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Editorial: Symposium: Simulation in Anaesthesia and Intensive Care Medicine 2000

Annual Meeting of the 'Society in Europe for Simulation Applied to Medicine' (SESAM) [1]

In April, the University of Mainz (Simulation Centre of the Department of Anaesthesiology) organized the SESAM 2000 meeting.

The meeting focused on research and training issues for patient simulation in health care. As the concept of realistic full-scale simulation is quite young, the need to exchange ideas and strategies is very strong. The development of new technical simulation features and software models is one aspect in the science of simulation. Another aspect is the psychology of simulation training. Therefore, the meeting was interdisciplinary, including technicians from simulator companies, researchers from technology institutes and psychologists with different research foci.

The use of realistic patient simulators is increasing rapidly. The benefits of simulation team training for improving patient safety is meanwhile accepted by official agencies [2,3]. A new concept to improve patient safety is the involvement of psychologists in training and evaluation strategies. Not as external advisers but as an integral part of the simulation team, where the psychologists have a thorough understanding of the clinical procedures and error-prone situations. The University of Tübingen was the first research group to implement this interdisciplinary approach on a long-term basis. The work and organizational psychologists of the Swiss Federal Institute of Technology (ETH) Zürich, spent many weeks in the real Operating Room (OR) to learn all aspects of anaesthesia patient care and the working conditions. For the involved physicians, it is important to learn psychological principles, human error theories and establish a common vocabulary with the psychological research partners.

Debriefing (discussion after a simulator session) is seen as a key element of simulator training [4]. Therefore, debriefing will be the main topic for the SESAM meeting next year in Scotland.

Still unsolved for many users is the problem of performance assessment during simulations and the proof that simulator training enhances patient safety. For the problem of performance assessment, it may be said that it is not inherent in simulator training but in the assessment of medical care in general. In medicine (for example compared with the aviation industry) there are only a few accepted 'Standard Operating Procedures', a lot of 'guidelines' are controversial and the need to adapt the management to the individual patient is often mentioned. In my opinion, the simulator community can not and need not solve these problems, even though simulators have the unique possibility to create realistic and reproducible patient care scenarios. Concerning the proof of increasing patient safety, it is important to know that no other high-risk industry using simulator training for improving the safety of operations (including flight simulators) has ever been able to show an increase in safety. This, of course, does not mean that there is no safety impact. Who would like to fly with a pilot not being simulator-trained in emergency flight procedures? We should not wait for that probably impossible proof in medical care before establishing simulator training and research programmes. The future is now!

Dr Marcus Rall

Department of Anaesthesiology,
University Hospital Tuebingen, Tuebingen, Germany
[Dr.Rall@t-online.de]

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Abstracts

ABSTRACT NO. 1

Management of an emergency care unit – simulation of a trauma patient on a full-scale simulator

A. Depta, S. Moenk, M. David, L. Hofmann and W. Heinrichs
Department of Anesthesiology, Johannes Gutenberg-University, Mainz, Germany

Management of the trauma patient has a lot of different demands in the work of the anaesthesiologist. Guidelines for the treatment of brain injured patients (causing, e.g. elevated intracranial pressure), management of thorax trauma patients (adverse effect on ventilation or circulation) or treatment of those with abdominal trauma (severe blood loss and haemorrhagic shock) have to be known [1–4]. Routine anaesthesiological skills (intubation, setting up central venous or arterial lines) should be done qickly and in a safe way. It is extremely important that interaction with other disciplines (neurosurgery, radiology, chest and abdominal surgery) should be performed efficiently [5].

With one group of anaesthetists (residents and consultants) with different experience in emergency room management (all members of the Department of Anesthesiology, University School of Medicine, Mainz, Germany) we trained theoretically and practically on a full-scale simulator in a realistic environment setting a guideline-oriented trauma-patient treatment. After a determined time, we compared any improvement of theoretical and practical skills in emergency room management with another group, which only had theoretical lessons in emergency room management.

The aim of this study was to show that theoretical and practical training of anaesthesiologists (with different experiences and educational background) on a full-scale simulator in a realistic environment setting improves knowledge of head, chest and abdominal trauma management and it can help to make therapeutic decisions faster and safer than theoretical training alone.

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ABSTRACT NO. 2

Key elements of debriefing for simulator training

M. Rall*, T. Manser† and S. K. Howard‡
**Department of Anaesthesiology, University of Tuebingen, Tuebingen, Germany (E-mail: Dr.Rall@t-online.de), †Department of Work and Organisational Psychology, Swiss Federal Institute of Technology (ETH), Zürich, Switzerland, and ‡Department of Anaesthesiology, VA Palo Alto Health Care System, Stanford University School of Medicine, USA*

Introduction The use of simulators to train crisis resource management is increasing constantly [1,2]. The detailed, video-based discussion of a simulator scenario with all participants directly after the session, with the aim to enhance self-reflection, is called 'debriefing'.

Methods A small survey was undertaken at 14 European simulator centres and at an interdisciplinary simulator workshop during the SESAM 2000 meeting in order to define the key elements of debriefing. As the numbers are very small only descriptive results are mentioned.

Results Respondents claim that debriefing is the most important part of realistic simulator training. Debriefing is crucial for a successful learning process, but if performed badly it can be the source of severe harm to the trainee. Debriefing can 'make or break' a simulator session and can be attributed as the 'heart and soul of simulator training'. Therefore, training of instructors in the art of debriefing should be emphasized. The debriefing instructor requires both clinical and teaching experience. As the setting of simulator training is very intense, coaching of the instructor by a psychologist is recommended.

Good debriefing requires a thorough briefing beforehand. Briefing should include (a) explaining to the participants that the session concerns learning, not performance assessment, (b) that confidentiality is maintained, and (c) that making errors is important for the training benefit. A nonthreatening atmosphere should be established and the crisis management terminology should be explained. The simulator should be explained in detail. Limitations of the simulation and how to deal with them should be stated. Admitting that the simulator is not completely realistic helps trainees suspend disbelief.

Elements of successful debriefing include: creating a good and friendly atmosphere, open-ended questions, facilitating of self-debriefing, positive reinforcement, open discussions on management aspects, pointing out underlying principles that lead to misconceptions/errors, using cognitive aids, showing alternatives, stressing that everybody makes errors, concentrating on few key learning points, and pointing out the good parts with the assistance of the audio-visual equipment.

Elements that should be avoided during debriefing are: closed questions, criticism using destructive language, concentrating on errors, blaming and ridiculing participants, focusing too much discussion on medical points rather than on crisis management aspects, too much instructor talking, too many teaching points, too long a debriefing period.

Conclusion Debriefing is the most important part of simulator training. Serious harm to trainees may result from poorly debriefed sessions. Training and coaching of instructors should be emphasized. Continuous studying and training of debriefing techniques in an interdisciplinary team involving psychologists should be the future.

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ABSTRACT NO. 3

From mega-code training to simulator session. What is the benefit for the patient?

H. Kuhnigk
Department of Anaesthesiology, University of Würzburg, Josef-Schneider Str.2, D-97080 Würzburg, Germany

Simulation is becoming more and more important in medicine, since it represents close approximation to reality. 'Full-scale' simulators developed for training and research imitating a real patient in respect of physiological and anatomical properties enables further development of and training in diagnostic and therapeutic progress without endangering the patient. If placed in a realistic environment they also enable individual training in the management of emergency situations, rare complications or special anaesthetic techniques as well as in the development of a teamwork approach.

In view of the high costs involved in sophisticated simulation technology it will be necessary to discuss differences in training systems, training concepts, and educational targets for different groups of health care providers and actual benefit for the trainee and the patient. However, experiences from other branches of technology show that the systematic introduction of simulation techniques has triggered optimization processes in many structures of application and organization.

Approaches to show a better outcome for the patient after simulator-based training are often associated with methodological or ethical problems. Valid criteria to demonstrate benefits for the patients have not yet been sufficiently assessed and will be part of future research.

ABSTRACT NO. 4

Training and evaluation of instructors

C. Lussi
Department of Anesthesiology, University of Erlangen, Krankenhaus Str. 12, 91054 Erlangen, Germany

Introduction Fidelity of human patient simulators cannot be compared to high fidelity flight or ship simulators. Therefore, instructors' training demonstrating the strength of simulation in dynamic moments and introducing the effect of illusion during static simulations play an important role in ensuring good student instruction. Furthermore, the introduction of human factors issues to medicine are an innovative aspect to tutors. This brief abstract describes an approach to structuring tutors' training and evaluation at the Erlangen institution.

Choice of tutors Future instructors should always volunteer for the task, as personal motivation is the driving force for a good tutor. If there is a choice of tutors, we look for the good all-round clinician with a more extroverted and warm personality, because making mistakes and leading students to correcting those in a good atmosphere is a key issue of training.

Initial phase Candidates undergo a typical crisis resource management (CRM) weekend course as a participant to experience the role of a student. With the help of an experienced instructor, the candidate then learns the basic commands of the simulator and gathers basic instructor experience during medical student courses with simple scenarios.

Second phase The candidate is invited to a human factors seminar conducted by a psychologist to learn basics of debriefing. S/he is then trained by debriefing scenarios from motion pictures, actual video sequences from past courses with other instructors and participating as a shadow instructor during a CRM course. This provides an insight into the work of instructors during such a course. A typical job during such a course might be playing the 'surgeon', preparing the scenarios and choosing video sequences for debriefing.

Final phase The candidate acts as an instructor of a course with an experienced back-up during a CRM course. This ensures high quality instruction and guarantees thorough feed-back for the candidate.

This instructor training course makes early use of candidates in educating medical students, but has high respect for quality aspects expected in CRM courses. Tutor training takes roughly 6–9 months. Evaluation is on a one-to-one basis during actual training, but in a written form by course participants from the medical student to the experienced physician. Only an open atmosphere with room for constructive criticism and early responsibilities of future tutors have led to a high level of tutor motivation. After all, the larger the team, the better the feedback, so the better the courses are going to be.

ABSTRACT NO. 5

When reality is difficult to simulate

A. Rettedal
Stavanger University College, Norway

Introduction The number of simulator centres in anaesthesia and intensive care has increased rapidly and the 'hands-on' simulators include progressively better functions and features. Nevertheless it is not possible to simulate a patient with all possible functions and systems. You have to choose the most important ones in order to maximize the outcome of the simulation scenarios you wish to use.

Methods The use of medical technology is increasing, and so is our attention to the different kinds of monitoring equipment. Every parameter you can look upon by means of a monitor, you can simulate – at least to a certain extent. What about the clinical signs impossible (for the time being) to pick up by a transducer and display on a screen? Anaesthetic and intensive care nurses are asking for the 'impossible': lip colour, rash, perspiration, tears, movements, sounds, pupils reflexes, etc. PatSim [1] is a simulator that has these types of clinical signs included. Lip colour and rash are given by light emitting diodes under the skin of the manikin. Perspiration, tears, secretion in the airways, gastric regurgitation, diuresis, bleeding are made by pumps or by pressurised reservoirs and controlled by valves. Movements are pneumatic.

Results Although these signs are not exactly 'true to nature', they give requisite inputs to the resident in order to give a more complete review of the 'patient'. They also play important roles in making the simulation scenarios more realistic (Fig. 1).

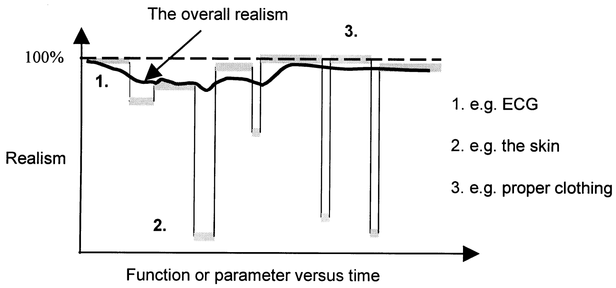

Fig. 1. Keeping the overall 'Illusion of Realism' up.

Even more trivial details such as proper clothing, correct surroundings, etc. influence the success of the scenario. To make an illusion successful, it is important to make the details – even the trivial ones – as realistic as possible. This has a 'forgiving' effect for the 'impossible' features, e.g. 'it is only plastic'. In slow-going scenarios typical in intensive care, increased workload of the resident together with manipulated time-scale, may raise the chance that the imperfections of the simulator escape notice.

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ABSTRACT NO. 6

Assessment of clinical performance during simulated crises occurring in dental conscious sedation

D. Buckley
Oral Surgery and Sedation Unit, Australian Health Management Group (E-mail: david.buckley@ahmg.com.au)

Although rare, life-threatening medical emergencies do occur in the administration of conscious sedation in dentistry. Dentists who incorporate the use of this modality within their practices have a professional responsibility to ensure that they are capable of managing any event which may result from treatment or occur at or around the time of treatment.

High-fidelity patient simulators have been shown to be of value in the training of anaesthetists and other health care personnel in dealing with emergencies. The Sydney Medical Simulation Centre, one of four simulation centres in Australasia is situated on the campus of the Royal North Shore Hospital and functions under the umbrella of the Department of Anaesthesia and Pain Management – University of Sydney. Several courses, specific to the special needs of different patient care settings, have been developed at the Centre, including a 2-day course specifically designed for conscious sedation in dentistry.

Performance assessment in dental conscious sedation has relied primarily on written and oral examination and on evaluation of actual clinical performance. However, examinations cannot easily assess what the examinee would actually do in a critical event, nor can they determine how well the candidate would interact with the rest of the clinical team. Realistic patient simulators offer a tool for the reproducible presentation of complex critical events – making it easier to compare performance in managing a crisis from one clinician to another or against a specific standard.

Based on strong analogies to performance during management of critical events in other complex, dynamic domains such as aviation, two separate aspects of skilled performance in managing clinical crisis situations have been defined: implementing appropriate technical actions (technical performance) and manifesting appropriate crisis management behaviours (behavioural performance). Technical performance concerns the adequacy of the actions taken from a medical and technical perspective. Behavioural performance concerns the decision-making and team interaction processes.

Techniques to evaluate the clinical performance of dental sedationists during critical perioperative incidents ('crises') are desirable for several purposes. These include assessing the educational progress or clinical competence of trainees or experienced practitioners and studying the efficacy of training methodologies.

The aim of this study is to design and evaluate a set of assessment tools that may be used in measuring the technical and behavioural performance of dentists in their management of realistic simulations of perioperative crises during the administration of conscious sedation.

ABSTRACT NO. 7

To err is human – a summary of the IOM-Report

M. Rall
Department of Anaesthesiology, University Hospital Tuebingen, Tuebingen, Germany (E-mail: Dr.Rall@t-online.de)

The report of the Institute of Medicine [1] published in December 1999 is a groundbreaking aggressive report about errors in medicine and how to improve patient safety. The core elements are of significant relevance for anaesthesiologists.

Adverse Events (AE) occur in 3–4% of all hospital admissions. Over 50% of AE are due to medical errors and could have been prevented theoretically! Approximately 10% of AE lead to death. If the numbers of two studies are extrapolated to all US admissions 44 000–98 000 Americans die each year due to errors. Taking these numbers into account, medical errors are the 8th leading cause of death in the US (breast cancer: 42 000 deaths).

The costs are estimated to be 17–29 billions a year. The report wants to break the cycle of inaction. Envisaged is a 50% reduction of AE in the next 5 years. This seems possible because the know-how exists to prevent many of these mistakes. Health care is just a decade or more behind other high-risk industries in its attention to ensuring basic safety. This means that dramatic, system-wide changes are required.

The report recommends: The focus must shift from blaming individuals to preventing future errors by designing safety into the system. Establishing a national Patient Safety Center to enhance the knowledge base about safety. Implementing periodic re-examinations and re-licensing. Paying special attention to the safe use of drugs and using proven medication safety practices. Designing of reporting systems: mandatory and public for severe injuries and deaths; voluntary and protected for minor injuries and incidents. Raising standards and expectations for safety issues and creating a safety culture: Safety as a declared serious aim, interdisciplinary team training programs and the use of simulators ('proven method') whenever possible. Finally the efforts should lead to safe practices at the delivery level, because 'it may be part of human nature to err, but it is also part of human nature to create solutions, find better alternatives and meet the challenges ahead' [2].

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ABSTRACT NO. 8

Teaching the management of medical emergencies

G. R. Nimmo*†, R. Glavin‡, M. Baruch† and S. Hartley†
**Acute Receiving Unit and †Resuscitation Training Department, Western General Hospital, Edinburgh, UK and ‡Scottish Clinical Simulation Centre, Stirling, UK*

Training students and doctors to deal with medical emergencies is problematic. Patients present sporadically at uncontrolled times. Learning by trial and error is unacceptable. In Anaesthesia and Surgery many of the core skills and emergency routines can be learned under direct senior supervision but the same is often not the case in Medicine. There is also a distinct gap between possession of knowledge and skills and their application: adequate knowledge in theory may not be translated into effective patient management.

In order to address these issues a Medical Emergencies Teaching Programme has been developed for final year Medical Students and new-start Medical Senior House Officers (SHO). This consists of a series of tutorials, skills stations and simulated acutely ill patient management scenarios which are filmed and used for debriefing. A Medical Emergencies Handbook has been written and provides the core materials for the course.

Tutorials are all interactive and based on real cases. They are organized through the seven weeks of the student course and are condensed in the SHO 2-day course. They include 'Initial Assessment and Management of the Acutely Ill Adult', LVF, shock, haemorrhage, anaphylaxis, acute coronary syndromes, respiratory emergencies, basic and advanced life support, prescribing drugs and talking to bereaved relatives.

Practical skill stations run in the 2nd and 3rd weeks of the student course. These cover airway support, how to administer oxygen and nebulisers, rapid infusion, using monitoring (ECG, pulse oximetry, cuff BP), the cardiac arrest trolley, basic and advanced life support and defibrillation.

Simulated patient management. Once the above skills have been learned the students then manage emergencies in real-time as a team of four, with access to all of the equipment and communications they would have in an acute clinical area, working on a 'low-tech' simulator. This is video-recorded and a debriefing teaching session immediately follows the case.

Scottish Clinical Simulation Centre. The final full day of the course involves real-time emergency patient management in teams using a high fidelity clinical simulator with video-recording and debriefing.

Summary This course combines cognitive and practical training early. The core philosophy of the management of the acutely ill patient is emphasized and standard core material issued from the start. There is early inclusion of real-time, hands-on patient management using a 'low-tech' system with video recording. These structured, sequential elements ensure that the students are familiar with the management of the acutely ill and with the teaching processes such that they gain maximally from the exposure to the high tech simulator. Feedback from the first 140 students completing the course has been unanimously positive. The next step is to evaluate the influence this teaching has on clinical management.

ABSTRACT NO. 9

Simulating desaturation

J. W. J. Bloor
Bristol University Medical School, Bristol, UK

When using simulation to teach acute emergency medicine the most fundamental emergency that it should be able to replicate is the interruption to oxygen supply. As part of a Special Study Module (SSM) at Bristol University Medical School and subsequently as part of my elective at the Royal Perth Hospital (Western Australia) I was able to investigate the simulation of desaturation.

The findings of my previous work [1] on the Medical Educational Technologies Inc. (METI) preceeded a change in their modelling. It was now possible to evaluate the changes they had made and extend the work to run the same experiments on a different simulator (Eagle MedSim) and compare the results. As there is no gold standard model for desaturation a mathematical model of desaturation was chosen and realizing its limitations it was compared with the modelling of the two simulators.

The METI and Eagle data-logging facilities were used to record the timecourse of fall in oxyhaemoglobin saturation following imposition of a 100% neuromuscular blockade. This was repeated for both simulators at various settings of Functional Residual Capacity (FRC 1530 mL, 2700 mL) and Fractional Inspired Concentration of Oxygen (FiO_2 21%, 100%). Oxygen consumption (250 mL min^{-1}), pulmonary venous admixture ('shunt' 2%) and respiratory quotient (0.8) were fixed for all runs. The timecourse of desaturation for both simulators was compared with that predicted by the mathematical model of Farmery & Roe [2] (Fig. 1).

To make the comparison between the three models as accurate as possible it was decided to omit the runs performed with FiO_2 100%. The reasoning behind this decision being that (a) it is known that the Farmery model has no apnoeic ventilation and (b) following preoxygenation PaO_2 values differed greatly prior to onset of apnoea.

The remaining runs all had a different timecourse of desaturation. By grouping the runs into their respective FRCs the different timecourses still remained. Knowing that the relationship between PaO_2 and SaO_2 is accurate [3,4] for each model, two obvious reasons for the discrepancies remained: (a) the pH effect on the oxygen dissociation curve described by Bohr; (b) differences in software modelling. Neither the pH effect or software modelling could account for the discrepancies alone.

METI had been able to improve their modelling of desaturation. Both METI and Eagle are now able to simulate the sense of urgency associated with desaturation in the clinical setting. They are not yet sophisticated enough to model the effects of pH and CO_2 changes during apnoea. This work has highlighted some of the problems of modelling complex human physiology and that there are areas that could

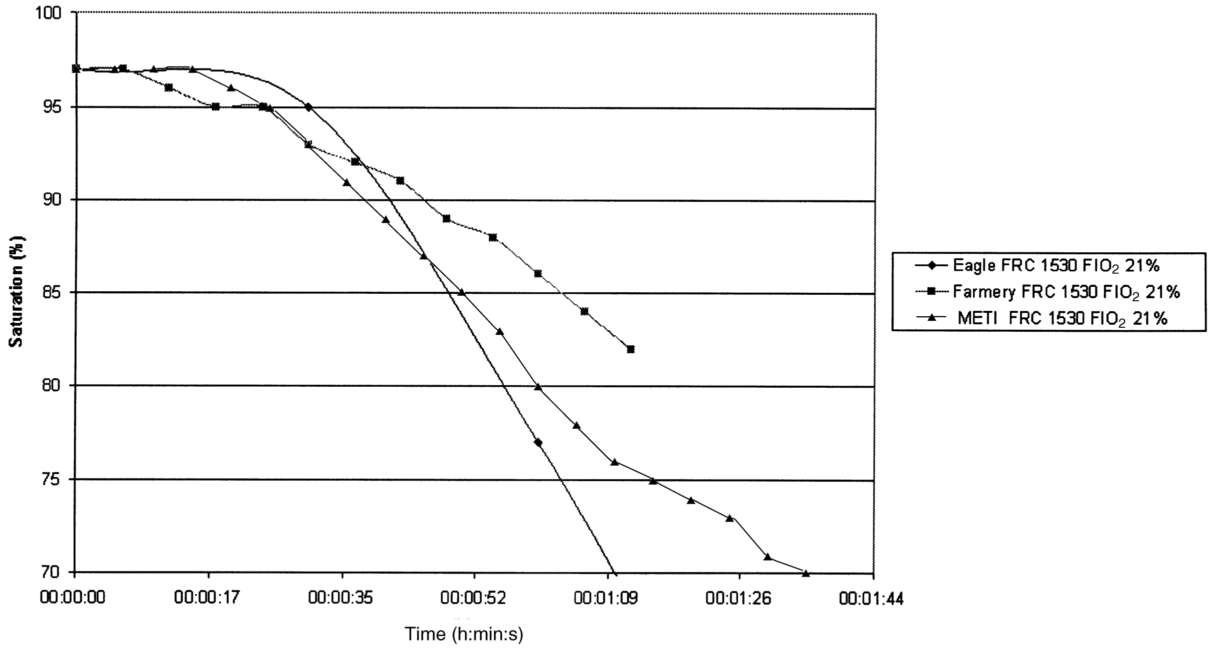

Fig. 1. Simulation of desaturation using the Eagle, Farmery, new METI systems.

be addressed to further improve the simulation of desaturation.

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ABSTRACT NO. 10

Two optimizing procedures for the solution of complex systems of equations: a powerful tool for modelling and simulation of metabolism

U. Fauth*, A. Rümelin* M. Klemm†, P. Beckmann† and M. Halmágyi*

**Department of Anesthesiology, School of Medicine, †Department of Physics, Johannes Gutenberg University, Mainz, Germany*

Introduction Standard calculations for the evaluation of indirect calorimetry (IC) are based on two-dimensional nonlinear systems of equations. For a more sophisticated evaluation metabolic models can be used, which are described by complex systems of equations. Since the solutions are multidimensional, a concrete result must be selected by means of constraints, using optimizing procedures. These multidimensional optimizations are critical concerning processing time and reproducibility of minimum detection.

Methods In order to simulate the status of metabolism of ICU patients on the basis of IC data, a complex model of metabolism was developed. The model was described by a system of equations consisting of 13 equations and 25 variables. The final result is selected out of the nine-dimensional space of solutions by optimization, considering a total of 69 constraints. Two optimizing procedures (Simplex algorithm [1] SPX, Powell procedure [2] POW) were modified, and analysed referring to processing time (PT), variance and reproducibility (VK, VC) of results. Test data as well as

Table 1. Variance (VK) and reproducibility (VC) for the Simplex algorithm (SPX) and the Powell procedure (POW) for four different enzymes (PDH, CS, KDC, MDH)

	VC		VK	
	SPX	POW	SPX	POW
PDH	3.5% ± 1.7%	2.1% ± 1.7%	5.1% ± 1.7%	2.8% ± 2.3%
CS	3.6% ± 1.6%	1.4% ± 1.4%	10.1% ± 2.1%	4.7% ± 5.8%
KDC	0.1% ± 0.0%	0.0% ± 0.0%	1.5% ± 0.0%	0.0% ± 0.0%
MDH	1.5% ± 0.7%	0.5% ± 0.4%	3.0% ± 1.3%	2.5% ± 1.5%

long-term IC measurements in ICU patients were evaluated. Modifications including 'meta procedures', which multiply restart the 'core' of the optimization (SPX) or find an optimal starting point for the core by a deformation of optimal sets of IC data with already known solutions, were necessary. VC and VK were tested for four representative parameters of the metabolic simulation (enzymes pyruvate dehydrogenase PDH, citrate synthase CS, ketoglutarate decarboxylase KDC, malate dehydrogenase MDH) by means of seven sets of calculated IC data. Penalty values as a measure of the quality of the simulation and processing time (Pentium 120 MHz) were determined using real data of a ventilated patient.

Results Both optimization procedures showed a high reproducibility and a low variance (all but one VK/VC values below 10%); there were no differences between Simplex and Powell algorithm (see Table 1). Evaluating real data, we found a lower frequency of outliers (nonevaluable data) for SPX (3.7% vs. 5.7%), while processing time was shorter for POW (1.95 ± 0.87 vs. 8.88 ± 3.06 min; both $P < 0.05$; $n = 800$).

Conclusion The evaluation of IC data using a model for the simulation of metabolism was successful even in clinical situations, where standard procedures usually fail. Multidimensional nonlinear systems of equations, as used for this simulation, are a considerable extension of available tools for the interpretation of IC data, if a powerful optimizing procedure is used. Both of the analysed procedures have shown to be suitable to reduce the nine-dimensional space of solutions of the system of equations to a concrete result, and can be applied to online metabolic simulations, if fast PC hardware is available.

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ABSTRACT NO. 11

Ventilation workshop – a new concept

C. Beyer, L. Hofmann, S. Mönk and W. Heinrichs

Clinic of Anaesthesiology, Johannes Gutenberg University, Mainz, Germany

The use of simulator technology to practice crisis resource management or to train standardised procedures in anaesthesia is a proven concept [1–4], although its setup in clinical practice is still in progress. To get a better understanding of the complex pathophysiological and clinical relations in the pulmonary system and the kind of alterations that could be induced by changing the ventilation of an intensive care unit patient, we modified the current concept. We created a workshop, which employs more than just the simulator training in the classical sense. During this workshop the participants attend one patient from admission to an emergency room, until discharge from an intensive care unit (ICU). This is not practicable in real time: therefore the pathophysiological and clinical relations are focused on key scenarios. The participants should develop and try their treatment concepts together with an instructor as an analogy to an ICU round.

In lectures and classes we present the specific theory, demonstrate ventilators and we offer the opportunity for self-ventilation.

To avoid peer pressure, we prefer small groups and we employ no cameras. The course priority is to teach the participants the concept of modern mechanical ventilation rather than checking their capability for crisis resource management (CRM).

We use an animal model to illustrate the effects of special ventilation methods, which can not be demonstrated with the simulator due to hardware preconditions. This is an anaesthetized pig, ventilated and monitored invasively (pulmonary artery catheter, arterial catheter inserted via the femoral vessels) with adult respiratory distress syndrome artificially induced by saline lavage. Among the registration of various cardiovascular parameters, the use of a Paratrend monitor (continuous measurement of arterial blood gases via an arterial line) is necessary.

Subsequently we demonstrate the positive or negative effects of different ventilation methods, which could also be applied, to our 'patient' at several stages of his disease.

We enhance this impression by employing a natural isolated pig lung, prepared in a special way to preserve the original compliance and resistance especially to demonstrate the high frequency oscillation ventilation.

The ventilator workshop is not a typical simulator course with respect to the training of CRM methods. We rather emphasize the pathophysiological points of interest.

The idea to develop such a course was born in 1997 at the congress of the German Interdisciplinary Association of Intensivists (DIVI). During a cardiovascular scenario, different ventilation strategies or the use of a pulmonary arterial catheter were necessary. We noticed great interest even from experienced intensivists in such a course.

This concept is applicable to other organ systems. Currently a haemodynamic workshop is in preparation, to contribute to the task of improving medical education with simulator training.

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ABSTRACT NO. 12

Model for educational simulation of the effects of propofol on the EEG – based on band power

M. B. M. Grit*†, G. C. Thorne‡, M. A. Tooley‡ and W. L. van Meurs*†

**Medical Education Technologies, Inc. – European Office, Porto, Portugal, †INEB – Instituto de Engenharia Biomédica, Porto, Portugal, and ‡Sir Humphrey Davy Department of Anaesthesia and Department of Medical Physics and Bioengineering, Bristol Royal Infirmary, UK.*

Introduction Complex procedures and complex equipment are used during EEG monitoring. Simulation is a valuable tool in teaching the use of this equipment and these procedures, without the need to teach on human patients. This abstract outlines a model for the effects of propofol on the EEG.

Methods The basic EEG signal generator is presented in Fig. 1. A Gaussian noise signal containing all frequencies is transformed into five signals with limited frequency range, corresponding to the five conventional EEG frequency bands (alpha, delta, etc.). The power of each of these five signals can be indepen-

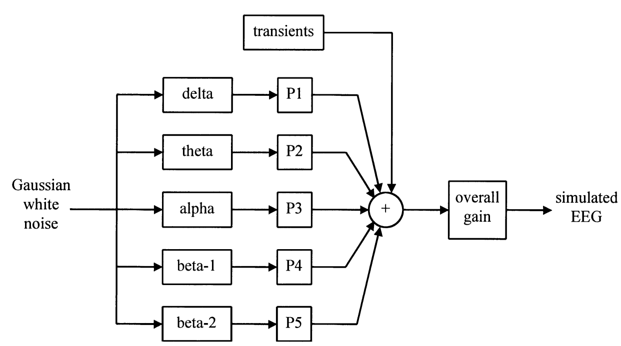

Fig. 1. EEG signal generator.

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dently determined by drug concentration and oxygenation.

A standard three-compartment pharmacokinetic model calculates the brain concentration of propofol. A pharmacodynamic (PD) model determines the five band powers based on this brain concentration. EEGs of 52 human patients with different stationary propofol plasma levels are used to obtain the PD relationships. Absolute and relative band powers were computed from the raw EEGs, using a carefully selected spectral analysis technique. From these results, the desired relationships between effect site concentration and individual band powers were constructed.

Results The resulting model realistically simulates static EEG segments. Dynamic effects still require formal evaluation, but initial results are encouraging.

ABSTRACT NO. 13

Educational simulation of the oxygen delivery to the fetus

W. L. van Meurs*†‡§, P. Sá Couto†‡, J. F. Bernardes‡¶, J. P. Marques de Sá‡** and J. A. Goodwin§

**Medical Education Technologies, Inc. – European Office – Porto, Portugal (http://www.meti.com), †Faculdade de Ciências, U. do Porto, Portugal, ‡INEB – Instituto de Engenharia Biomédica, Porto, Portugal §Department of Anesthesiology, U. of Florida, Gainesville FL, USA, ¶Faculdade de Medicina, U. do Porto, Portugal and **Faculdade de Engenharia, U. do Porto, Portugal*

Introduction Maternal hypotension or cardiac arrest, maternal hypoxia associated to ventilatory complications, and fetal asphyxia caused by compression of the umbilical cord are examples of critical situations in obstetrics and in anaesthesia of the pregnant woman. These incidents are rare and associated with a high risk to the woman and fetus. Therefore, simulation is a valuable tool in teaching the diagnostic and therapeutic skills in this context. The target audience of such simulations consists of residents in obstetrics and anaesthesia, midwives and nurse anaesthetists in training. We described a component of a simulator for fetal distress, namely a mathematical model for the educational simulation of the oxygen delivery to the fetus [1]. This abstract outlines this model and the main simulation results.

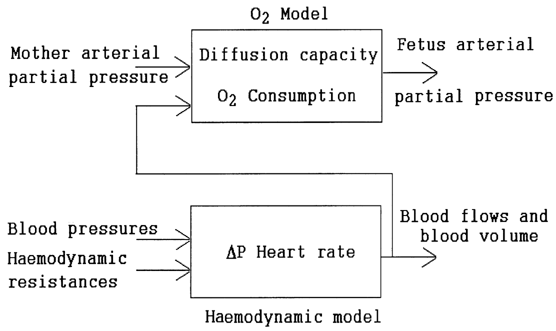

Fig. 1. Model block diagram.

Methods The underlying physiology is represented using a multiple modeling approach (Fig. 1). The haemodynamic model simulates the uterine, placental and umbilical blood flow rates as a function of maternal and fetal blood pressures. The model parameter: resistance to umbilical cord blood flow rate permits simulation of occlusion. The flow rates of the haemodynamic model are inputs to the oxygen uptake and distribution model. This model simulates the O_2 supply to the placenta, the exchange of O_2 across the placental barrier, the O_2 transport in the umbilical cord, and the fetal O_2 consumption. The differences in O_2 dissociation between maternal and fetal blood are taken into account. Model parameters for the human placenta and fetus were found in the literature [2]. To validate the model response to simulated critical situations we used fetal lamb data, as no data on humans were available.

Results Figure 2 shows the model output: O_2 partial pressure in the fetal arterial blood, following simulated maternal hypotension [1] and partial occlusion of the umbilical cord [2]. The reduction in partial pressure for these two situations compares favourably with data from the literature [3,4].

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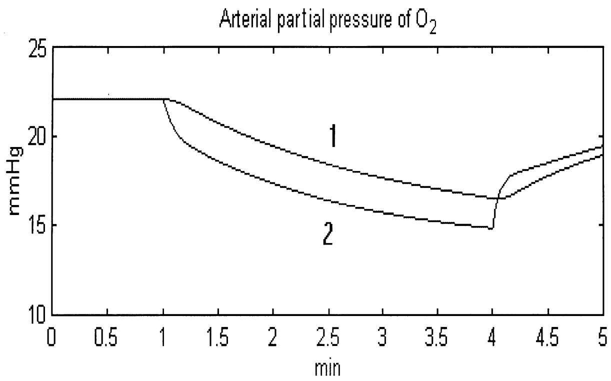

Fig. 2. Simulation results.

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ABSTRACT NO. 14

Analysing action sequences in anaesthesia

T. Manser[1], T. Wehner[1] and M. Rall†

[*]Swiss Federal Institute of Technology (ETH), Work and Organisational Psychology, Nelkenstrasse 11, CH - 8092 Zürich, Switzerland (E-mail: manser@ifap.bepr.ethz.ch), and †Department of Anaesthesiology, University of Tuebingen, Tuebingen, Germany (E-mail: Dr.Rall@t-online.de)

Since the early seventies, several systematic time and motion studies have been undertaken focusing on the actions of anaesthetists in operating theatres or simulators [1,2]. One recurring methodical problem has been the recording and the interpretation of concurrent operations [3].

The aim of our present study is to encounter this problem and to develop an observation method sensitive to overlapping operations in action sequences. Therefore, all operations performed by the anaesthetist are recorded by applying a set of 41 predefined codes – each of them representing a single operation. A new computer based recording technique allows us to identify any empirical overlapping of operations resulting in the definition of a new code. For each category we generate quantitative indicators which help to reveal the extent to which total activity and particular operations fluctuate during anaesthesia.

The results provide confirmation for a number of intuitive beliefs about action sequences in anaesthesia. For example, periods characterized by increased action density are the induction of and the emergence from anaesthesia. From the point of view of work psychology this may be interpreted as a pattern of dealing with varying task complexity.

Applying these considerations to simulators in anaesthesia the method should contribute to the design and evaluation of settings for research and training. The question of whether simulator settings represent the salient characteristics of real work situations is still unanswered. Analysing action sequences across various settings applying the method described opens up new possibilities to assess the ecological validity of simulator settings on an empirical basis.

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