STA 17th Annual Meeting & the 29th Computers in Anesthesia Meeting

January 17-20, 2007

Rosen Plaza Hotel
Orlando, Florida

Meeting Syllabus

Society for Technology in Anesthesia
2 Summit Park Drive, Suite 140, Cleveland, OH 44131
Phone: (216) 447-7864
Fax: (216) 642-1127
Email: STAhq@AnesTech.org
Web: www.AnesTech.org

Society for Technology in Anesthesia

2 Summit Park Drive, #140
Cleveland, OH 44131
216-447-7864 (Phone) 216-642-1127 (Fax)
Email: STAhq@AnesTech.org Web: www.AnesTech.org

The Society for Technology in Anesthesia (STA) is an international membership-based non-profit organization. Members are physicians, engineers, students and other non-physicians who represent the users, teachers and developers of anesthesia-related technologies, computing, and simulators.

The Society for Technology in Anesthesia (STA) is pleased to be a Component Society of the IARS and the sponsor of the Section in *Anesthesia and Analgesia* on Technology, Computing and Simulation. *Anesthesia and Analgesia* is STA's Official Journal.

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STA 17th Annual Meeting & 29th Computers in Anesthesia Meeting

On behalf of the program committee and the Board of Directors, welcome to this year's STA meetings. We would personally like to thank the outstanding faculty who have generously given their time to prepare and present their lectures and demonstrations.

Please make every opportunity to network with our corporate member exhibits, faculty and members during the meeting. This type of learning is important and beneficial to everyone. STA is a unique organization whose members represent the practice of anesthesiology as well as industry involved in development and production of technologies used by anesthesiologists in education and medical care. Interaction between the members is one of the strengths of STA. If you are interested in becoming more active in STA and its educational programs, please contact one of the Board members. We welcome participation and involvement at all levels.

Julian M. Goldman, MD
STA President

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STA 2007

MISSION STATEMENT

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

MEETING OBJECTIVES

- Explore the many facets of anesthesia-related technologies in use now and in the future.
- Recognize the the ergonomics of the anesthesia work environment.
- Discuss how departments determine the need and access options for new technologies.
- Advance use of simulation, computers and hand-held technologies for patient care, quality improvement and education.
- Define the roles of anesthesia information systems in today's healthcare climate.
- Discuss the procedures for developing, manufacturing, funding, and marketing a new technology.

CME ACCREDITATION STATEMENT

This activity has been planned and implemented in accordance with the Essential Areas of the Accreditation Council for Continuing Medical Education through the joint sponsorship of the Society for Technology in Anesthesia (STA) and the International Anesthesia Research Society (IARS). The IARS is accredited by the ACCME to provide continuing medical education for physicians. The IARS designates this continuing medical education as meeting the criteria for a maximum of *twenty (20) AMA PRA Category 1 Credit(s)*™. Each physician should claim only those hours of credit that he/she actually spent in the educational activity.

SPEAKER AND PRESENTER DISCLOSURE STATEMENT

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

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Speakers and Moderators

Terry Aasen
Sonitor Technologies, Inc.
Largo, FL

David M. Feinstein, MD
Beth Israel Deaconess Medical Center
Boston, MA

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

Tong J. Gan, MB, FRCA
Duke University Medical Center
Durham, NC

Julian M. Goldman, MD
Massachusetts General Hospital
Boston, MA

Jeffrey A. Green, MD
VA Commonwealth University
Richmond, VA

Leslie Jameson, MD
University of Colorado HSC
Denver, CO

Peter Lichtenthal, MD
University of Arizona
Tucson, AZ

Michael O'Reilly, MD
University of Michigan Medical Center
Ann Arbor, MI

Joseph Orr, PhD
University of Utah
Salt Lake City, UT

John Pantano
Radianse, Inc.
Lawrence, MA

James H. Philip, MEE, MD, CCE
Harvard Medical School
Boston, MA

Jeffrey S. Plagenhoef, MD
SE Alabama Medical Center
Birmingham, AL

Jeffrey Robbins
LiveData, Inc.
Cambridge, MA

Warren S. Sandberg, MD, PhD
Massachusetts General Hospital
Boston, MA

Michael Schulien
Intel Corporation
Woodstock, IL

Irene Tremblay
Vocera Communications
Cupertino, CA

Michael Vigoda, MD, MBA
Jackson Memorial Medical Center
Miami, FL

David Wax, MD
Mount Sinai Medical Center
New York, NY

Sandy Weininger, PhD
US Food & Drug Administration
Rockville, MD

Olivier C. Wenker, MD, MBA, DEAA
University of Texas MD Anderson
Cancer Center
Houston, TX

David Whitlinger
Continua Health Alliance
Woodstock, IL

Stephan Ziegeler, MD
University of Saarland
Saar, Germany

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STA 2007

Wednesday, January 17, 2007

7:00 a.m. - 5:30 p.m.	Registration	Registration Desk C/D
8:00 a.m. - 1:00 p.m.	STA Board of Director's Meeting	Salon 14
8:00 a.m. - 5:00 p.m.	Anesthesia 101: An Introduction to a Complex Micro Environment (Registration Fee - $150)	Ballroom C/D
6:00 - 7:30 p.m.	Welcome Reception in Technology Showcase Area	Ballroom B

Thursday, January 18, 2007

7:00 a.m. - 6:00 p.m.	Registration	Registration Desk C/D
7:00 a.m. - 2:00 p.m.	Technology Showcase and Poster Area	Ballroom B
7:00 - 8:00 a.m.	Continental Breakfast in Technology Showcase Area	Ballroom B
8:00 - 8:15 a.m.	Opening Remarks, Meeting Overview Co-chairs: **Olivier Wenker, MD, MBA, DEAA** **Joseph Orr, PhD**	Ballroom C
8:15 - 9:30 a.m.	Technical Problems in Anesthesia: Progress & Identification **James H. Philip, MEE, MD, CCE** **Associate Professor of Anesthesia** **Harvard Medical School**	
9:30 - 10:30 a.m.	Break and research poster walk-arounds	Ballroom B
10:30 a.m. - 12:00 p.m.	Update on Interoperability in Healthcare	Ballroom C

- Medical Device Interoperability: Enabling Improvements in Patient Safety and Healthcare Efficiency
  Julian M. Goldman, MD
  Department of Anesthesia
  Massachusetts General Hospital

- Personal Telehealth Solutions
  David Whitlinger, President and Chairman
  Continua Health Alliance

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10:30 a.m. - 12:00 p.m.	Update on Interoperability in Healthcare (continued)	Ballroom C
	• How long must we wait? Are standards required for interoperability? **Jeffrey Robbins, Founder and CEO** **LiveData, Inc.**	
12:15 - 1:45 p.m.	STA Annual Awards and Business Luncheon and Presentation of the J. S. Gravenstein Technology Award	Ballroom D
2:00 - 5:00 p.m.	Where do we go from here? **Joseph Orr, PhD** **Department of Anesthesiology Bioengineering Division** **University of Utah**	Ballroom C
	Facilitated group collaboration activities to identify the anesthesia technology problems that need to be solved	
	1) Anesthesia Information Systems Group 1	Ballroom C
	2) Anesthesia Information Systems Group 2	Salon 9
	3) Anesthesia delivery systems	Salon 10
	4) Patient Monitoring in the O.R.	Salon 11
	5) Patient monitoring outside the O.R. (procedural sedation)	Salon 17
	6) Pain Service (PCA)	Salon 18
	• Real-time Integration of Workshop results into Systems Solutions	Ballroom C
5:00 - 6:00 p.m.	Research poster walk-arounds	Ballroom B
5:00 - 7:30 p.m.	**Edwards Lifesciences LLC** Focus Group	Salon 9

Friday, January 19, 2007

7:00 - 2:00 p.m.	Registration	Registration Desk C/D
7:00 - 2:00 p.m.	Technology Showcase and Poster Area	Ballroom B
7:00 – 8:00 a.m.	Online Technology Review Committee Meeting	Salon 9
7:00 - 8:00 a.m.	Continental Breakfast in Technology Showcase Area	Ballroom B

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8:00 - 9:45 a.m. Cardiac Output Monitoring: Is Invasiveness the only Obstacle? Ballroom C

Jeffrey Feldman, MD
Division Chief, General Anesthesia
Department of Anesthesiology and
Critical Care Medicine
Children's Hospital of Philadelphia

Panel Agenda

8:00 - 8:15 a.m. Introduction
Jeffrey Feldman, MD

- Definition of the clinical problem
  - Is Cardiac Output measurement compelling?
  - How do you document that it works?
- Introduction of panelists

8:15 - 9:15 a.m. Panel Presentation of Methods of Cardiac Output Measurement. Each panelist will describe a particular technique or techniques with special attention to:
1) Recent advances in the technique
2) The role in clinical practice and
3) Research questions that remain to be addressed

Panel Topics and Speakers

• Transpulmonary (PiCCO)
Stephan Ziegeler, MD

• Bioimpedance (Solar IKG)
Stephan Ziegeler, MD

• Pulse Contour (FloTrac)
T. J. Gan, MB, FRCA

• Esophageal Doppler (CardioQ)
T. J. Gan, MB, FRCA

• Transthoracic Ultrasound (USCOM)
Peter Lichtenthal, MD

• CO2 Rebreathing – Modified Fick (NICO)
Joseph Orr, PhD

9:15 - 9:45 a.m. Question and Answer Session
Interactive session with audience to address questions about individual technologies and debate the role of these technologies in clinical practice.

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9:45 - 10:30 a.m.	Break, Research Poster Viewing, Show & Tell	Ballroom B
10:30 a.m. - 1:00 p.m.	Emerging Technologies in the Operating Room of the Future: An Overview **Olivier Wenker, MD, MBA, DEAA** **Professor of Anesthesiology** **The University of Texas MD Anderson Cancer Center**	Ballroom C
	• Wireless Convergence: Getting There **Michael Schulien, Sr. Solutions Architect Healthcare** **Intel Corporation**	
	• Real World Experience with Location Systems in the O.R. **John Pantano** **Vice President of Marketing** **Radianse, Inc.**	
	• Opportunities of Real Time Indoor Positioning Technology which tracks Patients, Equipment and Staff with reliable Bed or Room-level Location Accuracy **Terry Aasen** **CEO & President** **Sonitor Technologies, Inc.**	
	• Wireless Voice Communications in Heathcare **Irene Tremblay** **Director of Sales, USA** **Vocera Communications**	
1:00 - 2:00 p.m.	Box Lunch with Hands-on Demos of RFID, VOIP, UIP, and Show & Tell	Ballroom B
1:00 - 2:00 p.m.	Abstracts Award Session	Ballroom C
2:00 - 6:00 p.m.	Social Activities (On Own) Geocaching Treasure Hunt **STA Coordinator: James Szocik**	
6:00 - 10:00 p.m.	Sleuths Mystery Dinner Show - An evening of fun and intrigue! 6:00 – Depart for Dinner Show 6:30 – Sleuths Mystery Show 10:30 – Depart for Hotel	Convention/Ballroom Foyer

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Saturday, January 20, 2007

7:00 a.m. - 12:00 p.m.	Registration	Registration Desk C/D
7:00 a.m. - 12:00 p.m.	Technology Showcase & Poster Area	Ballroom B
7:00 - 8:00 a.m.	STA Board of Director's Meeting #2	Salon 14
7:00 - 8:00 a.m.	Continental Breakfast in Technology Showcase Area	Ballroom B
8:00 - 10:00 a.m.	Anesthesia Information Systems: Tips, Tricks and Traps An Overview **Michael O'Reilly, MD** **University of Michigan Medical Center**	Ballroom C

- Lessons Learned: Features and Functionality
  Jeffrey A. Green, MD
  Cardiac Thoracic Anesthesia
  VA Commonwealth University

- The AIMS and Decision Support: Opportunities, Test Cases and Financial Impact
  Warren S. Sandberg, MD, PhD
  Staff Anesthesia
  Massachusetts General Hospital

- Pimp My AIMS
  David Wax, MD
  Assistant Professor, Anesthesiology
  Mount Sinai Medical Center

- O.R. Drug Delivery...Obvious QI Opportunity
  Jeffrey S. Plagenhoef, MD
  Chairman
  Department of Anesthesiology
  SE Alabama Medical Center

- Medical Legal Considerations when using an AIMS
  Michael Vigoda, MD, MBA
  Assistant Professor of Clinical Anesthesia
  Jackson Memorial Medical Center

- Negotiating Land Mines -- How to know what you want matches what the vendor offers
  Leslie Jameson, MD
  Vice Chair, Department of Anesthesiology
  University of Colorado

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10:00 - 10:30 a.m.	Break, Research Poster Viewing, and Show & Tell	Ballroom B
10:30 - 11:30 a.m.	Anesthesia Information Systems: Tips, Tricks and Traps (continued) **Michael O'Reilly, MD** **University of Michigan Medical Center**	Ballroom C
11:30 a.m. - 12:30 p.m.	Assuring the Quality of AIMS Data Preliminary discussion points: - What do you do to assure that we can trust AIMS data for clinical care? - How is the data validated? Is this done on-site? - How are updates to medical devices or their communication components managed within the system? - What is the hospital/biomed/IS responsibility? - How much "locking down" of the entire system is required? - Are viruses a problem? - How is the V&V process affected by the data source or need for data transformation/scaling? - Can software updates change the appearance of archived data when it is reviewed? - Can AIMS be used as the primary information display and alarm system? **Julian M. Goldman, MD** **Department of Anesthesia** **Massachusetts General Hospital** **Sandy Weininger, PhD** **Center for Devices & Radiological Health** **US Food & Drug Administration** **Office of Science & Engineering Laboratories** **Division of Electronics and Software Engineering**	Ballroom C
12:30 - 2:00 p.m.	Industry Liaison Luncheon/Meeting	Ballroom D

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Speaker Disclosure Information

The following invited speakers have voluntarily acknowledged the below disclosure information:

Terry Aasen
Stock Shareholder (Directly Purchased) - Sonitor Technologies

Peter Lichtenthal, MD
Grants/Research Support - USCOM
Consultant - USCOM

Michael O'Reilly, MD
Grants/Research Support - GE Healthcare
Consultant - GE Healthcare

John Pantano
Other Material or Financial Support - Employee

James H. Philip, MEE, MD, CCE
Stock Shareholder (Directly Purchased) - Med Man Simulations Inc and Gas Man
Honorarium - Baxter, Abbott, GE

Jeffrey S. Plagenhoef, MD
Stock Shareholder (Directly Purchased) - DocuSys

The following invited speakers have disclosed that they have no actual or potential relationship(s) that have bearing on the subject matter of this activity:

Jeffrey Feldman, MD, MSE

Warren S. Sandberg, MD, PhD

Michael Schulien

Michael Vigoda, MD, MBA

Olivier Wenker, MD, MBA, DEAA

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Milford, CT

Cardiopulmonary Corp. is all about improving healthcare. We have a broad vision and a strong dedication to clinica excellence. We are shifting the paradigm in hospital-based medicine. Cardiopulmonary Corp. designs, develops, an implements medical enterprise software for mission-critical decision support used in a wide-range of acute car applications. The Company, based in Connecticut, is a market leader of hospital-wide, IT-centric solutions used in th real-time management and surveillance of critically ill patients.

CERNER CORPORATION

Booth: 6

Kansas City, MO

Today's practice of anesthesia demands electronic access to complete, accurate information. Cerner Millennium® SurgiNet® unifies the practice of surgery and anesthesia to enhance throughput and utilization of the service, while supporting effective care delivery and business practice management.

Cerner Corporation is the leading U.S. supplier of healthcare information technology solutions.

CRITICARE SYSTEMS, INC.

Waukesha, WI

Criticare Systems, Inc. has established technological leadership in anesthetic gas monitoring and vital signs monitoring. CSI develops, markets, and distributes a wide range of patient monitoring devices that incorporate technological innovation and cost-containment features. The company's products address patient monitoring needs in anesthesia, critical care, respiratory care, transport, and outpatient care environments. Comprehensive customer support, equipment service and technical support programs make even our most advanced systems affordable and easy to use.

DOCUSYS, INC.

Booth: 1

Mobile, AL

DocuSys, providing comprehensive digitization of anesthetics, incorporates customizable decision support, professional fee capture, comorbid condition documentation and automatic documentation, tracking and billing of drugs to maximize quality and financial return. The system incorporates an intravenous drug monitor, DocuJect®, which utilizes bar-coding and digital imaging to digitize drug delivery data.

DRAEGER MEDICAL

Booth: 3

Telford, PA

Draeger Medical AG & Co. KG is one of the world's leading manufacturers of medical equipment. The Company offers products, services and integrated CareArea™ Solutions throughout the patient care process - Emergency Care, Perioperative Care, Critical Care, Perinatal Care and Home Care. Draeger Medical employs nearly 6,000 people worldwide. Additional information is available on the Company's website www.draegermedical.com.

EDWARDS LIFESCIENCES

Booth: 5

Irvine, CA

Edwards Lifesciences is the world leader in hemodynamic monitoring systems which are used to measure a patient's heart function in the intensive care, surgical and emergency room settings. Since introducing the Swan-Ganz® catheter, the company has offered an extensive line of technologies which include the PreSep™ Central Venous Oximetry Catheter, Vigileo™ Monitor, Vigilance™ CCO SvO2/CEDV Monitor, TruWave™ disposable pressure transducers, VAMP™ closed arterial blood sampling systems, and Vantex™ central venous antimicrobial catheters. In 2005, Edwards launched the innovative FloTrac™ System, which provides real-time hemodynamic monitoring (including continuous cardiac output, stroke volume, stroke volume variation, and systemic vascular resistance) directly from an arterial line.

Be sure to visit our booth to learn more about our product lines.

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HOSPIRA WORLDWIDE, INC. T-1 Table Top

Lake Forest, IL

For more information, stop by Hospira's booth or please call 1-877-946-7747 to learn the latest regarding SEDLine™ Brain Function Monitoring Systems. Hospira is a global specialty pharmaceutical and medication delivery company dedicated to Advancing Wellness™ by developing, manufacturing and marketing products that help improve productivity, safety and efficacy of patient care. With 70 years of service to the hospital industry, Hospira's portfolio includes generic acute-care injectables, integrated medication management and infusion therapy solutions, and injectable contract manufacturing.

iMDSoft T-2 Table Top

Needham, MA

iMDsoft develops clinical information systems for critical care. The company's MetaVision Suite was first implemented in 1999 and has since become a leader in the CIS and AIMS marketplace, with customers in the US, Europe, and Asia.

INTRASAFE MEDICAL, INC. T-3 Table Top

Frisco, TX

SurePort Safety Infusion™ Device allows for needle-less administration of IV fluids and drugs. This device helps maintain a sterile field with its mounting option, improving safety, and saving time.

MASIMO Booth: 2

Irvine, CA

Masimo is the inventor of motion and low perfusion tolerant pulse oximetry. Over 90 independent studies demonstrate the superior performance of Masimo SET™ pulse oximetry technology. Masimo now offers Rainbow SET Pulse CO-Oximetry™ technology which noninvasively and continuously measures Methemoglobin and Carboxyhemoglobin, along with Oxygen Saturation, Pulse Rate and Signal IQ.

NELLCOR/TYCO HEALTHCARE Booth: 4

Pleasanton, CA

Nellcor is dedicated to developing innovative, clinically relevant medical products with an emphasis on noninvasive patient safety monitoring and respiratory care. A part of Tyco Healthcare, Nellcor is the world's foremost supplier of pulse oximetry, and airway management products. The company also offers a wide range of products for measuring and regulating patient body temperature.

ORIDION CAPNOGRAPHY USA T-5 Table Top

Needham, MA

Oridion's Microstream® capnography: effective, proven airway management providing the earliest indication of airway compromise.

Microstream® capnography combines proprietary sensing technology, eliminating the need for gas compensation. Situation-specific patient interfaces, for oral, nasal and intubated sampling provide accurate and easy-to-use assessment of your patient's ventilation in any clinical setting, including PCA and procedural sedation.

PHILIPS T-8 Table Top

Andover, MA

Philips Medical Systems, focused on the anesthesia community since 1988, offers the gold standards in patient monitoring and anesthesia information systems. The IntelliVue patient monitor is configured specifically for the anesthesiologist, providing a common user interface across the entire range of monitors from low to high acuity settings. The CompuRecord Anesthesia Information System, focused on the process of anesthesia, has been meeting the needs of practicing anesthesiologists for over 25-years. Philips IntelliVue patient monitors and the CompuRecord System work with leading anesthesia machines and third-party devices to allow anesthesiologists to build their optimal workspace.

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PROMPTE, LLC T-4 Table Top

Chicago, IL

Prompte's preoperative solutions offer a modern approach to streamlining and standardizing to the historically cumbersome, costly and ineffective preoperative processes. Our solutions start with a multilingual, patient-driven web based health questionnaire that generates a risk stratifying score along with patient specific instructions and algorithms to guide caregivers through the preoperative process.

PULSION MEDICAL, INC. Booth: 7

East Brunswick, NJ

The PiCCO Technology is a less invasive hemodynamic monitoring providing a complete picture of the patient's hemodynamic situation. This includes beat-by-beat stroke volume and cardiac output, volumetric preload measurements volume responsiveness, afterload, and contractility. Furthermore it is the only available technology to detect and monitor a pulmonary edema at the bedside. Using this range of information, diagnosis and therapy decision making gets more easy without having side effects or complications as those associated with the use of Swan Ganz catheters.

PiCCO Technology is based on two techniques: Transpulmonary thermodilution and Pulse contour analysis. A standard central venous catheter and special arterial line are the only accesses needed. Thus, the accuracy of a thermodilution is combined with the possibilities of continuous pulse contour analysis. This combination enables the adaption of the measurements and calculations on the hemodynamic characteristics of any specific patient. Re-calibration in certain circumstances such as extreme changes in vascular resistance or others remains a major advantage in monitoring critically ill patients.

Parameters:

- CO (continuous/intermittent)
- Volumetric Preload
- Volume Responsiveness
- Contractility
- Lung Water
- Pulmonary Vascular Permeability
- Afterload
- Intracardiac R-L-Shunt

SONITOR TECHNOLOGIES, INC. T-9 Table Top

Largo, FL

Real Time Location System (RTLS); Guaranteed Bed/Room-level accuracy.

Sonitor Technologies' ultrasonic Indoor Positioning System (IPS) automatically tracks the real-time location of equipment and people in hospitals with 100% room or bed-level accuracy. Other advantages over RFID and WiFi: Zero risk of electromagnetic interference. Minimal LAN bandwidth requirements. Lower cost. www.sonitor.com

SURGICAL INFORMATION SYSTEMS

Alpharetta, GA

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

USCOM, Inc. T-10 Table Top

Benicia, CA

USCOM is a noninvasive hemodynamic monitor that provides real-time information, from either the left or right heart, regarding preload, contractility and afterload. USCOM has been validated against flow-probes, echo, PAC and artificial hearts in animals, pediatrics and adults. It has numerous applications in the PICU, ED and MICU.

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Platinum

Masimo	www.masimo.com
Oridion Capnography USA	www.oridion.com

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Select Lecture Summaries

Panel: Update on Interoperability in Healthcare
How long must we wait? Are standards required for interoperability?
Jeffrey Robbins, Founder and CEO
LiveData, Inc.

Summary: The purpose of this talk is to give an overview of what role do standards play in enabling interoperability of medical devices, software systems, and people. Emphasis will be placed on the need for a robust interoperability ecosystem designed to support different clinical scenarios to improve patient safety, system efficiency, and overall patient and staff satisfaction. All without imposing undue burdens or unrealistic complexity on regulators, vendors, biomed engineering, and clinicians. A tall order -- are current standards efforts up to the task to deliver? Can you achieve interoperability without standards? Expect an in-depth report from the trenches.

Panel: Cardiac Output Monitoring: Is Invasiveness the only Obstacle?

Introduction: Cardiac output (CO) measurement by a thermodilution pulmonary artery catheter is the most commonly used method of monitoring CO despite the complications related to the invasive nature of this technique. In recent years, several technologies have been introduced and progressively refined that are designed to reduce or eliminate the invasive nature of cardiac output measurement. Notwithstanding these advances, cardiac output monitoring has yet to be widely adopted as a monitoring tool. What are the obstacles to adopting cardiac output monitoring into clinical practice? Are non-invasive techniques sufficiently compelling? Is the cost prohibitive? Do these devices fail to perform sufficiently well to warrant acceptance? These and other questions will be addressed by this panel.

Panel Objectives:
- Review the state of the art in technologies available for cardiac output monitoring in the operating room and intensive care unit
- Review approaches to documenting the performance of methods for cardiac output monitoring
- Debate the obstacles to acceptance of cardiac output monitoring in modern anesthesia practice especially now that many non-invasive techniques are available
- Identify research questions that need to be answered to document the utility of cardiac output monitoring

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Panel: Emerging Technologies in the Operating Room of the Future:
Wireless Voice Communications in Heathcare
Irene Tremblay, Director of Sales, USA
Vocera Communications

Summary: Wireless networks in hospitals have enabled a wide variety of applications for mobile workers in healthcare. One of the most compelling applications using the wireless network is voice communications. Mobile healthcare workers, who need to be connected to others, are using wearable wireless voice communications systems to improve patient care, staff satisfaction, patient safety. Wireless voice communications allow clinicians to instantly find the right person. They can transform communication patterns and save valuable time by improving processes. This session will present a variety of case studies where a wireless voice application from Vocera Communications has transformed patient care in hospitals.

Society for Technology in Anesthesia

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STA 2007

Select Lecture Summaries

Panel: Anesthesia Information Systems: Tips, Tricks and Traps
Medical-Legal Considerations when using an AIMS
Michael Vigoda, MD, MBA
Assistant Professor of Clinical Anesthesia
Jackson Memorial Medical Center

The presentation will focus on: Why AIMS are considered helpful from a medical-legal perspective; does having an AIMS help or hurt anesthesiologists (users' responses); The current variation in Documentation Practices.

Handouts included:
Thursday: Technical Problems in Anesthesia: Progress & Identification
- **James H. Philip, MEE, MD, CCE**

Friday: Cardiac Output Monitoring: Is Invasiveness the only Obstacle?
- **Stephan Ziegeler, MD**
- **T. J. Gan, MB, FRCA**
- **Peter Lichtenthal, MD**
- **Joseph Orr, PhD**

Saturday : Anesthesia Information Systems: Tips, Tricks and Traps
- **Warren S. Sandberg, MD, PhD**

Techincal Problems in Anesthesia: Progress and Identification

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Anesthesia is crucial to all clinical interventions which cause pain or require patient immobility for prolonged periods of time. General anesthesia is required for most of these interventions. Regional anesthesia or Monitored Anesthesia Care (MAC) can suffice for some.

General anesthesia is inherently dangerous. The drugs we administer would be lethal if administration were not monitored or if continuous resuscitation were not maintained. Because these drugs depress most body functions, the anesthesia care we provide must restore many of them to normal. When anesthesia is required for patients who are very ill, the burden becomes even greater.

The anesthesiologist's duty is to provide the care required and simultaneously protect the patient from any and all bad outcomes. Protection requires careful monitoring combined with careful therapy. If any element of the patient's care fails or is inadequate, the patient is at grave risk.

Anesthesia monitoring traditionally relied on our senses to assess the patient's state or condition. In the distant past, we considered a finger on the pulse, a hand on the reservoir bag, and a precordial stethoscope sufficient. While these techniques provided continuous qualitative patient assessment, we made quantitative measurements, specifically, ventilation rate, pulse rate, and blood pressure every 5 minutes.

ECG monitors aid pulse rate measurement and allow diagnosis of specific arrhythmias. But arrhythmias are not commonly a result of anesthesia, and are not encouraged by the newer anesthetic agents. S-T segment monitoring, however, keeps the ECG a valuable tool. Automated non-invasive blood pressure (NIBP) monitors make blood pressure monitoring more convenient and frequent display of measurements probably lessens undetected and uncorrected blood pressure swings. If an undesirable blood pressure is not appreciated, it certainly cannot be corrected. New non-invasive devices allow continuous or continual noninvasive blood pressure monitoring from the wrist. They are beginning to take a place in routine patient care.

Ventilation monitoring traditionally relied on manual palpation of the reservoir bag during spontaneous or manual breathing. During mechanical ventilation, pressure-sensitive disconnect alarms became common. These often failed to detect disconnection if inspiratory flow rate or circuit resistance was high. As an additional danger, most pressure-sensitive alarms failed to detect occlusion, whether caused by tracheal tube kink or misconnected PEEP valve or other circuit components. Today, ventilation monitors are more sophisticated. Some Anesthesia Delivery Systems (ADSs) provide continuous monitoring of Resistance and Compliance beyond the breathing circuit.

In the USA, monitoring changed dramatically beginning in 1985. It was then that healthy patients became the focus of monitoring. Since that time, our mind-set has changed. We used to think that occasional anesthesia mortality was inevitable. Today we believe that healthy patients should never suffer significant injury due to anesthesia. Unfortunately, there is little solid data on anesthesia mortality in the USA. But, the best estimates we have suggest that severe morbidity has fallen from 1/3,000 in 1985 to as low as 1/300,000 today.

During the period since 1985, many things have changed in anesthesia practice. In 1985, 22% of US anesthesiologists used pulse oximeters and 18% used capnographs. By 1990, almost 100% used pulse oximeters and capnographs. In addition, anesthetic agent monitors have become almost universal. For multi-gas monitoring, the focus shifted from shared systems to stand-alone monitors for each operating room. These allow not only routine safety monitoring but provide breath-by-breath control of anesthetic depth.

James H. Philip, M.E.(E.), M.D., C.C.E.

Standards have played an important role in the years since 1985. The 1985 Harvard Monitoring Standard required: 1) continuous presence of a physician or CRNA, 2) blood pressure and heart rate measurement every five minutes, 3) electrocardiogram continuously displayed, 4) circulation continuously monitored, 5) ventilation continuously monitored, 6) a disconnect device used during mechanical ventilation, 7) oxygen in the breathing circuit monitored, and 8) the ability to monitor temperature. This standard was superseded by the ASA Monitoring Standard of 1986. This standard required continual assessment of circulation and ventilation, and encouraged oximetry, capnography, and airway flow or volume. In 1988, this standard was enlarged to require universal use of pulse oximetry and by 1990 capnography was added to the universal monitoring list.

Oximetry and capnography are now in use routinely in operating rooms in the USA. Some states require their use. Some insurance companies have effectively bought them for those they insure. The results have been dramatic. In the State of Massachusetts, an average of 4.5 preventable deaths or severe injuries occurred each year from 1975 through 1984. After the institution of universal oximetry and capnography in 1986, no lives were lost in four years. Oximetry detects hypoxemia from any cause while capnography detects most airway problems the moment they occur. The combination of these two seems particularly effective in avoiding mishaps. No studies have yet proven a cause and effect relationship. But, most anesthesiologists who use these devices would never again practice without them.

Now that anesthesia mortality in healthy patients appears to be very low, the next frontier for technology is improving overall care of the patient. The new inhalation anesthetics promise fewer side effects and more rapid induction and emergence. Anesthetic agent monitors allow better control of new and old inhalation anesthetics. Better integration of variables monitored and therapy administered provides clearer patient information. And better assessment of heart function through continuous cardiac output allows even those patients with compromised hearts and vascular systems to gain the benefit of modern surgery and anesthesia. Now that anesthesia has become safer for all patients, we can dedicate our efforts to making anesthesia better for each patient.

We can now monitor the function of the heart and vascular system non-invasively several different ways. It is true that we still use Automated Non-Invasive Blood Pressure (A-NIBP) monitors like we used in 1975; and, Eintoven's electrocardiograph is still in use. But during the last decade, and especially since 1997, we have seen a surge of monitors to assess myocardial function. The Trans-Esophageal Echocardiograph (TEE) is an expensive ($150,000) piece of capital equipment which uses an expensive ($50,000) fragile reusable probe. Successful use of this device requires significant training and practice. In TEE, sound frequencies too high to hear (ultrasound) are bounced off the heart, blood vessels, and blood - to show function and structure of the heart. Several simpler-to-use products use Ultrasound Doppler shift to measure blood flow and cardiac output by pointing the probe along the axis of the aorta. Some do this with the probe on the surface of the chest or neck. Others use a probe in the esophagus. Transesophegeal ultlrasound cardiac output monitor probes are available for $100 and require no capital outlay. All of the ultrasound equipment I have listed are being replaced with smaller and simpler models which place them in reach of all care providers. Another new commercial device monitors cardiac output using the Indirect Fick method with partial rebreathing of the respiratory gas - carbon dioxide.

Recent advances allow us to predict and control drug levels in blood and target organs such as the brain. With inhaled anesthetics, we routinely measure alveolar tension as a surrogate for blood tension of anesthetic. Now, even propofol levels in blood can be measured in exhaled gas, albeit, with difficulty. Advanced systems to help the anesthetist navigate trough the complex array of administered drugs and even allows calculation of effect-site concentrations and drug interactions. One new product allows enhancement of the kinetics of soluble and insoluble inhalation anesthetics, augmenting the change in alveolar, blood, and brain tension dramatically.

The end of the last century also brought brain function, sedation, and sleep monitoring into clinical practice in some centers. There are several products to measure hypnosis. One device uses three electrodes to measure a Bispectral Index. Another device monitors brain wave propagation across an array of electrodes from forehead to temples combined with theta activity. Another measures brain response to auditory signals. Yet another measures discoherence of brain activity (i.e., Entropy). Use of brain monitors is still controversial and strongly debated by various sectors of the anesthesia community. Other measures of localized and general brain function are available through evoked potentials and other modalities.

Oxygen utilization is a general measure of adequacy of oxygen delivery to tissues. Tissue oxygen level is more easily measured and provides value in detecting decreased perfusion. One product does this noninvasively for brain tissue. Another does this for other this for tissues with a slightly invasive probe. A measure that is sensitive to generalized decrease (or increase) in oxygen utilization is Mixed Venous Oxygen Saturation. This can be monitored by opto-electronics built into a balloon-tipped pulmonary artery flotation catheter. This has been available for many years. Mixed-venous saturation is best used when combined with a continuous measure of cardiac output. Commercial equipment and products use continuous thermal dilution for this purpose.

Our anesthesia delivery systems (ADSs) have become more complex in recent years. ADSs on the world market now provide choices of electronic or mechanical gas mixing and vaporization. One system available in some countries allows delivery of set inspired oxygen and set end-tidal vapor concentration while minimizing gas and vapor use through low fresh gas flow and closed circuit anesthesia. New ADSs allow for ventilation of all potential candidates for surgery. No longer must the OR and its limited anesthesia ventilators be averted to insure the safety of patients in ventilatory failure. Today's ventilators suffice for almost all patients.

Our job today and into the future is to continue to engineer our way to better patient care. We must remember that the patient's physiology dictates what we monitor and control. It is our job to monitor and control all the physiologic processes that are required for a good outcome. And, of course, we must monitor or mitigate all the derangements in these processes that can lead to bad outcomes. The challenge for us and our successors is to identify the physiologic processes that count, and then communicate the need to monitor or control them to our industry colleagues who will produce the instruments we will use to ensure a good outcome for all.

Finally, it is important that our regulators, in the FDA, JCAHO, and other organizations, keep pace with the evolving needs and capabilities of patient care. If they fail to keep pace with current capabilities, they retard rather than foster the best in patient care. The combined strength of insightful clinicians and creative manufacturers along with supportive regulators are the key to our future and the future of our patients.

Impedance Cardiography

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The following basic description of the presented technology is taken from the recent publication

Ziegeler S, Grundmann U, Fuerst O, Raddatz A, Kreuer S. Hemodynamic response to exercise as measured by the Solar IKG impedance cardiography module and correlation with metabolic variables. J Clin Monit Comput 2006; E-Pub ahead of print Nov. 4; DOI 10.1007/s10877-006-9053-9

For references, please, refer to this publication.

Impedance cardiography (ICG) is a completely non-invasive method for measurement of CO. It has been applied to actual monitor technology in numerous variations since the 1940ies. The correlation with thermodilution or direct fick methods is variable depending on the investigated patient population and the specific underlying algorithm. Lately, validation studies using newer ICG algorithms have revealed good correlation values in comparison to thermodilution-CO.

Basic Electricity

The calculation of CO by ICG is based on the fact, that CO is proportional to the pressure drop over the whole of the arterial-venous circuit (MAP – CVP) and inversely proportional to the total peripheral resistance (TPR), thus leading to the formula: $CO \approx (MAP - CVP)/TPR$. In electricity, an analogous relationship is described by Ohm's law. Here, a flow of current (I, analogous to CO) is equal to the voltage drop between two ends of a circuit (E, analogous to the pressure drop) divided by the resistance to current flow (R, analogous to TPR) ($I = E/R$). Impedance (Z) is the resistance to an alternating current and is a complex, frequency-

dependent parameter. Therefore, for alternating current flow, the equation converts to: $I = E/Z$. With I remaining constant, periodic changes in voltage produce concurrent changes in impedance: $\Delta Z \approx \Delta E$. Impedance of a cylindrical electrical conductor is determined as $Z = \rho \times L/A$, with ρ = specific resistance of the conductor, L = length and A = cross-sectional area.

Impedance Cardiography

If the thorax is simplified as a cylindrical conductor that has a second cylindrical conductor representing the great vessels embedded, this electrical model can be transferred to calculate SV. Therefore, it is postulated, that both cylinders have a defined length, that the sum of the cross-sectional areas of both cylinders is the cross-sectional area of the entire thorax and that both cylinders are confined of homogenous volumes with a defined resistance. It is further assumed, that the great vessels have a varying cross-sectional area due to the pulsatile blood flow with each heart beat and that the specific resistance of blood is significantly smaller than that of the thorax ($\rho_B << \rho_T$). With ventilation suspended, this means that changes in Z (ΔZ) are caused mostly by the changes in the cross-sectional area of the great vessels. Periodic changes of blood volume with the cardiac cycle must lead to concomitant decreases and increases in thoracic impedance. The impedance changes, however, are proportional to the measured voltage changes, as shown above. It could further been shown, that these impedance changes are directly proportional to the pulsatile changes in aortic and pulmonic blood volume ($\Delta V(t) \approx \rho_B \times L^2/Z_0^2 \times \Delta Z(t)$, with $\Delta V(t)$ = volume change over time and Z_0 = nonpulsatile base impedance).

Clinically, these basic principles are used to determine the SV of any single heart beat. Therefore, an alternating current of constant magnitude, low amplitude (1-4 mA) and high frequency (30-100 kHz) is applied to the thorax via two pairs of electrodes, one on both sides of the neck and the other one on both sides of the lower thorax. The voltage changes are then

measured by two other electrode pairs below the current-injecting pair on the neck and above the current-injecting pair on the thorax.

The base impedance Z_0 consists of various tissue impedances (fat, skeletal and cardiac muscle, lung, bone and vascular tissue) and the air-to-liquid ratio in the thorax. The mean value of Z_0 is approximately 30 Ω, but may change with the frequency of the alternating current used. Superimposed on Z_0 are impedance changes corresponding to ventilation and pulsatile blood flow. Therefore, the total impedance at any time is: $Z(t) = Z_0 + \Delta Z(t)$. By magnitude, the respiratory part of ΔZ is by far larger than the part caused by ventricular ejection, which lies in the range of 0.1 to 0.2 Ω. These parts can be differentiated when viewed in conjunction with the ECG tracing. For each ECG pulse there is a corresponding ΔZ signal with a slightly delayed onset. Since blood is a good conductor, impedance decreases with filling of the great vessels in systole and, to a lesser extend, with filling of the ventricles in diastole. By convention, these decreases in impedance are expressed as positive values. Kim et al. concluded from calculations, that the ΔZ-part related to the cardiac cycle is nearly linearly related to the volume changes in the aorta, i.e. the left ventricular SV. In conjunction with the heart rate, CO and related parameters can be calculated.

A wide variety of users has applied the basic principles to actual monitors. Lately, more sophisticated algorithms have been introduced.

Solar IKG module

The volumetric changes of the aorta, that cause corresponding impedance changes, are not exclusively dependent on SV but also on the compliance of the aorta itself. With increasing age, the aortic wall becomes more rigid, i.e. less compliant, meaning, that the same SV ejected by the left ventricle causes a smaller contribution to ΔZ in older than in younger individuals. The software of the Solar IKG module, GE Healthcare, Freiburg, Germany, has taken these

physiologic changes with age into account by using the Z MARC^{TM}-algorithm (**Z** for impedance, **M**odulating **A**o**R**tic **C**ompliance) for calculation of SV. CardioDynamics Int. Corp., San Diego, CA, has developed this sophisticated algorithm based on waveform analysis with a comprehensive waveform library. The specific details of the algorithm are kept confidential by the company. It is based on the Sramek-Bernstein equation: SV = $(dZ/dt)/Z_0$ x LVET x VEPT, with dZ/dt = change in impedance over the change in time, LVET = left ventricular ejection time and VEPT = volume of electrically participating tissue. The methodology has been validated in several studies against thermodilution or direct fick methods. Van de Water and colleagues have, furthermore, provided data, that this new ICG-technology represents a marked improvement in agreement to CO measured by thermodilution via a pulmonary artery catheter in comparison to older ICG-technology.

Pulse Contour Continous Cardiac Output

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The Pulse Contour Continous Cardiac Output (PiCCO) technology is a less invasive hemodynamic monitoring providing a complete picture of the patient's hemodynamic situation. This includes beat-by-beat stroke volume and cardiac output, volumetric preload measurements, volume responsiveness and afterload. Furthermore, it has the capability to detect and monitor pulmonary edema at the bedside.

PiCCO Technology is based on two techniques: Transpulmonary thermodilution and Pulse contour analysis. A standard central venous catheter and special arterial line are the only accesses needed. Thus, the accuracy of thermodilution is combined with the possibilities of continuous pulse contour analysis (Figure 1).

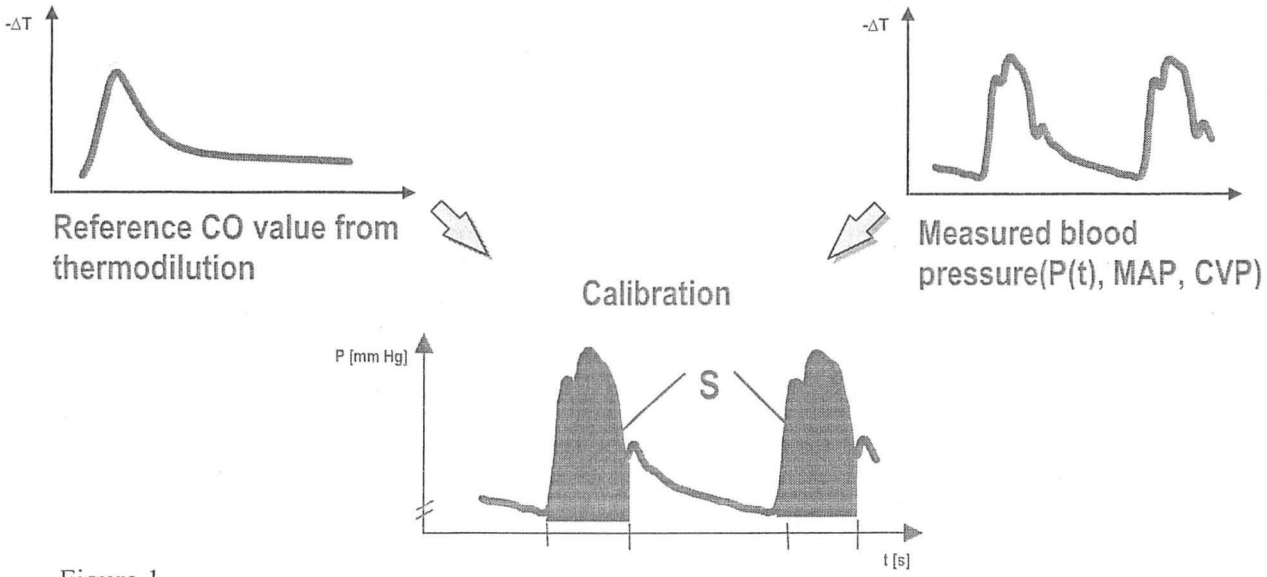

Figure 1

Cardiac output is calculated by analysis of the thermodilution curve using a modified Stewart-Hamilton algorithm:

$$CO_{TDa} = \frac{(T_b - T_i) \cdot V_i \cdot K}{\int \Delta T_b \cdot dt}$$

with T_b = blood temperature, T_i = injectate temperature, V_i = injectate volume, $\int \Delta T_b \cdot dt$ = area under the thermodilution curve and K = correction constant, made up of specific weight and specific heat of blood and injectate.

The important calculations of the intrathoracic blood volume (ITBV) and the extravascular lung water (EVLW) are based on further calculations of the thermodilution curve. For these

calculations, the mean transit time (MTt)(time when half of the indicator has passed the point of detection in the artery) and the down slope time (DSt)(exponential downslope time of the thermodilution curve) are important.

After injection, the indicator passes the following intrathoracic compartments (figure 2) with the lungs being the largest compartment.

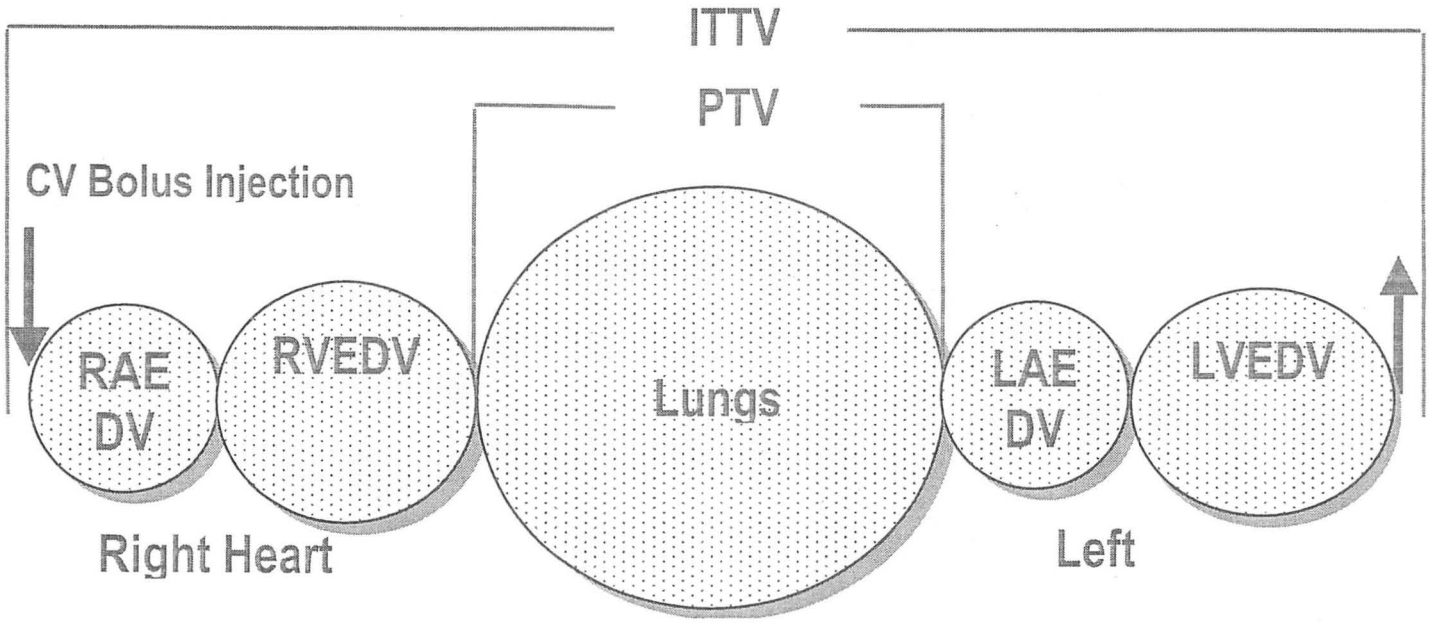

Figure 2
RAEDV=right atrial end-diastolic volume; RVEDV=right ventricular end-diastolic volume; LAEDV=left atrial end-diastolic volume; LVEDV=left ventricular end-diastolic volume; ITTV=intrathoracic thermal volume; PTV=pulmonary thermal volume

Multiplication of the MTt with CO results in the complete intrathoracic thermal volume (ITTV = RAEDV + RVEDV + Lungs + LAEDV + LVEDV = MTt x $Flow_{(CO)}$).
Multiplication of DSt (Downslope time) with CO yields the pulmonary thermal volume (PTV = DSt x $Flow_{(CO)}$).
The global end-diastolic volume (GEDV) represents the blood volume in all four heart chambers and is calculated as follows: GEDV = ITTV – PTV.

The ITBV, representing the global preload, represents the GEDV + the blood volume of the pulmonary vessels (PBV) and was traditionally measured with a complex double-indicator method requiring thermo- and dye-dilution at the same time. This double-dilution ITBV has been shown to be consistently 25% larger than the GEDV calculated from single transpulmonary thermodilution[1]. Therefore, the PiCCO-system calculates ITBV as 1.25 x GEDV.

Finally, for the calculation of EVLW, which corresponds to interstitial pulmonary fluids i.e. pulmonary edema, ITBV is subtracted from ITTV (ITTV – ITBV = EVLW). Again, the gold standard to assess EVLW is the double-indicator technology. The single thermodilution EVLW as measured by PiCCO has been shown to correlate well with this standard method in various studies[1,2].

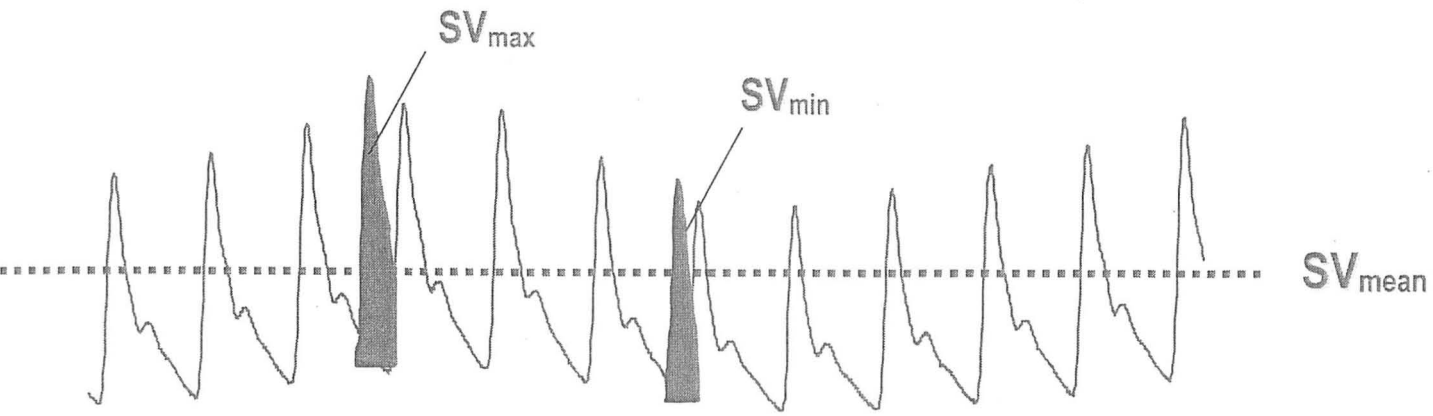

Figure 3

A third valuable volume parameter calculated from the pulse contour analysis is the stroke volume variation (SVV) (figure 3). It represents the variation of stroke volume over the ventilatory cycle and is only applicable in mechanically ventilated patients. It is calculated as follows:

$$SVV = (SV_{max} - SV_{min}) / SV_{mean}$$

It correlates well with the preload status of the patient[3] with a variation of greater 10% representing a state of volume depletion.

In Europe, PiCCO is widely used to monitor the hemodynamic status of critically ill patients and to guide differentiated volume and catecholamine therapy.

Stephan Ziegeler, MD

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ESOPHAGEAL DOPPLER MONITORING

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Historical Perspective and Physical Principles of Doppler Effect

In 1842, Christian Doppler determined how the velocity of a moving object is proportional to the shift in reflected frequency of an optic wave of known frequency. This has later come to be known as the Doppler effect. The relationship can be expressed by the following equation.

$V = c.\Delta F/(2Fe \times \text{Cos } \theta)$

Where V is the velocity of the red blood cells, c is the speed of the ultrasound waves through the biological tissues, ΔF the Doppler frequency shift (in kHz), Fe the emitted frequency of the ultrasound, and Cos θ the cosine angle between the sound beam axis and the velocity vector.

This formula relates frequency shift to velocity and other parameters such as the angulation of the observer to the moving object and the speed of sound. If these variables were kept constant then the proportionality between changes in frequency shift and velocity would be maintained.

The medical applications of the Doppler effect did not become a practical reality until the 1960s, when Franklin and Satomura used the Doppler principle to measure the velocity of the red blood cells in animals and humans[1,2] . Since their pioneering work, the principle of Doppler flow velocity has been developed for measuring blood flow in many specialties in medicine. In the perioperative environment, the focus has been on measurement of stroke volume, aortic blood flow and cardiac output.

Doppler measurement of the aortic blood flow was first described by Light in 1969[3]. However, it was not well accepted in routine clinical practice due to poor signal processing and high degree of noise. Over the last decade, with the advancement of technology that allows both superior processing and on-line measurement there has been a resurgent of interest in using the Doppler technology for management of hemodynaimcs in the perioperative environment. There have been numerous advances resulting in improvement of the monitor as well as the esophageal probe, which in the current form, measures about 6 mm in diameter (the size of a nasogastric tube). The esophageal Doppler Monitor (CardioQ™, Deltex Medical Inc., Irvine, TX) (Figure 1) display information on aortic waveform, cardiac output, stroke volume, and other related hemodynamic parameters.

T. J. Gan, MB, FRCA

Practical Aspect of Esophageal Doppler Monitor

The insertion of the esophageal Doppler probe (Figure 2) is relatively simple. The head of the esophageal Doppler probe is greased with lubricant jelly. After the patient had been anaesthetized and an endotracheal tube placed the probe was inserted into the esophagus, either blind or under direct laryngoscopic vision. Probe may also be inserted via the nasopharyngeal route in awake patients, similar to the insertion of nasogastric tube[4]. Relative contraindications of probe insertion include known esophageal pathology or grossly abnormal clotting disorders/ bleeding diatheses.

After insertion the probe is advanced until blood flow signals are detected at a distance of approximately 30-40 cm from the teeth (between the two markings on the probe). The probe was then rotated in an anti-clockwise direction until characteristic descending aortic velocity waveforms was seen on the monitor. Further fine rotations of the probe were performed until a sharp velocity outline with narrow spectral dispersion was obtained. The whole procedure from insertion to correct placement usually takes an average 2-3 minutes to perform. Once achieved, the satisfactory position was maintained by taping the probe to either the patient's face or the endotracheal tube catheter mount.

The EDM utilizes Fourier transform spectral analysis to process Doppler frequency shift signals. These are then displayed on a real-time color monitor scaled to indicate the signal power intensity distribution. The velocity (or frequency) amplitude is shown on the ordinate axis with time on the abscissa. Positive frequency shifts (i.e. flow towards the probe) are displayed according to convention above the line and negative shifts below the line (Figure 3). The shape of the flow velocity waveform also readily permits assessment of left ventricular contractility and filling, and systemic vascular resistance. Figure 4 represents EDM waveforms of various clinical states before and after treatment.

The EDM measures blood flow velocity in the descending thoracic aorta. When combined with a nomogram-based estimate of aortic cross sectional area, which was derived from the patient's age, height, and weight, it allows hemodynamic variables, including stroke volume and cardiac output to be calculated. The monitor, however, does not provide direct measurement of pulmonary artery and pulmonary artery occlusion pressures, although changes in the corrected systolic flow time have been shown to reflect qualitative changes in pulmonary artery occlusion pressures, allowing optimization in left ventricular filling[5].

While thermodilution technique is not an absolute gold standard for measurement of cardiac output, it is nevertheless widely accepted as the yardstick for comparison of new techniques in view of its relative ease of use in comparison with other established techniques such as dye dilution and Fick. Esophageal Doppler derived cardiac output and stroke volumes have been compared with thermodilution technique in a number of studies [6,7]. The results from these studies indicate that EDM derived cardiac output correlated well with thermodilution technique.

T. J. Gan, MB, FRCA

Clinical Studies with Esophageal Doppler Monitor

Esophageal Doppler monitoring has been shown to be a useful tool in assisting early detection of subsequent complication in critically ill patients. Poeze and colleagues [8] compared esophageal Doppler ultrasonography with standard hemodynamic variables for the prediction of postoperative complications after cardiac surgery. An esophageal Doppler probe was inserted for measurement of stroke volume, cardiac output, and other flow-related variables. Both these and routine hemodynamic variables (mean arterial pressure, central venous pressure, heart rate, arterial base deficit, urine output) were recorded regularly for the first 4 postoperative hours. They demonstrated that patients who developed subsequent complications were found to have lower stroke volume (from EDM), higher heart rate and greater base deficit at admission to the intensive care unit, suggesting hypovolemia. These differences persist throughout the 4 hours of study period. They concluded that a low stroke volume and a high heart rate, during the early period of admission to the intensive care unit were reliable prognostic factors for the development of complications after cardiac surgery.

Mythen and Webb [9] studied the relative importance of global and regional cardiovascular monitoring in the prediction of postoperative outcome in a group of patients undergoing cardio-pulmonary bypass. Patients who were having elective cardiac surgery requiring routine invasive cardiovascular monitoring of blood pressure and central venous pressure were studied. No attempt was made to influence the anesthetic or surgical management of the patients.

Beside routine anesthetic monitoring, an esophageal Doppler probe and a gastrointestinal tonometer were inserted through the patient's mouth immediately after induction of anesthesia. Doppler derived stroke volume and cardiac output were recorded shortly after the induction of anesthesia, and at the end of surgery.

Of the 51 patients studied, 32 (63%) had evidence of gastric mucosal hypoperfusion as indicated by gastric tonometer (pH<7.32) at the end of surgery, while 19 (37%) did not. The 32 patients with evidence of mucosal hypoperfusion had prolonged intensive care unit and hospital stay. Of the 14 patients in this group who developed major postoperative complications (hospital stay >14 days or death), 6 subsequently died. The authors concluded that the esophageal Doppler used in conjunction with gastrointestinal tonometer allowed both qualitative and quantitative assessment of cardiac function relatively non-invasively and these monitors were useful in predicting postoperative complications.

Esophageal Doppler monitor has been shown to be a viable alternative to PA catheter in pre-eclamptic women, where hemodynamic variables would be very helpful in the management of these patients. In a preliminary study, hemodynamic variables derived from the EDM were compared with that obtained from the PA catheter [4]. The esophageal Doppler probe was passed successfully either nasally or orally in all the 18 patients studied.

T. J. Gan, MB, FRCA

Esophageal Doppler Guided Intraoperative Fluid Optimization

To date, esophageal Doppler ultrasound is the only non-invasive technology used successfully to direct intraoperative fluid administration, resulting in improvement in outcome and reduction in hospital stay. These outcome benefits have been demonstrated in different surgical population including cardiac, orthopedic as well as general surgical patients undergoing moderate risk procedures. [10-12]

Conclusion

Esophageal Doppler monitor provides continuous online, real-time displays of hemodynamic data that allow early recognition of circulatory dysfunction as well as the means to titrate therapy to appropriate predetermined therapeutic goals. There is increasing body of evidence that intraoperative optimization of plasma volume decreases morbidity and length of hospital stay.

T. J. Gan, MB, FRCA

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Figure legend

Figure 1. An Esophageal Doppler Monitor (Cardio Q™).

Figure 2. An esophageal Doppler probe.

Figure 3. Doppler flow velocity waveform.

Figure 4. Typical EDM waveforms of various clinical states before and after appropriate treatment.

T. J. Gan, MB, FRCA
Figure 1

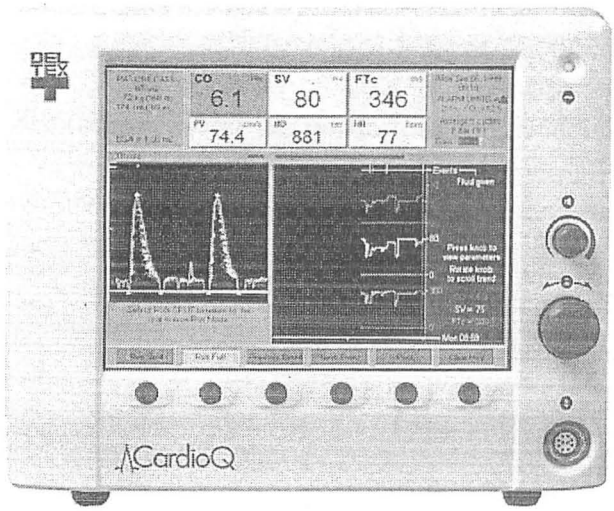
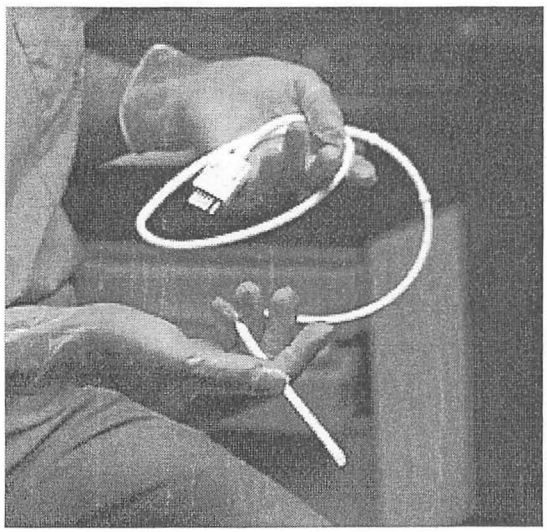


Figure 2



T. J. Gan, MB, FRCA
Figure 3

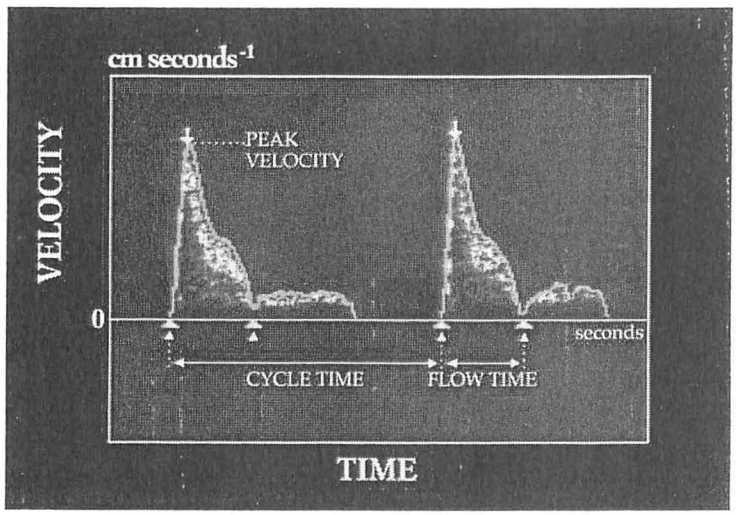
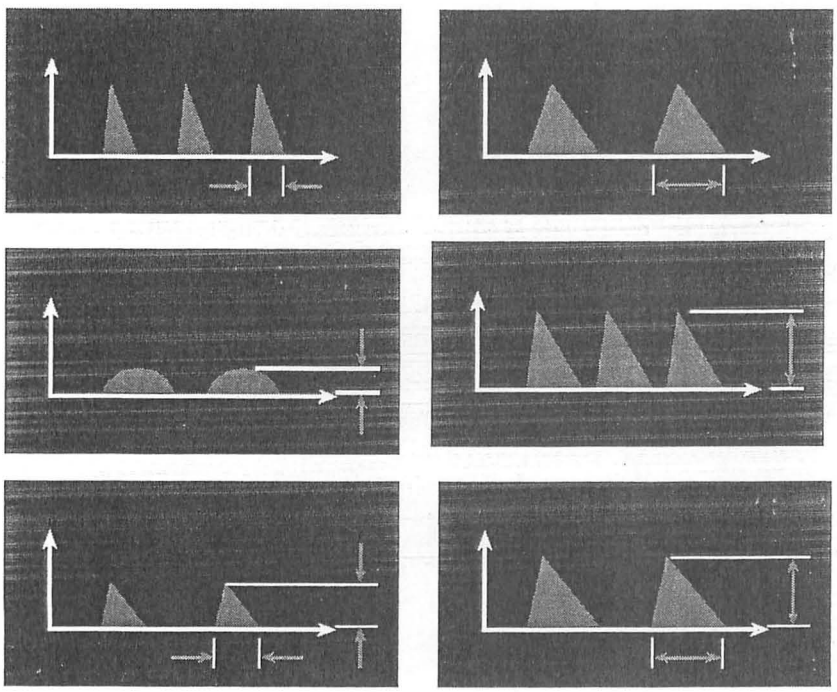


Figure 4



Arterial Pressure-Based Cardiac Output (FloTrac)

T. J. Gan, MB, FRCA
Duke University Medical Center
Durham, NC

The Arterial Pressure-Based Cardiac Output (APCO) algorithm is founded on calculating the variables included in the basic equation for measuring perfusion (CO = Heart Rate x Stroke Volume) using continuously measured arterial pressure and manually input patient parameters (i.e., age, gender, height, weight). Heart rate is determined as the pulse rate and is measured through conventional methods commonly found in pressure monitoring.
The system continuously calculates cardiac output based on the arterial pressure waveform analysis and updates its results every 20 seconds. The system then breaks down the components of cardiac output to guide the clinician in the precise management of heart rate, preload, afterload, and contractility.

The essence of this technology is founded on the application of advanced statistical analysis to basic physiological principles. APCO is based on the principle that aortic pulse pressure is proportional to stroke volume (SV) and inversely related to aortic compliance [1,2]. There are natural and pharmacological factors that vary from patient-to-patient and within any one patient at any given time that must be included in the calculation in order for this principle to hold true. Thus, the algorithm was designed to compensate for patient differences and physiological factors that affect SV through a robust analysis of arterial pressure, acquired and preprocessed by the FloTrac sensor, and the basic patient parameters of age, gender, height and weight.

Physiological assumptions under which the algorithm was created

The APCO algorithm is a new arterial waveform analysis technique which relates the blood flow to the arterial pressure using a hemodynamic model. The model is based on the pulsatile blood flow theory which considers the arteries as a system of interconnected tubes with a storage capacity [3]. According to the pulsatile blood flow theory, the arterial circulation, acting as an elastic storage system, transforms the discontinuous flow due to the pumping of the heart into steady flow in the periphery. The blood pumped intermittently by ventricular ejection is transformed to steady outflow at the periphery based on the pressure gradient, the vascular compliance, and the peripheral resistance.

The arterial system is, in essence, a system of conduits of significant volume and distensibility and has both active and passive tone characteristics [4,5]. This composition is, in effect, a hydraulic system analogous to the resistance-capacitance circuit in electrical systems [6]. The hydraulic effect produced within the vessels enables the intermittent pumping of the heart to be converted to a steady flow through the arteries and capillaries. The composition of arteries provides a resistance and elasticity (compliance) that can be observed in the characteristics of the pressure waveform [7]. This function of the arteries was first explained by Ernst Weber in 1834. He described the similarities between distensible arteries and the *Windkessel* common to fire engines in his day. In a *Windkessel*, a large volume of air is trapped in a container between the

inflow and outflow ends of the engine. Intermittent flow is converted to steady flow at the outlet of the fire hose nozzle [8].

The resistance and compliance of the vessel, or of the *Windkessel*, will direct the effectiveness of the hydraulic pump. In very distensible arterial systems, hydraulic filtering is very effective and the pressure remains constant through the cardiac cycle. In stiffer systems, as with increasing age, the volume pumped decreases with a constant pressure[9]. The waveform produced in such a hydraulic system will demonstrate characteristics dependent on the pressure and timing of the flow. This pressure and timing is, in turn, dependent on the resistance and compliance of the arterial system. Since vascular tone is a primary determinant of the relationship between stroke volume and arterial pressure, our algorithm estimates the determinants of vascular tone as part of the analysis. For example, if arterial tone were to increase, then for the same pulse pressure, stroke volume would be less (Figure 1) [10]. The relation between stroke volume and mean arterial pressure on a beat-to-beat basis is described by the arterial elastance, which is the phasic equivalence to vascular resistance. Thus, to accurately use pulse pressure to estimate stroke volume one must also simultaneously assess the determinants of vasomotor tone.

The presentation will focus on the technology and clinical utiltity of the Arterial Pressure-Based Cardiac Output (APCO).

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Figure 1

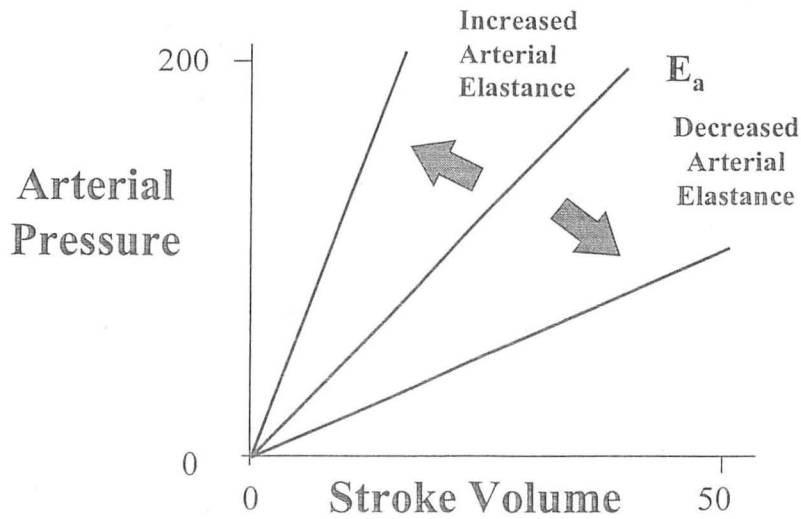
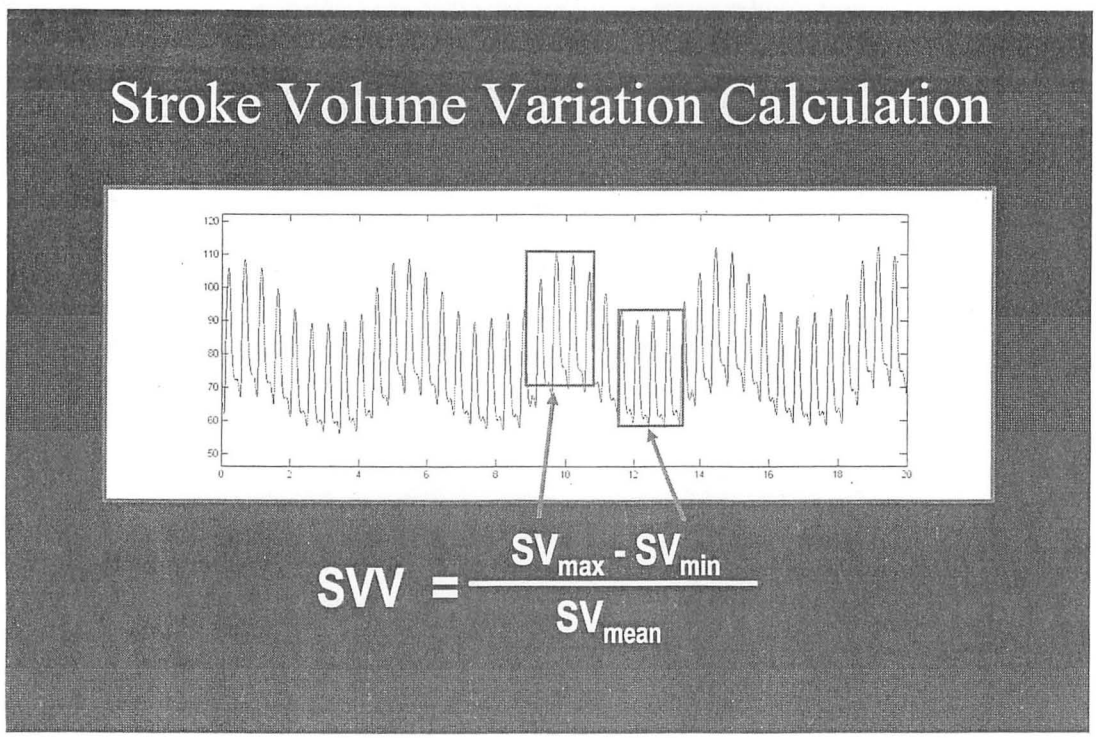


Figure 2



T. J. Gan, MB, FRCA Figure 3

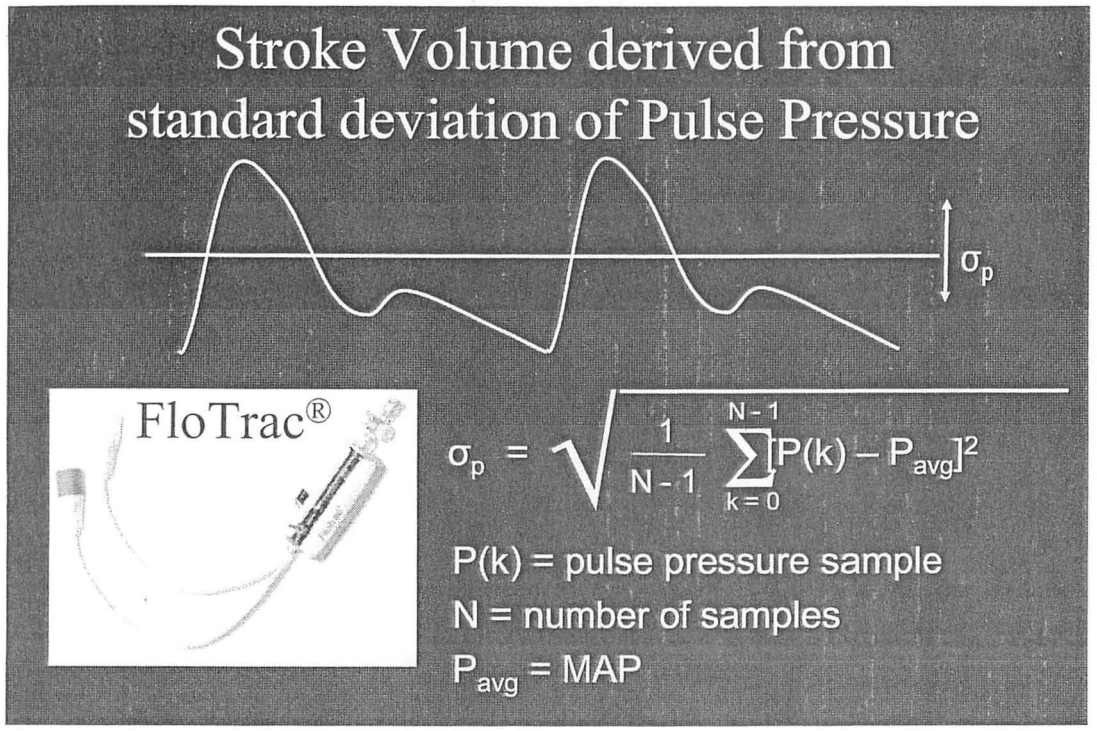
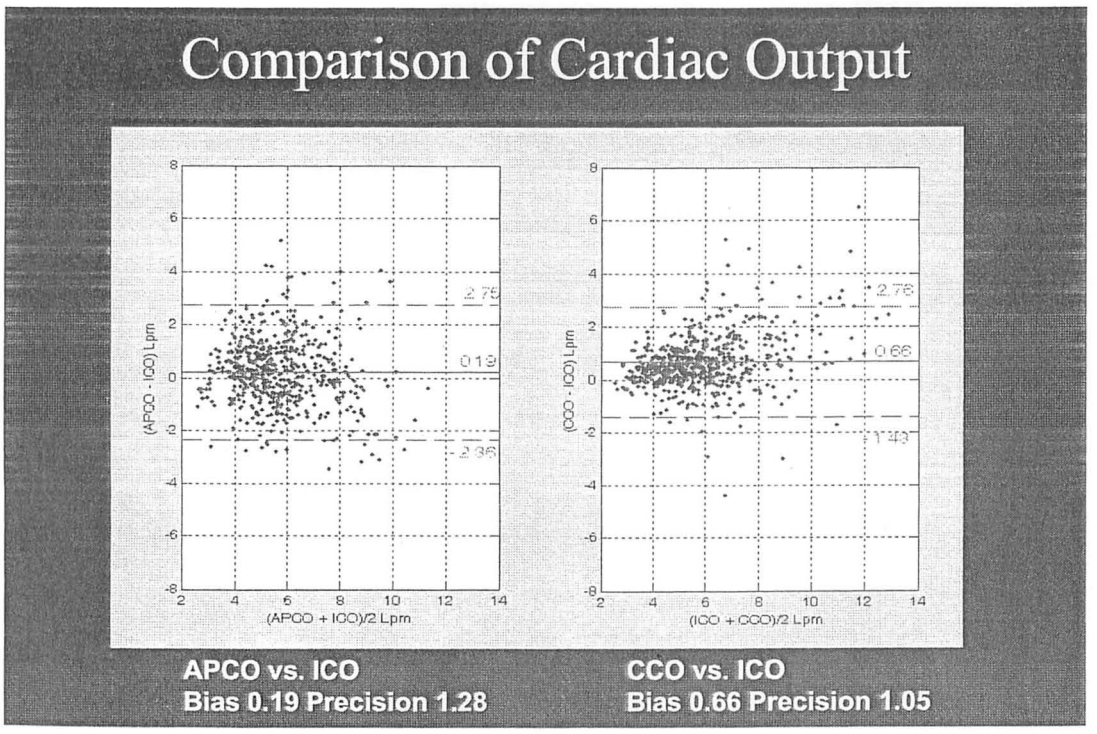
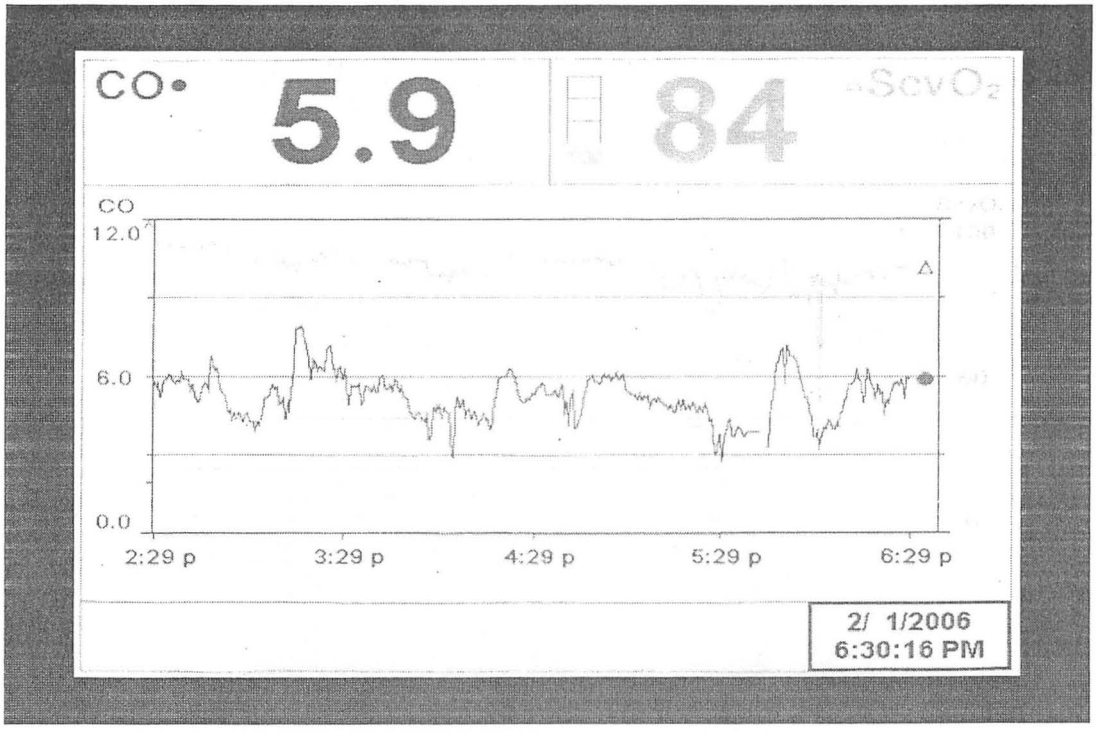


Figure 4

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CONTINUOUS WAVE DOPPLER CARDIAC OUTPUT MONITORING

Peter Lichtenthal, MD
University of Arizona

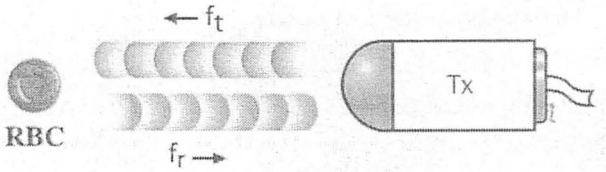
The USCOM device is a Continuous Wave Doppler. Below is a summary of the technology and equations involved.

Continuous Wave Doppler

Continuous Wave Doppler (CW) uses ultrasound waves (frequency > 20,000 Hz) to provide information on the velocity and direction of blood flow.

CW is a form of Doppler that continuously transmits sound waves. At the same time, it receives the reflected sound waves with the Doppler shift information caused by a moving target.
Moving targets are red blood cells in the heart and great arteries.

A unique feature of CW Doppler is that it continuously reflects from each moving red blood cell within its beam. This beam, when aimed at the transaortic flow, (suprasternal notch position) will reflect flow from the aorta, aortic valve, left ventricular outflow tract and the left ventricle.

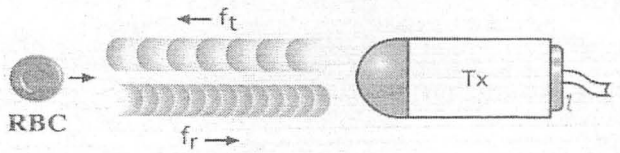


RBC	Red blood cells
Tx	Transducer
ft	Transmitted frequency
fr	Received frequency

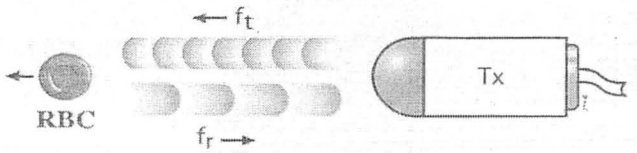
Continuous wave Doppler continuously sends and receives sound waves.

Doppler Angle

The aim is to direct the beam to reflect off the red blood cells 'head on' or 'in line with the direction of blood flow'.
When the Doppler beam is in line with the direction of blood flow, an optimal velocity is measured.



Blood travelling in line with the ultrasound beam, toward the transducer.



RBC	Red blood cells
Tx	Transducer
ft	Transmitted frequency
fr	Received frequency

Blood travelling in line with the ultrasound beam, away from the transducer.

Peter Lichtenthal, MD

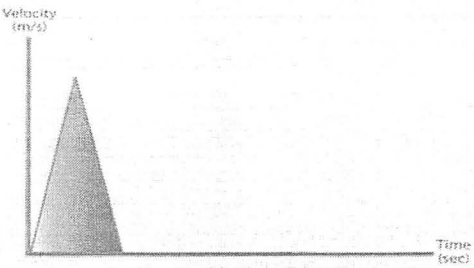
Doppler Display

The frequency change is displayed as a Doppler shift and the velocity of the moving red blood cells is calculated using the Doppler equation.

$$Fd = \frac{2Ft \times (V \times \cos \theta)}{C}$$

Fd is the Doppler frequency, Ft is transmitted frequency, V is velocity of red blood cells, θ is the angle between the direction of the moving target and the ultrasound beam, C is velocity of sound in soft tissue and 2 is the constant.

The Doppler shift is displayed on a velocity-time graph.
Velocity is displayed on the Y axis.
Time is displayed on the X axis.



Doppler shift displayed as a velocity-time graph.

Calculations

(Basic) Volume = Area x Height

Area = Outflow Tract Area = πr^2

SV = OT Area x Stroke Distance
(Vti)

CO = HR x SV

Partial CO_2 Rebreathing Cardiac Output Measurement

Joseph Orr, Ph.D
University of Utah, Department of Anesthesiology, Bioengineering Division
Salt Lake City, Utah

Principle of Operation, *How it works*

Partial CO_2 rebreathing cardiac output is based on a differential form of the Fick equation. Applying the CO_2 Fick equation at two different ventilatory states (rebreathing and non-rebreathing), gives a difference that can be used to calculate cardiac output. The textbox shows the derivation of the differential Fick equation for CO_2.

CO_2 Fick Equation: $$Q = \frac{VCO_2}{CvCO_2 - CaCO_2}$$

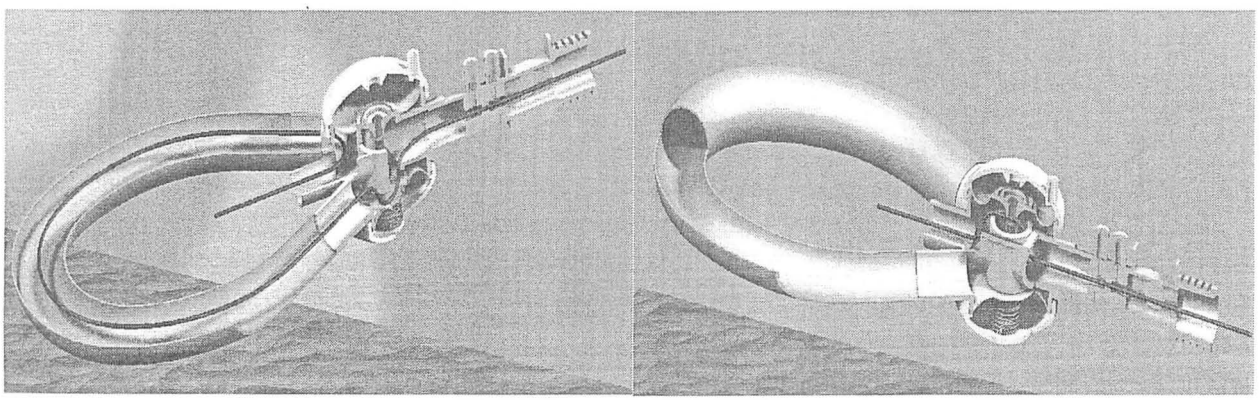
Applied with & without Rebreathing:

$$Q = \frac{VCO_{2\,1}}{Cv_1 - Ca_1} = \frac{VCO_{2\,2}}{Cv_2 - Ca_2}$$

Combining to form Differential Fick Equation:

$$Q = \frac{VCO_{2\,1} - VCO_{2\,2}}{(Cv_1 - Ca_1) - (Cv_2 - Ca_2)} = \frac{\Delta VCO_2}{\Delta CaCO_2} = \frac{\Delta VCO_2}{S\Delta ETCO_2}$$

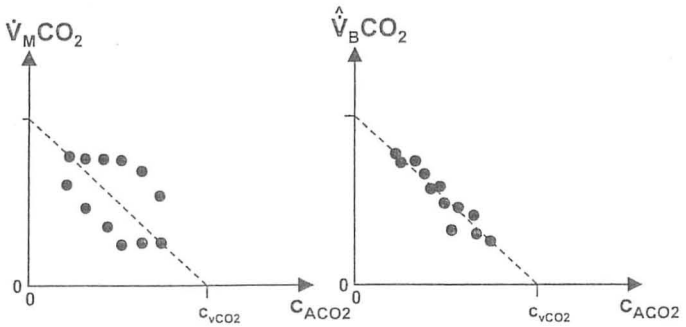
Partial rebreathing is used to create the different ventilatory states. A combination CO_2 and airway flow sensor is used to measure end-tidal CO_2 and the rate of CO2 excretion (V_{CO2}). A pneumatically controlled valve diverts gas through a dead-space volume that creates partial



ebreathing.

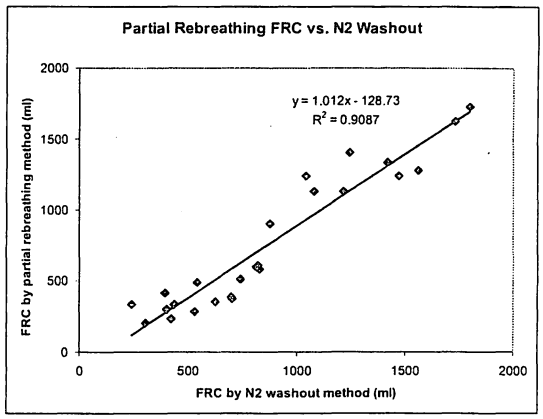
low it *really* works

he actual algorithm applied in ie NICO$_2$ system does not irectly apply the differential ick equation derived above. ather a revised calculation based n a simple model that accounts or CO_2 flux into, and out of, the RC volume is applied. In this gorithm, a plot of CO_2 excretion



Joseph Orr, Ph.D

(VCO_2) vs. CO_2 content measurements for each breath that occurs before, during and after rebreathing is drawn (see figure). Because CO_2 flows to and from the FRC volume, the plot is forms a loop rather than a line. A search algorithm is applied to select the FRC volume that best collapses the loop to a line. The slope of the line gives the cardiac output. This algorithm removes the need to wait for steady state conditions during rebreathing and therefore reduces the number of breaths needed to obtain a measurement. It also allows the system to perform when ventilation us unstable. This modification has improved performance significantly over that of early versions of the $NICO_2$ device.



As a further test of the method, we evaluated the accuracy of the FRC as measured in the algorithm. The figure at right shows the FRC, as measured by partial rebreathing, in laboratory animals as compared to a nitrogen washout reference standard.

Technically, the $NICO_2$ system measures pulmonary capillary blood flow (PCBF) rather than cardiac output. PCBF represents the non-shunted blood flow through the lungs. An estimate of shunt is derived from the user entered FiO_2 and the measured SpO_2. Using this shunt estimate, directly measured PCBF is converted to cardiac output.

Cardiac output measurement accuracy

There are over 130 published abstracts and papers describing the performance of the $NICO_2$ system. Over 90% show acceptable accuracy as compared to the reference standard. The other 10% of these publications describe use of the system in situations where partial CO_2 rebreathing cardiac output measurements will not be accurate. Users should be aware of these conditions prior to using the system. Partial rebreathing measurements may not be accurate under the following conditions:

- Extremes of patient/ventilator dyssynchrony
- Immediately following a sudden change in cardiac output or minute ventilation
- Immediately following a sudden non-metabolic release of CO_2
- Patients in whom there are extremes of intrapulmonary shunt (>40%) or alveolar dead space (V/Q mismatch)

Conclusion:

The $NICO_2$ partial CO_2 rebreathing cardiac output monitor is completely non-invasive. The set-up time is less than 1 minute, and the system runs completely automatically. The system has been clinically tested and shown to compare well against invasive measurements under most normal clinical conditions.

Joseph Orr, Ph.D
References:

Jaffe MB, Partial CO2 rebreathing cardiac output--operating principles of the NICO system., J Clin Monit Comput. 1999 Aug;15(6):387-401.

Botero M, Kirby D, Lobato EB, Staples ED, Gravenstein N., Measurement of cardiac output before and after cardiopulmonary bypass: Comparison among aortic transit-time ultrasound, thermodilution, and noninvasive partial CO2 rebreathing., J Cardiothorac Vasc Anesth. 2004 Oct;18(5):563-72.

Odenstedt H, Stenqvist O, Lundin S., Clinical evaluation of a partial CO2 rebreathing technique for cardiac output monitoring in critically ill patients., Acta Anaesthesiol Scand. 2002 Feb;46(2):152-9.

The AIMS and Decision Support: Opportunities, Test Cases and Financial Impact

Warren S. Sandberg, M.D., Ph.D.

We have created a system that contains all of the elements required for completely automated process monitoring and real-time quality control: (1) automatic data collection, (2) a model of the expected process, (3) rules for comparing the actual process to that expected based on the model and (4) an annunciation pathway that is not easily ignored. The use of the paging system allows alerts to be propagated to clinicians even when they are not paying attention to the AIMS workstation. The ABAS requires no human intervention to detect pre-defined errors and bring them o the attention of providers. Thus, the system supports pay-for-performance data collection while at the same time automatically improving performance on the same metrics, thus improving hospital financial returns and patient care.

The AIMS and Decision Support: Opportunities, Test Cases and Financial Impact

Warren S. Sandberg, M.D., Ph.D.

SUMMARY

The operating room is a financial hot spot with high costs and higher revenue potential. The clinical risks to the patients are also high, in part because patients are unconscious and unable to participate in their own care. Systems that simultaneously improve clinical and financial performance would thus be doubly welcome. Pay-for-performance reimbursement plans reward high performance on defined metrics, and the OR is a prime environment where these plans can reward hospitals while improving patient care. The OR is becoming an immersive computing environment, and the same systems that document clinical care also provide performance data for process improvement.

One OR information source is the anesthesia information management system (AIMS), which documents events, medications and physiologic data captured in the OR. We installed an AIMS and then created new software (Anesthesia Billing Alert System, ABAS) to assure the accuracy and completeness of documentation related to billing. We extended the scope of this application to improve clinical performance as well.

The ABAS performs real-time searches of the anesthesia record for defined 'errors'. We created logical rules pertaining to completeness of documentation, the order of events, concurrencies and overlaps between cases in the same OR and completeness of physiologic data. When errors are detected the ABAS automatically generates pages through the hospital paging system. These are sent to the individual logged on to the AIMS workstation where the error occurred.

The ABAS is in full production use, processing roughly 3000 cases per month. It functions independently of the AIMS, and we have successfully used the ABAS while transitioning between AIMS vendors.

The ABAS improved our department's financial performance. Upon full implementation, the ABAS reduced the number of charts with missing or incorrect billing documentation from approximately 190 to well below 10 per month. To maximize billing effectiveness, the ABAS sends pages and E-mails to providers on a daily basis until the error has been corrected. The AIMS / ABAS implementation allows us to bill for 140 to 240 cases per month that were previously non-billable, with obvious favorable financial consequences for the department. The system cost approximately $180,000 to develop, and approximately $40,000 per year for maintenance and system improvements (which generate additional revenue). The operational & financial impact of the system was to eliminate billing errors, retrieving approximately $20,000 per OR each year. In our OR suite, with 50 operating rooms, the time to return on investment was under 6 months, and the system generates a continuous revenue stream.

We have also used the ABAS to measure and improve documentation of key clinical data such as patient medication allergies.[1] A single, timely alert significantly improves performance on this metric. We have also quantified the timing and duration of gaps in physiologic monitoring during surgery, and have developed alerting paradigms to improve monitoring performance. The ABAS also captures medication administration, and can provide real-time alerts to improve on-time preoperative antibiotic prophylaxis and stratification for perioperative beta blockade. Data regarding patient temperature and warming strategies are also captured. In short, the AIMS and ABAS can capture, process and improve execution on many potential pay-for-performance metrics in the OR.

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STA 2007

Poster Timetable & Abstract Presenter Disclosure Information

Poster Setup:

Wednesday, January 17	7:00 a.m. - 5:30 p.m.
Thursday, January 18	Before 7:00 a.m.

Authors will be in attendance with their posters during the following times:

Thursday, January 18	7:00 a.m. - 8:00 a.m.
	9:30 a.m. - 10:30 a.m.
	5:00 p.m. - 6:00 p.m.
Friday, January 19	7:00 a.m. - 8:00 a.m.
	9:45 a.m. - 10:30 a.m.
	1:00 p.m. - 2:00 p.m.
Saturday, January 20	7:00 a.m. - 8:00 a.m.
	10:00 a.m. - 10:30 a.m.

Poster take down: Saturday, January 20, 12:00 p.m. - 1:00 p.m.

The following abstract presenters have voluntarily acknowledged disclosure information:

Wendy Bernstein, MD - Stryker Endoscopy, US Army TATRC (Telemedicine and Advanced Technologies Research Command)

Jeffrey A. Green, MD - Dräger Medical

Mark Macknet, MD - Masimo

Penelope Sanderson, PhD - The respiratory sonification is the subject of US patent 7070570 and the blood pressure earcons are in the PCT stage.

Hanne Storm, MD, PhD - Med-Storm Innovation is developing the skin conductance equipment and I am a co-owner of this company.

Dwayne Westenskow, PhD - Dräger Medical AG&Co

The following abstract presenters have disclosed that they have no actual or potential relationship(s) that have bearing on the subject matter of this activity:

Erica Amari, BA
Jeremy Daniels, BASc
Dustin Dunsmuir, BASc
Ludwik Fedorko, MD, PhD
John Fiadjoe, MD
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STA 2007
Poster Presentations

Poster #	Abstract Title	Presenting Author
1	Searching Google(™) About Awareness Under Anesthesia	Paul Tan, MD
2	Measuring the quality of day case surgery: comparing telephone and web-based questionnaires	Erica Amari, BA
3	Enhancing Compliance with Standard Indicators via an Electronic Data Collection System	Paul St. Jacques, MD
4	Extending simulators to improve support for patient monitoring display research	David Liu, BEng
5	iKnow: A Knowledge Authoring Tool for Clinical Decision Support	Dustin Dunsmuir, BASc
6	A Framework for Evaluating Usability of Clinical Monitoring Technology	Jeremy Daniels, BASc
7	Touch Your Patient- A Human Simulation Centre Based Assessment of a Novel Vibrotactile Display	Simon Ford, MB, ChB
8	Right ventricular diastolic dimensions with acute hypovolemia – predominance of maximal minor axis and right ventricular septal length changes.	Qingbing Zhy, MD
9	A simple paperless way for anesthesia scheduling, documentation and submission of claims.	Udaya Padakandla, MD
10	Anesthesia systems for use in situations with limited logistical support (electrical power and medical gas)	Dwayne Westenskow, PhD
11	Application of the ISO Essential Principles to Medical Equipment Intended for Use in Situations and Regions of the World with Limited Logistical Support	Dwayne Westenskow, PhD
12	Electronic monitoring in an acute pain management service	David Goldstein, MSc MB BCh BAO FRCP
13	A systematic review of adoption of electronic information systems: Attributes of clinical users	Elizabeth Van Den Kerkhof, RN, DrPH

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Poster Presentations

Poster #	Abstract Title	Presenting Author
14	A Survey of Anesthesia Information System Utilization in Arizona	Jeff Mueller, MD
15	Number of skin conductance fluctuations increased differently from BIS during tetanic stimuli. Increasing doses of remifentanil attenuated the skin conductance response	Hanne Storm, MD, PhD
16	Telemedicine Consultation and Monitoring for Pediatric Liver Transplant	John Fiadjoe, MD
17	Advanced auditory displays and head-mounted displays: Advantages and disadvantages for monitoring by the distracted anesthesiologist	Penelope Sanderson, PhD
18	Simulating high workload situations to evaluate patient monitors	Penelope Sanderson, PhD
19	Blood gas measurements using the Bayer Rapid Point 405: Are we basing our decisions on accurate data?	Frederic Sarrazin, MD
20	Use of multimedia message service technology in the operation theatre.	Anurag Tewari, MD
21	Negative pressure applied to the hand leads to an early decrease in brachial artery blood flow	Judi Thai, MD
22	Comparison Over Time of the Efficiency of an Anesthesia Record Keeper (ARK) as Evaluated by Anesthesia Practitioners in an Academic Medical Center	Jeffrey A. Green, MD
23	Virtual 3D Multidisciplinary Anatomic Review of Complex Upper Airway for Pre-Procedural Planning and Clinical Education	Wendy Bernstein, MD
24	A Point of Care Method for the Improvement of Medication Cycle Management in Operating Rooms	Ludwik Fedorko, MD, PhD
25	Central venous pulse pressure analysis using R-synchronized pressure measurement system	Yoshihisa Fujita, MD
26	Neuromuscular Junction Monitoring for the Organon Protocol 19.4.308 Suggamedex Trial	Rasheed Amao, MBBS
27	Failure to Display a Significant Change in ETCO2 on Printed Automated Anesthesia Record: Case Report and Medicolegal Implications	Jeffrey A. Green, MD

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Poster Presentations

Poster #	Abstract Title	Presenting Author
28	Parallel and Vector Processing Optimization of Approximate Entropy Algorithms	Jeff E. Mandel, MD, MS
29	Accuracy of a novel bioacoustic sensor in adult postoperative patients	Mark Macknet, MD
30	Accuracy of a novel bioacoustic sensor in pediatric postoperative patients	Mark Macknet, MD
31	Continuous Non-Invasive Measurement of Hemoglobin via Pulse CO-oximetry During Liver Transplantation, a Case Report	Mark Macknet, MD
32	Continuous Non-Invasive Measurement of Hemoglobin via Pulse CO-oximetry	Mark Macknet, MD
33	Changes in the Pulse Oximeter Waveform Predict Pre-syncope during Lower Body Negative Pressure	Suzanne Wendelken, MS
34	Gas Man Version 4 - A work in progress	James H. Philip, MEE, MD, CCE
35	Gas Man Core Competency Abstract	James H. Philip, MEE, MD, CCE
36	Y2K7: Time and Calendar Deja Vu, This Time in 2007	S. Mark Poler, MD
37	A Comprehensive Computing Solution on a Zero Budget.	J. M. Watkins-Pitchford, MBBS, FRCA