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Society for Technology in Anesthesia

Abstracts of Posters Presented at the STA 17th Annual Meeting & 29th Computers in Anesthesia Meeting January 17–20, 2007 Orlando, Florida

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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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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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S-26	Neuromuscular Junction Monitoring for the Organon Protocol 19.4.308 Suggamedex Trial	Rasheed Amao, MBBS
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S-39	Device to Measure Tissue Hydraulic Impedance	James H. Philip, MEE, MD, CCE
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Abstract Presenter Disclosure Information

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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:

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SEARCHING GOOGLE ABOUT AWARENESS UNDER ANESTHESIA

PJ Tan, MD, DJ Doyle, MD, PhD
Cleveland Clinic, Cleveland, Ohio

Introduction: Patients are increasingly turning to the Internet as a source of information. In one study, 85% had searched the internet for information and 98% of those considered the information useful. In another, >50% said that internet information influenced their decision regarding acceptance of treatment. There has been increasing media attention on awareness under anesthesia, thus, we analyzed the internet information available.

Methods: Three search terms were considered most likely to be used by patients concerned about awareness under anesthesia. The terms "awake during surgery", "awareness under anesthesia", and "anesthesia awareness" were submitted to the search engine *google.com* in October 2006. The first 20 websites from each search were categorized by type. Each informative site was analyzed for topics addressed, readability, and quality.

Results: Results are summarized in tables below. Only three sites were duplicated between two of the three searches. None were duplicated in all three. ASA brochure for patients only appeared in one search.

Type of Website

Search Term	Health Information Site	Web Dictionary	Commercial Site (Attorney/ Health Clinic)	Government Site (JCAHO)	News Site	Blog Site	Scientific Article or citation	Unrelated site (i.e. awake craniotomy)	Inaccessible
Awake During Surgery	1	0	2	0	4	2	4	5	2
Awareness Under Anesthesia	5	0	0	1	0	1	10	3	0
Anesthesia Awareness	8	3	1	3	3	1	1	0	0
Analysis									
Flesch Reading Ease	25.78 +/- 16.2	21.77 +/- 11.1	23.63 +/- 4.0	0.3 +/- 0	47.19 +/- 11.6	46.27 +/- 5.3			
Flesch-Kincaid Grade Level	14.16 +/- 3.70	14.93 +/- 2.17	16.23 +/- 1.01	18.0 +/- 0	11.09 +/- 2.48	10.77 +/- 0.93			
DISCERN score	1.95 +/- 0.69	2.83 +/- 0.84	1.35 +/- 0.21	3.93 +/- 0	1.73 +/- 0.54	1.39 +/- 0.47			

Informative Sites

Search Term	Incidence correctly noted at 1-2/1000	Brain Monitoring	JCAHO	Specific scientific research noted	PTSD	Personal story of awareness	Flesch Reading Ease	Flesch-Kincaid Grade Level	DISCERN score
Awake During Surgery (n=9)	9/9 100%	8/9 89%	6/9 67%	2/9 22%	4/9 44%	6/9 67%	44.5 +/- 13.2	11.59 +/- 3.02	1.48 +/- 0.42
Awareness Under Anesthesia (n=7)	4/7 57%	7/7 100%	3/7 43%	2/7 29%	5/7 71%	3/7 43%	31.9 +/- 19.5	13.81 +/- 3.98	2.49 +/- 1.10
Anesthesia Awareness (n=19)	14/19 74%	15/19 79%	10/19 53%	6/19 32%	14/19 74%	7/19 37%	20.5 +/- 15.4	15.44 +/- 2.79	2.24 +/- 0.95

Conclusion: Most sites agreed with the literature in terms of incidence. Overall, the quality of the websites was fair to poor. The information patients obtain from the internet greatly depends on which keywords/search terms are used. In order to effectively disseminate accurate information on the internet and educate our patients, we must take into account the search terms they will likely be using.

References:

1. Charnock, D. The DISCERN Handbook. Abington, Oxford: Radcliffe Medical Press. 1998.

Measuring the quality of day case surgery: comparing telephone and web-based questionnaires

Erica Amari, BA, Christine Vandebeek, MBA, J Mark Ansermino, FCA

Introduction

Measuring the quality of pediatric day surgery from the parents' perspective is important in directing quality improvement. To better assess quality, we have developed a valid and reliable computer-assisted telephone interview. Yet, a more convenient and cost effective alternative would be a web-based administration of the same version. The aim of this study was to determine whether a web-based questionnaire would be a suitable substitute of the telephone version.

Methods

With ethical approval, we administered over the telephone, a 54-item questionnaire to parents of day case surgery patients. Parents had the option of additionally completing a web-based version. We compared Cronbach's alpha scores of theoretically derived scales of the two versions. To find trends in response changes, we tallied the instances of increased and decreased responses. We compared the responses with the duration between completing the two versions.

Results

Of the 435 who completed the telephone questionnaire, 290 agreed to the web-based version and 232 completed it. Reliability was higher in the web-based by Cronbach's alpha scores of 0.09-0.14. The majority (78%) of responses did not change between the versions and 17% had a one point change. Of the changed responses, 77% decreased in score. Overall rating of care and receiving an adequate amount of time for questions were weakly correlated with duration between completing the two versions ($r=-0.139$ and -0.166 $p<0.05$, respectively).

Discussion

The web-based questionnaire may be a better alternative to the telephone interview. Its scales have stronger construct reliability. Further, it may have decreased acquiescence bias since the majority of changed responses were a decrease in score. Participants may have felt more comfortable indicating their true opinion if they were not responding directly to a person. The web-based version should be completed within 72 hours of hospital discharge as some response scores decreased with time.

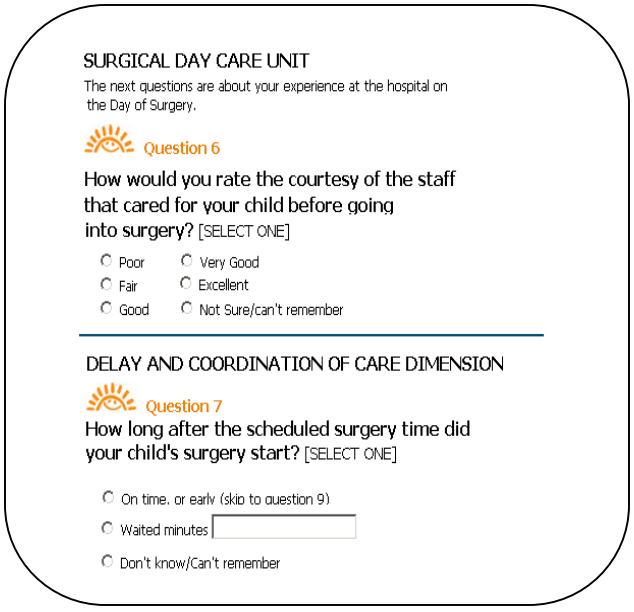


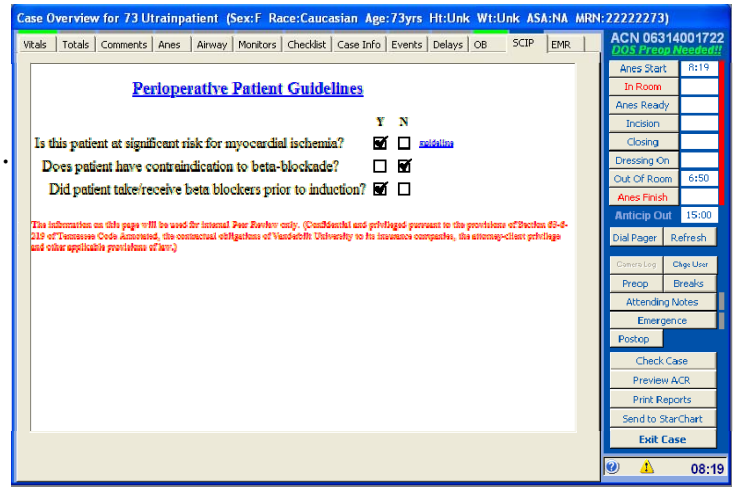
Figure 1. Sample of the questionnaire

Enhancing Compliance with Standard Indicators via an Electronic Data Collection System

Paul St. Jacques, M.D., Vanderbilt University Medical Center, Nashville, TN

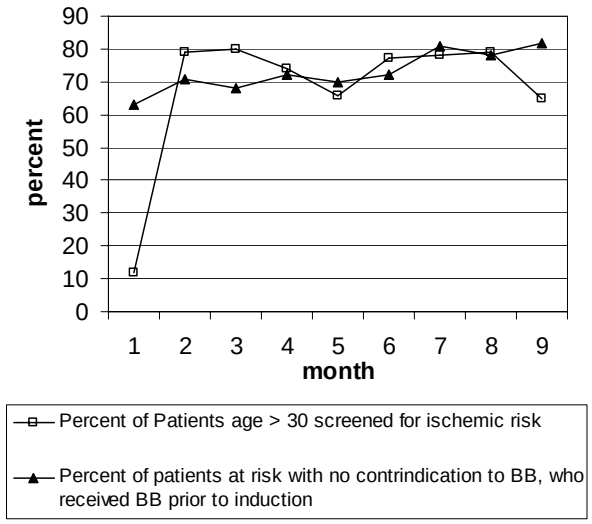
Introduction: National groups and standards organizations are rapidly developing guidelines aimed at increasing patient safety and reducing morbidity and mortality. Documentation of compliance with these guidelines is increasingly important as groups move toward incentivizing compliance and penalizing non-compliance. We demonstrate how an electronic data collection system can be rapidly modified to collect and report compliance with a newly developed standard indicator.

Fig 1.



Methods: As a demonstration of the utility of electronic documentation, The Vanderbilt Perioperative Information Management system, a locally developed clinical interface and database, was modified to collect data related to the Surgical Care Improvement Project (SCIP) adverse cardiac events indicators(Fig 1.). The anesthesia information management module was modified to include three new fields: Is the patient at risk for myocardial ischemia?; Does the patient have a contraindication to beta-blockade?; Did the patient receive a beta blocker prior to induction? To minimize user effort the questions appear sequentially. Additionally, if the user has a question regarding the guideline, a link is provided to the departmental standard guideline on perioperative beta blockade administration. Data collection was non-mandatory and users were provided monthly reports with group and individual compliance.

Fig 2.



Results: Data was collected over a nine month period of time. Documentation compliance increased from 11.0% in the first month to 79.6% during the second month. With the exception of the last month, this increase was maintained at between 71% and 78% for the remainder of the period examined.(Fig 2) During the study period, the patients who were deemed at risk for cardiac ischemia and who received beta blockade according to the guideline increased from 63% to 82%.(Fig 2)

Discussion: Implementation of the new documentation procedure yielded a rapid and sustained increase in documentation compliance for this guideline. However, of those patients screened and determined to be at risk, even with the improved documentation and information provided to the clinicians, not all of eligible patients received the indicated therapy. Further work will be needed to examine methods to increase compliance with documentation, such as making these new fields mandatory. Additionally, further modifications may be required to explore reasons that clinicians do not completely apply known guidelines.

Conclusion: Electronic data collection systems can be utilized to rapidly modify documentation habits toward the goal of compliance with novel guidelines and standards. Institutions utilizing an electronic data collection system may be at an advantage as health economics moves to reward those institutions who are able to demonstrate compliance with these standards.

Extending simulators to improve support for patient monitoring display research

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Background: In addition to being used for education and training [1], anesthesia simulators have been used to evaluate novel monitoring displays—specifically, how effectively displays convey physiological information to the anesthesiologist [2, 3]. Human factors evaluations using patient simulators can help researchers detect latent errors and design faults earlier in the equipment development cycle [4].

Methods: During our research on monitoring displays, we observed four major shortcomings of existing high-fidelity simulators when used for display evaluations:

1. It can be difficult to manipulate patients in model-based simulators via indirect parameters (e.g. drugs and fluids) to achieve a specific pattern of physiological parameters.
2. Not all of the monitors used in the operating room are simulated, e.g. Body^{TM} does not provide a plethysmography waveform and the METI ECS^{TM} lacks gas monitoring.
3. High-fidelity simulators provide more fidelity at the expense of less control, e.g. P_ACO_2 can be directly manipulated on the METI HPS^{TM}, but not the capnograph.
4. Many important aspects of monitor use are not simulated, including probe disconnection, interference, leaks, and failures.

To mitigate these factors, we developed software extensions to the Body^{TM} and METI ECS^{TM} simulators using the Java programming language. The vital signs data was broadcast to our auditory and head-mounted display-based monitor prototypes over a TCP/IP-based protocol.

Results: Our software extensions allowed us to incorporate the following controller-driven simulated patient variables in our scenarios:

- Capnography waveforms and E_TCO_2 and F_ICO_2 values
- Non-invasive BP (cycling delays, automatic re-sampling, immediate re-sampling)
- Controller-driven gas analysis: inspired and expired percentages for agent, N_2O, O_2
- Pulse oximetry plethysmography waveforms
- ECG lead disconnection

Conclusions: These extensions have made our scenario design and development more flexible. They have allowed us to program a variety of events which include equipment events such as disconnections during scenarios and thus have made simulator scenarios more realistic.

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iKnow: A Knowledge Authoring Tool for Clinical Decision Support

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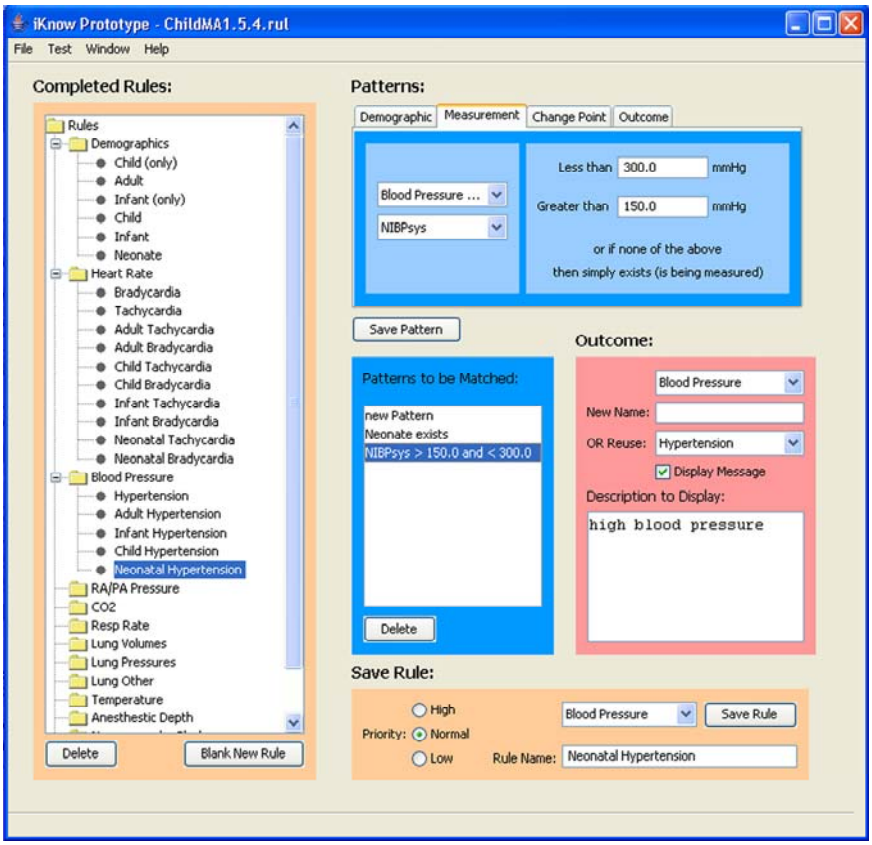
Introduction: Clinicians are unable to constantly monitor more than a small percent of the real-time data generated by a physiological monitor. An expert system could offer assistance in this data-rich environment. Previous clinical expert systems have not been adopted because traditional methods of knowledge encoding required both expert medical and programming skills, making knowledge acquisition difficult.

We have developed a knowledge authoring tool for physiological monitoring (*iKnow*). This software enables clinicians to produce knowledge *rules* without the need for a knowledge engineer or programmer. These *rules* allow reasoning from physiological and demographic data sources to provide clinical explanations and advice. Once created within *iKnow,* these *rules* can be used by an expert system in real-time.



Design: *iKnow's* design allows open collaboration between communities of clinicians to build a library of clinical knowledge *rules*. The knowledge authoring process is simplified by limiting connective relationships between *rule* elements. Within *rules*, incoming data is represented as *patterns* and resulting clinical advice as *outcomes. Patterns* are based on static case data, measured data, or the result of change point algorithms [1]. *Outcomes* describe the condition of a patient and advise actions to the clinician. The *rule* structure is easily understood by a clinician and chains of *rules* can be viewed in a simple visualization window.

Implementation: *Rules* from *iKnow* are coded in the rule-based programming language CLIPS (C Language Integrated Production System)[2]. *iKnow* itself is created using Java® (Sun Microsystems) and manipulates CLIPS code through the Jess [3] rule engine. The *rule* structure can be manipulated within *iKnow* by a clinician with minimal computer skills. Standard *rule* sets can act as clinical guidelines, encouraging standard procedures and providing memory aids.

Conclusion: *iKnow* offers a new knowledge encoding method that will allow the everyday anesthesiologist to create a set of rules to be implemented in a clinical expert system.

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A Framework for Evaluating Usability of Clinical Monitoring Technology

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Importance

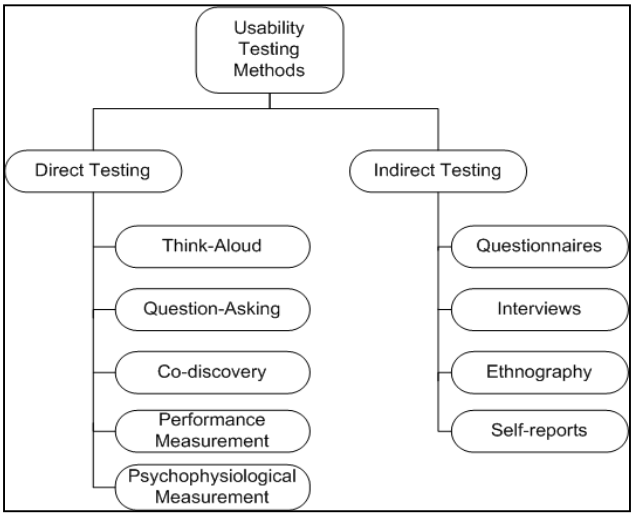
Technology is accepted when usability is central to its design. Evaluating usability is a challenge for purchasers and developers of technology. We developed a framework for usability evaluation of clinical monitoring technology.

Methods

We reviewed usability testing techniques using the Institute for Electrical & Electronics Engineers (IEEE) Electronic Library, the Association for Computing Machinery's (ACM) Digital Library, the Web of Science Database, and the Google Scholar Search Engine for the string "*usability testing" & "clinical monitoring*". We grouped the methods according to their degree of objectivity.

Results

We located 17 peer-reviewed papers from Google Scholar, and 4 from ACM's Digital Library. None were obtained using the IEEE Electronic Library and Web of Science. Cited references produced 9 relevant textbooks.



Our usability testing framework contains five direct methods: Think-Aloud, Question-Asking, Co-Discovery, Performance Measurement, and Psychophysiology. Also included are four indirect methods: Questionnaires, Interviews, Ethnography, and Self-Reports. It is thought that these approaches constitute a balanced approach. Additionally, our framework has been successfully employed in a usability study of a novel clinical monitor (1).

Conclusions

We developed a framework for assessing usability that may be used to enhance usability and acceptance of clinical monitoring technology. We hope that this will encourage the increased use of usability evaluation methodologies prior to implementation of new monitoring technology.

1. Daniels et al. Evaluation of Two Novel Vibrotactile Devices for Enhanced Situation Awareness in Anesthesia. Proceedings of the 2007 Information Technology and Communications in Healthcare Conference (Victoria, Canada).

Touch Your Patient- A Human Simulation Centre Based Assessment of a Novel Vibrotactile Display

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Introduction: Highly trained anesthesiologists often exceed their limits of interpreting clinical physiological patient data for a given modality when using standard operating room monitoring (1). Building on previous results (2), we have designed a vibrotactile belt to transfer information to the anesthesiologist *via* the modality of touch. We conducted a prospective, randomized, controlled, parallel group trial to test our prototype in a high-fidelity human patient simulator (HPS).

Method: Following IRB approval, two groups of volunteer anesthesiologists (n = 10 each) were randomized before exposure to a clinical scenario of anaphylaxis in an HPS (HPS-245, METI Corp., Florida, USA). One group was equipped with standard monitoring and the other with standard monitoring plus the vibrotactile belt. The belt alerted subjects when the patient's peak airway pressure or respiratory minute volume deviated by more than 25% above or below post induction baseline values. The primary endpoint was time to administration of epinephrine. *Post hoc* question probes were used to assess if an improvement in situational awareness could be demonstrated.

Results: The time to administer epinephrine was significantly reduced in the vibrotactile group (Figure 1; Student's t test, P = 0.016; Mean: Non-vibro 437 sec; Vibro 245 sec). *Post hoc* question probes assessing situational awareness showed no difference between the 2 groups

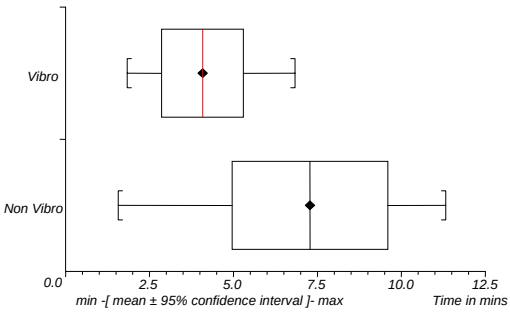

Figure 1: Time taken to administer epinephrine

Discussion: Using our novel vibrotactile belt, we have demonstrated a significant reduction in the time taken to deliver definitive emergency treatment for a scenario of anaphylaxis. The HPS provided an appropriate environment and objective evidence, unavailable in a clinical setting, to assess the efficacy of our new technology. We believe that the HPS can be used in a similar fashion to test the efficacy of other technologies designed to improve patient safety in the future.

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Right ventricular diastolic dimensions with acute hypovolemia – predominance of maximal minor axis and right ventricular septal length changes.

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Introduction: The relative impact of acute hypovolemia on the transesophageal echocardiographic depiction of the various diastolic dimensions of the right ventricle (RV) has not been established. This study was performed to address this issue.
Methods: Twenty-two coronary bypass graft surgery patients, with normal left ventricular function, were studied in the immediate pre-cardiopulmonary bypass period. Long axis (LA) 2-D echo images (transesophageal 5.0 MHz phased-array transducer) of the RV at the level of the anterior mitral leaflet were analyzed in terms of end diastolic dimensions. Dimensions included maximal minor axis diameter (MMD), interventricular septal length (SL), the tricuspid annulus (TA) and the distance between MMD and TA (MMDR) (Figure 1). Exclusion criteria included anatomy not conducive to valid MMD measurement (dilated aorta root, dilated RV with apex out of interrogation field). Measurements were acquired before and immediately following phlebotomy, routinely performed for aortic cannula de-airing and platelet preservation purposes. Results were analyzed by paired/unpaired t-text.
Results: The LA view was compatible with consistent imaging of the tricuspid valve annulus, RV apex and maximal minor axis within the same frames. MMD and SL decreased significantly ($P < 0.05$). Changes in TA and MMDR did not attain significance. There was no significant difference between MMD and SL changes. The underlying data are presented in Table 1. Relative differences are contrasted in Figure 2.
Comment: Findings indicated non-uniformity of dimensional changes of RV with acute hypovolemia. Thus, acute changes in RV shape should alert the clinician to a change in volume status.

Figure 1.

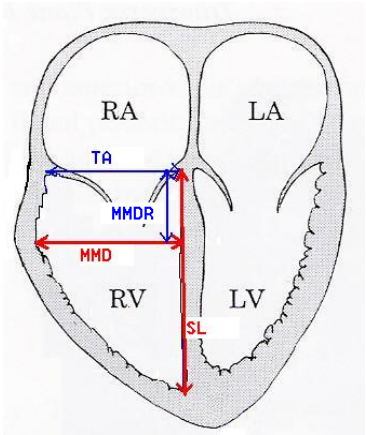

Figure 2.

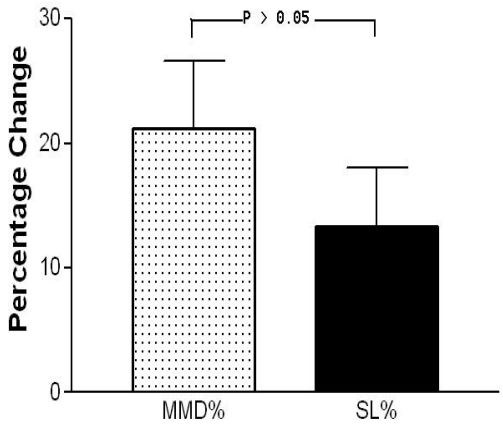

Table 1.

		Mean ± SEM	P value
Pre-phlebotomy MMD (cm)	pre-MMD	4.57 ± 0.19	
Post-phlebotomy MMD (cm)	post-MMD	3.56 ± 0.22	P<0.05
Pre-phlebotomy Septal Length (cm)	pre-SL	6.15 ± 0.30	
Post-phlebotomy Septal Length (cm)	post-SL	5.34 ± 0.40	P<0.05
Pre-phlebotomy MMDR (cm)	pre-MMDR	2.06 ± 0.23	
Post-phlebotomy MMDR (cm)	post-MMDR	1.97 ± 0.17	NS
Pre-phlebotomy TA (cm)	pre-TRA	3.49 ± 0.11	
Post-phlebotomy TA (cm)	post-TRA	3.10 ± 0.19	NS
Phlebotomy volume (L)	V	0.46 ± 0.03	

A simple paperless way for anesthesia scheduling, documentation and submission of claims.

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Baylor University Medical Center
Dallas, TX

Purpose: Paperless anesthesia practice does not have to be extremely complicated, or expensive, as shown in my current practice. I have used my system for the past three years.

Methods: Setup required for my paperless practice include : a blackberry PDA/phone, a laptop, and Adobe Acrobat Professional Software, and a subscription to an email service. A backup hard drive at home/office is mandatory.

Pre-anesthesia assessment: Schedule sent by my office is received on my Blackberry as email attachment. The displayed text message lets me call the patient straight from the PDA/phone.

Anesthesia record: I created a Filling Form on Adobe Acrobat Software, and the resulting anesthesia record looks the same as the current anesthesia record used at Baylor Healthcare system. At the end of the individual anesthesia case, I print out a record on Adobe PDF and/or a printer.

Submitting Claims: The Filling Form on Acrobat also generates anesthesia claim form at the same time. I submit the resulting claim form, along with the anesthesia record and the patient Insurance information (also available online from Hospital Web portal) to my billing office using Secure PDF Delivery service provided by Adobe Acrobat. This provides 128-bit encryption and a password protection. The software uses the default email client available on the workstation. Upon receiving my email, my office manager retrieves my PDF files by entering the password, and the file is now available for filing claims.

Advantages: No handwriting the anesthesia records, incredible legibility, 100% “clean claims” achievement, no papers to mail or carry around.

Anesthesia systems for use in situations with limited logistical support (electrical power and medical gas)

Carl Wallroth, Ph.D.[1], Alan Green[2], Norman Jones[3], Terry Longman[4], Gerald Panitz, Ph,D[1],, Hansel de Sousa, M.D.[5], Helmut Thiemann[1], Mark Graber[6], Julian Goldman, M.D. [7], Ty Smith, MD [8], Daniel Leibundgut, Ph.D. [9], Peter Schumacher, Ph.D. [9] and Dwayne Westenskow, Ph.D. [10]
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University of Bern, [10] University of Utah

The three standards organizations (ISO, CEN and ASTM) give design teams some guidance on how to balance increased risk associated with the complexity of modern workstations when designing devices for in-hospital use. None address the design of equipment for use in remote areas with limited logistical support regarding both electrical and gas supplies as well as logistics for consumables, spare parts and technical services. Resources and operator characteristics vary considerably in alternate locations, having considerable impact on device design requirements.

Limited logistical support areas include civil emergencies and disaster areas as well as wide regions of the populous and developing countries where support typically includes:

- Electric power via diesel/gasoline generator
- Oxygen concentrator and bottled oxygen
- Oxygen flow meter
- Non-rebreathing anesthetic system
- Draw-over vaporizer
- Ventilator (manual or mechanical)
- Limited pharmacy
- Limited patient and machine monitoring

A standard is being developed for systems used in such situations. The standard specifies quantitative methods, qualitative methods, or the use of pre-use checks as appropriate methods of risk control. The application of some of these risk control measures transfers the risk control from the equipment to the user or responsible organization. This takes into account the relative simplicity of the equipment, and is in recognition of the limited logistical support in the intended application.

Advances in the use of technology in the care and treatment of patients have been a key factor in the improvement in health-care in many parts of the world. These advances have involved ever more complex devices with corresponding supply and support infrastructures and related monitoring and alarm support to minimize errors in busy healthcare establishments. A key role of standards and regulation in this area has been to ensure that the increased potential risks associated with complexity have been more than balanced by adequate monitoring and control. This intent is transposed into device requirements for risk control such as fail safe design, alarms, monitoring, or instructions for device use.

There is an implicit assumption with these standards that there exists adequate technical support and that there are available reliable supplies of compressed medical gases and uninterrupted electricity, which in turn depend upon a highly developed infrastructure of transport facilities and power generation. Such equipment is simply not suitable for use in areas from cottage hospitals in not-so-highly developed regions to disaster scenarios and the practice of medicine in war zones. To cover appropriate devices, methods of risk control are introduced that shift some risk control functions from the equipment to the operator, depending on the inherent safety of the system, the work environment and patient characteristics recognizing the prime responsibility of the medical practitioner to continuously assess the patients' condition to ensure appropriate treatment.

Application of the ISO Essential Principles to Medical Equipment Intended for Use in Situations and Regions of the World with Limited Logistical Support

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Dräger Medical AG & Co. KG, 1 Medical Engineering Consultant, 2 Northwood Surgery Center, 3 Massachusetts General Hospital, USA, 4 GE, USA, 5 Penlon Limited, UK, 6 Universität Göttingen, 7 Terry Longman Consultancy Services, UK, 8, 9 PACEM (Pacific Academy of Ecclesiastical Music), 10 Dräger Medical, Inc., 11 University of Utah

Concern has been expressed internationally regarding current standards in support of the regulatory requirements to meet the essential principles for medical devices that will be used in certain remote and under-resourced geographic areas, in some emergency situations (such as in disaster relief) and in unforeseen military activities. An ad-hoc group has been working to address such issues with respect to anesthetic workstations and has prepared proposals for a second standard covering basic equipment. Relative to current standards, the proposed new standard introduces methods of risk control that shift some of the risk control functions from the equipment to the operator selecting the third level of risk control identified in ISO 14971[Ref 1]. This allows quantitative or qualitative measurement and display of the monitored parameters; imposing the alarm feature upon the operator. By this means both standards will prescribe risk control methods but with different technology levels; allowing countries with limited resources and logistical infrastructure to use simple anesthetic systems with appropriate risk control measures for patient safety, thus meeting the regulatory requirements.

It has always been recognized that, irrespective of the sophistication of the anesthetic system being used, a prime responsibility of the medical practitioner is to continuously and directly assess the condition of the patient in order to ensure that the treatment is appropriate. Patient monitoring systems and machine monitoring systems should always be seen as supplements. Therefore, relative to the current standard for anesthetic systems intended for use in hospitals and surgical and dental offices, in this proposed standard new methods of risk control will be introduced.

This is in conformance with the current requirements for risk management which specify the use of a risk reduction analysis using one or more of three levels of risk control options, in decreasing order of priority, i.e.:

a) Direct safety by design, such as O2 supply failure protection, hypoxic mixture prevention, maximum pressure limitation and adjustable pressure imitation;

b) Protective measures or means integrated in the medical device or manufacturing process, such as alarm systems for electrical power failure, gas supply failure, inspiratory oxygen concentration, inspiratory anesthetic agent concentration, airway pressure, expired volume, breathing system integrity and end tidal CO2;

c) Information for safety, such as the quantitative or qualitative display of a monitored parameter (e.g. anesthetic agent concentration, MAC, expired volume, end tidal CO2), instructions for use, training and preventive maintenance.

The result is that for direct safety by design both standards will be identical. For the current standard the second level has been identified to monitor and alarm for the identified hazards. For the proposed standard, the third level of risk control has been selected, allowing quantitative or qualitative measurement and display of the monitored parameters and imposing the alarm feature upon the operator. By this means both standards prescribe risk control methods, but with different technology levels - allowing countries with limited resources and logistical infrastructure to use anesthetic systems which have appropriate risk control measures to provide patient safety from a risk management perspective

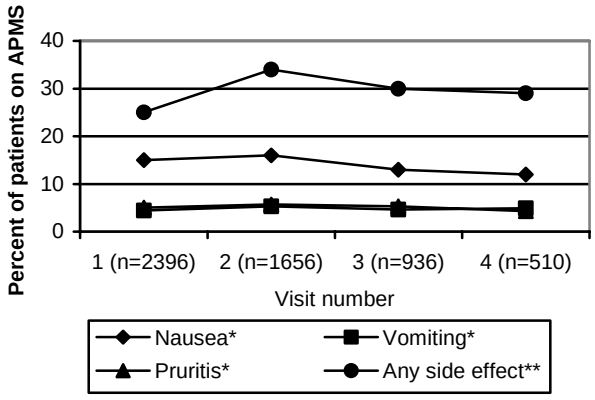
Electronic monitoring on an acute pain management service

Authors: Goldstein DH, Wilson RA, Van Den Kerkhof EG.

Objectives: To outline the process involved in the development and implementation of a clinician-driven portable electronic chart on an Acute Pain Management Service. We describe the latest version of the acute pain program and provide one year of clinical data.
Setting: Tertiary care centre in Kingston, Ontario, Canada.
Patients: All patients admitted to the Acute Pain Management Service between August 1, 2005 and July 31, 2006.
Results: Patient assessment data is entered into an electronic chart using Tablet computers (Figure 1). Eight thousand seven hundred and twenty-six Acute Pain Management Service visits were made to 2,528 patients. Mean length of stay on the Service was 2.3 days. Sixty-one percent of patients reported an active pain score > 3/10. Pain scores were highest with hip or knee surgery. Nausea was the most common side effect reported (Figure 2).
Conclusions: Executive sponsorship, alignment with institutional priorities, and user input are essential to the development, implementation, adoption and sustainability of an electronic patient record. Ready access to data at the bedside can improve quality of care, while ongoing, comprehensive data can contribute to Phase IV drug trials. Incorporating both clinical and research outcomes in the database improves data quality and usability, but must be balanced with the impact of clinical time constraints on documentation. Wireless technology and Tablet computers provide portability and adequate screen size for documentation and reviewing of patient data on an acute pain service. It is necessary to provide solutions to process issues, such as printing electronic records during the transition from paper to electronic records.

Figure 1. Example of Acute Pain Management Patient List screen

Figure 2. Number of patients reporting side effects stratified by the number of times a patient was "visited" by the Acute Pain Management Service



*Only side effects requiring treatment; **Any reported side effect whether it required treatment or not.

A systematic review of adoption of electronic information systems: Attributes of clinical users

Authors: Hall S, Wilson, RA, Goldstein DH, Van Den Kerkhof EG.

Objective: The implementation and adoption of computer information systems in health care has had mixed results. The objective of this study was to conduct a systematic review of the literature on the user attributes associated with adoption of computerized information systems.

Methods: Five databases were searched for papers published between 1996 and May 2006. The final results are based on forty observational studies. Twenty-nine were cross sectional surveys and eleven were pre and post implementation surveys. The factors assessed included demographic characteristics, experience, and attitudes towards electronic documentation. Data was also captured on factors related to ease of use, barriers to use, and impact of use of computerized health records.

Results: Professional experience was positively associated with attitudes towards adoption. Confidence that computers would allow more time to provide patient care increased from 45% pre-implementation to 80% post-implementation ($p < 0.001$). Barriers to adoption included ergonomics, access and support, system inadequacies (hardware and software), disturbances in workflow, concerns related to security of patient information and patient satisfaction, implementation of other functions simultaneously (e.g. new charting format), training (time, quality and amount), and limited administrative support. User attributes were found to be dynamic, and multiple determinants impacted on user adoption.

Conclusions: Strategically addressing the important determinants of user acceptance within each context impacts on implementation and adoption. A multi-level intervention strategy is necessary for successful implementation. Further research is required to validate multi-level intervention models.

A Survey of Anesthesia Information Management System Utilization in Arizona

Authors: Jeff T. Mueller, MD
Affiliation: Mayo Clinic, Scottsdale, AZ

Introduction: A survey was performed to estimate the utilization of anesthesia information management systems (AIMS) in Arizona.

Methods: Anesthesiologists attending the Arizona Society of Anesthesiologists (AzSA) Annual Meeting, held February 17-19, 2006, were surveyed regarding their use of AIMS.

Results: The 231 physician attendees of the AzSA Annual Meeting were given surveys regarding their use of AIMS. 203 meeting attendees practiced in Arizona; 28 practiced in other states. 74 Arizona anesthesiologists completed the survey (Arizona response rate=36%). No Arizona anesthesiologists reported current use of an AIMS in any of their practice locations (0%). 10 Arizona anesthesiologists reported using an AIMS sometime in the past (13.5%). 16 non-Arizona anesthesiologists completed the survey (response rate=57%). One non-Arizona anesthesiologist reported current use of an AIMS (3.6%). No non-Arizona anesthesiologist reported past AIMS use (0%).

Discussion: It is estimated that 15-20% of U.S. physicians' offices and 20-25% of hospitals utilize an electronic medical record (EMR) (1). It has also been reported that physician use of electronic access patient records increased from 36.6% in 2001 to 50.4% in 2005 (2). An AIMS is the anesthesia component of an overall EMR. A literature review revealed no documented data describing the number of AIMS installations in the United States. It is accepted that AIMS utilization lags that of other EMR components. A recent publication provided an undocumented national estimate of "less than 5% of U.S. hospitals" (3). An earlier publication included an undocumented estimate of "no more than … 1% of all (anesthesia) departments in the United States" (4). The survey data presented in this report suggests that AIMS utilization in the state of Arizona is either very low or nonexistent. Additional state or national surveys may help to delineate more accurately the utilization of these systems.

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H. Storm, I. Røeggen, R. Støen, E. Qvigstad, P. Klepstad, F. Skorpen, J. Raeder

Background and goal: Number of skin conductance fluctuations per sec (NSCF) in the palmar surface correlates well with sympathetic nerve activity. NSCF has been proposed to measure pain responses. The BIS index measures disorders in the EEG signal and is associated with awakening. The purpose of the study was to examine if NSCF and BIS could detect the pain response from tetanic stimuli, and to further examine if the tetanic stimuli response was stronger in a situation without analgesic infusion compared to a situation with ongoing analgesic target control infusion (TCI).

Materials and methods: 28 patients in ASA 1 or 2 were studied after induction of general anaesthesia with propofol (BIS between 40-50), but before intubation and start of laparoscopic surgery. The patients were given 3 series of tetanic stimulus of 50mA that lasted for 30 sec: Tetanic 1 (T1) without ongoing remifentanil analgesic infusion, Tetanic 2 (T2) after 4 min with TCI 4 ng/ml remifentanil and Tetanic 3 (T3) after 4 min with TCI 10 ng/ml remifentanil. The NSCF and BIS responses were registered continuously, starting 30 sec before stimuli and ending 30 sec after the stimuli started. The maximum values for NSCF and BIS during the tetanic pre stimuli periods were compared with the maximum values of the tetanic post stimuli periods. Moreover, NSCF and BIS responses during T1 were compared with the responses during T2 and T3. The Wilcoxon non-parametric test was used.

Result and discussion:

	pre-post T1 NSCF	pre-post T2 NSCF	pre-post T3 NSCF	pre-post T1 BIS	pre-post T2 BIS	pre-post T3 BIS
Mean(SD)	0.00(0.01)-0.07(0.07)	0.00(0.00)-0.02(0.04)	0.00(0.00)-0.01(0.06)	43(9)-44(13)	42(9)-44(12)	42(6)-44(7)
P value	0.000	0.027	0.180	0.272	0.393	0.227

	Response T1-T2: NSCF	Response T1-T3: NSCF	Response T1-T2: BIS	Response T1-T3: BIS
Mean (SD)	0.07(0.07)-0.02(0.04)	0.07(0.07)-0.01(0.06)	44(13)-44(12)	44(13)-44(7)
P value	0.000	0.001	0.873	0.882

The NSCF post stimulus level was higher than the pre stimulus level during T1 and T2, contrasting BIS, which did not change significantly. After 4 min with TCI 10 ng/ml remifentanil, no differences between post stimulus and pre stimulus levels during T3 was observed for NSCF and BIS. The NSCF response during tetanic stimuli was reduced when the remifentanil doses was increased different from BIS.

Conclusion: In contrast to BIS, this study showed that NSCF is sensitive to tetanic noxious stimuli during sleep, and the measured response is attenuated when an ongoing analgesic infusion is given.

Title: Telemedicine Consultation and Monitoring for Pediatric Liver Transplant
Author(s): Mohamed Rehman, MD, John Fiadjoe,MD, Harshad Gurnaney, MD, kanchi Muralidhar, MD, Surya Mohanty, MD, John Kumar, MD, Raja Viswanath, MD, Srinivas Sonar, MD, Steve Dunn, MD Affiliation(s): Children's Hospital of Philadelphia, Narayana Hrudayalaya Institute of Medical Sciences

Introduction: We describe two cases of living related pediatric liver transplant at the Narayana Hrudayalaya Institute of Medical Sciences in Bangalore, India with intraoperative consultation provided by physicians at the Children's Hospital of Philadelphia (CHOP) using teleconferencing. The application of telemedicine to anesthesia [Tele-anesthesia] has been limited. It involves a connection between two institutions that enables a live video and audio feed with minimal delay to facilitate direct communication between the anesthesia teams. Previous work by Cone et al. demonstrated the ability to direct an anesthetic in a remote location using satellite communication.(1,2) Our case is the first reported case using teleconferencing to manage anesthesia for a pediatric liver transplant.

Methods: We directed two liver transplants in patients aged 4yr and 16 months old. The equipment used in Bangalore consisted of a video camera, a video conference device by Polycom and a ISDN (Integrated Services Digital Network) line with 128 kb/s bandwidth. ISDN allows voice and data to be transmitted simultaneously using end to end digital connectivity. We used the Karl Storz Endoscopy-America, Inc. "OR1" Operating Room Control system at CHOP. This system provides the ability to perform video and audio conferencing using ISDN. A week prior to the date of surgery GoToMeeting online software was used to present a lecture on pediatric liver transplantation to the anesthesia providers in Bangalore. GoToMeeting also served as a backup communication system during the anesthetic course. This is the first application of teleconferencing and a web based connection (GoToMeeting) to facilitate remote anesthesia management in real time. Future endeavors include having the entire consulting team operate remotely i.e. the surgeon would operate remotely using robotics in conjunction with teleanesthesia. The surgeon in our case was from Delaware, USA, robotic equipment would allow him to operate in the USA and potentially decrease the cost of providing the service.

Conclusion: Tele-anesthesia provides the ability to direct anesthesia for liver transplantation remotely. There are however several challenges such as time zone differences, medical liability , setting adequate backup systems, obtaining informed consent and maintaining a ongoing patient record at both locations simultaneously. Despite these issues teleanesthesia remains an option to provide intraoperative consultation or medical direction of a anesthetic by experts at a distant location

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Advanced auditory displays and head-mounted displays: Advantages and disadvantages for monitoring by the distracted anesthesiologist

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Background: Advanced auditory displays for monitoring patient vital signs have been shown to support faster detection of simulated patient events (1) and better timesharing performance (2). Head-mounted displays (HMDs) offer similar advantages to advanced auditory displays, such as faster detection of patient events (3) and less need to rely upon visual scanning (4), but they might produce attentional capture and cause events to be overlooked, as has been the case for head-up displays in cockpits (5). We examined the relative effectiveness of advanced auditory displays and HMDs for patient monitoring by anaesthesiologists when distracted, and therefore challenged in their ability to maintain situational awareness and preserve patient safety.

Methods: Participants were 16 anesthesia registrars and consultants at Royal Adelaide Hospital. All participants served in four 22-minute anesthesia scenarios in a full-scale anesthesia simulator. Scenarios started with induction and proceeded through maintenance. Four display conditions were experienced by all participants and were presented in a counterbalanced order that varied across participants:

1. *Visual*—Standard visual monitor with variable-tone pulse oximetry.
2. *HMD—Visual* plus HMD (monocular transparent Microvision™ Nomad)
3. *Audio—Visual* plus respiratory sonification (continuous two-tone auditory display of RR, ETCO2 and Vt) and blood pressure earcons (intermittent musical motifs for SBP and DBP from NIBP cuff)
4. *Both—Visual* plus *HMD* plus *Audio*.

Participants supervised the activities of a junior anesthesia colleague while carrying out a reading-based distractor task that oriented them away from the visual monitor. If participants detected an anesthesia event that could harm the simulated patient, they either informed their junior colleague verbally, pressed a button on the computer screen, and/or informed a nearby assistant who recorded a response.

Results: Compared with the Visual condition where average detection rate was 52% of the events, participants detected significantly more events in the Audio (90%, p=0.001) and Both (92%, p=0.0006) conditions, but not in the HMD condition (75%, p=0.07). There were no main effects or interactions with expertise. Questionnaire results indicated that compared with the Visual condition, monitoring was rated easier in the HMD (p=0.0002), Audio (p=0.0005) and Both (p=0.0002) conditions. Participants' views of the advantages and disadvantages of the different displays were noted.

Conclusions: Auditory displays give the distracted anesthesiologist an advantage in maintaining peripheral awareness of a simulated patient's status. The HMD did not significantly improve performance over a conventional visual monitor plus variable-tone pulse oximetry, and it did not give a significant further advantage to monitoring with auditory displays. Participants' strong belief in the ease of monitoring with the HMD by itself was not matched by equally strong event detection performance with the HMD. The clear performance advantage for the HMD seen in other studies (3) was not replicated. A limitation of the study is that its findings generalise only to extreme cases of anesthesiologist distraction. We are testing the displays under less extreme conditions.

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Simulating high workload situations to evaluate patient monitors

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Background: Anesthesia simulators are being used to evaluate how effectively different displays convey physiological information to the anesthesiologist [1, 2]. Anesthesiologists' vigilance levels are often higher in simulators than in the operating room because anesthesiologists expect adverse events to occur in the simulator. The increased levels of vigilance could mean that results from simulator trials may not represent anesthesiologists' performance in the operating room. Because vigilance based errors occur more frequently at low arousal levels and under high task load when people are limited by their cognitive resources [3], anesthesiologists' workload may be manipulated in simulators to overcome the heightened levels of vigilance.
Methods: We have developed a task that produces a controlled level of distraction for anesthesiologists while they participate in simulated scenarios. The abstract classification task (ACT) requires the anesthesiologist to read a series of anesthesia abstracts and to classify each abstract according to (a) general area of research (e.g. *cardiac anesthesia*), (b) research evidence class (*e.g. research class II*), (c) year of publication (e.g. *2003-2004*), and (d) likely impact of the research on anesthesia (e.g. *very likely*). Performance feedback (percentage correct) was provided on the first three classifications. To motivate participants to focus on the task, the performance feedback also indicated the best performance achieved for each task.
Results: The ACT made it easier to identify significant differences in anesthesiologists' ability to detect simulated patient events with a range of patient monitoring displays [4] with only 16 participants. Some anesthesiologists were distracted for periods exceeding two minutes even though they expected adverse patient events to occur throughout the scenarios.
Conclusions: Without requiring hundreds of hours of simulator time, the ACT successfully simulated occasions on which anesthesiologists become distracted in the operating room. Although artificial in nature, such distractor tasks have the potential to produce patient monitoring behavior closer to those observed in operating theatres.

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Blood gas measurements using the Bayer Rapid Point 405: are we basing our decisions on accurate data?

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Introduction: In the operating room therapeutic decisions are often made based solely upon results obtained from arterial blood gas machines. To our knowledge, there have been no published reports on how accurate and precise the Bayer RP405 is in the hands of the operating room staff. We evaluated how precise and accurate the results obtained from these analyzers were vis-à-vis those of the routine blood gas laboratory and if they met the accepted standards.

Methods: Ninety (90) patients requiring an arterial catheter were included. For each patient, 3 ml of blood from the arterial catheter was drawn into a heparinized syringe (FIMS Portex Inc.) and immediately analyzed by the two RP405 and in the ICU blood gas machine (Instrumentation Laboratories GEM 3000). The remaining 2.8 ml of blood was used to measure Hematocrit and sent to the hospital's main biochemistry laboratory for electrolyte measurement using an indirect ion selective method (Roche Diagnostics Modular ISE Module). A survey was distributed to each of the 19 anesthesiologists at the SMBD-JGH. Their opinions for accuracy and treatment thresholds for each of the twelve variables measured by the RP405 were sought.

Results:

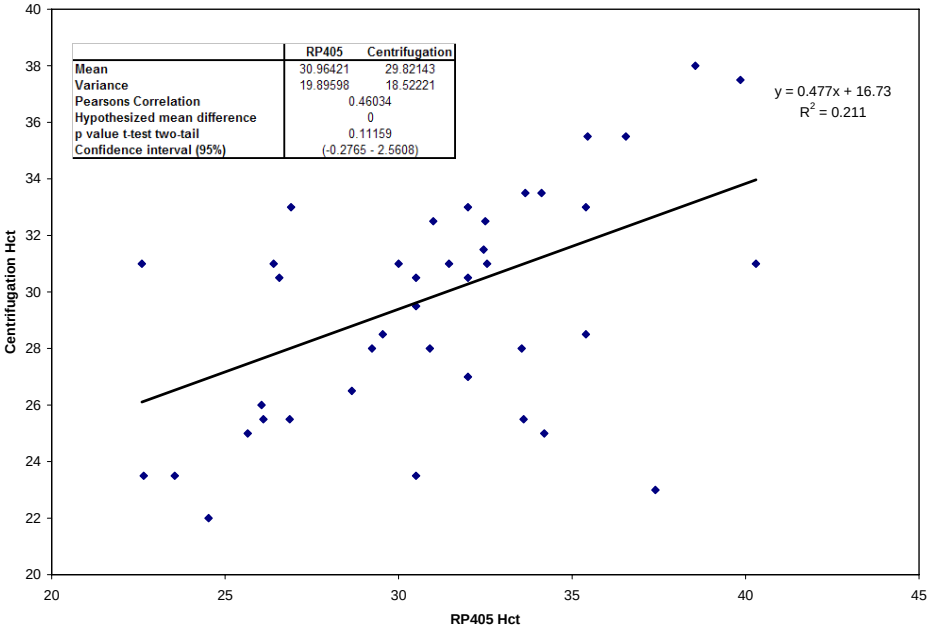

Figure 1. Hematocrit by centrifugation versus RP405

	Variable: Hct		
	Accuracy/ Precision	Treatment threshold (inf value)	Treatment threshold (sup value)
Average	1.2704	24.3048	46.6289
Standard deviation	0.7583	6.7119	14.0468
Median	1	25	50
Mode	1	25	50

Table 1. Survey results for the Hematocrit variable

Discussion: Our results show that the RP405 analyzers produce accurate, precise and reproducible measurements. These results were within the limits of acceptability to our sample of experts. In the context of rapidly changing clinical status, anesthesiologists must be confident that the information they receive is accurate.

Use of multimedia message service technology in the operation theatre.

Anurag Tewari, MD

Abstract: The use of mobile phones has long been controversial in the operation theatres citing various incidences wherein aberration of the electronic equipments has occurred due to their use. We hereby report a case where we used mobile phone to capture a dysrhythmia occurring intra-operatively in a patient via multimedia messaging service (MMS) technology, and sending it to the consultant in charge as well as a cardiologist and taking immediate remedial action. MMS technology could be useful for the anaesthesiologists to transfer visual data to the concerned supervising senior regarding threatening ECG changes, anticipated difficult intubation, cardiopulmonary cerebral resuscitation etc. We would like to reinforce the "1 meter rule" proposed by Irnich and Tobisch[5]. We hope that hospital managers and clinical directors will reconsider the issue and will adopt a more flexible policy towards use of mobile phones in the operation theatres. A practical approach would help remove the aggressive over reaction of some staff and public to their use in the hospitals. With the advent of advanced mobile phone technology that might prove more beneficial in future we should take measures that anaesthetic equipment be manufactured in a way so as to resist EMI from mobile phones.

Keywords: Electromagnetic interference, Mobile phones, multimedia message service, operation theatre.

Negative pressure applied to the hand leads to an early decrease in brachial artery blood flow

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Introduction: Vitalheat™ (Dynatherm Medical Inc, Fremont, California) is a novel system in which the hand is enclosed in a perspex glove with a thermal pad for the palm. Once air tight, negative pressure applied to the glove results in dilatation of superficial vessels, the blood within which can then be warmed or cooled by the thermal pad.[1]
The aim of this study was to measure brachial artery flow changes that accompanied the application of negative pressure to the hand. The thermal component was turned off in this study.
Materials and Methods: Informed consent was obtained from nine healthy adult volunteers (7 males, 2 females) to participate in this IRB approved study.
Doppler blood flow measurement was accomplished using the Phillips iU22 ultrasound system (Phillips Medical Systems, Andover, Masachussetts, USA) with the help of a L9-3 probe placed on the brachial artery just above the antecubital fossa. Measurements were made at baseline (BL) and 1 and 5 minutes following application of negative pressure and repeated.

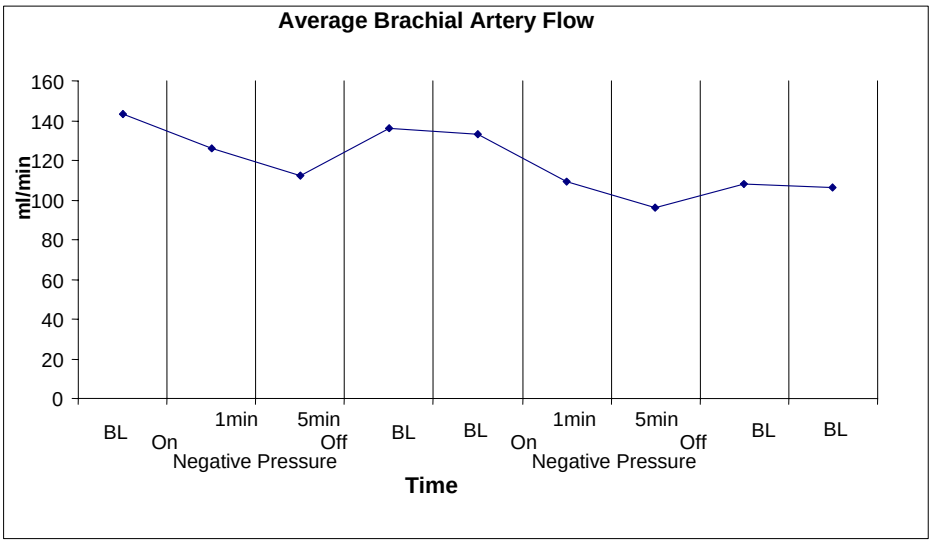

Figure 1

Results: There is a decrease in brachial artery flow from a mean of 143 ml/min (± 43ml SD) at baseline, to 112ml/min (±59ml SD) five minutes after the application of negative pressure (Figure 1). On removal of negative pressure the flow rises to 136ml (±57ml SD). Five minutes after the reapplication of negative pressure the flow has decreased to 96ml/min (± 43ml SD).
Conclusion: Application of negative pressure (- 40mmHg) to the hand results in an early decrease in brachial arterial flow.
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Comparison Over Time of the Efficiency of an Anesthesia Record Keeper (ARK) as Evaluated by Anesthesia Practitioners in an Academic Medical Center

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Introduction: ARKs have been in existence for over 20 years and yet only a minority of medical centers have made the transition from paper charting. Some possible explanations for this scarcity of ARK users include expense, reluctance to change, perceived disruptive impact of daily use in the operating room, and lack of demonstrated improvement in efficiency and accuracy, among other things. 3 months after the successful deployment of an ARK we evaluated the impact of this system on an academic anesthesia department. We now seek to compare those results with a new evaluation at 18 months.

Methods: In June 2005, 3 months after installation of an intra-operative ARK (Innovian, Drager Medical, Inc.), 91 clinical anesthesia staff members received an anonymous 37-question survey. Then, in September 2006, 18 months after installation, 96 clinical anesthesia staff members received an anonymous 42-question survey. Both surveys evaluated demographic data, efficiency, accuracy, vigilance, and provider preference using true/false and numeric responses. Results were compiled and analyzed using chi squared and two-sample t-test where appropriate.

Results: *=p<0.05 **Question**		**Attending Physician**	**CRNA**	**Resident**	**All**
Respondents #returned/distributed	(%)	3mo / 18mo 20/27(74.1) / 22/29(75.9)	3mo / 18mo 29/29(100) / 21/29(72.4)	3mo / 18mo 21/35(60) / 22/38(57.9)	3mo / 18mo 70/91(76.9) / 65/96(67.7)
Efficiency					
PACU time editing (min)	(mean)	5.7 / 4.4	4.9 / 3.3	6.6 / 2.9	5.6 / 3.6
Charts revised/week (#)	(mean)	2.5 / 1.5	0.8 / 0.4	1.1 / 2.5	1.4 / 1.5
More efficient	(%)	66.7 / 94.4 *	61.5 / 84.2 *	85.0 / 90.5	70.3 / 90.0 *
More accurate	(%)	94.4 / 81.0 *	64.3 / 90.9 *	70.0 / 100 *	74.2 / 90.5 *
More vigilant	(%)	84.2 / 80.0	58.3 / 76.2 *	80.0 / 90.5 *	73.0 / 82.3 *
Preferences					
Prefer paper chart	(%)	15.0 / 11.1	24.1 / 5.0 *	0.0 / 0.0	14.3 / 5.1 *
Prefer review paper chart	(%)	30.0 / 23.5	69.0 / 17.6 *	38.1 / 11.8 *	48.6 / 17.6 *
Overall like ARK	(%)	100 / 95.2	86.2 / 95.2 *	95.2 / 100	92.9 / 96.8

Discussion: Overall satisfaction with the ARK has improved from the 3 month to the 18 month period. Most popular features of the ARK continued to include automatic charting of vitals, neatness/legibility, accuracy/reliability, as well as allowing more time to focus on the patient. Least popular features continued to include the recording of artifacts and the unclear display of patient data/paper printouts. Two new complaints from the 18 month study were that rare glitches did take significant time away from patient care and that it was difficult to retrieve archive data. Time spent editing and number of chart revisions remained minimal and, in most cases, decreased. In nearly all groups, efficiency, accuracy, and vigilance improved over time. The number of anesthesia providers who preferred hand-written charts also decreased. This finding was particularly significant for the CRNAs who initially had large numbers preferring hand-written to computerized charting.

Virtual 3D Multidisciplinary Anatomic Review of Complex Upper Airway for Pre-Procedural Planning and Clinical Education

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Abstract:

At the University of Maryland Medical Center we continue the use of Computerized Volumetric Analysis Systems (CVAS)[1] in multiple surgical disciplines. The suite of tools and methodologies that CVAS encompasses enables us to present a stereoscopic virtual tour of an actual patient's airway anatomy as it relates to interventional planning by Anesthesiology and Ear, Nose, and Throat (ENT) specialists.

We demonstrate the ease of preoperative planning using stereoscopic and CVAS technologies that facilitate the evaluation of 2-dimensional Computed Tomography in a 3-dimensional manner in a patient with recurrent airway stenosis. The end user (clinician) is able to virtually navigate through the actual patient anatomy as well as to easily establish landmarks and metrics that facilitate diagnostic laryngoscopy and naso/endotracheal intubation.

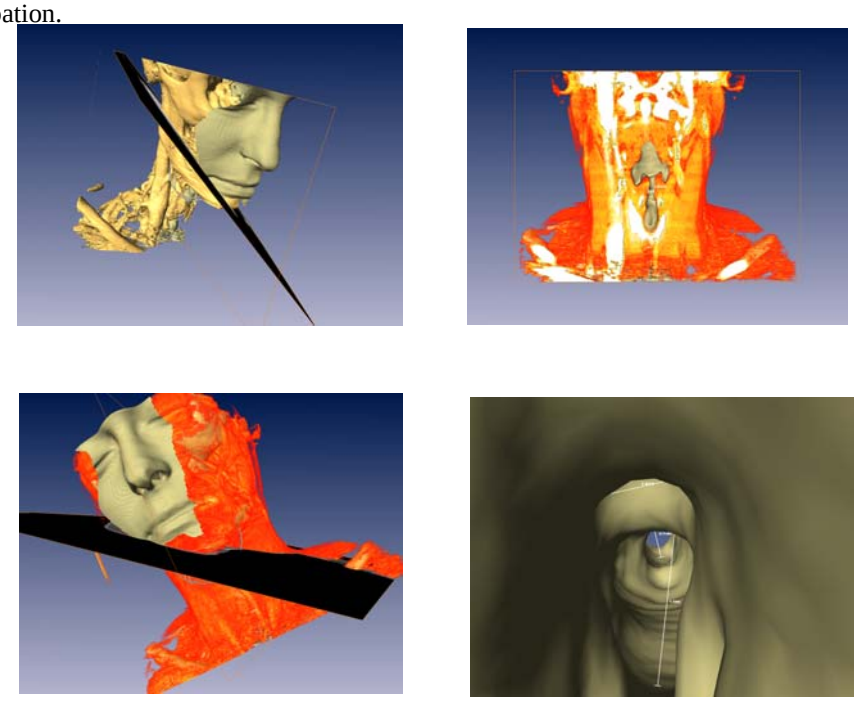

Fig 1 Various stereoscopic views with both volume projection and surface-rendering imaging techniques displayed.

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A Point of Care Method for the Improvement of Medication Cycle Management in Operating Rooms

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It is well recognized that most anesthesiologist will experience at least one drug error or a near miss. The most common are syringe swaps and label misidentification.(1) The rates of medication errors have been estimated from 0.11% (2) to 0.75% (3). Medication errors continue to be prominent in successful litigations against anesthesia providers.(4)

We have developed a method, which can be used in operating room (OR) facilities with or without existing automated anesthesia information systems (AIMS), as well as in critical care areas, where a single medical provider is involved in procurement, re-packaging, re-labeling and administration of multiple drugs.

The method relies on the supply by the hospital pharmacy of **all** drugs to the OR with bar-coded ampoules. A computer with an embedded high-density scanner in combination with a printer is then used to read the ampoules and produce labels with names and concentrations of the drugs and specific barcodes, while being drawn into a syringe. The barcode may also contain additional information, time stamp, ID, etc. No other labels are available, therefore the non recoverable error of mislabeling the syringe is eliminated. An omni-directional scanner is then used close to the site(s) of injection to input the drug information to an AIMS based or stand alone computer/printer. It provides an immediate audible feedback of drug identity therefore, minimizing the chance of completing a potential syringe swap error. The system is currently being evaluated in the University Health Network Operating Rooms.

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Central venous pulse pressure analysis using R-synchronized pressure measurement system

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The information of central venous pressure (CVP) is underused. We developed an EKG–R synchronization and averaging system to take the most advantage of CVP in the operating rooms and intensive care unit. It visualizes CVP waveforms and permit accurates measurements of its components (a, c, v and x, y). In addition, the mean value of CVP (CVP_{mean}) and the CVP at end-diastolic point ($CVP_{preload}$) are digitally displayed.
Although the difference of the two variables, CVP_{mean} and $CVP_{preload}$, is thought to be small, at least in patients with normal subjects, the exact difference has not been reported. The aim of the study is to compare CVP_{mean} and $CVP_{preload}$ in patients under mechanical ventilation and to determine the relative value of CVP waveform components (*a, c, v* and *x, y*), by using the newly developed system.

Patients and Methods

This study was approved by the Kawasaki Medical School Ethical Committee. Data collection was performed from patients in the operating rooms from October 2002 to June 2005. All pressure measurements were performed through the catheters that were already in place for clinical care using the hemodynamic monitor. Twenty-five patients who had regular sinus rhythm on EKG were studied. CVP was measured through the central venous catheter (AK-16702-J, Arrow, Japan) positioned in the superior vena cava. Zero reference was obtained at the mid-axial level. Measurements were performed after induction of anesthesia and surgery during surgery, while the lungs were mechanically ventilated.

R-synchronization and averaging CVP measuring system

EKG signals and the pressure signals were sampled for ten seconds at 1kHz Hz from the hemodynamic monitor to a PC computer equipped with A-D interface (PCI-3156, Interface Co. Hiroshima, Japan) and custom-made software (R-Synch, Version 1). The code was written by one of the authors (Y.F.) in Visual C^{++} 6.0 (Microsoft, USA). The program to view data can be downloaded from the site via the Internet from our URL (http://www.kawasaki-m.ac.jp/anesicu/). The system provides an auto-gain-display of the mean EKG, arterial pressure and CVP traces for ten seconds or the R-synchronized average traces of the three signals as well as digital readouts of their values (Fig. 1).

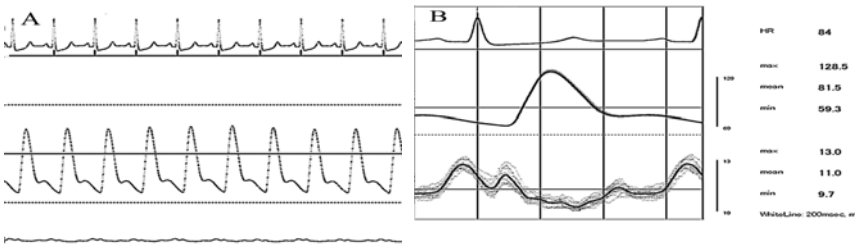


Fig. 1 EKG, arterial pressure and CVP signals in 61-year-old man for ten seconds. The signals are sampled from a hemodynamic monitor at 1 kHz and transferred to a PC computer (A). The CVP and arterial pressure signals are processed by EKG-R-synchronization, and the averaged curves and digital readouts appear displayed on the display. All components of CVP waveform are clearly visualized on the auto-gain scale. (B).

Statistics and Data Analysis

All data were presented as means ± S.D. Analysis of variance for repeated measurements followed by the least significance test was used to detect significant changes in hemodynamic parameters. The level of statistical significance was $p<0.05$

Results

The hemodynamic data including arterial pressure, heart rate and the CVP_{mean} are summarized in the Table 1. CPV amplitude of the averaged signals was 3.4 ± 1.2 mmHg, while CVP changed from the maximal value of 10.7 ± 3.8 mmHg to the minimum value of 4.5 ± 3.8 mmHg through respiratory cycles for ten second. Table 2 shows the mean values of each CVP waveform component. Each value is presented as a difference from the CVP_{mean}. It revealed that *a* peak was 1.8 ± 0.7mmHg above the CVP_{mean} and highest among the three peaks (*c* and *v* peaks, 0.6 ± 0.6 and 0.5 ± 0.7mmHg, respectively), and that *x* trough was greater than and *y* trough (- 1.6 ± 0.7 and - 0.9 ± 0.5 mmHg), respectively. The CVP_{mean} was by 0.58 ± 0.81 mmHg less than the $CVP_{preload}$.

Table 1. Hemodynamic data

HR(bpm)	BPsys(mmHg)	BPdiat (mmHg)	CVP_{mean} (mmHg)	$CVP_{preload}$ (mmHg)
60.5 ± 9.6	112.9 ± 18.0	57.7 ± 10.1	7.3 ± 3.7	7.9 ± 4.1

Data of 75 measurements from 25 patients were expressed as the means ± SD. Abbreviations, HR: heart rate,BPsys: systolic arterial pressure, BPdia: diastolic arterial pressure, CVP_{mean}: the geometric mean of the CVP, $CVP_{preload}$: the CVP at end-diastole during expiration.

Table 2. The mean values of each CVP pulse wave component.

	a	*c*	*v*	*x*	*y*
mmHg	1.8 ± 0.7*	0.6 ± 0.6	0.5 ± 0.7	- 1.6 ± 0.7#	- 0.9 ± 0.5

*Values are expressed as differences from the geometric average of CVP. Data of 75 measurements from 25 patients were expressed as the means ± SD. *: significantly greater than c or v ($p<0.05$). #: significantly less than y ($p<0.05$).*

Discussion

This study revealed that the difference between CVP_{mean} and $CVP_{preload}$ was so small as 0.58 ± 0.81 mmHg in paralyzed patients with sinus rhythm under mechanical ventilation. Analysis of the averaged CVP waveform revealed that *a* peak is higher than *c* or *v* wave, while there is no difference between *c* and *v* waves, and *x* trough was greater than *y* troughs.

Our algorithm to average pressure signals with R-synchronization and to display signals with adequate amplitude by auto-gain display permits preservation of the cardiac cycle induced changes of CVP and reduction of respiratory influence, emphasizing clinical usefulness of the system and education in circulatory physiology. Although we analyzed only CVP in this study, this system is also applicable to other central vascular pressures such as arterial, pulmonary artery, pulmonary artery wedge pressures.

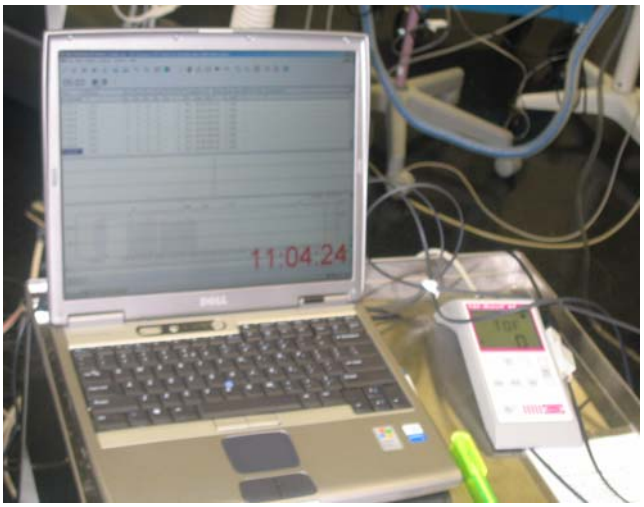
$CVP_{preload}$ is determined at the end of expiration to minimize the effects of intrathoracic pressure. Because of the technical difficulty to determine it, CVP_{mean}, *i.e.*, the readout of the clinical monitor, is used for the clinical purpose. This is the main reason of the discrepancy between digital readouts and the graphic method . Comparative studies indicated that digital readouts are not reliable and the authors note that the graphic method is necessary for accurate measurements. This study, however, suggested that use of CVP_{mean} as the index of right ventricular preload ($CVP_{preload}$) is acceptable, at least, in paralyzed patients with normal CVP waveform under mechanical ventilation.

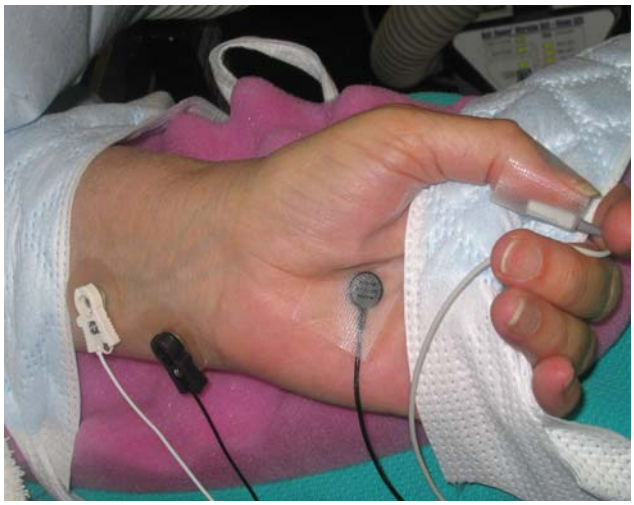
While CVP changed between 10.7 and 3.4 mmHg during respiratory cycles, the amplitude of CVP waveform is 3.4 ± 1.2 mmHg. This contrast is the main reason for the difficulty to obtain distinct CVP waveform on clinical monitor and to determine the level of each component. This study using the newly developed system delineated it. It revealed that *a* peak is the highest among the three peaks. Accordingly, it will be inferred that if *c* peak is greater than *a* peak, it means the non-constricting atrium or tricuspid regurgitation. Greater *v* peak than *a* peak (*c*-*v* wave) in patients with sinus rhythm is compatible with tricuspid regurgitation.

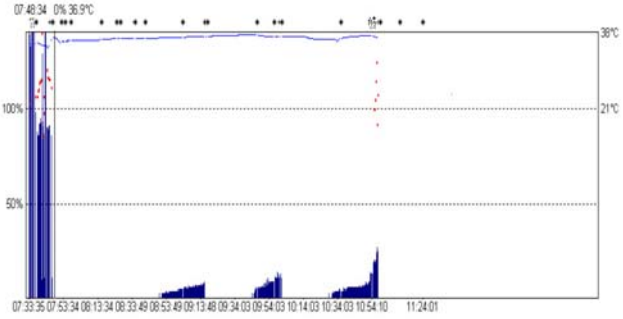
In conclusion, CVP_{mean} can be used as $CVP_{preload}$, at least, in paralyzed patients with regular sinus rhythm under mechanical ventilation.

NEUROMUSCULAR JUNCTION MONITORING FOR THE ORGANON PROTOCOL 19.4.308 SUGGAMEDEX TRIAL

There are various methods currently in use to monitor the neuromuscular junction (NMJ) for clinical and research purposes, we present a descriptive poster of the method used for NMJ monitoring for the Organon protocol 19.4.308 – A multicenter, randomized, parallel group comparative, safety-assessor blinded phase IIIa trial in adult surgical subjects under general anesthesia at increased risk of pulmonary complication.
It is our opinion based on our cohort of 18 patients that the combination of the TOF-Watch SX and the TOF-Watch® SX monitor PC program on the Dell Lattitude D600 represents one of the most comprehensive and most accurate systems of monitoring the neuromuscular junction using the ulnar nerve.







The only downside of the system is the average 15minutes set-up/calibration time, which in our opinion can be built into time used for other procedures such as foley catheter placement. Also set up/calibration and monitoring might be difficult for solo practitioners.
We feel very strongly that the introduction of a comprehensive neuromuscular junction monitoring system such as the TOF-Watch SX and the associated TOF-Watch SX Monitoring program into everyday anesthesia practice will be of great value to practitioners and the patients we serve.

Failure to Display a Significant Change in ETCO2 on Printed Automated Anesthesia Record: Case Report and Medicolegal Implications

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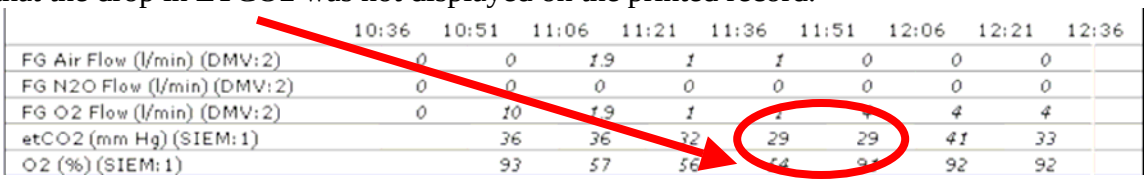
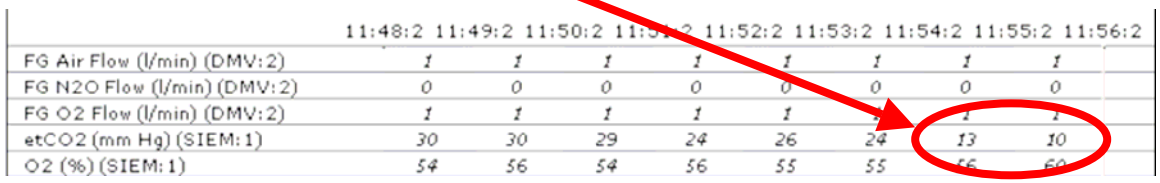
Department of Anesthesiology, Virginia Commonwealth University Medical Center, Richmond, VA

Case Report: A 78-year-old male with a previous surgical history significant for resection of a renal mass, presented for an exploratory laparotomy for resection of hepatic mass. In the operating rooms at VCU Medical Center, anesthesia providers use an anesthesia record keeper (ARK) to document anesthetic care (Innovian, Draeger Medical, Inc.). Surgery proceeded uneventfully for approximately one hour until the patient experienced acute hypotension, accompanied by a precipitous drop in ETCO2, related to a large surgical blood loss. The patient was resuscitated and the procedure was completed uneventfully. In the PACU, the anesthesia provider printed a copy of the anesthesia record for the medical record but noticed that the drop in ETCO2 was not displayed on the printed record.



	10:36	10:51	11:06	11:21	11:36	11:51	12:06	12:21	12:36
FG Air Flow (l/min) (DMV:2)	0	0	1.9	1	1	0	0	0	
FG N2O Flow (l/min) (DMV:2)	0	0	0	0	0	0	0	0	
FG O2 Flow (l/min) (DMV:2)	0	10	1.9	1	1	4	4	4	
etCO2 (mm Hg) (SIEM:1)		36	36	32	29	29	41	33	
O2 (%) (SIEM:1)		93	57	56	54	94	92	92	

However, when the record was examined at a higher resolution (every 60 seconds), the change in ETCO2 became apparent.



	11:48:2	11:49:2	11:50:2	11:51:2	11:52:2	11:53:2	11:54:2	11:55:2	11:56:2
FG Air Flow (l/min) (DMV:2)	1	1	1	1	1	1	1	1	
FG N2O Flow (l/min) (DMV:2)	0	0	0	0	0	0	0	0	
FG O2 Flow (l/min) (DMV:2)	1	1	1	1	1	1	1	1	
etCO2 (mm Hg) (SIEM:1)	30	30	29	24	26	24	13	10	
O2 (%) (SIEM:1)	54	56	54	56	55	55	56	60	

Discussion: This case highlights an important consideration for anesthesiologists using ARKs. With a handwritten record, anesthesia providers choose which data to record. When using an ARK, the automated capture of data results in both the addition of artifactual data and the subtraction of other data that may be important for documentation during the procedure. In this instance, the selected print granularity (15 minutes) did not allow for enough detail of events that occurred during that window of time. This particular ARK displays the median value of any parameter to display in a column, leaving it up to the interpretation of the reader to determine if this is a representative value for the selected time span.

There are several important medicolegal questions raised by this case. Is the printed record or the data stored in the database (currently set to record at 30 second intervals) the "official" medical record for this case? Is the ARK database discoverable? Should anesthesia providers be permitted to edit or remove automated data and artifacts from a record? As the anesthesia community continues to adopt ARKs, these and other medicolegal considerations will need to be explored.

Parallel and Vector Processing Optimization of Approximate Entropy Algorithms

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Department of Anesthesiology and Critical Care
University of Pennsylvania School of Medicine

Approximate entropy and cross approximate entropy are measures of signals which attempt to find similarities with a given signal at different times, or similarities between two signals at similar times. Approximate entropy is attractive due to the lack of necessity of a precise definition of the signal generation model, or even the probability density function for the signal. The calculations involved are simple, permitting easy implementation on inexpensive computers. Most efforts have ignored the computational aspects of the algorithms, as real-time performance can be easily achieve on embedded processors.

Our group is investigating long term changes in EEG patterns associated with exposures to anesthetic agents in mice; typical experiments require analysis of up to 72 hours of EEG on 8 simultaneous animals. This has led us to examine the computational gains achievable with modern high speed computers.

Modern processors such as the Xeon and G5 employ multiple computational cores and vector processors to improve computational performance. Use of these facilities can increase the speed of computation by a factor of 10 over that seen in single core scalar code on the same chip. Higher performance still can be achieved with multiple CPU machines. To achieve this performance, the algorithm must reorganize the work into multiple independent threads of execution which heavily utilize the vector pipelines. We will present results obtained using the widely available gcc 4.0 compiler for autovectorization and the POSIX pthreads library for parallel threading. Benchmarks for both Xeon and G5 architecture will be presented.

Title: Accuracy of a novel bioacoustic sensor in adult postoperative patients.
Authors: M. Macknet MD, P. Kimball-Jones MD, R. Applegate II MD, R. Martin MD, M. Allard M.B.Ch.B FRCA
Institution: Loma Linda University, Department of Anesthesiology

Introduction:
Monitoring respiration of spontaneously breathing patients is a concern in a variety of clinical areas including the operating room, post anesthesia care unit (PACU), and on the general care wards. Most current devices are limited because they require either a cannula system positioned in line with airflow to detect respiration or impedance pneumography which is prone to missing obstructive apnea.[1] A novel bioacoustic sensor for continuously monitoring respiration has been developed. We evaluated the accuracy of the prototype sensor in adult postoperative patients in the post anesthesia care unit.

Materials and Methods:
Following institutional IRB approval and informed consent, 10 postoperative patients, upon arrival to the PACU, were monitored in the standard fashion. In addition, a nasal cannula was placed, secured with tape, and connected to a BCI capnometer (SIMS, Waukesha WI). An adhesive bioacoustic sensor connected to a breathing frequency monitor prototype (Masimo Corp, Irvine Ca) was applied to the patient's neck just lateral to the cricoid cartilage. Both the capnometer and the bioacoustic monitor were connected to a computer for continuous data recording and subsequent data analysis. The accuracy of the new acoustic sensor and the capnometer were compared to a reference respiratory rate from a manual scoring system. Bias, precision and A_{RMS} were calculated in the usual fashion, as either bioacoustic sensor – reference or capnometer - reference.

Results:
All data is expressed as mean $\pm$ standard deviation. 10 patients (age = 57.8 $\pm$ 25.4 years, weight = 76.3 $\pm$ 23.6 kg) were enrolled. Duration of monitoring time in PACU was 55.2 $\pm$ 38.9 min. Respiratory rate varied 3 to 28 bpm during this time. The resultant bias, precision and A_{RMS} for the capnometer compared to the reference value was -0.53, 2.11, and 2.23 respectively. The bias, precision and A_{RMS} for the bioacoustic sensor compared to the reference sensor was -0.15, 2.23, and 2.36 respectively.

Conclusion:
The new prototype bioacoustic respiratory sensor demonstrates accuracy for respiratory rate monitoring as good as capnometry, in this population of patients in the PACU. This data suggests the new bioacoustic sensor may provide a system at least as accurate as capnometry for monitoring respiration in spontaneously breathing patients. This device offers multiple benefits over existing devices and has a potential to improve monitoring in a general care setting.

References:
1) Medical and Biological Engineering and Computing 2003;41;377-383

Title: Accuracy of a novel bioacoustic sensor in pediatric postoperative patients
Authors: M. Macknet MD, P. Kimball-Jones MD, R. Applegate II MD, R. Martin MD, M. Allard M.B.Ch.B FRCA
Institution: Loma Linda University, Department of Anesthesiology

Introduction:
Monitoring respiration of spontaneously breathing patients is a concern in the operating room, post anesthesia care unit (PACU), and on general care wards. Present technology has focused on capnometry attached to the patient's airway via a nasal cannula as the best method of providing this monitoring. [1] There are multiple problems with this method of monitoring respiration including cannula dislodgement or occlusion leading to inaccurate data or complete loss of monitoring.[2] A novel bioacoustic sensor for monitoring respiration has been developed. We evaluated the accuracy of the new bioacoustic sensor compared to the capnometer cannula system in pediatric postoperative patients.
Methods:
Following institutional IRB approval and informed consent, 6 pediatric patients admitted to the PACU were monitored in the standard fashion. In addition, a nasal cannula was placed, secured with tape, and connected to a BCI capnometer (SIMS, Waukesha WI). An adhesive bioacoustic sensor connected to a breathing frequency monitor prototype (Masimo Corp, Irvine Ca) was applied to the patient's neck just lateral to the cricoid cartilage. Both the capnometer and the bioacoustic monitor were connected to a computer for continuous data recording. The accuracy of the new bioacoustic sensor and the capnometer were compared to a reference respiratory rate from a manual scoring system. Bias, precision and A_{RMS} were calculated in the usual fashion, as either bioacoustic – reference or capnometer – reference.
Results:
All data is expressed as mean ± standard deviation. 6 patients (age = 11 ± 6.3 years, weight = 23.8 ± 89.4 kg) were enrolled to date in the accuracy trial. Respiratory rate varied 3 to 35 bpm during this time. The resultant bias, precision and A_{RMS} for the capnometer was -1.17, 3.74, and 3.92 bpm respectively. The bias, precision and A_{RMS} for the bioacoustic sensor was -0.03, 3.49, and 3.49 bpm respectively.
Discussion:
The new prototype bioacoustic respiratory sensor demonstrates accuracy for respiratory rate monitoring as good as capnometry, in this population of pediatric patients in the PACU. This device offers multiple benefits over existing devices and has a potential to improve monitoring in a general care setting. In clinical settings where continuous and reliable monitoring of spontaneous respiration is important the new bioacoustic sensor provides equivalent accuracy; however, does not require a cannula system. This should lead to significantly more reliable monitoring of respiration rate.

References:
1) Pediatrics 2006;117;1170-1178
2) Medical and Biological Engineering and Computing 2003;41;377-383

Title – Continuous Non-Invasive Measurement of Hemoglobin via Pulse CO-oximetry During Liver Transplantation, a Case Report

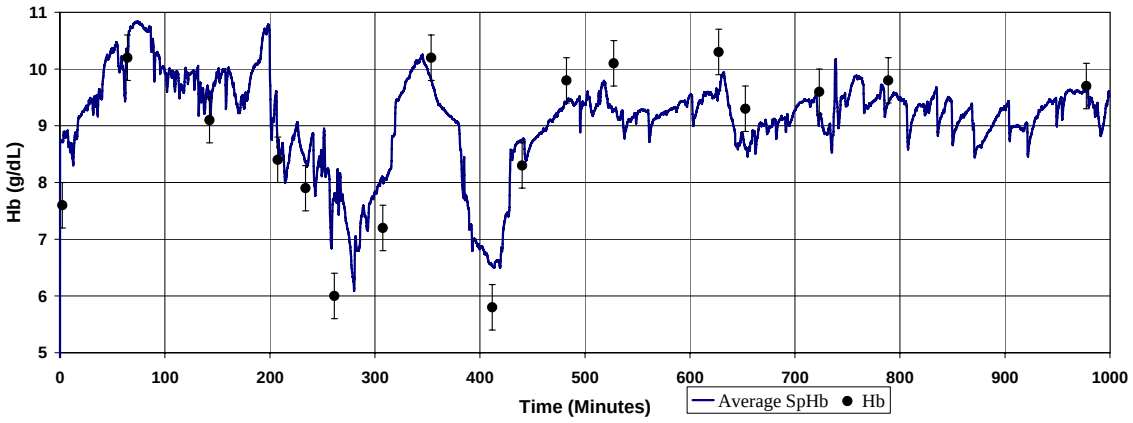
Authors – M. R. Macknet MD, P. Kimball-Jones MD, R. Applegate II MD, R. Martin MD, M. Allard M.B.Ch.B FRCA
Institution - Loma Linda University, Department of Anesthesiology

Background: New advances in pulse oximetry technology have led to the development of a prototype multi-wavelength pulse CO-oximeter designed to continuously and non-invasively measure hemoglobin concentration (SpHb). This case report examines this device's ability to measure continuous SpHb during liver transplantation surgery and evaluates the accuracy compared with hemoglobin concentration (Hb) measured by a laboratory CO-oximeter.

Methods: After IRB approval and informed consent, a 65 year old female scheduled to undergo liver and kidney transplantation was monitored with three prototype SpHb sensors, optically isolated from each other, attached to a data collection system (Masimo Inc., Irvine, CA). Routine anesthetic care of this patient was not altered and no treatment decisions were made based on the SpHb numbers. Data was collected throughout the course of the surgery. Per routine blood samples were gathered a minimum of every hour and more frequently if clinically indicated. Arterial blood samples were analyzed by laboratory CO-oximeter (Radiometer ABL735), and the resulting Hb measurements were compared with the data collected from the corresponding SpHb readings.

Results:

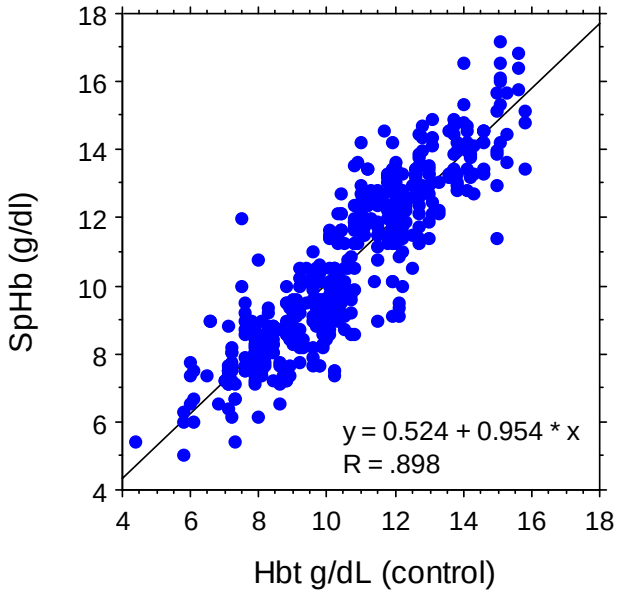
The patient was monitored for a total of 16.6 hours. During that time 17 Hb/SpHb data pairs were collected. The hemoglobin concentration ranged from 5.8 to 10.3 and the bias of the SpHb sensors was 0.146 and precision was 0.740. The graph displays the average of the three SpHb sensors and corresponding CO-oximeter measurements. The precision of the Co-oximeter is 0.4 g/dL.



Discussion: SpHb correlated well with CO-oximeter determined Hb during most of this complicated procedure. Measurements showed good correlation during times of rapidly changing Hb concentration related to surgical blood loss and transfusion. Continuous and non-invasive hemoglobin monitoring would be an extremely useful tool in many clinical scenarios. This technology has the potential to greatly improve patient care and safety during surgical procedures.

Title – Continuous Non-Invasive Measurement of Hemoglobin via Pulse CO-oximetry
Authors – M. R. Macknet MD, S. Norton MD, P. Kimball-Jones MD, R. Applegate II MD, R. Martin MD, M. Allard M.B.Ch.B FRCA
Institution - Loma Linda University, Department of Anesthesiology

Background: New advances in pulse oximetry technology have led to the development of multi-wavelength pulse CO-oximeters designed to measure multiple physiologic parameters. The utilization of multiple wavelengths has led to the development of a prototype pulse CO-oximeter that allows for measurement of continuous hemoglobin concentration (SpHb). This study examines this device's ability to measure continuous SpHb and evaluates the accuracy compared with hemoglobin concentration (Hb) measured in a laboratory CO-oximeter.
Methods: After IRB approval and informed consent, 19 patients scheduled to undergo surgery and 9 healthy volunteers undergoing a hemodilution protocol were enrolled in this ongoing study. Each subject was monitored with ASA standard monitors and a radial artery cannula. Three prototype SpHb sensors, optically isolated from each other, were attached to a data collection system (Masimo Inc., Irvine, CA). Routine anesthetic care of these patients was not altered. The hemodilution protocol consisted of withdrawal of 1 unit of blood and replacement with 30ml\kg of saline. Data was collected throughout the course of each surgery and during hemodilution. Arterial blood samples were analyzed by laboratory CO-oximeter (Radiometer ABL735), and the resulting Hb measurements were compared with the data collected from the corresponding SpHb readings. Regression analysis and bias, precision and A_{RMS} were calculated.
Results: 458 data pairs were collected from a total of 28 subjects (16.3 $\pm$ 8.1 per subject). The mean ($\pm$ SD) and range of Hb values were 10.6 ($\pm$ 2.3) and 4.4 to 15.8 g/dl respectively. Bias, precision and A_{RMS} were -0.039, 1.09, 1.09 respectively. The figure shows the correlation between Hb and SpHb and the regression analysis. The y intercept is 0.524 and the slope is 0.954 and the correlation coefficient is 0.898.
Discussion: This device is the first device developed that can continuously and non-invasively measure hemoglobin concentration in addition to the other common hemoglobin species, and therefore provides a significant expansion of existing physiologic monitoring technology. Rapid measurement of hemoglobin would be an extremely useful tool in many clinical scenarios. This technology in combination with methemoglobin and carboxyhemoglobin measurements should allow for significant advances in patient care.



Changes in the Pulse Oximeter Waveform Predict Pre-syncope during Lower Body Negative Pressure

Suzanne M. Wendelken*, George T. Blike**,Susan P. McGrath*
*Thayer School of Engineering, Dartmouth College; Hanover, NH; **Department of Anesthesiology, Dartmouth Hitchcock Medical Center, Hanover, NH

Introduction: Continuous noninvasive monitoring of patient physiology is needed outside the operating room to identify patients who develop unanticipated acute deterioration**.** We have previously examined using the pulse oximeter waveform to determine airway patency and respiration [2-4]. We now investigate its utility as a monitor of circulation. The pulse oximeter waveform, or photoplethysmogram (PPG), measures changes in blood volume under the sensor and closely resembles an arterial waveform. Some have suggested that it correlates with hemodynamic parameters such as blood pressure and cardiac output [5-7]. The PPG has previously been studied in patients sustaining blood loss or other hemodynamic stress during surgical procedures [5, 7-10] and moderate blood loss for conscious patients [11]. In this experiment, we studied the PPG in both the time and frequency domain in subjects undergoing simulated hypovolemia during lower body negative pressure (LBNP). LBNP simulates blood loss by sequestering blood in the lower extremities [1]. This method can safely simulate stage III hypovolemia in healthy subjects in the absence of complicating effects from pharmaceuticals [1]. We hypothesize that changes in certain parameters derived from the PPG will predict hypotension and pre-syncope in subjects undergoing LBNP.

LBNP Level	est. blood vol. loss	n	Stroke Volume (IC)	
mm Hg	ml		% change	p
15	400 - 550	20	-13	0.06
30	500-1000	20	-30	2.E-03
45	1000-1500	18	-46	4.E-04
60	1500-2000*	10	-61	2.E-04
70	2000-2300*	6	-68	3.E-04
80	2300-2600*	1	-76	0.15
Recovery		20	-2	0.62

Table 1: LBNP level, estimated blood volume loss, n - the number of subjects completing each LBNP level, and stroke volume change from baseline calculated from impedance cardiography. P values are from the Wilcoxon rank-sum test for equal medians. * denotes data extrapolated from [1].

Methods: With IRB approval, 20 healthy subjects aged 18 to 30 were monitored continuously with a Nonin® forehead, finger, and ear pulse oximeter sensors (OEM III module, sample frequency of 75 Hz) in addition to the standard monitoring equipment including ECG, Finometer blood pressure impedance cardiography (stroke volume), and nasal cannula. Five minutes of baseline were recorded followed by five minute increments of increasing lower body negative pressure until the subject reached pre-syncope. Data was also collected for five minutes following pre-syncope.

Information describing each cardiac cycle including the pulse height, full width half max, and instantaneous heart rate, was automatically extracted from the PPG using a mixed state feature extractor written in Matlab® programming language. In the frequency domain, the power density of the respiratory and cardiac components were computed using the periodogram method (nfft = 2^{14} data points) with a Hamming window. The mean and standard deviation of all parameters was computed for each LBNP level for all subjects and all PPG sensors. The Wilcoxon rank-sum test for equal medians was used to test for statistically significant changes in all parameters.

Results: Lower body negative pressure levels, estimated blood loss, and stroke volume changes calculated from impedance cardiography are shown in Table 1. Statistically significant changes were observed in the pulse height, pulse width, instantaneous heart rate, and in power densities of the respiratory and cardiac component of the PPG for all sensor locations. These results are summarized in Table 2. Often these changes were observed as early as the first stage of LBNP, equivalent to Stage 1 hemorrhagic shock, and up to twenty minutes before pre-syncope. In addition, many parameters from the PPG correlate with changes in stroke volume (e.g pulse height in Figure 1).

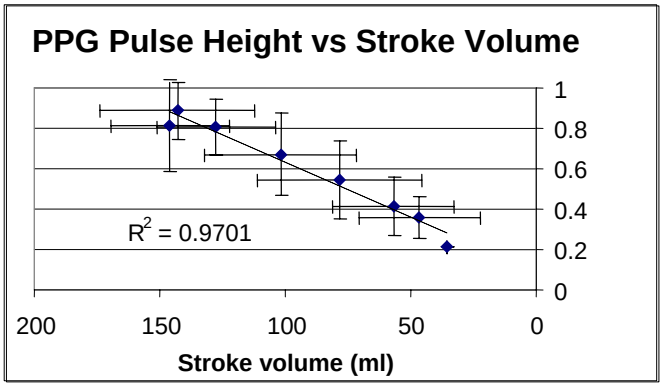


Figure 1: Normalized pulse height from the forehead PPG decreases linearly with stroke volume during LBNP. Error bars represent the standard deviations of each measurement.

Conclusion: Statistically significant changes in the PPG in both the time and frequency domain were observed ten to twenty minutes before pre-syncope during lower body negative pressure in all pulse ox sensor locations. Further analysis is needed to determine which PPG sensor location is the best for monitoring blood volume status. These results support using the pulse oximeter waveform to detect clinically significant hypotension secondary to hypovolemia.

Acknowledgement: Special thanks to Dr. Kathy Ryan, Dr. Victor Convertino and the rest of the research staff at the Institute for Surgical Research, Ft. Sam Houston, San Antonio, TX for their clinical and technical support.

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Ear Pulse Ox

LBNP Level	Pulse Height		Pulse Width		Instantaneous HR		Respiratory Power		HR Power	
mm Hg	% change	p	% change	P	% change	p	% change	p	% change	p
15	-12	0.38	3	0.60	1	0.76	35	0.20	3	0.84
30	-25	0.04	0	0.09	8	0.32	47	0.15	-2	0.60
45	-41	4.E-04	-11	4.E-04	21	0.02	155	0.01	-28	6.E-05
60	-57	1.E-04	-28	3.E-05	29	5.E-03	152	0.05	-75	2.E-05
70	-62	9.E-04	-42	3.E-04	41	4.E-03	38	0.90	-79	4.E-04
80	-74	0.12	-46	0.11	31	0.22	211	0.16	-51	0.11
pre-syncope	-39	4.E-03	-48	1.E-07	59	4.E-08	251	3.E-06	-60	1.E-07
Recovery	34	5.E-04	-6	0.08	-3	0.66	-24	0.26	-59	4.E-07

Finger Pulse Ox

LBNP Level	Pulse Height		Pulse Width		Instantaneous HR		Respiratory Power		HR Power	
mm Hg	% change	p	% change	P	% change	p	% change	p	% change	p
15	-32	0.04	-4	0.53	1	0.84	13	0.49	4	0.93
30	-22	0.04	-5	0.23	-1	0.35	-17	0.62	-2	0.53
45	-36	0.03	-21	3.E-04	24	0.02	61	0.06	-23	7.E-04
60	-43	0.05	-33	1.E-05	35	5.E-03	103	0.03	-78	5.E-05
70	-51	0.02	-38	3.E-04	63	5.E-04	-22	0.98	-81	4.E-04
80	-40	0.68	-38	0.12	60	1.E-01	77	0.36	-85	0.16
pre-syncope	-43	6.E-03	-31	6.E-06	73	5.E-08	145	6.E-04	-58	3.E-05
Recovery	63	4.E-06	15	2.E-05	-2	0.76	33	0.25	-43	2.E-04

Forehead Pulse Ox

LBNP Level	Pulse Height		Pulse Width		Instantaneous HR		Respiratory Power		HR Power	
mm Hg	% change	p	% change	P	% change	p	% change	p	% change	p
15	-1	0.42	2	0.35	1	0.92	15	0.39	-8	0.29
30	-18	0.03	0	0.80	2	0.31	32	0.24	-11	0.19
45	-33	5.E-04	-7	5.E-03	20	0.02	60	0.01	-38	2.E-04
60	-49	4.E-04	-23	3.E-05	29	2.E-03	87	0.03	-82	1.E-05
70	-56	2.E-03	-36	3.E-04	40	2.E-03	65	0.06	-89	2.E-04
80	-73	0.16	-46	0.12	45	0.12	99	0.36	-85	0.11
pre-syncope	-43	2.E-04	-36	1.E-07	52	1.E-07	151	2.E-05	-82	8.E-08
Recovery	9	0.30	0	0.54	-2	0.80	10	0.43	-48	8.E-06

Table 2: This table details changes from baseline in pulse height, pulse width, instantaneous heart rate, respiratory power, and cardiac power densities of the PPG for each level of LBNP for all three pulse oximeter sensors. *P* values are the significance level of the Wilcoxon rank-sum test for equal medians. Statistically significant changes exceeding the $p<=0.05$ significance level are highlighted.

Gas Man® Version 4 – A Work in Progress

James H Philip, M.E.(E.), M.D.[1,2,3,4], Hal M. Franklin B.S.[5]

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Gas Man® (GM) is a computer simulation of inhalation anesthesia kinetics. The program was conceived and written for the Apple 2+ Computer by James Philip in 1980 under a Grant from the Apple Educational Foundation to Brigham and Women's Hospital (BWH). Gas Man was first shown publicly as a Scientific Exhibit at ASA in 1982. In 1983, BWH transferred copyright and title to the author.

In 1984 GM Ver 1 program and textbook was published by Addison-Wesley Medical/Nursing Division (AWMND); copyright was returned to Dr. Philip in 1986 when AWMND closed. In 1989, the GM Ver 1 program and textbook was tested and shown to be effective in teaching knowledge, skills, behavior, and attitude concerning inhaled anesthetics(1).

In 1989 GM Ver 2 for Macintosh was written by IntelliMetrics Inc of Billerica MA. Dr. Philip first presented GM Ver 2 at the FDA-sponsored Simulator Conference in 1989.

In 1991, H M Franklin Associates (HMFA) of San Ramon CA <www.hmfa.com> wrote GM Ver 3, adding new features and targeting Microsoft and Macintosh OSs via the Microsoft Foundation Class Library (MFC). Emphasis was placed on creating a professional product with device independence, commercial installation features, integrated online help, and modern appearance.

In the mid 1990's, Microsoft ceased to support MFC on non-Microsoft platforms. Since 2000, MFC has been supplanted with newer technology. As a result, there was no progress on the Macintosh platform since 1995 while the more advanced GM Ver 3.1.9 is the current version for evolving Microsoft Windows platforms.

In 2005, HMFA and RIC International of Cambridge MA <www.ricintl.com> translated GM Ver 3.1.9 and its Help System to French. In 2007 this will be provided free throughout France by Abbott.

In 2006, to respond to mounting requests for additional features and a more modern interface and to regain the ability to perform on all major operating systems and hardware including OS X, HMFA and ICS of Bedford MA <www.ics.com> began migrating GM to the implementation-neutral Qt framework by Trolltech of Oslo Norway <www.trolltech.com>. This will allow operation on Windows 2000, XP, and Vista, and Mac OS X. First showing of GM Ver 4 is planned for January 2007.

When complete, Gas Man Ver 4 by Med Man Simulations Inc of Chestnut Hill MA, a nonprofit corporation, <www.gasmanweb.com> will have most of the following new features: Lung Shunt; Alveolar Dead Space; Ether, Cyclopropane, Xenon, He, Ar; BMI (Obesity not just size); Ventilation-CBF interaction; Compartment Sums, Differences, Ratios; Continuous Circuit Infusion of Liquid Inhalants; Achieve any Target in any Compartment; Ramped change in Del (Underwater ascents); External Links; Editable Scripts; same ".gas" file for all platforms; Pictures of Compartments Scale with Volume and Solubility; Cost in Any Currency; Unified Tabbed Dialog Box for Parameters; Combined Picture-Graph Display; All Controls on Active Display; Add Additional Agents while Simulation runs.

Reference:

1) Garfield JM, Paskin S, Philip JH. An evaluation of the effectiveness of a computer simulation of anesthetic uptake and distribution as a teaching tool. Med Educ. 1989;23:457-462.

Residents Can Complete Gas Man Homework and Demonstrate Core Competency in Inhalation Kinetics

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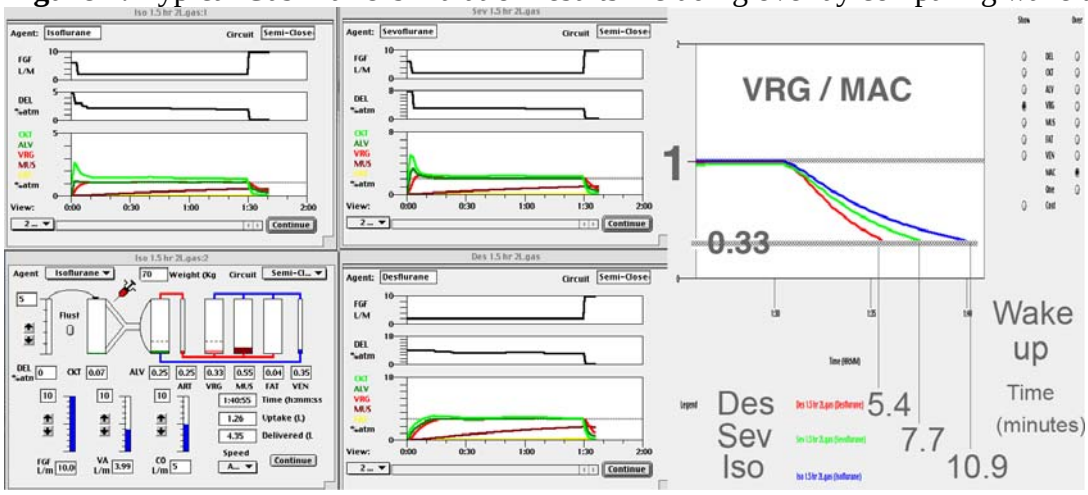
Introduction: Core competency in inhalation anesthesia is important for Anesthesiology Residents. In 2005, Eger and Shafer published a Tutorial that demonstrated that the Gas Man® Computer Simulation Program[1] can teach complex topics in inhalation anesthesia kinetics. Their example was context-sensitive decrement times[2]. In order to understand whether Anesthesia Residents could demonstrate Core Competency in Inhalation Kinetics, we began assigning Gas Man homework to residents on the BWH Ambulatory Anesthesia service.

Methods: An e-mail stating the homework assignment was sent to each resident at the beginning of their 1-month rotation. The assignment was to simulate administering 1 MAC (alveolar) anesthesia for 1.5 hours, simulate emergence, and measure wake up time (time for Brain to reach 0.33 MAC). This was to be performed with Isoflurane (I), Sevoflurane (S) and Desflurane (D) using a standard semi-closed breathing circuit. The educational goals were: 1) maintenance of anesthesia at constant depth, 2) wake up with high fresh gas flow and normal ventilation, and 3) ability to use the Gas Man® program.

Results: Twenty-five (25) of 26 residents received the assignment. All 25 completed the homework. Of these, 22 of 25 demonstrated they mastered all 3 goals. Three (3) residents failed to grasp 1 goal: administering anesthesia at constant depth. Instead, they gave constant inspired concentration resulting in increasing depth. All 25 responders used the Gas Man® program successfully. Wake up (VRG = 0.33 MAC) times (Mean ± SD [min]) reported by residents were I = 10.7 ± 1.8, S = 7.9 ± 2.2, D = 5.8 ± 1.0 min. These did not differ from the instructor's times of I = 10.9, S = 7.7, D = 5.4 minutes.

Figure 1: Typical Gas Man® simulation results including overlay comparing wake up**.**



Summary: Residents can demonstrate core competency in inhalation kinetics by using the Gas Man® computer simulation. Those residents who did not initially grasp the didactic concepts were identified, given additional instruction, and then demonstrated competency.

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1, Philip JH. GAS MAN® - Understanding anesthesia uptake and distribution. Med Man Simulations Inc., Chestnut Hill MA, a nonprofit corporation, 2004.
2. Eger EI, Shafer SL. Tutorial: Context-Sensitive Decrement Times for Inhaled Anesthetics. Anesth Analg 2005 101: 688-696.

Y2K7: Time and Calendar Deja Vu, This Time in 2007

S. Mark Poler, MD, Dale W. Palmer, Robert J. Murcek
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In 2005 a bill was passed by Congress and signed into law by the President that increases the duration of Daylight Saving Time by 4 weeks, changing the assigned dates for transition from Standard Time to Savings Time in United States time zones (1,5). The primary purpose of Daylight Saving Time is to reduce overall national energy consumption (2,4). It has unintended operational implications for correct representation and allocation of time, and for keeping of correct time notations in medical records for practical and legal reasons. Special consideration is due for automated devices that may not be properly programmed for the new rules (e.g. embedded, application, or operating system software not updated for new rules).

The Y2K problem involved a single transition between centuries in the year 2000. Unlike the Y2K problem perpetrated by programming practices employing two digit abbreviated representation of 4 digit years; the impact of this legislative act will apply twice every year starting in 2007. Time references based on UTC and standard time zone offsets will not be affected by the one hour Saving Time offset.

Computers, networks, servers, and software applications need to have software modifications (a.k.a. “patches”) applied in order to properly handle time changes. Because of system differences, operating systems based on Microsoft Windows, unix type systems (including Linux, Apple Mac OS X and others), and Java applications require different management strategies (3).

Devices with internal clocks, microprocessors programmed using previous transition date rules could supply incorrect time annotations of clinical consequence for periods of weeks starting in 2007. Legacy devices programmed to make transitions between Standard Time and Daylight Saving Time on weekends designated to start or end Saving Time in years before 2007 will not execute changes on the newly designated dates without re-programming.

This presentation is primarily intended to make readers aware that changes in transition dates between Standard and Saving protocols has clinical implications. The presentation will provide additional details and resources.

References (accessed 5 January 2007)

(1) Energy Policy Act of 2005, Public Law 109-58, 42 USC 15801.
(2) http://globelogger.com/item.php?id=839
(3) http://www.ibm.com/support/alerts/daylightsavingstimealert.html
(4) http://webexhibits.org/daylightsaving/b.html
(5) http://aa.usno.navy.mil/faq/docs/daylight_time.html

Title: A Comprehensive Computing Solution on a Zero Budget.

Authors: J M Watkins-Pitchford MBBS FRCA, D Jablonka MD, N Vadivelu MD, K H Shelly MD PhD, R Sinatra MD PhD,

Summary: A server-client cluster for anesthesia faculty and residents was constructed and maintained legally on a zero budget for 3 years. Services provided included a web-server, mailserver with list-server, and 5 clients with an office suite, web browsing, schedule publishing, desktop publishing, graphics and statistical analysis.

Method:

A server computer was assembled from derelict and outdated computers from our institution, resulting in a reliable machine, now up for 4 years. Open source software based on Linux included Apache webserver, Exim and Sendmail mailservers, WordPress discussion boards, and our own "Sgt Joe" fax-to-webpage software. Dynamic websites were constructed with HTML PHP and MySQL. The 5 client worksations were built from similar hardware, and each were equipped with Microsoft-compatible Office suite (Open Office.org), Mozilla-Firefox web browsing. A Microsoft-compatibility layer was added to provide Anesthesia Simutaor and TEE Tutor capability. A novel self-maintaining system has kept both server and workstations virus-and malware free for 4 years.

Results:

A Web and mail server has run now for 3 years one month, with no involuntary downtime. The 5 workstaions are used over this period by some 30 faculty and 50 residents. No security breach has been detected, and mail server has yet to serve the first spam. User opinion is overwhelmingly positive, though greater speed is often requested -without the modest financial support to achieve it.

Discussion:

Choosing free Linux was not easy, as only one of us had a little exposure to UNIX. Four years of stable operation and no forced reinstallations have convinced us of the wisdom of the choice. Security is several layers deep: state-aware NAT firewalls, proxies, port-monitoring and automatic response to attack while maintaining an open and welcoming user interface. Linux has no commonly encountered viruses, but we check for their presence. We considered a kiosk implementation of the workstions, but we designed a more flexible and user-friendly approach, our own "Houseclean". Each night, userspace and other critical areas are backed up, and then they are completely erased. A secure restore is then performed from a 'clean' template, followed by a restart We then have no viruses, malware, only a certified clean system. If an important item was erased, it can be recovered from the backup. A novel system for secure posting of faxed schedules and assignments has been created. This make it easy for non-computerate colleagues to post hand-written documents on a web page. Other popular features are the ability to post lectures with batch security-watermarked slides together with MP3 sound. We also have One-Stop-Shopping for meetings and events; a single web page announces, give travel directions and maps, distributes essential reading, and compiles a list of attendees.

Conclusion:

A stable computing system has been constructed and maintained on a zeero budget. The educational value has been transformational. We now move on to a fast server - thin client replacement for this project.

References:

Per Andersen: The Texas Tech Tornado Cluster: A Linux/MPI Cluster For Parallel Programming Education And Research
http://www.acm.org/crossroads/xrds6-1/tornado.html

Robert W. Lucke.Building Clustered Linux Systems. ISBN-10: 0-13-144853-6; ISBN-13: 978-0-13-144853-7; Sep 21, 2004; Copyright 2005 Prentice Hall.

Title: Lack of Check Valves on Secondary IV Sets may lead to inadequate anesthesia during induction

Authors: James H Philip, M.D., M.Eng.,
Affiliation: Anesthesiology, Perioperative and Pain Medicine, Brigham and Women's Hospital, Boston, MA, United States.

Background: The ASA Practice Advisory for Intraoperative Awareness and Brain Function Monitoring (ASA HOD 10-25-2005) included the words [During the] pre-induction phase of anesthesia verify the proper functioning of intravenous access, including the presence of appropriate back-flow check valves. The purpose of this communication is to demonstrate that appropriate back flow check valves (CV) include one on the Primary IV Access Set and another on a Secondary IV Set which might be used for antibiotics or other infusions.

Methods: As part of CQI, a survey was sent to the Anesthesiology Residents, Fellows and Faculty at a major teaching hospital. Clinicians were asked Have you had induction drugs not get to your patient because they back up into the antibiotic or other IV line? All Anesthesia Primary IV Sets in the institution have a CV located above the first injection port. There is no CV in the Secondary IV Set used to administer antibiotics and other infusions. A separate Luer lock CV is available in the drawer of every Anesthesia Supply Cart.

Results: Responses were received from 27 Staff, 1 Fellow, and 25 Resident Anesthesiologists, 52 in all. Because there was only one Fellow respondent, Residents and Fellows are combined and called Residents hereafter.

Of the 52 respondents, 32 responded yes and 20 responded no. Thus 62% of respondents reported induction drugs not getting to their patient because the drug backed up into the Secondary IV Set used for antibiotics or other infusions.

When Faculty and Residents were compared, they reported yes 48% and 76%, respectively ($p<.05$ Chi Sq).

Table 1: Response yes to induction drug back up question

RESPONSES	No	Yes	Total
Staff	14	13	27
Residents	6	19	25
Total	20	32	52

Table 2: Percentage yes to induction drug back up question

PERCENTAGE	No	Yes	Total
Staff	52%	48%	100%
Residents	24%	76%	100%
Chi square	<0.05		

Discussion: Even when a CV is part of the Anesthesia Primary IV Set, if there is no CV in the Secondary IV set used for antibiotics and other infusions, a very high percentage of Residents, and to a lesser degree Faculty, observed anesthesia induction drugs not getting to their patient because the drugs backed up into the Secondary IV Set.

It is therefore recommended that for Anesthesia, in addition to Primary IV Sets, each Secondary IV Set should contain a Back Flow Check Valve (CV) to protect against backup of induction drugs and inadvertent light anesthesia.

Summary: Many Anesthesiologists observe induction drugs back up into Secondary IV Sets during induction. This suggests the need for a Back Flow Check Valve in Secondary IV Sets.

Title: Device to Measure Tissue Hydraulic Impedance
Authors: Thomas Edrich Ph.D., M.D., James H Philip, M.D., M.Eng
Department of Anesthesiology, Perioperative, and Pain Medicine
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Introduction:
Tissue Hydraulic Impedance can be defined as the complex resistance that is felt when injecting fluid into biological tissue spaces. Anesthesiologists use this method on a qualitative level when advancing a needle into the epidural space to place an epidural catheter. The sudden “loss of resistance” occurs when the needle tip passes from a ligament with high impedance to the epidural space which has very low impedance. Pitfalls include reaching a “false space” with low impedance to the initial injection. This can be recognized by the increasing hydraulic impedance after subsequent fluid injections.

Method:
A device is placed between the syringe and the needle. It consists of a channel with 2 pressure transducer ports as shown in the figure below. As the user tests the hydraulic impedance in the usual fashion by depressing the plunger of the syringe with her thumb, the flow of fluid past a mild stenosis between the ports causes a pressure difference to build up. This is a measure of the instantaneous flow rate. The hydraulic impedance (Z) can be calculated by dividing the distal pressure (P) by the flow rate (I): $Z=P/I$.

Results:
In-vitro testing was performed using a prototype of the depicted device. The device was placed between an epidural needle (17 Gauge, 3.5 inches) and a 5 mL glass syringe filled with saline. Clinical pressure transducers (Edwards Life Sciences, Inc.) and an Eagle Monitor (Marquette) were used to measure continuous pressures at both ports. Pressure readings were transmitted to a PC using BedMaster software® (Excel Medical Electronics, Inc.) and processed using MATLAB®. An experienced anesthesiologist tested the setup by inserting the needle and injecting saline into several different Styrofoam blocks. The consistency of these blocks was chosen to simulate different biological tissue types. Variable pressure was applied to the foam to modulate the hydraulic impedance. Certain foam types exhibited the phenomenon of the “false space,” increasing the hydraulic impedance rapidly after subsequent fluid aliquots had been injected.

Conclusion:
We have created a new device that is able to identify a simulated tissue plane by quantifying the impedance to fluid injection. It fits between the needle and the syringe and should not significantly disturb the clinician in his usual technique. In-vitro testing using simulated tissue blocks showed this technique to be promising. It augments the clinician’s tactile sense by evaluating the hydraulic impedance in a quantitative fashion. This technique may find application in other clinical settings where needle tips must be guided to tissue planes beneath the surface.

Summary:
A new device that measures tissue hydraulic impedance was developed and tested with an in-vitro model. It may assist in identifying the epidural space or other desired tissue planes.

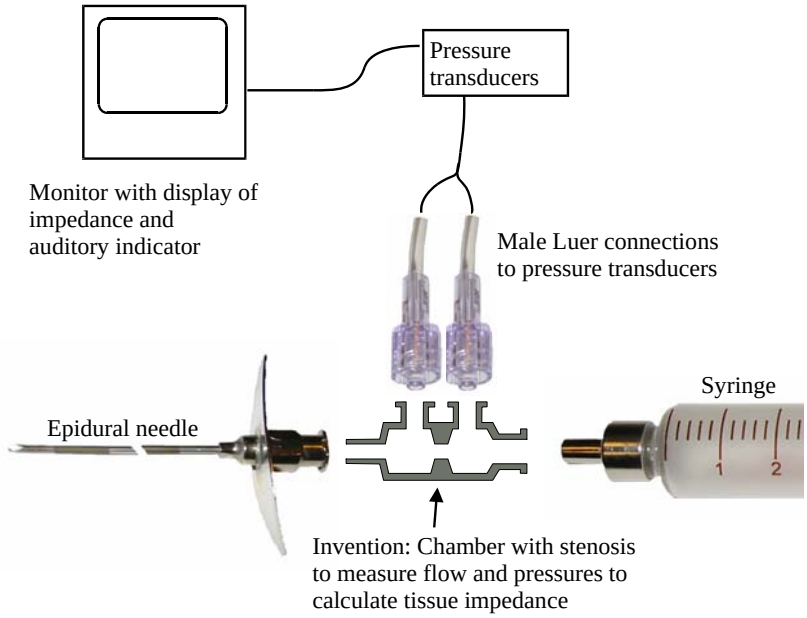

Figure 1. Setup to measure tissue impedance

Installation and Operational Implications of Primex GPS Synchronized Clocks

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Consistent and accurate references for time of day are very important in medical institutions. Recorded times especially serve as the basis for scheduling and billing, to record times of occurrence and duration of clinical events. Accurate and synchronized time references are essential for representation and interpretation of time-based data.

At our institution discrepancies among independent timepieces in close proximity including wall clocks, wrist watches, cell phones and PDAs, free-standing computers, and networked computers commonly were on the order of 5 minutes, and occasionally in the range of 10-15 minutes (1). The legacy Simplex synchronized clocks installed in some areas of the medical center became unreliable or non-functional. Even with daily auditing, efforts to sustain reasonable synchronization of independent clocks proved futile. In order to address the inconsistency of time references a program to systematically replace independent clocks with synchronized clocks has been undertaken.

Two alternative approaches to synchronizing a large number of clocks were considered. One employs base stations transmitting synchronizing radio signals (2, 3). The other employs network wiring to each clock location, each clock being a special-purpose networked computer (various vendors, e.g. Ref 3). There are trade-offs to each approach, including ease and cost of initial deployment, preventative maintenance and support, and monitoring and management. A significant distinction between these synchronization approaches is whether auditing of the status of clocks can be automated. The wireless clocks have no status feedback except user reports or reconnaissance. Networked clocks are amenable to centralized management and may be configured to send regularly scheduled reports or respond to queries with polled reports.

Primex radio-synchronized clock systems were chosen for installation (2). The first areas to be deployed have been the clinical arenas where timeliness and determining temporal sequences of events are most frequently consequential. These include obstetrics (the Labor and Delivery Suite), the operating room areas, and the Emergency Department. So far 8 master transmitters, 3 slave transmitters, about 350 analog clocks, and 35 digital display clocks have been installed.

While the consistency of displayed time on Primex clocks has been a substantial improvement relative to having numerous unsynchronized time references, inconsistencies remain. Even adjacent Primex clocks can display different times (most often failure to associate with a base station, or association with unsynchronized base stations). Contributing factors include dates of manufacture, inconsistent battery performance and lifetimes, radio signal propagation and attenuation, configuration switch settings for radio base stations and slaves, delayed or missed transitions between Standard and Saving time periods, and small residual time differences among clocks in groups that should be synchronized. Many timekeeping devices, computers, and physiological monitors are still found in the facilities that are not synchronized to the Primex base stations. Thus inconsistent time-keeping persists.

Transitions between Standard and Saving time periods create theoretical and practical challenges during ongoing clinical matters. Digital clocks immediately display appropriate time after a transition, but mechanical dial clocks undergo a period of accelerated (i.e. incorrect, ambiguous) display change to reach the adjusted time.

Other selected characteristics of Primex clocks are worthy of mention. After losing synchronization, analog dial clocks begin to advance in two second increments; digital clocks simply begin to display dashes rather than numerals. There is currently no way to directly synchronize time of networked computers to the Primex systems. No network port option with time server (e.g. NTP) and monitoring functions is currently available. Availability of this expected feature has been delayed and is now expected in June 2007.

References (accessed 5 January 2007)
(1) http://www.anestech.org/media/Publications/Annual_2004/Poler2.pdf
(2) http://www.primexwireless.com/
(3) http://www.brgprecision.com/

www.AnesTech.org

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