload to overwhelming levels will result in a mitral valve trace that mimics normalcy and coincident with a definitively abnormal pulmonary vein trace.

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AUTOMATIC ULTRASOUND NERVE DETECTION

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Introduction: The purpose of this project is to derive an optimal algorithm to allow for automatic ultrasound (US) detection of the sciatic nerve at the popliteal fossa.

Methods: The software was written in MATLAB® R2011b (MathWorks®, Natick, MA, USA). The first step was to apply a Wiener filter on the US image, in order to reduce noise. Next, K-means clustering was used to divide the US image into three clusters, one of which contains the nerve. The appropriate cluster was the one containing the brightest pixels as these tissues appear as the brightest regions in an US image. Muscle fascia was then eliminated by discarding objects having a width greater than two times the length. The largest remaining object was then assumed to be the popliteal nerve. The study consisted of two parts; in part 1, 20 US images were obtained (TH) from both sciatic nerves in 5 authors. To evaluate the algorithm, two US-experienced anesthesiologists were asked to manually locate the nerve in the US images. Both anesthesiologists detected the same regions on all of the US images as being the sciatic nerve. The manual nerve locations were then compared with those detected automatically using two levels of comparison: first, whether the center of the automatically identified nerve lies within the area of the manually identified nerve; and second, the percentage of overlap of areas created around the nerve centre by drawing circles ranging in diameter from 1 mm to 1 cm around the centers of the automatically identified nerves and the manually drawn area (Figure 1). In part 2 of the study, 100 US images of the sciatic nerve (5 per side and author) were taken in 5 authors. The algorithm was applied with the objective to determine the percent of the images where the automatically defined nerve centre was within the manually detected nerve area and to determine whether the maximum area drawn around this centre to allow for a minimum of 95% overlap between manually identified nerve area and automatically drawn area around the nerve centre – as determined in part 1 of the study – could be confirmed in this larger number of US images.

Results: In part 1, the automatic nerve centre was within the manual nerve area in 96% of the US images. Percentages of overlap ranged between 92% (1 mm diameter) decreasing to an overlap of 63% (1 cm diameter). The maximum diameter for at least 95% overlap was determined as 0.5 cm. In part 2, the automatically detected nerve centre was within the manually detected nerve area in 99% of the images. Overlap ranged between 100% (1 mm diameter) and 69% (1 cm diameter) Figure 2. Percentage of overlap at a diameter of 0.5 cm was 95% and at 0.4 cm 98%, respectively.

Conclusion: The automatic ultrasound nerve detection system proved to be reliable in detecting the sciatic nerve in the popliteal fossa. Using this system, drawing a circle of 0.4 cm around an automatically detected nerve centre produces an overlap of almost 100% with a manually detected nerve area. A target area of a circle with 0.4 cm diameter seems a clinically sufficiently large target area for nerve block needle placement. This system will pave the way for the development of a completely automated robotic nerve block system.

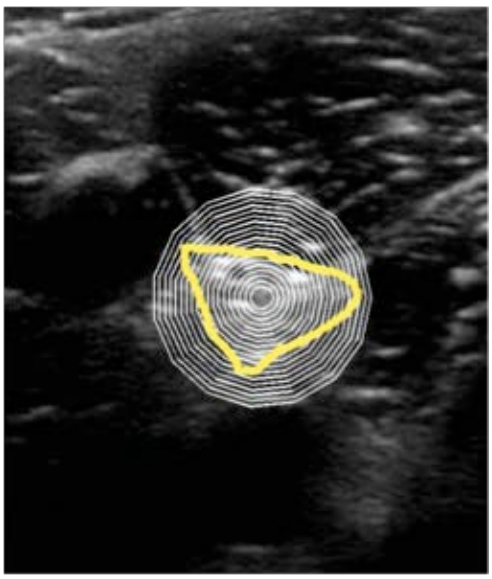

Figure 1: Automatic detection areas (white), and manual detection (yellow)

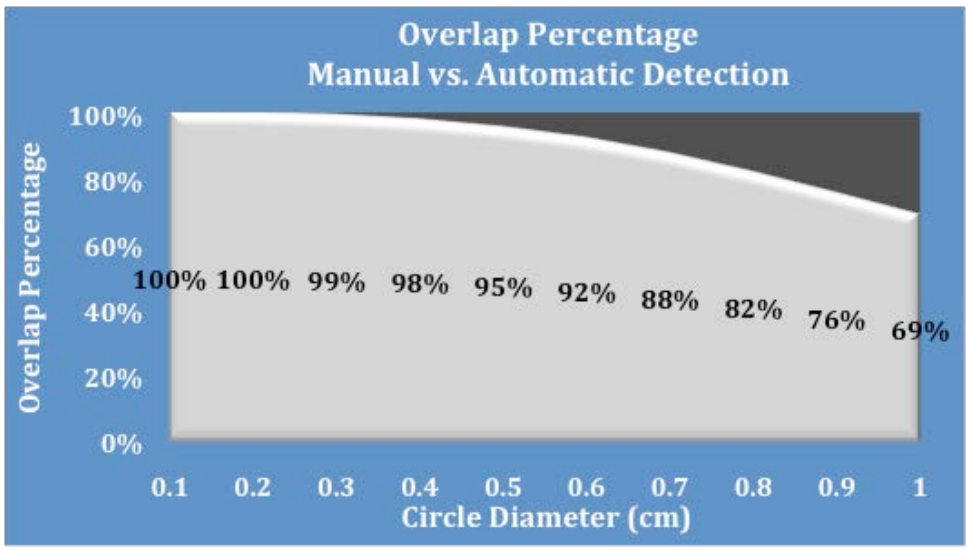

Figure 2: Percentage of Overlap between the automatic and the manual detections

THE MAGELLAN™ – FIRST ROBOTIC ULTRASOUND-GUIDED NERVE BLOCK IN HUMANS

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McGill University, Montreal, Canada

Background: Ultrasound(US)-guided nerve blocks are very popular in modern anesthesia. The aim of the present study was to develop a robotic US-guided system (The Magellan™) to perform nerve blocks in humans using a remote control centre and to determine its feasibility defined as success rate.

Methods: In this pilot study, 13 patients were enrolled after approval of the local Ethics board and written informed consent..The Magellan™ (Fig. 1) consists of three main components: a ThrustMaster T.Flight Hotas X joystick (Guillemot Inc., New York, NY, USA), a JACO robotic arm (Kinova Rehab, Montreal, QC, Canada), and a software control system. The Magellan™ consists of a remote control centre (joystick and nerve block cockpit) linked to both a webcam and a US machine for image transmission (Fig. 2). The joystick allows simulation of wrist or arm movements of a human operator. After manual localization of the sciatic nerve, 35 ml of bupivacaine 0.25% were injected. Success rate of popliteal nerve blocks and block performance times (performance time = interval of time from the start of the ultrasound search for the nerve to the end of the injection of the drug; robotic time = interval of time from the detection of the nerve to the end of the injection of the drug) were measured. Data are shown as median (interquartiles; min, max) and categorical data. Trend was analyzed using linear regression.

Results: Seven men and 8 women aged 37 yrs were included in this study. Three out of 16 patients received a bilateral block. Nerve blocks were successful in all patients. Nerve performance time was 189 s (150, 233; 90, 305), robotic time was 164 s (121, 210; 73, 271). The linear regression of the mean nerve performance time showed a negative slope, denoting that each successive trial required less time (Fig. 3). The negative regression coefficient of the slope was more distant from 0 when the patients receiving bilateral blocks were excluded (Fig. 4).

Conclusions: We present the first human testing of a robotic US-guided nerve block system. The success rate was 100%. The total robotic block performance time ranged from 3 to 4 min.

Figure 1

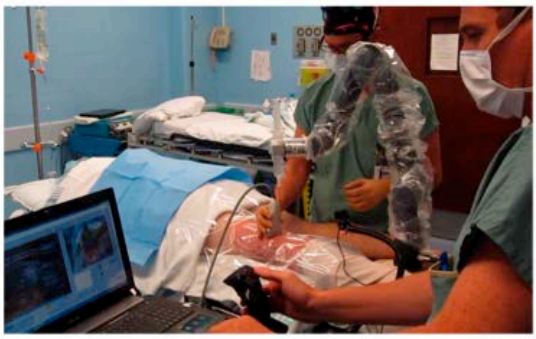


Figure 3

Figure 2

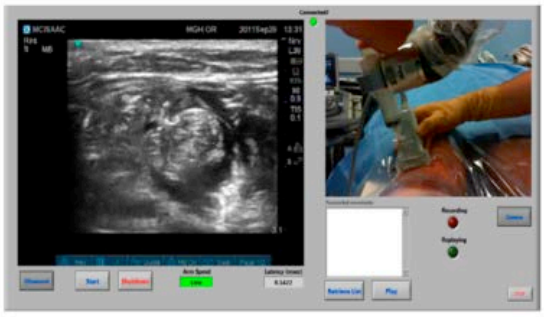
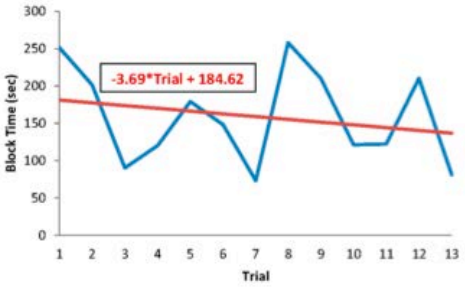


Figure 4



KEPLER INTUBATION SYSTEM (KIS) – FIRST INTUBATION ROBOT

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McGill University, Montreal, Canada

Background: Intubation is one of the most important anesthetic skills. The aim of the present study was to develop a robotic intubation system (Kepler Intubation System, KIS) for oral endotracheal intubation in humans and to determine its feasibility defined as success rate of intubation.

Methods: The KIS (Fig. 1) consists of four main components: a ThrustMaster T.Flight Hotas X joystick (Guillemot Inc., New York, NY, USA), a JACO robotic arm (Kinova Rehab, Montreal, QC, Canada), a Pentax AWS video laryngoscope (Ambu A/S, Ballerup, Denmark), and a software control system. The KIS was developed consisting of a remote control centre (joystick and Intubation cockpit) linked to a standard video laryngoscope via a robotic arm (Fig. 2). The joystick allows simulation of wrist or arm movements of a human operator. The study was structured in two steps. The first step of the study was to determine the success rate of intubation in mannequins in 3 different groups. The first group of 30 intubations was performed with the operator in direct view of the mannequin (Direct View group). The second group of 30 intubations was performed with the operator unable to see the mannequin (Indirect View group). Thirty semi-automated intubations were also performed where the robotic system replayed a trace of a previously recorded intubation maneuver (Semi-automated group). The second step of the study assessed the success rate in humans. Success rate of intubation and intubation times were measured in both mannequins and humans. Data are shown as median (interquartiles; min, max) and categorical data. Trends were analyzed using linear regression.

Results: In mannequins, all intubations were successful at first attempt. The mean intubation times were 46(18) s, 51(19) s, and 41(1) s for the Direct View, Indirect View, and Semi-automated group, respectively. Both the Direct and Indirect View groups had a negative slope, denoting that each successive trial required less time. The Semi-automated group had a slope of 0 and a low standard deviation of 1 s, illustrating the high reproducibility of automated intubations (Fig. 3). During the second step of the study, 12 patients aged 66 years were included. Intubation was successful in 12 out of 13 patients at a total time of 93 s (87, 109; 76, 153) (Table 1). In one patient, fogging of the video-laryngoscope prevented intubation using KIS.

Conclusions: We conclude that a robotic intubation system was developed that can even allow remote intubations. We present the first human testing for oral endotracheal intubation. Success rate was high at 91%. Future studies are needed to further evaluate performance and safety of such a system.

Figure 1

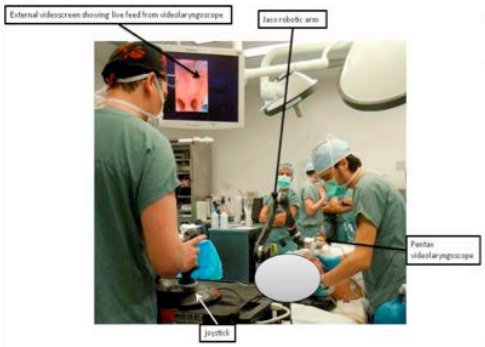


Table 1 Intubation time for 11 patients.

Patient (N=11)	Positioning Time (s)	Intubation Time (s)	Extraction Time (s)	Total Time (s)
1	10	69	22	101
2	14	46	21	81
3	28	69	20	117
4	9	48	30	87
5	7	46	67	120
6	7	47	22	76
7	10	60	20	90
8	11	58	24	93
9	27	123	3	153
10	25	57	15	97
11	20	46	20	86

Figure 2

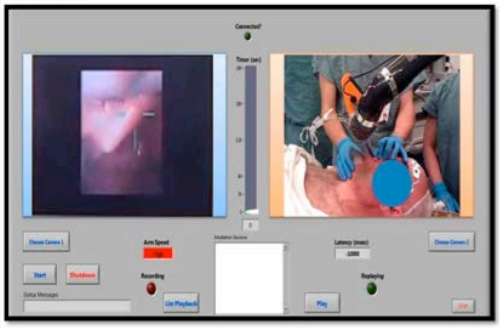
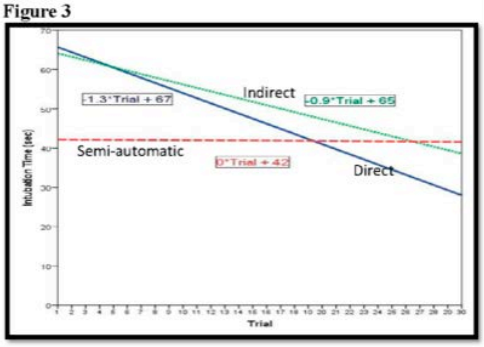


Figure 3



THE 180 IV TUBING SUPPORT SYSTEM

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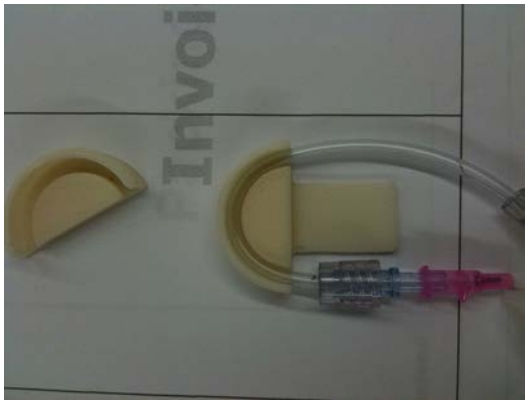
University of California Irvine, Long Beach, CA

Introduction: In modern medical practice up to 80% of hospitalized patients receive infusion therapy during their stay requiring the placement of an IV catheter.[1] Intravenous tube kinking has been a problem since the creation of the intravenous line in 1945.[2] Other than being an inconvenience, significant complication can result.



The 180 is an external plastic device designed to support and redirect intravenous line tubing. This device safely and effectively repositions the IV line 180 degrees so that it bends back proximally toward the patient. It consists of a semicircular arc with a groove designed to tightly fit around the IV tubing. It connects right up against the rigid distal end of an IV line safely securing the pliable plastic tubing. This enables securing the IV tubing line in a standardized fashion and minimizing the risk of kinking. Because it sits external to the tubing there is now concern for systemic reactions.

Method: To discover the incidence of kinking at in an academic institution, a study was conducted entitled Frequency and Outcomes of Peripheral IV Tube Kinking in an Academic Hospital. Researchers visited intensive care units, medicine floors, and operating rooms where IV's were being utilized. Nurses or physicians were asked how many patients under their care had IV's and if kinking, accidental removal, or IV failure occurred in the last 24 hours. For times where kinking had occurred, the location of the kink and any complications or delays that resulted were recorded. A second study was conducted utilizing an online survey to determine if healthcare providers found IV kinking to be a clinically significant problem.

Results: The observational study demonstrated an incidence of kinking of 10.2%. In the encounters recorded in this study, 17/167 revealed that IV kinking had been observed by the healthcare provider within the last 24 hours. In at least one instance, delay of medication administration occurred. The online survey had 144 responses and found that 47.5% of healthcare providers felt that kinking was a problem and 31.3% felt that they had insufficient tools to prevent kinking from occurring.

Conclusions: Intravenous line kinking is a fairly common phenomenon. Many practitioners believe that the incidence is related mostly to the way in which IV tubing is secured. Furthermore, IV tubing is secured in many different ways depending on the location of the IV catheter and on the preference of the provider that placed the IV. The goals of this device are to create a standardization of IV line securing, decrease IV rate failure, decrease delays from IV kinking, increase nurse/physician satisfaction, and most importantly increase patient satisfaction.

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ASSESSMENT OF THE ACCURACY OF ATTESTATION STATEMENTS IN AN ANESTHETIC RECORD

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Introduction: Attestations made by physicians in the medical record play an important role in assessing compliance with regulatory agencies and various policies such as the Surgical Care Improvement Project (SCIP). We aimed to retrospectively examine the accuracy of three specific attestations of SCIP measures - antibiotic compliance, maintenance of normothermia, and the use of standard central line sterility techniques.

Methods: Cases between June 2006 and September 2011 were examined for the agreement between the attestations and a "gold standard" - the charting of antibiotics, active warming devices and temperatures in the anesthetic record in the case of the former two attestations, and the standard practice of following a set of sterility guidelines during central line placement in the cardiac operating rooms in the case of the latter. In each case, the attestation as well as all supporting documentation was identified in the anesthetic record; if they agreed in all respects the attestation was regarded as accurate, otherwise it was considered inaccurate.

Results: For antibiotic attestation accuracy 60% of cases followed the examined protocol (Cefazolin given only once). Active warming attestations took two forms. The presence of a warming device was accurately attested to in 88.7% of cases; measurement of a normothermic temperature within thirty minutes of anesthesia end was correctly attested to in only 14.4% of cases. 97.84% of non-emergent cases in the cardiac operating rooms attested to all measures of sterility.

Conclusion: The accuracy of attestations proved to be highly variable but was the most accurate when individuals were attesting to actions they had already performed, such as central line sterility, and least accurate when attesting to the performance of future actions (such as the measurement of temperature at the end of the case).

AN ELECTRONIC REMINDER TO PREVENT PERIOPERATIVE HYPOTHERMIA RESULTED IN A SIGNIFICANT INCREASE IN POSTOPERATIVE BODY TEMPERATURE AND IMPROVED SCIP COMPLIANCE

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Introduction: Anesthetics and surgery may impair thermoregulation thereby increasing the potential for adverse perioperative events. Hypothermia has been shown to increase surgical wound infection, lengthen the duration of hospitalization, increase intraoperative blood loss, slow drug metabolism and prolong recovery. Accordingly, the Surgical Care Improvement Project (SCIP) mandates that measures be taken to achieve a target temperature of 96.8oF within thirty minutes of procedure end or that active warming techniques be used.

Methods: In an effort to improve our compliance with the SCIP goals, an 'alert' was incorporated into the Anesthesia Information Management System (AIMS) to remind clinicians to prevent hypothermia. Following IRB approval, 25,665 anesthetic records spanning twenty-four months were retrospectively reviewed to quantify the immediate post-operative body temperature before and after implementing the AIMS 'alert'.

Results: Sample groups before (n=11,250) and after (n=14,415) the intervention were similar in age, gender, ASA Physical Status and duration of anesthetic. Implementating the AIMS 'alert' was associated with a significant increase in mean post-operative body temperature, from 97.2oF to 98.0oF ($p<0.01$). Additionally, our compliance with the SCIP mandate to achieve a post-operative temperature of 96.8oF improved from 67.2% before the intervention to 99.0% after implementing the AIMS 'alert'.

Conclusion: An AIMS 'alert' to address perioperative hypothermia is an effective method for increasing immediate post-operative body temperature and improving compliance with the SCIP goals.

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WHAT IS "DEAD SPACE"? - METHODOLOGICAL ISSUES

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Introduction: Dead space measurement provides insight into the distribution of ventilation and matching of ventilation and perfusion.[1] The term "Wasted Ventilation" or respiratory dead space (VD) is considered to be that volume of each breath that is inhaled but does not participate in gas exchange. As well as the volume of the airway in which there is no significant exchange of oxygen and carbon dioxide.[2] However, in clinical settings and in the literature the term is used inconsistently and may describe all or any combination of the following; total, physiologic, anatomic, alveolar, and apparatus V_D.

Discussion: A partial explanation for the confusion in terminology is that the volume of VD that is measured is dependent upon a number of factors including the "type" of VD, the method of measurement, and patient particulars (e.g. intubated? spontaneously or mechanically assisted, body position).[3]

Apparatus dead space (VDapp) or equipment dead space (or mechanical or instrumental) refers to the dead space introduced in a breathing circuit used for mechanical ventilation or in some cases added volume used in the measurement of VDapp. It may be expressed as a dynamic or effective dead space (e.g. masks) to distinguish itself from geometric or physical dead space (measured volumetrically or estimated dimensionally).

Anatomic' dead space methods do not quite measure the same volume as the morphological definition. The 1 ml per lb. rule of thumb has been shown to poorly correlate body weight with measured "anatomic" dead space (r2= -0002)[4] Instead a functional definition needs to be adapted based upon the method used to estimate the anatomic dead space, often referred to as airway dead space. Methods for estimating airway dead space include equal area method, linear extrapolation of expired CO2 volume, and polynomial curve fits which have greater numerical and algorithmic complexity.

Physiologic dead space (VDphys), the sum of apparatus, anatomic and alveolar dead space, has been shown as a dead space fraction to be clinically useful including as a predictor of outcome in ALI/ARDS. While alveolar CO2 is used in the mass balance derivation of VDphys, the Enghoff modification which assumes the near equality of the PCO2 in alveolar gas and arterial blood is often applied. However, a number of approaches have used other surrogates for PACO2 including end-tidal CO2 and extrapolated values from the volumetric capnogram.

Conclusion: Values for dead space used clinically and reported in the literature need to clearly define what dead space volume is being measured and how it measured to avoid confusion and problems with interpretation of values. Improved clarity through the development of standardized terminology is suggested.

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A RANDOMIZED TRIAL OF AUTOMATED ELECTRONIC ALERTS DEMONSTRATING SIGNIFICANTLY IMPROVED ANESTHESIA TIME DOCUMENTATION ACCURACY AND REVENUE

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University of Michigan Medical School, Ann Arbor, MI

Background: To date, there have been no prospective, randomized trials looking at the effect of automated alerts on the accuracy of time-based charges for anesthesiology services. We hypothesized that alerting providers to errors could result in more accurate documentation of anesthesia care and significantly improved revenue.

Methods: Anesthesia cases were evaluated to determine whether they met the institutional definition for appropriate anesthesia start time over four separate 45-day calendar cycles, including a baseline pre-study period. At the studied hospitals, anesthesia start time should be one or more minutes prior to patient in room time. Providers were randomly assigned to either a control or an alert group. Providers in the alert cohort received an automated alphanumeric page if the anesthesia start time was concurrent with patient in the Operating room time or more than thirty minutes prior to patient in room. After the study period, all providers received the paging reminder and overall compliance was analyzed. Three years following the study period, overall compliance was analyzed to assess learned behavior.

Results: Baseline compliance was 33.5%. During the study period, providers in the alert group demonstrated 86.9% compliance compared to 40.5% compliance in the control group [$p<0.001$, odds ratio 9.8, 95% confidence interval (8.4-11.4)]. Long term follow up after cessation of the alerts was 85.1%, indicating a learned behavior. We estimate that the improvement in anesthesia start time documentation results in $471,117 (1.6 %) of incremental annual revenue.

Conclusions: Automated electronic reminders for time-based billing charges are effective and result significantly incremental ongoing reimbursement for institutions employing AIMS.

SYRINGE DESIGN INFLUENCES INFUSION ERRORS DUE TO CHANGES IN PUMP HEIGHT

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[1]Manukau Institute of Technology, Auckland, New Zealand, [2]Perelman School of Medicine at the University of Pennsylvania, Philadelphia, PA

Introduction: At low flow rates, syringe pumps exhibit some undesirable characteristics such as slow start-up to deliver at the set rate, prolonged time to alarm on line occlusion, release of bolus volume on removal of line occlusion and transient flow error on change in pump height.[1-3] These phenomena are due to the compliance of the fluid circuit. To assess the influence of the compliant syringe plunger component on infusion rates, infusion delivery using a standard syringe was compared with an identical system where the rubber plunger was replaced by a plunger constructed using non-compliant plastic.

Method: An infusion system was tested using a TOP-5100 syringe pump,60ml BD Plastipak® disposable syringe and an Alaris® 1.5m extension line with internal diameter 1.5mm (CareFusion, San Diego, CA). The syringe was primed with water at 20°C, connected to a primed extension line and inserted into the pump. The pump was set to infuse at 3ml/h. The rate of flow was measured using precision digital weighing.[4] The time from starting the infusion at 3ml/h to actually achieving that infusion rate was measured as the start-up time (A). The pump was then lowered by 24" (B) and the time until flow returned to the set rate was measured (C). The pump was then returned to its original height (D) and again the time until flow returned to the set rate was measured (E). The measured times were compared for an infusion set with a rubber plunger and an identical set with a non-compliant plunger. For both systems the time to alarm on line occlusion was measured along with the bolus volume produced by removing the occlusion.

Results: Data are shown for both the rubber (light color) and non-compliant (dark color) plungers. Start-up time for the rigid plunger system was 60s compared to 470s for the rubber plunger system. On lifting the pump back to reference height, the rigid plunger system produced a fluid bolus of 0.05ml compared to ca. 0.1ml for the rubber plunger system. The time-to-alarm on occlusion for the rubber plunger system was 18 minutes 20 seconds with a bolus of 0.63ml released when occlusion stopped, compared with 9 minutes 55 seconds and 0.25ml for the non-compliant plunger.

Conclusion: Infusion rates observed were closer to the desired rate for all conditions tested when the noncompliant plastic plunger was used. Observed errors even with the non-compliant syringe suggest that other factors also influence compliance and infusion performance. These variations in infusion rate can have undesirable consequences especially for concentrated potent vasoactive infusions given to small patients. Further investigation to optimize infusion pump design is indicated.

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BIOIMPEDANCE FOR IDENTIFICATION OF THE EPIDURAL SPACE

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Many have observed that medical device clocks are not set to the correct time. This is due to a number of causes. Most medical devices lack automatic clock-setting capabilities and cannot set their clocks using a network time reference. Also, there is no adopted standard for medical device time management. Consequently, clocks are typically set manually twice yearly for DST.

Most electronic medical devices contain an internal clock that is used to timestamp data. Depending on the configuration of the EMR and the data source, the EMR may insert the incorrectly time-stamped data into the wrong time slot, or reject the data altogether. Therefore, asynchronous time stamps may undermine the integrity of EMR data and the accurate reconstruction of clinical events or device failures.

To explore the problem, a sample of medical device clocks from the operating rooms, ICUs, and equipment storage facilities at Massachusetts General Hospital (Boston, MA) were recorded. Device clocks were compared to the NIST Internet Time Service to compare clock consistency and evaluate the deviance of the device clocks. Of 337 device clock-times that were recorded, 53% had an offset of > 1 min, 17% had an offset of > 30 minutes, and 11% had an offset of > 1 hour.

This pilot study supports anecdotal data and first principles that erroneous clock times are pervasive. Given the absence of automatic clock setting capabilities in most medical devices, and typical clock drift, these finding are not surprising. We are working on extending the study to other institutions and care areas.

RELIABILITY OF CRITICAL EVENT REPORTING IN AN ANESTHESIA INFORMATION MANAGEMENT SYSTEM (AIMS)

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Background: Implementation of a secure clinical event system linked to an AIMS has been shown to double the capture of significant clinical events, yet no evidence exists that an AIMS alone improves event reporting. Emesis during induction is a quality improvement (QI) event (i.e. a significant clinical event) at our institution. The anesthesia provider should both record an emesis event in the AIMS and submit a continuous QI (CQI) report. We evaluated retrospectively the reporting of emesis during induction during a recent clinical trial performed at our institution.

Methods: Research assistants (RAs) recorded fasting gastric volumes and emesis during induction in 1000 day-surgery patients aged 2-12 years. Following IRB approval, we analyzed the anesthesia records of 995 of these patients and determined whether emesis was recorded in the AIMS record and a CQI report of the event was filed. Given the original study's parameters, emesis recorded by the RAs was a true indicator of the event and was used as the standard of comparison in order to determine the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of the AIMS records and CQI reports.

Results: Of the 995 evaluated cases, RAs documented 8 instances of emesis during induction. Three of the emesis cases were recorded in the AIMS, while only one of the cases had a CQI report. Upon comparison of the AIMS record to the RA data, AIMS yielded a sensitivity of 38% (95% confidence interval [CI], 8.5% - 75.5%), a specificity of 100% (95% CI, 99.6% - 100%) and a PPV of 100% (CI, 29.2% - 100%). Comparing the CQI reports to the RA data, the sensitivity of CQI reporting was 13% (95% CI, 0.3% - 52.7%), the specificity was 100% (95% CI, 99.6% - 100%) and PPV was 100% (CI, 2.5% - 100%). Emesis during induction was too rare of an event for the NPV of AIMS and CQI to be realized in this retrospective analysis.

Conclusion: The low sensitivity of the AIMS record suggests that events dependent on user input (e.g. emesis during induction) may not be recorded reliably in the anesthesia record. CQI reports had even poorer sensitivity to detect clinical events—approximately one-third that of AIMS documentation. These results indicate under-reporting of significant clinical events and suggest that user-reported data extracted from the AIMS record may not be a reliable source

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THE IMPACT OF AMBULATORY SURGICAL CENTERS ON SURGICAL PATIENT ACUITY AT A TERTIARY CARE CENTER

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Introduction: Ambulatory surgical centers (ASCs) are facilities where patients undergo select surgical procedures outside the hospital setting. With advances in medicine and technology, certain procedures that were once performed solely in the inpatient hospital setting have moved to ASCs. The first ASC associated with our tertiary care pediatric hospital opened in 1997. We postulated that since that time, the proportion of surgical patients with American Society of Anesthesiologists Physical Status (ASA PS) 3 or 4 has increased and the proportion of surgical patients with ASA PS 1 or 2 has decreased at our institution.

Method: We retrospectively analyzed anesthesia records (CompuRecord, Philips Medical Systems, Andover, Mass) from the year 2000 to August 15, 2011 to determine the ASA PS distribution in percentage of cases by year. Data analyses were mainly descriptive. Percentages and 95% confidence intervals of ASA PS were calculated by year. The trend of ASA PS change over time was displayed graphically.

For the primary analysis, we sought to provide evidence that ASA PS 1-2 cases decreased and ASA PS 3-4 cases increased from the years 2000 to 2011. A simple linear regression was used to estimate cases change per year (slope); we tested whether the slope was different from zero for each ASA group. To adjust multiple comparisons, P-value less than 0.008 was declared as statistically significant. All analyses were performed using the statistical software package SAS version 9.2 (SAS Institute Inc., Cary, NC) and Stata 11 (StataCorp LP., College Station, TX).

Results: Table 1 shows the ASA PS cases (%) and 95% confidence intervals by year and ASA PS. The majority of cases were ASA PS 1 to 3 from 2000 to 2011. There were very few cases in ASA PS groups 5 and 6. Figure 1 displays the stacked bar chart of relative frequency in percentage of cases by year. It shows that ASA PS 1 cases have a greater relative frequency in 2000, but not by the later years in 2009 to 2011. On the other hand, ASA PS 3 cases have a lesser relative frequency in 2000 to 2001, but greater in years 2010 and 2011.

Figure 2 displays percentage of ASA PS cases over time. It indicates that the ASA PS 1 cases declined between 2000 and 2011 by 48% from 34.3% to 17.9% (Table 1), as well as a gradual increase for ASA PS 2 cases. ASA PS 3 cases increased between 2000 and 2011 by 42% from 25.3% to 35.8% (Table 1). Figure 2 does not indicate any changes for ASA PS 4, 5, and 6 cases due to the small numbers of cases and corresponding percentages.

Table 2 depicts the estimated slope of ASA PS cases (%) change per year by ASA PS. ASA PS 1 cases (%) declined significantly by 1.14% per year ($P<0.0005$) between 2000 and 2011. ASA PS 2 cases (%) increased from 2000 to 2011 by 0.4% per year, but that change did not reach statistical significance. ASA PS 3 cases (%) increased significantly by 0.88% per year ($P<0.0005$) between 2000 and 2011. The estimated slopes for ASA PS 4, 5, and 6 were too small to make conclusive inference.

Discussion: Since the opening of ASCs at our institution, the inpatient surgical population has experienced a significant decrease in ASA PS 1 patients and a significant increase in ASA PS 3 patients. The noted trends may be due to ASCs drawing the healthier (i.e., ASA PS 1) patients, thereby increasing the proportion of ASA PS 2 and 3 patients in the inpatient surgical population. Other factors to consider include variability in the interpretation and assignment of ASA classification[4, 5, 6] an overall sicker general population, or an increase in patients that have deferred their medical and surgical care until later in the disease processes due to socioeconomic or other factors.[8]

Table 1. ASA PS distribution percentage by year from the year 2000 to August 15, 2011.

ASA Physical Status % (95% CI)						
Year	1	2	3	4	5	6
2000	34.30(33.55,35.05)	36.05(35.29,36.81)	25.30(24.61,25.98)	4.22(3.90, 4.54)	0.11(0.06, 0.16)	0.03(0.00, 0.06)
2001	28.04(27.33,28.74)	41.35(40.58,42.12)	26.48(25.79,27.18)	3.90(3.60, 4.21)	0.15(0.09, 0.22)	0.07(0.03, 0.11)
2002	26.93(26.23,27.63)	41.12(40.35,41.90)	28.60(27.89,29.32)	3.22(2.95, 3.50)	0.08(0.04, 0.13)	0.03(0.00, 0.06)
2003	26.26(25.57,26.95)	41.60(40.83,42.37)	28.38(27.67,29.08)	3.60(3.31, 3.89)	0.14(0.08, 0.20)	0.03(0.00, 0.06)
2004	25.41(24.76,26.07)	39.38(38.64,40.12)	30.74(30.04,31.43)	4.37(4.06, 4.68)	0.09(0.04, 0.13)	0.01(-0.00, 0.03)
2005	25.75(25.08,26.41)	41.22(40.48,41.97)	29.41(28.72,30.10)	3.48(3.20, 3.76)	0.13(0.07, 0.18)	0.02(-0.00, 0.04)
2006	24.51(23.86,25.15)	40.48(39.75,41.22)	31.58(30.88,32.28)	3.32(3.05, 3.59)	0.11(0.06, 0.15)	0.01(-0.01, 0.02)
2007	24.13(23.51,24.76)	37.40(36.69,38.10)	34.76(34.07,35.45)	3.62(3.35, 3.90)	0.08(0.04, 0.12)	0.01(-0.00, 0.03)
2008	24.52(23.91,25.14)	40.14(39.44,40.84)	32.35(31.68,33.02)	2.89(2.65, 3.13)	0.07(0.04, 0.11)	0.02(0.00, 0.04)
2009	20.71(20.14,21.28)	44.09(43.39,44.78)	32.43(31.77,33.08)	2.72(2.49, 2.95)	0.04(0.01, 0.07)	0.01(-0.00, 0.02)
2010	18.24(17.72,18.77)	44.09(43.41,44.76)	34.95(34.31,35.60)	2.62(2.40, 2.84)	0.07(0.03, 0.10)	0.03(0.01, 0.05)
2011	17.91(17.27,18.54)	44.06(43.24,44.88)	35.80(35.01,36.60)	2.15(1.91, 2.39)	0.06(0.02, 0.10)	0.01(-0.01, 0.03)

Table 2. Slope of ASA cases (%) change per year by ASA physical status.

ASA	Slope (SD), %/year	95% CI	P-value
1	-1.14 (0.509)	-1.47, -0.81	<0.0005
2	0.4 (0.6)	0.015, 0.787	0.043
3	0.88 (0.336)	0.667, 1.1	<0.0005
4	-0.15 (0.112)	-0.225, -0.081	0.001
5	-0.0068 (0.0071)	-0.011, -0.002	0.008
6	-0.0027 (0.0043)	-0.0054, 0.0004	0.053

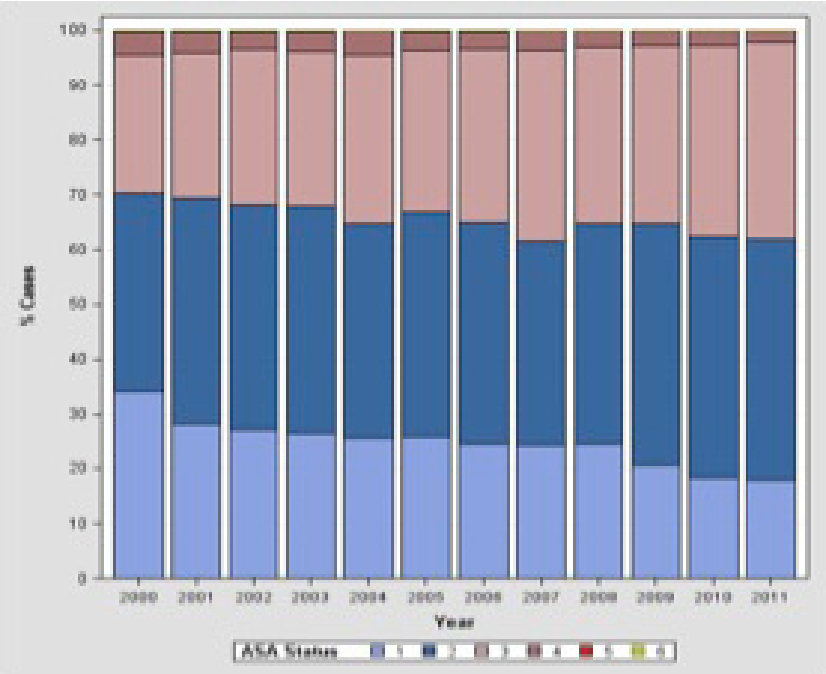

Figure 1. Relative frequency in percentage of ASA cases (%) by year

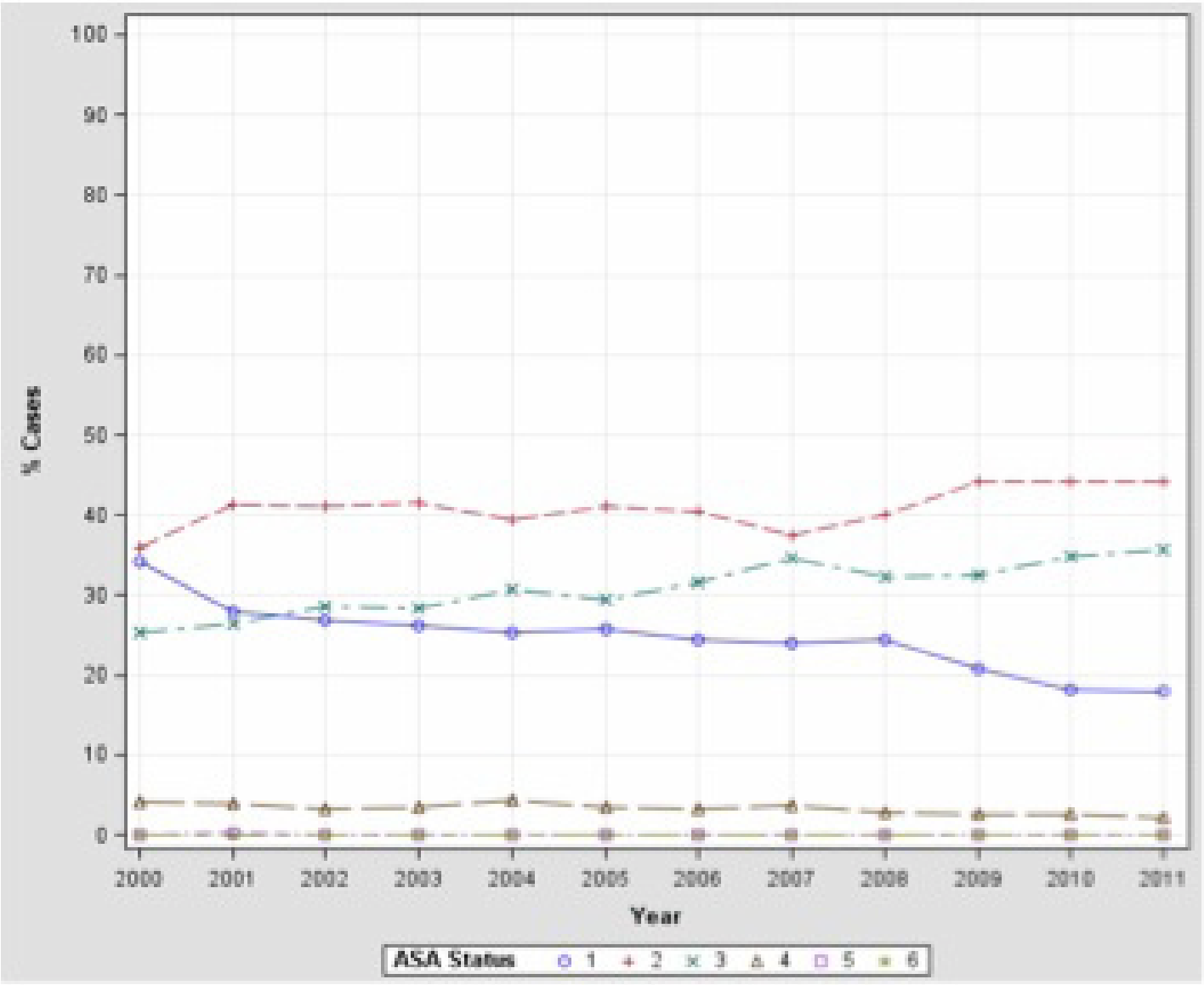

Figure 2. Percentages of ASA cases (%) by year

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GAS MAN VERSION 4.1 TEACHES INHALATION KINETICS

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Introduction: Gas Man® version 4.1 computer simulation of inhalation anesthesia uptake and distribution was completed in 2011 after 27 years of evolution.[1,2] Inhaled anesthetics are part of most anesthesias given around the world, and their evolving use makes understanding this subject important to all anesthesiologists.

Objectives: We sought to determine if Gas Man Version 4.1 teaches relevant aspects of inhalation kinetics.

Methods: We reviewed the Gas Man Workbook and Program that teaches inhalation anesthesia kinetics. Gas Man program runs on all modern Microsoft and Apple operating systems and conforms to the latest graphical user interface customs. The C++ program is compiled to platform-specific software using QT (Nokia, Finland). It is written in English and has been translated into Chinese and an earlier version was translated into French.

Results: Earlier versions of Gas Man that were shown to be accurate[3], educationally valid[4], and able to teach important clinical subjects.[5] The Gas Man Workbook of version 4.1 is a course in inhalation anesthesia kinetics that guides the user through exercises that demonstrate aspects of inhalation anesthesia kinetics through interaction and visualization. Beginning Workbook chapters teach single-compartment wash-in and the alveolar tension curve including initial rise, plateau, knee and tail. Later chapters teach routine and advanced clinical techniques. Vaporizer overpressure and brief high fresh gas flow quickly change anesthetic depth. Multiple agents interact with concentration effect and second-gas effect.. Open, semi-closed, closed, and ideal breathing circuits perform differently. Low fresh gas flow can reduce cost. Displaying quantity of drug delivered from vaporizer and taken up by patient demonstrates efficiency and waste. Changing body weight shows kinetic differences between children and adults.

Users can demonstrate many interactions. Vital Capacity Induction can be achieved in less than one minute using a breathing circuit primed with anesthetic agent. Hyperventilation and reduced cardiac output increases anesthesia depth and causes overdose with soluble agents. Hypoventilation after emergence leads to reanesthetization if muscle tissue has achieved 1 MAC anesthetic tension.

During 2011 Gas Man 4.1 was used for CME courses in inhalation kinetics for over 600 anesthesiologists in India and 1000 anesthesiologists in China (Chinese version).

Discussion: Gas Man version 4.1 appears to be capable of teaching inhalation anesthesia kinetics and is appropriate for use in developing and developed countries. Creating a group of teachers who can teach other teachers appears warranted.

Conclusion: Gas Man Version 4.1 functions effectively as an educational tool on all modern computer platforms and in 2011 was used in CME courses to teach over 1600 anesthesiologists in India and China inhalation anesthesia kinetics including identifying inspired, expired and brain anesthetic agent tensions.

Potential Conflicts: Gas Man and Med Man Simulations, Inc., is a nonprofit charitable organization as 501(c)(3) certified by the US Government. James H Philip is the author of the program and workbook. Dr. James Philip and Dr. Beverly Philip received honoraria for teaching some of the Gas Man courses.

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EVALUATION OF ADAPTIVE AND NON-LINEAR PKPD MODELS FOR BIVALIRUDIN IN POST-CARDIAC SURGICAL PATIENTS

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Introduction: Bivalirudin is a direct thrombin inhibitor that is known to decrease thrombo-embolic complications due to heparin-induced thrombocytopenia (HIT). It is an anticoagulant that raises the partial thromboplastin time (PTT). Although it is FDA-approved for catheter interventions only, it is increasingly being used for prolonged anticoagulation in patients after cardiac surgery. Yet, experience with dosing in this setting is sparse. A mathematical model of the dose-response relationship may be useful to guide dosing of bivalirudin in the future.

Hypotheses:

- The patient's PTT response can be simulated with a one-compartment PKPD model.
- Performance of the model can be improved when taking the fluctuating, renal elimination into account.
- Modeling tachyphylaxis and allowing for an adaptive adjustment based on past performance will improve the model.

Methods: In a retrospective chart review of 149 post-cardiac surgical ICU patients, the PTT, the estimated GFR and the continuous infusion rate of bivalirudin was collected. After randomly assigning subjects to a derivation and a validation cohort, eight PKPD models (linear, non-linear, each with or without tachyphylaxis and adaptive capability) were fitted to the derivation data resulting in coefficients which were averaged. The non-linear PKPD models incorporate variable eGFR while the linear models do not. The derived "average" models were then tested in the validation cohort.

Results: In the derivation and validation cohorts of 74 and 75 patients, respectively, the median duration of bivalirudin infusion was similar at 12.3 and 8.8 days. Figure 1 illustrates the non-linear model with and without the adaptive capability. When testing the derived models in each patient of the validation cohort we found root-mean-square (RMS) errors (between the actual and predicted PTT) and Pearson's correlation coefficients. The mean values for the 75 validation patients are given in table 1.

Conclusions: We found that the patient's PTT response to bivalirudin can be simulated with PKPD models leading to mean RMS errors ranging from 13.8 to 23.1 seconds. The predicted and actual PTT courses show moderate correlation. The predictive power of the model is greatly improved when an adaptive feature is included. This allows the model to "learn" from past discrepancies between actual and predicted PTTs. Modeling of tachyphylaxis during prolonged infusions did not improve model performance (see table 1). The addition of a non-linear component accounting for changing eGFR did not significantly improve accuracy.

Table 1. Comparing actual to predicted PTT
Root-Mean-Squared error / Pearson's correlation coefficient

	Linear model	***Non-linear model***
Basic model	23.1/ 0.53	22.8/ 0.53
With tachyphylaxis	22.8/ 0.53	21.7/ 0.52
With adaptation	13.8/ 0.55	13.9/ 0.55
With both tachyphylaxis and adaptation	13.8/ 0.54	14.0/ 0.55

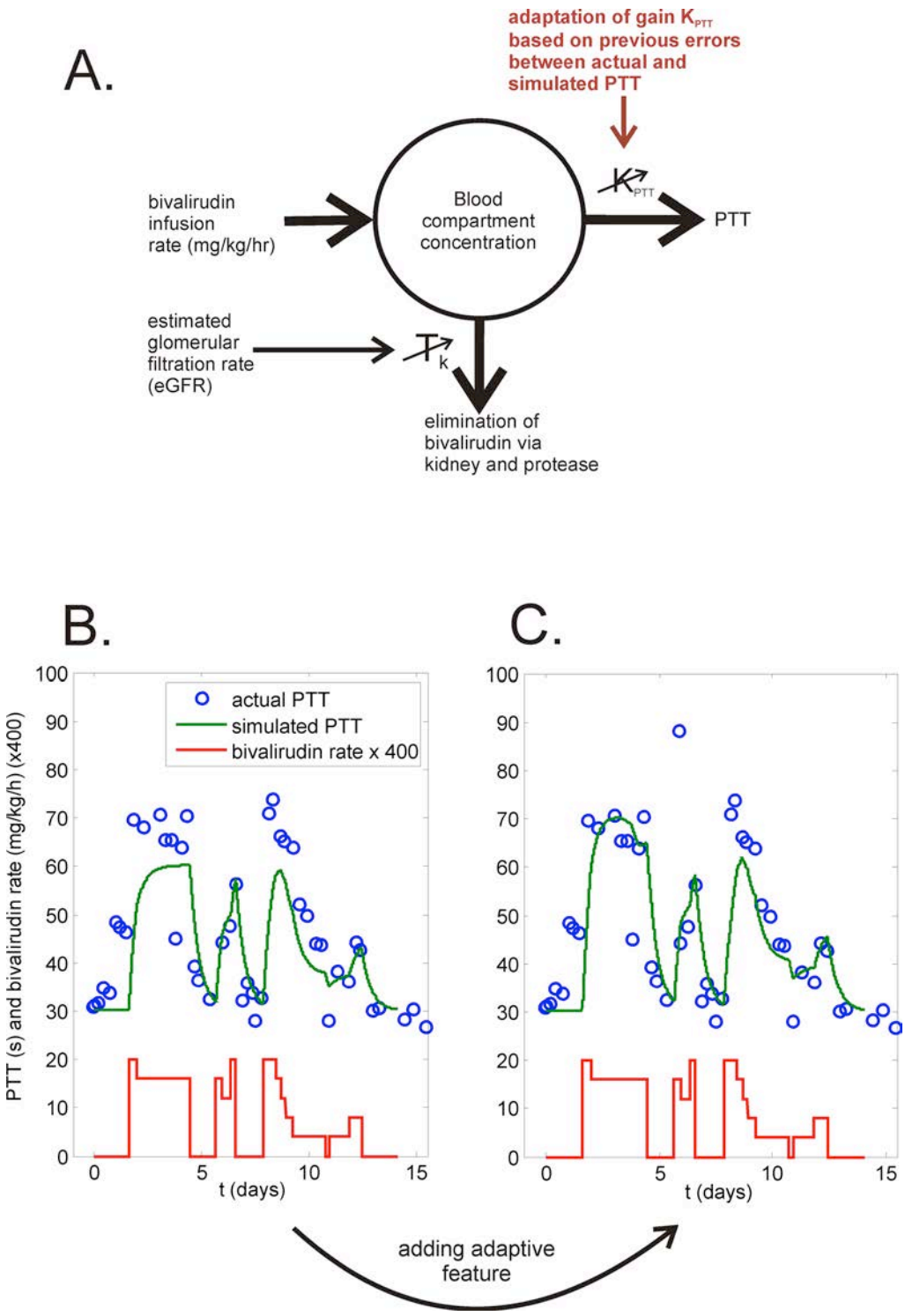

Figure 1. Nonlinear PKPD model (panel A) with an adaptive gain KPTT. As shown in a sample patient (panels B and C), the addition of the adaptive feature improves the fit. The root-mean square (RMS) error decreases from 9.6 to 8.5 (s) in this patient.

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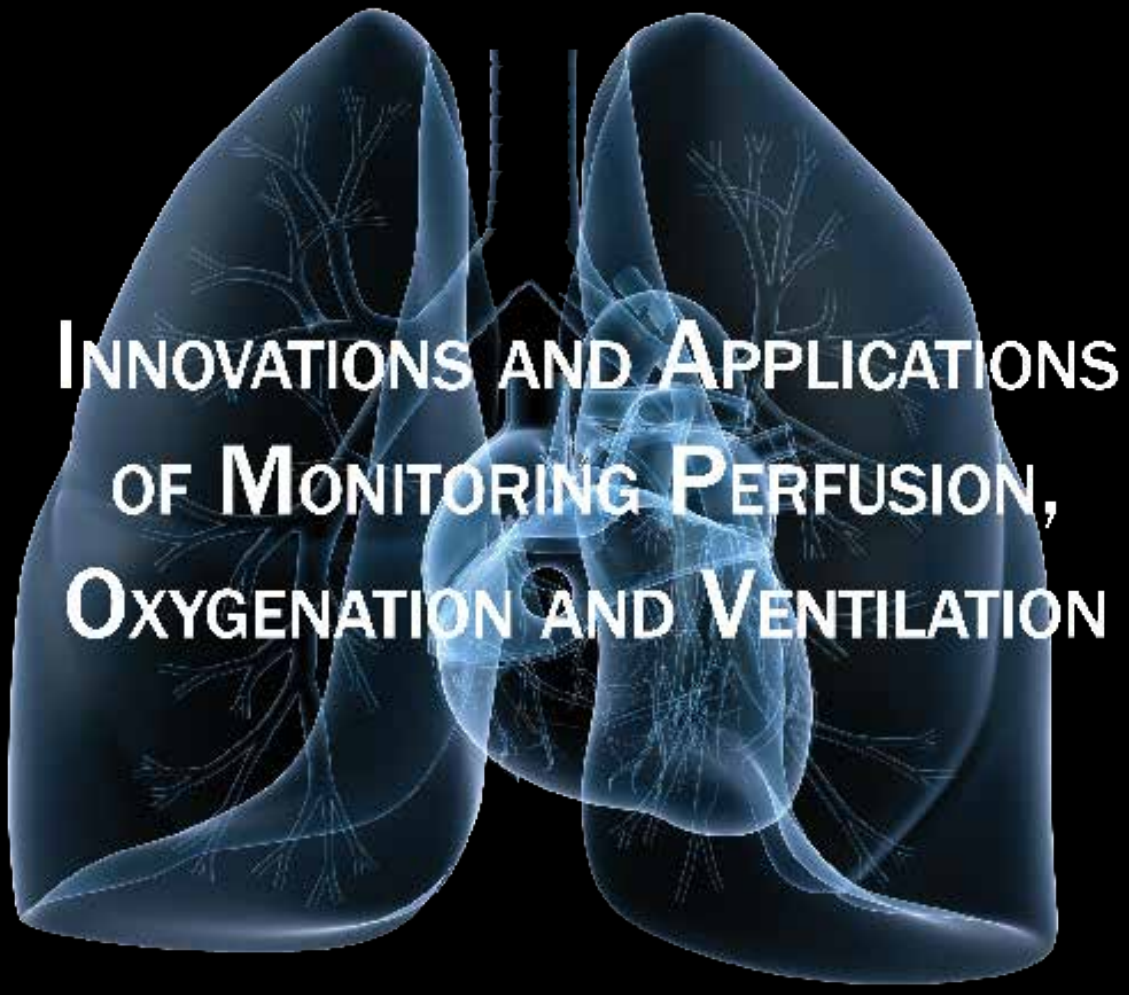

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