ICU MANAGEMENT

THE OFFICIAL MANAGEMENT AND PRACTICE JOURNAL

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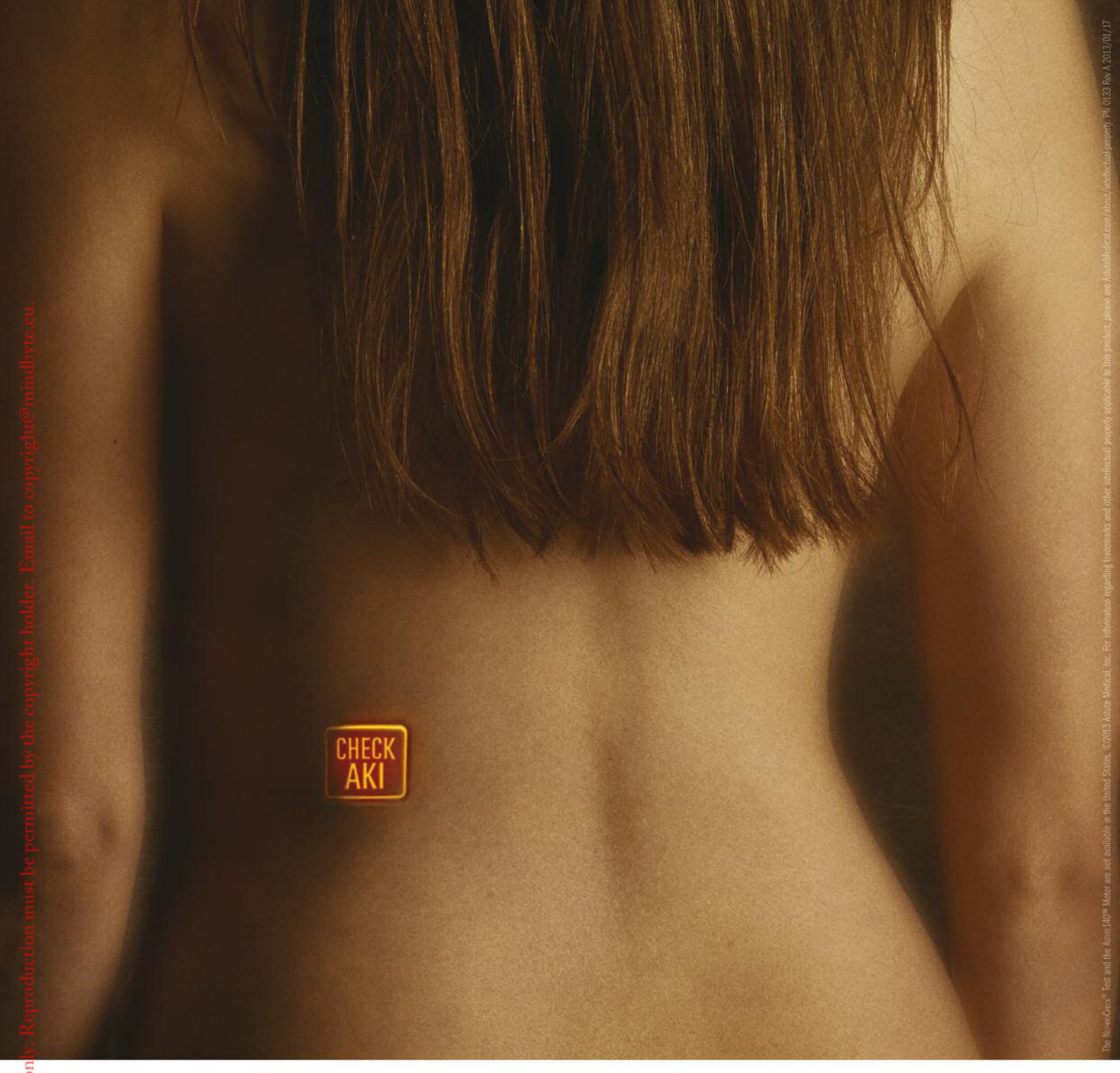
Organisation & Design

PLUS:

- Patient-Ventilator Asynchrony
- Glycaemic Control in the Critically Ill
- The ECMO Retrieval Team
- Implementing an Echocardiography Service
- Lean Methodology
- Interview with Jerry Nolan
- Country Focus: Australia & New Zealand



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ORGANISATION & DESIGN

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Is there such a thing as a perfect ICU? Organisation and design of the ICU has evolved exponentially since the first units delivering intensive care were set up in the 1950s. Organisation and design of the perfect ICU involves many factors – architecture, equipment and technology, staffing, patients and families. In our cover story this issue we include two articles, which suggest there is much still to be done in improving ICUs. High reliability organisations apply systems engineering in industries requiring minimal errors, such as aviation and nuclear power. In the first article, Alan D. Ravitz, Peter J. Pronovost and Adam Sapirstein describe the application of systems engineering in healthcare, and outline the elements of their plan to integrate the subsystems comprising ICU care to create a system of systems in order to reduce error and improve efficiency. Secondly, Pronovost and colleagues describe the process and results of a workshop, which aimed to think 'outside the box' to design an ideal ICU.

In the first Matrix feature Federico Longhini and colleagues examine the issue of patient-ventilator asynchrony, which occurs more frequently than previously thought. Next, James Krinsley considers what has been learned about glycaemic control since NICE-SUGAR, and focuses on the independent association of three domains of glycaemic control on mortality, the possible emergence of a fourth domain, glucose complexity, the relationship of diabetic status to the domains of glycaemic control and issues relating to monitoring frequency.

Initiating ECMO before transfer to tertiary centres greatly improves survival. Alain Combes and Guillaume Lebreton review the advantages and logistics of ECMO retrieval, which has even been performed between the French Caribbean and Paris. They reiterate the importance of establishing networks of hospitals with standardised protocols.

Anthony McLean explains how to implement an echocardiography service in the ICU. Factors to consider include machine selection, acquisition and maintenance, image acquisition and archiving, and training. In the last article in the Matrix section, Emanuel Rivers puts forward his views on critical care in the emergency department.

In the Management section, the area of focus is lean methodology. Sarah Clark and Gary Masterson explain how the methodology can be used in critical care medicine, and give examples of the methodology in action.

Our interview for this issue is with Jerry Nolan, Consultant in Anaesthesia and Intensive Care Medicine at the Royal United Hospital, Bath in the UK. Nolan is Vice Chairman of the European Resuscitation Council and was co-editor of the European Resuscitation Council Guidelines for Resuscitation 2010. In this interview he considers current challenges in resuscitation and priorities for research.

Our country focus this issue visits the Antipodes. Ross Freebairn outlines the new College of Intensive Care Medicine training programme for critical care physicians. David Pilcher, Peter Hicks and Sue Huckson explain how intensive care registries in Australia and New Zealand operate and what the data shows.

As always, if you would like to get in touch, please email **editorial@icu-management.org.**

Jean-Louis Vincent

You are Cordially Invited to our Scientific Symposia

Hemodynamic Optimization: The Latest Strategies for Fluid and Blood Management in the ICU

Space is Limited
RSVP Required

Location: 300 Hall
Date and Time: Tuesday, March 18 • 12:30 –14:00, Lunch will be provided
Chairperson: Michael R. Pinsky

Presenters

The Evolving Role of Hemodynamic Monitoring in the ICU

Michael R. Pinsky, MD, CM, Dr hc, FCCP, FCCM
Professor of Critical Care Medicine, Bioengineering, Anesthesiology, Cardiovascular Diseases, and Clinical & Translational Sciences
Vice Chair for Academic Affairs
UPMC, Pittsburgh, Pennsylvania

Patient Blood Management and Transfusion Optimization

Aryeh Shander, MD, FCCM, FCCP
Chief, Department of Anesthesiology
Pain Management and Hyperbaric Medicine
Englewood Hospital and Medical Center
Clinical Professor of Anesthesiology
Mount Sinai School of Medicine
Mount Sinai Hospital, New York

Non-Invasive Assessment of Fluid Responsiveness

Patrice Forget, MD
Department of Anesthesiology,
Cliniques Universitaires Saint-Luc,
Université Catholique de Louvain, Brussels, Belgium.

The Expanding Role of Brain Function Monitoring and Regional Oxygenation in the ICU

Location: Salle M (Bozar)
Date and Time: Thursday, March 20 • 12:30 –13:30, Lunch will be provided
Chairperson: Maxime Cannesson

Presenters

Anesthesia and Sedation Impact on the Brain: Processed EEG Monitoring Brain - Implications for ICU Care

Emery N. Brown, MD, PhD
Warren M. Zapol Professor of Anaesthesia
Massachusetts General Hospital/Harvard Medical School
Edward Hood Taplin Professor of Medical Engineering
Professor of Computational Neuroscience
Massachusetts Institute of Technology,
Cambridge, Massachusetts

The Brain is Not Just a Number - Applications for Processed EEG Monitoring in the ICU

Michael Ramsay, MD, FRCA
Chairman Department of Anesthesiology and Pain Management,
Baylor University Medical Center and Research Institute
President Baylor Research Institute, Dallas, Texas

Central and Regional Oxygenation in the Changing ICU Environment

Maxime Cannesson, MD, PhD
Associate Professor of Anesthesiology
Director, Clinical Research
Director, Cardiac Anesthesia
Department of Anesthesiology & Perioperative Care
University of California, Irvine

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and **www.masimo.com/Brainisnotjustanumber**

ICU Management

is the Official Management and Practice Journal of the International Symposium on Intensive Care and Emergency Medicine and was previously published as Hospital Critical Care.

Author Correction
ICU Management Volume 13, Issue 4
Pilgrimage to Mecca in Saudi Arabia: A Model for Healthcare for Mass Gatherings (*Mariam A. Alansari, A.H. Alzeer*): page 46 refers to 95 new mobile intensive care units in 2013. The correct number is 45.

RESEARCH NEWS

Severe Sepsis: Are Outcomes Better if Hospitals Treat a High Volume of Patients?

A study from the Boston University School of Medicine, published recently in the American Journal of Respiratory and Critical Care Medicine, looked at the associations between hospital sepsis caseload and outcomes, and found that academic hospitals with higher severe sepsis case volume have lower severe sepsis hospital mortality without higher costs.

Using data from US academic hospitals the researchers identified 56,997 patients with severe sepsis admitted to 124 US academic hospitals during 2011. Hospitals admitted 460±216 patients with severe sepsis, with median length of stay 12.5 days (IQR 11.1-14.2), median direct costs $26,304 (IQR $21,900-32,090), and average hospital mortality 25.6±5.3%. The analysis showed that higher severe sepsis case volume was associated with lower unadjusted severe sepsis mortality ration (R2=0.10, p=0.01) and risk-adjusted severe sepsis mortality (R2=0.21, p<0.001).

After adjustment, hospitals in the highest severe sepsis case volume quartile had an absolute 7% (95% CI 2.4-11.6%) lower hospital mortality than hospitals in the lowest quartile. The authors did not identify associations between case volume and resource utilisation.

Lead author, Allan J. Walkey, assistant professor of medicine, BUSM, and attending physician, pulmonary, critical care and allergy medicine, Boston Medical Centre states, "We wanted to adjust for potential confounding variables in the association between cave volume and outcomes. We adjusted for patient-level severity of illness by using a standardised mortality ration and then adjusted for hospital-level factors that were either associated with severe sepsis case volume (eg., # of beds) or associated with mortality (eg, geography, long term acute care referral practices)."

Walkey pointed out, "In patients with severe sepsis the only therapies that have thus far been shown to improve outcomes are those that are basically processes of care: for example early sepsis recognition, early administration of appropriate antibiotics, early goal directed fluid resuscitation. We hypothesised that 'practice makes perfect' when it comes to treatment of patients with severe sepsis and that outcomes would be better as high severe sepsis volume hospitals."

ICU Management asked Dr. Walkey about the implications for changing the processes of care in those hospitals which do not have a high sepsis caseload. He said, "There are a few possibilities for addressing the differences in outcome based on case volume. One is studying whether simulation training in severe sepsis may be a way to improve processes and outcomes at low volume centres. Also, we need to study more thoroughly the way severe sepsis care is implemented in high volume hospitals, and how this care may differ from the lower volume centres. For example: Are high sepsis volume centres more likely to have checklists or protocols? Do high volume hospitals recognise patients with sepsis sooner and is time to antibiotics shorter or use of lung protective ventilation more frequent? How are transfers between services accomplished? If disparities in sepsis outcomes can't be closed, then the last alternative is that 'centres of excellence' be created whereby patients are shunted to centres with more experience/better outcomes. More research obviously needs to be done to address these questions."

Walkey added, "We chose to restrict our analysis only to academic hospitals to eliminate potential confounding by hospital teaching status. Whether recognition of sepsis differs by hospital case volume is worthy of further study."

Reference

Walkey AJ, Wiener RS (2014) Hospital case volume and outcomes among patients hospitalized with severe sepsis.Am J Respir Crit Care Med, 189(5): 548-55.

ICU Patients with Kidney Injury Show High Mortality and Elevated Urinary Protein

Follow up over four years of 1,464 participants in the randomised controlled trial Randomised Evaluation of Normal vs. Augmented Levels of RRT (RENAL) study found that patients with acute kidney injury (AKI) in an intensive care unit who require renal replacement therapy (RRT; haemodialysis combined with haemofiltration) do not benefit from higher intensity RRT.

At a median of 43.9 months follow up, mortality (63% in the low intensity and 63% in the high intensity group), as well as quality of life among those who survived, were the same in both groups. Albuminuria (elevated protein levels in urine, signifying persistent kidney injury) was common among survivors and with equal rates in both groups (40% in the low intensity and 44% in the high intensity group).

The authors explain, "Our study highlights the increased long-term risk of death associated with AKI treated with RRT in an ICU. Only one third of randomised patients were alive 3.5 years later, a lower survival than seen in recognised high mortality conditions such as acute respiratory distress syndrome. Although, in our patients the risk of subsequent maintenance dialysis dependence is low, almost half have evidence of significant proteinuria, portending further risk in the years to come. These findings support the view that survivors of AKI are at increased risk and that closer surveillance may be justified. In addition, our findings suggest that chronic proteinuria reduction strategies, which have shown benefit in some patient groups with proteinuria, may warrant investigation as a therapeutic intervention."

Limitations of the study are that the patients were enrolled in a randomised trial and did not represent patients in ICUs with AKI in general, and not all patients agreed to long term follow up.

The authors conclude, "In a large cohort of patients with acute kidney injury randomised to differing doses of continuous renal replacement therapy in the ICU, the increased risk of death continues well beyond hospital discharge and is not altered by increased intensity of dialysis. The proportion of patients entering a maintenance dialysis program is small but there is a high prevalence of proteinuria amongst survivors, suggesting significant ongoing risk of chronic kidney disease and mortality."

Reference

Gallagher M, Alan Cass A, Rinaldo Bellomo R et al. (2014) Long-term survival and dialysis dependency following acute kidney injury in intensive care: extended follow-up of a randomized controlled trial. PLoS Medicine, 11 (2).

Statin Use Reduces Delirium in Critically Ill Patients

Continued use of statins may help prevent delirium in critically ill patients who received statins before hospital admission, according to a study of 470 intensive care patients in the UK published online in the American Journal of Respiratory and Critical Care Medicine.

"This is the first study using a validated delirium screening tool, the Confusion Assessment Method-ICU (CAM-ICU), to show that the administration of statins reduces delirium in these patients," said lead author Dr. Valerie J. Page, of the Watford General Hospital in Watford, UK. "This benefit may be mediated by a reduction in systemic inflammation."

151 of the 470 patients included in the study received statins. Statins were only administered to patients who had received statins prior to admission.

After adjustment for age, sex and illness severity, administration of statins the previous evening was associated with a significantly lower risk of delirium and a concomitant reduction in serum C-reactive protein (CRP), a marker of systemic inflammation, the following day. The strength of the relationship between statin use and a lower risk of delirium was reduced when CRP was adjusted for.

"Although the pathogenesis of delirium is not fully understood, these data are consistent with a neuro-inflammatory cause and suggest that the anti-inflammatory effects of statins may contribute to the effects of statin treatment on delirium," said Dr. Page. "Our study on statin use and the risk of delirium in critically ill subjects included extensive data on a large, broadly representative population of consecutive intensive care patients, increasing its strength."

Study limitations include the possibility that not all potential confounding factors were adjusted for and the limits of cognitive assessment tools in critically ill patients.

"Our findings suggest that statin treatment should be continued to help prevent delirium in critically ill patients who received statins before being admitted," said Dr. Page.

"The relationship between statin therapy and delirium and the mechanisms underlying this relationship are the subject of an ongoing randomised, placebo-controlled study in critically ill ventilated patients."

Reference

Page VJ, Davis D, Zhao XB et al. (2014) Statin use and risk of delirium in the critically ill. Am J Respir Crit Care Med, Jan 13. [Epub ahead of print]

Wise Choices in Critical Care for Doctors and Patients

The Critical Care Societies Collaborative, comprising the American Association of Critical-Care Nurses, the American College of Chest Physicians, the American Thoracic Society and the Society of Critical Care Medicine has published a list of "Five Things Physicians and Patients Should Question" in critical care as part of the Choosing Wisely® campaign, led by the ABIM Foundation.

The list is five targeted, evidence-based recommendations that can support physicians and patients in making wise choices about their care:

1. Don't order diagnostic tests at regular intervals (such as every day),

but rather in response to specific clinical questions.
2. Don't transfuse red blood cells in haemodynamically stable, non-bleeding ICU patients with a haemoglobin concentration greater than 7 mg/dL.
3. Don't use parenteral nutrition in adequately nourished critically ill patients within the first seven days of an ICU stay.
4. Don't deeply sedate mechanically ventilated patients without a specific indication and without daily attempts to lighten sedation.
5. Don't continue life support for patients at high risk for death or severely impaired functional recovery without offering patients and their families the alternative of care focused entirely on comfort.

The list is the first Choosing Wisely list to include collaboration with a nursing organisation and only the second that's a product of collaboration instead of being issued by a sole medical society

Reference

http://www.choosingwisely.org/doctor-patient-lists/critical-care-societies-collaborative-critical-care/

Hôpital Erasme | ULB

Erasme Hospital Celebrates Significant Milestone

Erasme Hospital in Brussels, Belgium, recently admitted its 100,000th patient since its establishment in 1978. The service was set up by the late Professor Robert Kahn as a full service, with no distinction between medical and surgical patients. Kahn also had the nous to install the unit in the basement of the hospital, which had large areas that nobody wanted for obvious reasons of lack of light. Sadly Professor Kahn died in September 1996. He was succeeded by Professor Jean-Louis Vincent as acting Head of Department, who was confirmed in office a few months later.

The excellent reputation of the Department of Intensive Care is due to several factors. The medical team is very high level. However, the quality of intensive care depends as much on the other members of the team: nurses, physiotherapists, biotechnologists, psychologists and others. With a team of 200 people, the Department of Intensive Care is the largest department in the hospital.

Communication is essential. The service has established procedures for structured presentations during morning rounds (with the three doctors who hand over), late morning (at the bedside of each patient) and evening with the three doctors beginning their care. Nurses and other members of the healthcare team are actively encouraged to contribute actively to discussions.

The quality of care is closely linked to the quality of the research performed. The Department of Intensive Care has the highest scientific production per doctor at the institution. The department is also involved in early trials of new treatments and the provision of new advanced equipment. The trainees see their training as full, somewhat stressful, but very informative, and are eager to return.

These qualities of clinical practice, research and education also attract many foreign doctors from all continents. The service has strong links with Brazil in particular (more than 100 Brazilian doctors have been trained to date), Italy (known today almost as much Italian as French in the service) and Spain.

The ICU is known for organising ISICEM, the annual symposium of intensive care and emergency medicine, which has become the largest in the world in the area, attracting 6000 participants from around the world.

Responding to the needs of patients and their families is another priority. Thanks to a special fund to help patients and their families, the service was able to add a psychologist to the team as well as accommodation for relatives.

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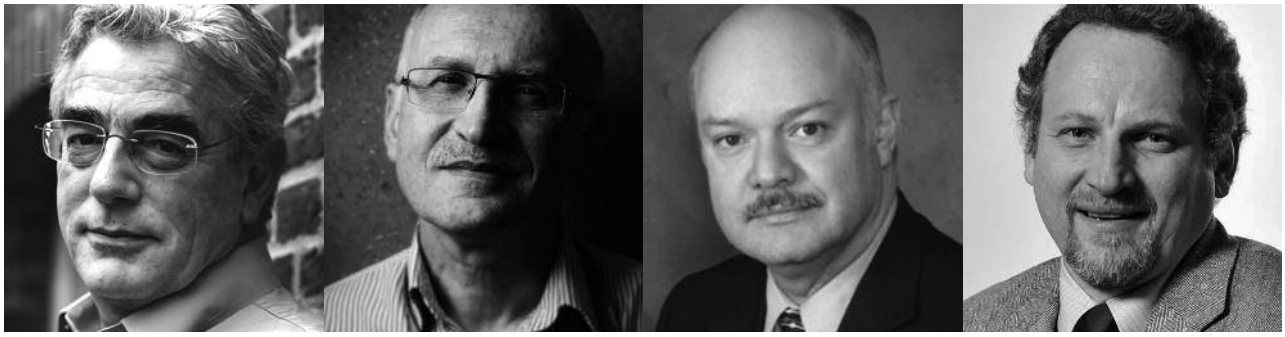
EDITOR-IN-CHIEF WELCOMES

Distinguished Intensivists to Editorial Board

ICU Management is pleased to announce that Jan Bakker, Rinaldo Bellomo, Edgar Jimenez, John Kellum, John Marshall, Shirish Prayag and Gordon Rubenfeld have joined the Editorial Board.

Editor-in-Chief, Jean-Louis Vincent, said, "ICU Management greatly values the expertise of its Editorial Board. We are delighted to welcome our distinguished colleagues to the Board."



L-R: Jan Bakker, Rinaldo Bellomo, Edgar Jimenez, John Kellum

Professor Jan Bakker, the Netherlands

Jan Bakker is Professor of Medicine and Vice-chair of the Department of Intensive Care Adults at Erasmus Medical Centre in Rotterdam, the Netherlands. He is Visiting Professor at Columbia University - New York Presbyterian, U.S. and a Visiting Professor at the University Hospital Pontificia Católica de Chile. His research interests include blood lactate, ethics and end-of-life care. His clinical specialties are intensive care, haemodynamics, tissue perfusion, tissue oxygenation, early goal-directed therapy, infection prevention and end-of-life care. His management specialities are change management, costs and quality of care. He is a Scientific Advisor for the International Symposium on Intensive Care and Emergency Medicine.

An interview with Prof. Bakker, "The role of lactate", featured in ICU Management Vol. 13(4) http://bit.ly/1dWT3nS

Professor Rinaldo Bellomo, Australia

Rinaldo Bellomo is the Director of Intensive Care Research at Austin Health in Melbourne; Professorial Fellow, Faculty of Medicine, University of Melbourne, Australia; Honorary Professor, Faculty of Medicine, Monash University, Melbourne Australia; Honorary Professorial Fellow, Faculty of Medicine, The University of Sydney, Australia; Honorary Professorial Fellow, The George Institute, Sydney, Australia; Concurrent Professor, Faculty of Medicine, University of Nanjing, China; and Honorary Principal Research Fellow, Howard Florey Institute, University of Melbourne. He is the Founding Chair of the Australian and New Zealand Intensive Care (ANZIC) Society Clinical Trials Group, and is Co-Director of the Australian and New Zealand Intensive Care Research Centre, which has research programmes in traumatic brain injury, sepsis, transfusion, acute lung injury, nutrition and health economics.

Professor Edgar Jimenez, USA

Director, Medical Critical Care and Intermediate Critical Care, Orlando Regional Medical Center, Florida, USA. He is Associate Professor of Medicine, University of Florida, University of Central Florida and Florida State University. He is a Council Member and Past President of the World Federation of Societies of Intensive and Critical Care Medicine. His areas of interest are non-conventional ventilation, sepsis, difficult airway, haemodynamics and perfusion monitoring, mass casualty incidents and disaster preparedness. He was involved in the development of the Emergency Medical System (EMS) in Costa Rica, and worked as Chief Medical Advisor for the US Dept. of State, US Agency for International Development (US AID), Office of Foreign Disaster Assistance (OFDA), where he was also an International consultant on Disasters and Mass Casualty Incidents for the Pan American Health Organization (PAHO) and the Red Cross.

An interview with Prof. Jimenez, "Collective global action in critical care", featured in ICU Management Vol. 12(4) http://bit.ly/1n61Cmx

Professor John Kellum, USA

John Kellum is Professor and Vice Chair for Research at the Department for Critical Care Medicine; Professor of Medicine, Bioengineering and Clinical & Translational Science; Director, Center for Critical Care Nephrology; Director, Center for Assistance in Research using eRecord (CARe) (www.eresearch.pitt.edu) at the University of Pittsburgh in the United States. His research interests centre on critical care nephrology (including acid-base, and renal replacement therapy), sepsis and multi-organ failure (including blood purification), and clinical epidemiology. He is a founding member and past president of the Acute Dialysis Quality Initiative (www.ADQI.net) and is co-chair of the Kidney Diseases Improving Global Outcomes (KDIGO) clinical practice guideline on acute kidney injury (www.kdigo.org).

An interview with Prof. Kellum, Prof. Claudio Ronco and Prof. Michael Joannidis, "An emerging consensus for acute kidney injury" featured in ICU Management Vol. 12(1) http://bit.ly/1fXxCY2

See also "Biomarkers for acute kidney injury" by Prof. Lakhmir S. Chawla and Prof. Kellum in ICU Management Vol. 13(3) http://bit.ly/1i2OEmk

L-R: John Marshall, Shirish Prayag, Paul Pepe, Gordon Rubenfeld

Professor John Marshall, Canada

John Marshall is Director of Research, Critical Care Medicine, St. Michael's Hospital in Toronto and Professor of Surgery at the University of Toronto and Scientist in the Keenan Research Centre of the Li Ka Shing Knowledge Institute of St. Michael's Hospital. He has served as Chair of the Canadian Critical Care Trials Group since 2005, and is Secretary General of the World Federation of Societies of Intensive and Critical Care Medicine. His research interests include sepsis, innate immunity, critical care trials, host-microbial infections and nosocomial infection. He runs a laboratory funded by the Canadian Institutes of Health Research and the Physicians' Services Incorporated Foundation that studies the cellular mechanisms underlying prolonged neutrophil survival in trauma and sepsis. He has been the principal investigator of the Appropriate Antimicrobial Therapy In Critical Care (AATICC) trial of empiric antibiotic therapy for suspected ICU-acquired infection as well as a co-investigator on a number of Trials Group programs and a steering committee member for a number of industry-sponsored trials of novel therapies for sepsis. He is the inaugural chair of the International Forum for Acute Care Trialists (InFACT). He is an executive committee member of the International Severe Acute Respiratory Infections Consortium, and has previously served as president of the Surgical Infection Society and chair of the International Sepsis Forum. He is a Scientific Advisor for the International Symposium on Intensive Care and Emergency Medicine.

Professor Paul E. Pepe, USA

Paul E Pepe is Professor of Medicine, Surgery, Pediatrics, Public Health & Riggs Family Chair in Emergency Medicine, University of Texas, Southwestern Medical Center and Parkland Memorial Hospital, Dallas, Texas. In addition Prof. Pepe serves as City of Dallas Director of Medical Emergency Services for Public Safety, Public Health & Homeland Security, the jurisdictional Medical Director for the regional Emergency Medical Services system, Medical Director for special services for the DFW Airport, the Dallas Police Dept. and the Dallas Metropolitan Medical Response System for counter-terrorism and disaster mitigation. His clinical interests are emergency medicine and resuscitation. His research areas include cardiac arrest and trauma resuscitation, interventions for coronary artery syndrome, therapeutic hypothermia for paediatric head injury and optimisation of ventilatory techniques in severe haemorrhage and cardiac arrest. He has received numerous awards and recognition for his lifetime achievements in emergency medicine. He is one of the co-authors of the 1991 paper that introduced the "Chain of Survival" concept, and is known for his original measurements of physiological mechanisms (e.g., Auto-PEEP), intrepid clinical concepts (e.g., deferred rescue breaths in CPR), and ground-breaking clinical trials (e.g., deferred IV fluids for trauma).

Dr. Shirish V. Prayag, India

Shirish V. Prayag has practised as a Consultant in Critical Care Medicine in Pune, India since 1983. He established the first Critical Care Unit in Pune in 1985-6. He has been a pioneer in the development of critical care in India and Asia. He is a Founder Executive Committee member of the Indian Society of Critical Care Medicine since its inception in 1993 and Past President. He was the first Consultant from India to be awarded the Fellowship of the American College of Critical Care Medicine (FCCM) and the first consultant from India to be elected on the Executive Council of the World Federation of Societies for Intensive and Critical Care Medicine (2001-2009). He is a member of the WHO project International Partnership for Acute Care Safely (IPACS). He has also been a major contributor to developing and examining diploma and fellowship programmes in critical care in India. His areas of interest are mechanical ventilation, tropical infections, sepsis, shock, and teaching of critical care.

Professor Gordon Rubenfeld, Canada

Gordon Rubenfeld is Chief of the Trauma, Emergency & Critical Care Program at Sunnybrook Health Sciences Centre and Professor of Medicine at the University of Toronto, Canada. His research focuses on the clinical epidemiology and outcomes of critical illness syndromes, the transfer of evidence into clinical practice, and end-of-life care issues in the intensive care unit. He has served on numerous advisory panels and consensus groups in critical care, including the American European Consensus Conference on Acute Lung Injury, the working group that developed the Berlin ARDS (acute respiratory distress syndrome) definition and the surviving sepsis guideline committee.

An interview with Prof. Rubenfeld, "Critical care: the view from Canada" featured in ICU Management, Vol. 13 (3) http://bit.ly/OWcvMe

A MODEL FOR THE INTENSIVE CARE UNIT AS A HIGH RELIABILITY ORGANISATION

Alan D. Ravitz, *PE*[1]

Peter J. Pronovost, *MD, PhD*[2-4]

Adam Sapirstein, *MD*[2,3]

Johns Hopkins Applied Physics Laboratory, Laurel, USA.[1]; Armstrong Institute for Patient Safety and Quality, Johns Hopkins Medicine, Baltimore, USA[2]; School of Medicine, The Johns Hopkins University, Baltimore, USA[3]; Bloomberg School of Public Health, The Johns Hopkins University, Baltimore, USA[4]

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The intensive care unit (ICU) is broadly viewed as the epicentre of a high reliability organisation (HRO) in a healthcare system. After all, ICU clinicians care for the sickest patients with the most complex, high technology therapies and monitors. Moreover, the Leapfrog Group developed standards for the best models of care in the ICU – an intensivist led-care team (Leapfrog Group 2011).

However, the facts tell a very different story about reliability in the ICU. We know that only 42 percent of hospitals in the USA that responded to the Leapfrog Group's hospital survey reported compliance with the ICU Physician Staffing standard (unpublished data, Leapfrog Group, February 17, 2014). Therapies to prevent avoidable harm are delivered erratically. For example, of patients at risk for ventilator-associated lung injury, only 20 percent to 40 percent receive appropriate, weight-based tidal volumes on the ventilator (Pronovost et al. 2010). Clinicians may also be overly optimistic about the quality of care they provide. Scales and co-workers (2011) found that only 50% of eligible ventilated ICU patients had the head of their bed elevated to > 30 degrees before the quality improvement intervention was implemented. Most importantly, patients continue to experience harm at an unacceptable rate that far exceeds the level of harm in an HRO; avoidable error is considered to be the third leading cause of death in the USA (Wachter et al. 2013).

> *"Healthcare and the ICU community, in particular, should not accept the current models and outdated systems of care"*

The HRO model was developed by examining commonalities of industries that require near error-free performance, such as commercial aviation and nuclear power. Despite being very risky, HROs create systems to manage the complexity of technology and task performance (Sutcliffe 2011). High reliability organisations apply systems engineering to ensure the technology, work process, and culture are all carefully integrated and orchestrated to deliver high levels of safety. Compare this to the current ICU system design recommended by the Leapfrog Group. In this model, the core of the system, the data storage and knowledge management system, is the intensivist and the care team. This model has evolved naturally with the development of critical care, but its deficiencies are obvious. It relies on the flawless performance of an intensivist-led team, a model that depends on the heroic performance of individuals. A model we have argued is outdated, under-engineered, and doomed to fail at high frequency (Pronovost et al. 2014). If the ICU is to reduce harm and work toward becoming an HRO, the system design will need to mature.

Systems engineering has been applied successfully in HROs to virtually eliminate errors and catastrophic failure. Systems of systems (SoS) have been created, in which many subsystems are integrated, and become interdependent to reduce harmful errors and improve efficiency. Like an HRO, safe and high quality healthcare depends on the interaction of many systems, aligned purposefully to achieve common safety and quality care goals (Shekelle et al. 2013). By applying systems principles, we believe it is possible to create, a safe, productive SoS for ICU care (Christianson et al. 2011).

We have developed a comprehensive plan to start integrating the many constituent subsystems that comprise ICU care to create a SoS. Our plan is based on the US Navy's submarine force known as Advanced Processor Build (APB)/Acoustic Rapid COTS Insertion plan for submarines (Stevens 2008), which began in 1998 and continues today. Our plan will design, implement, iterate, and evaluate a systems approach, articulating the necessary components and partners. The SoS plan, adapted for healthcare, involves the following seven major elements (see Figure 1).

1. Concept for Integrated Healthcare Delivery System. The high-level description of an integrated healthcare delivery system is a system of systems (SoS). The constituent elements that comprise this SoS include all subsystems, such as ICU settings (eg, surgical ICU, medical ICU), operating rooms, emergency departments, primary care offices, home care. Subsystems are identified and their mutual interactions described. Subsystems are characterised as 'black boxes' with appropriate inputs and outputs between each box.

2. Concept for Integrated Healthcare Delivery Subsystems. The subsystems are detailed using a Concept of Operations (CONOPS). A CONOPS provides the vision and purpose for the (sub)system and an analysis of the system's operational needs and mission requirements. The CONOPS describes the roles and activities of each user, the operational

process, and operational command structures. Importantly, key performance parameters, interdependencies between subsystems, and the facilities, equipment, hardware, software, and personnel associated with the subsystem are defined. The CONOPS also describes known gaps with existing capabilities. These gaps are flags for innovators to develop new solutions that fulfil the vision described in the CONOPS. Healthcare has yet to produce such detailed CONOPS and this work will advance the field.

3. Call for Innovation for Candidate Solutions.

Innovators across industry and academia are asked to develop candidate solutions to the system gaps that are identified in stage 2 of the model. In contrast to the current top down approaches, the SoS program provides a goal-directed approach, focusing on a problem to be solved or a job to be done.

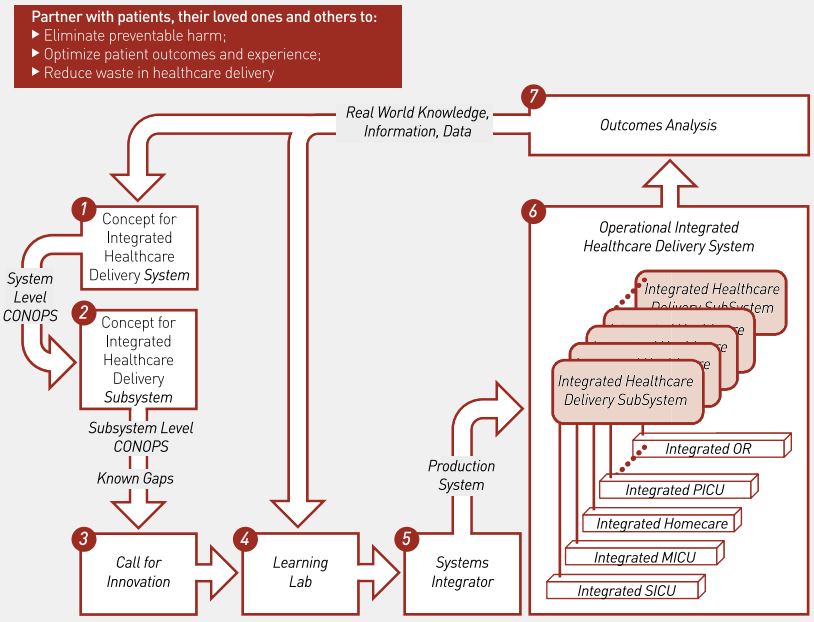
4. Learning Laboratory.

The Agency for Healthcare Research and Quality (AHRQ) defines a learning laboratory as: "…places and professional networks that allow multidisciplinary teams to identify interrelated threats to patient safety, stretch professional boundaries, envision bold design innovations, and take advantage of brainstorming and rapid prototyping techniques that other leading-edge sectors of the economy employ…" (U.S. Department of Health and Human Services 2013). The Johns Hopkins Armstrong Institute implemented a robust process to analyse novel candidate solutions to fill gaps across four dimensions: culture, workflow, technology, and learning and accountability. These four dimensions characterise the key aspects of integrated socio-technical solutions, purposefully designed and integrated to enhance overall safety and quality in the ICU.

5. Systems Integration.

After an evaluation in the Learning Laboratory, candidate solutions need further refinement before integration into an operational production system. Academia (eg, Johns Hopkins Armstrong Institute) and a Systems Integrator, such as the role that Lockheed Martin or Boeing serve in aviation, should collaborate on additional laboratory assessments and production level refinements. The goal of this interaction is to develop a product that can be broadly implemented. It is important to understand that this development includes both technical and social components. The product must be rigorously tested and evaluated to ensure the integration matches the needed performance and is aligned with the key performance parameters identified in the CONOPS.

Figure 1.



6. Production Integrated Healthcare Delivery System.

The vision described in elements one and two is realised here. The capabilities defined previously are integrated into a comprehensive care delivery model that is used in clinical settings. Because of the magnitude of building a healthcare SoS, it will be impossible to immediately implement a full set of integrated systems envisioned in Element 1. Instead, project teams must incrementally develop and build capabilities in sequence by repeatedly cycling through the plan (Figure 1).

7. Outcomes Analysis.

Measurement in clinical settings is essential for benchmarking performance of new systems and allows continuous improvement of overall SoS performance. Each successive pass through the development cycle described in Figure 1, will reveal unanticipated performance deficits and unintended consequences. Accordingly, an outcomes analysis is essential for keeping the overall effort precisely focused on the ultimate vision. This analysis allows the focus to adjust for changes in the challenges and gaps that are revealed in real-world settings.

While this SoS approach is mature in other industries, it is grossly underdeveloped in healthcare. Neither clinicians nor technology companies can do this alone. Healthcare needs a learning laboratory that convenes clinicians, engineers, researchers and others to design the healthcare systems patients deserve, clinicians want, and the country needs. ■

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There was no funding. Dr. Pronovost reports receiving grant or contract support from the Agency for Healthcare Research and Quality, the Gordon and Betty Moore Foundation (research related to patient safety and quality of care), the National Institutes of Health (acute lung injury research), and the American Medical Association Inc. (improve blood pressure control); honoraria from various healthcare organisations for speaking on patient safety and quality (the Leigh Bureau manages most of these engagements); book royalties from the Penguin Group for his book Safe Patients, Smart Hospitals; consultant fees as a strategic advisor to the Gordon and Betty Moore Foundation; and stock and fees to serve as a director for Cantel Medical. Dr. Pronovost is a founder of Patient Doctor Technologies, a start-up company that seeks to enhance the partnership between patients and clinicians with an application called Doctella. Dr. Ravitz and Dr. Sapirstein report no conflicts of interest.

For full references, please send a request to editorial@icu-management.org

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PATIENT SAFETY AND

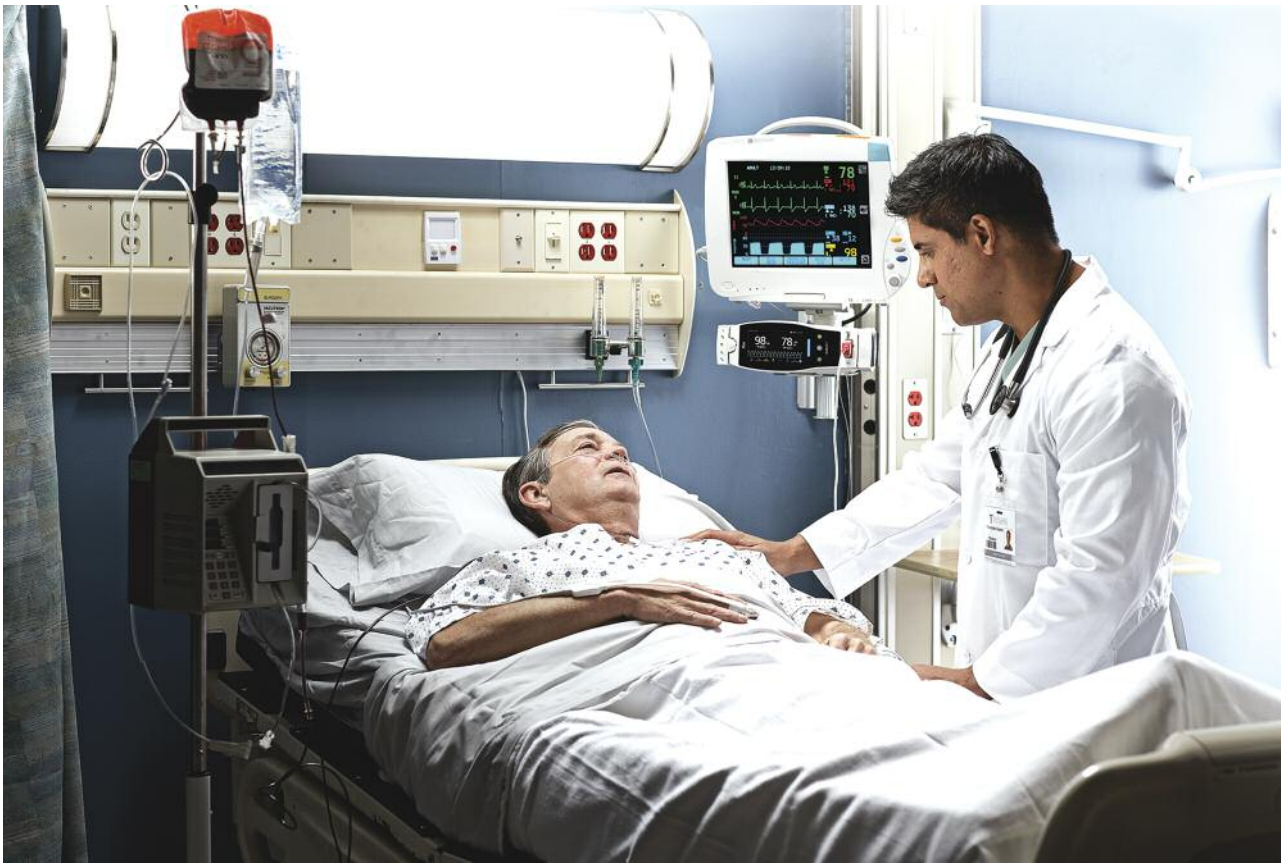
Innovation in medicine ranges from the implementation of simple processes to game-changing disruptive technologies. Washing hands between examining patients is a straightforward simple process, but it can saves lives. An example of a disruptive technology was the development of pulse oximeters, which can measure oxygenation through motion and low perfusion.

ICUs in particular require monitoring systems, which are reliable, and have relatively high sensitivity and specificity. With alarm hazards noted as the Top Health Technology Hazard by ECRI for 2014 [1], equipment with high sensitivity and specificity is essential in order to reduce false alarms and detect true alarms.

The advent of smartphones and tablets is also changing the practice of medicine. Now physicians expect to be able to use their own devices in the hospital, and they want connectivity to hospital machines and systems. Manufacturers who encourage connectivity will lead the field.

Industry experts predict that sensor technologies are close to eliminating margins of error in medicine. Such innovations include ingestible sensors, gloves with sensors, noninvasive measuring devices and devices with voice commands. Already systems are available that allow wireless sensing of devices, patients and hospital staff. Medical technology is also becoming available to consumers, with an ever increasing number of health apps for smartphones and devices that work with apps, such as the iSpO$_2$ which shows blood oxygen and pulse rate with a sensor attached to the finger [2].

In the future we will see 'wearable technology' with healthcare staff able to communicate across systems and monitoring devices, with no need to log in or even touch the device.



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2013 JEMS Hot Product Awards. Masimo was one of Two Companies (out of 300) to Win Two Awards (with iSpO2 and EMMA capnograph) at 31st Annual Industry-Leading Emergency Medical Services Event: http://www.prnewswire.com/news-releases/masimo-ispo2-pulse-oximeter--emma-emergency-capnometer-earn-jems-hot-products-awards-at-ems-today-2013-conference--exposition-205207961.html

2013 Medical Design Excellence Awards, Bronze winner in Over-the-Counter and Self-Care Products: http://www.mddionline.com/article/mdea-2013-winners

MONITORING IN THE ICU

As Head of the Department of Intensive Care at Erasme University Hospital in Brussels, Professor Jean-Louis Vincent has seen vast changes in intensive care practice. His Department has 35 beds in five intensive care units, currently treating 3,500 patients a year. The department is multidisciplinary, with no distinction between medical and surgical patients. It also includes a four-bed space called "lab room", where the seriously ill are admitted in collaboration with the Emergency Department, a rather unique system. With about 200 staff, the department is the largest in the hospital. The department's clinical, research and educational qualities attract many foreign doctors from all continents.

Prof. Jean-Louis Vincent comments on the importance of monitoring in the general hospital, not just in the ICU.

The EuSOS study was a landmark study in reporting post-operative outcomes at a European level and showed that post-operative mortality was higher than previously thought. In view of those findings, what role can ICUs and continuous monitoring in general wards play in reducing preventable deaths?

Advances in continuous monitoring have enabled a rapid response to any abnormality. Real time patient monitoring is very important, not only in the ICU, but also on the regular floors of the hospital.

What benefits does noninvasive monitoring bring to ICU patients and staff?

There is a compromise between noninvasiveness and reliability. A nonreliable, noninvasive system is useless. For comparable reliability only a noninvasive device is preferred. There are noninvasive variables, which are very useful, such as heart rate, arterial pressure or urine output. In addition it is helpful to have parameters such as end tidal CO_2 or capnography, blood lactate concentrations as well as haemoglobin trending to detect potential occult bleeding. Real time trending is important, for example trending of haemoglobin, which could alert us to catch occult bleeding.

What evaluation process does your department use before deciding on new monitoring systems?

The main factors are reliability and relevance (measuring something that will not influence management is useless).

With so many monitoring systems available, how important is it that they are connected and can communicate with each other and with other hospital systems?

This is a very important factor when it comes to choosing equipment.

Is there a balance between long standing technologies that evolve and leaps in innovation that are not yet considered standard of care?

In practice, it is hard to prioritise – evolving techniques are helpful as are new techniques.

What is your vision regarding smartphones, tablets and their role in medicine in the near future?

We will use them increasingly. There is no doubt!

What is your view on the potential role of wearable wireless medical technology?

This technology is very promising indeed. We will go in that direction.

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For more information, please visit:
http://www.masimo.com/hemoglobin

CREATING THE ICU OF THE FUTURE: A DAY OF INNOVATION

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In this manuscript, we describe the process and results of a workshop to apply a no pre-conceived notions, outside-the-box approach to design an ideal ICU that we can begin implementing now. This design effort largely focused on technology, but is mindful that the technology must be used by clinicians and will be embedded in work processes and culture.

Introduction

More than a decade has passed since the Institute of Medicine issued its report, Crossing the Quality Chasm: A New Health System for the 21st Century (Institute of Medicine 2001). In the interim, facets of the United States healthcare system have changed. A concerted effort to deliver quality care has decreased central line-associated bloodstream infections (CLABSI) in intensive care units (ICU) nationwide (Pronovost et al. 2011; AHRQ 2012). Overall, hospitalised patients continue to experience preventable harm, such as hospital-acquired infections, and receive therapies they neither wanted nor needed. Empirical evidence suggests that we can do better.

Hospitalised patients are exposed to harm in a myriad of distinct ways. A subtle but equally devastating harm is disrespectful or undignified care, in which patients and families are excluded from the decision-making process or from information essential to understand the course of care (Institute of Medicine 2001). The historic approach to managing harm has largely relied on the clinician's heroism, requiring them to recognise and immediately intervene when harm is imminent. This approach is inefficient, unreliable, and inferior to a safe systems approach that prevents many potentially harmful situations from arising. In the ICU, a patient receives almost 200 interventions daily (Donchin et al. 1995), most directed at avoiding the dozen or more consequential harms they are at risk of suffering (Unpublished data; Armstrong Institute workshop, December 7, 2012). Missing any one intervention could have catastrophic results. Yet, our healthcare system relies on the memory and vigilance of busy clinicians, rather than technology, to ensure that all of these therapies are delivered.

Technology has not provided healthcare with the safety or productivity benefits that other highly technological industries have experienced. In part, this shortcoming reflects a limited use of systems engineers to design care systems that support clinicians and protect patients. It also reflects a failure to integrate a composite of innovative technologies into an intelligent information ecosystem, in which the electronic medical record (EMR) is one part of the system. For example, an aeroplane cockpit is dramatically safer today. Thirty years ago a dizzying array of instruments bombarded pilots with vast quantities of unfiltered information that was difficult to assimilate. Today pilots rely on automation, and only receive context-sensitive information that provides exactly what he or she needs to make wise decisions.

Today an ICU is far more complex and potentially dangerous than 30 years ago. Each room is filled with more monitors, wires, and devices that typically do not communicate with each other or with clinical information systems. Clinicians are the safety net for patients. Clinicians are piloting a 30-year-old cockpit, bombarded with more data and left to prioritise or make sense of the information. Few tasks are automated. Despite significant investments, information technology does not help clinicians identify or predict patients at risk for harm. The systems do not describe what therapies are appropriate nor monitor the administration of needed treatments. Most tellingly, information technology lacks intelligence to learn or offer guidance that would improve global outcomes. Finally, patients and their families have not been actively engaged in the hospital setting, leaving them feeling isolated with inadequate information and unmet needs. The desired goal of truly personalised medicine, beyond genetic testing (Behrens et al. 2008), is not imminent.

> *"Drastic changes are needed in current ICU systems to partner with patients and families, eliminate preventable harm, optimise patient outcomes and experience, provide clinicians with better decision support tools, and reduce waste of healthcare resources"*

A systems approach to improve ICU care needs to address culture, people, processes, and technology. Substantial efforts have explored interventions, such as the Comprehensive Unit-based Safety Program, to improve ICU culture and teamwork. Minimal work has explored how to ensure that technology serves clinicians, rather than making clinicians support technology.

Methods

Researchers from the Armstrong Institute for Patient Safety and Quality (AI), an entity of Johns Hopkins Medicine, hosted a one-day workshop on December 7, 2012. A diverse group of 69 people representing patients and families, clinicians, patient safety researchers, hospital administrators, professional society leaders, and device manufacturing leaders participated in the workshop (See Appendix 1 [on website, www.icu-management.org] for a list of participants and their affiliations). The workshop format followed an innovation process. The overarching goal was to design an ideal ICU environment that eliminated preventable harms, optimised patient outcomes and the patient and family experience, and reduced waste in healthcare delivery. We identified four tasks or objectives based on this goal:

1. Better understand the needs of patients, family members, and caregivers in the ICU.
2. Work in multidisciplinary teams to brainstorm innovative solutions and build a system that met patient, family, and caregiver needs.
3. Include in that system a mechanism to identify new or unanticipated needs.
4. Ensure that the system is flexible enough to address new or unanticipated needs.

Strategy – The Innovation Process

We used an innovation process called design thinking that was created by IDEO (Ravitz et al. 2013), a global consultancy that takes a human-centred, design-based approach to help organisations innovate and solve problems (http://www.ideo.com/about). The workshop had three main phases: inspiration, ideation, and implementation (Figure 1).

Inspiration

The work was grounded in a presentation highlighting how current ICU medicine and healthcare in general are wasteful of human life, labour and money. The presenter (PJP) recounted real stories of young lives lost in ICUs because systems were not integrated. These stories anchored participants' perspectives in the experiences of patients, families, and clinicians. The presentation included examples of how care can be unintentionally disrespectful to patients, and also to clinicians, who struggle with poorly designed systems and ever-increasing workloads, prompting some to eventually leave the ICU workforce.

Figure 1. Innovation Process Using Design Thinking.
Shows the innovation process used during the workshop to draw participants into designing an idealised intensive care unit (ICU). It involved three sequential phases, beginning with inspiration, in which a presentation, intensive care unit visits, and patient interviews set the stage for why change was needed. In phase 2, ideation, participants were divided into small teams to brainstorm what an ideal ICU would include and choose two themes or areas for improvement in the ICU. In phase 3, teams implemented their ideas by constructing a prototype ICU.

The presenter described ways current ICU systems cannot handle the complexities inherent in caring for critically ill patients, and how this overburdens clinicians. Workshop participants were challenged to understand the demands and the often obscure interactions that connect seemingly independent systems in an ICU and to develop a new ICU that met the needs of patients, family members, and clinicians (Stokols et al. 2008; Pronovost and Bo-Linn 2012).

The presentation was followed by a visit to seven ICUs (adult: medical, coronary care, general surgery, cardiac surgical, trauma, neurosurgical, surgical oncology, and paediatrics) at The Johns Hopkins Hospital. Workshop participants also visited several patients who were recently discharged from an ICU to an intermediate care unit. Appropriate permission was obtained and Health Insurance Portability and Accountability Act compliance maintained. The participants were briefed for 30 minutes on observation methods, given an observation guide (Appendices 2a to 2c, available on the website), and asked to write down their observations. Careful observation while immersed in a real world environment plus context-driven inquiry of individuals functioning within the system is a common method to deconstruct complex systems and then reconstruct innovative alternatives (Gurses et al. 2009).

To obtain a broad range of observations in a short period of time, workshop participants were divided into three groups. Each group was assigned a specific area of observation:

- People (e.g., communication, human interactions, human-machine interaction), including interviews with patients and families;
- Technology and physical space (e.g., available space, ICU environment, monitors, alarm systems, other technologies, EMR);
- Processes and workflows (e.g., tasks, work processes, sequencing of tasks, interdependency of tasks).

Observers worked in pairs, with each member from a different specialty or area of interest. Assignments forced participants to observe and evaluate unfamiliar environments, activities or situations. For example, we asked ICU physicians and ICU nurses to interview patients recently transferred to a step-down inpatient unit, and we asked technologists and engineers to observe people rather than devices. All participants reported that this approach brought another perspective and provided novel insight.

After visiting the ICUs, participants were organised into seven teams of 8 to 10 people. We constructed teams that represented each field, each ICU visited, and each observation assignment. Findings were shared with other team members, summarised, and grouped based on similar themes. The teams then named each group of observations based on common characteristics. This exercise helped participants organise their observations of people (patients, health workers, and families), technology, space, and processes around themes that impressed them as key determinants of current paradigms in the ICUs.

Ideation

In this next phase, teams chose two themes or areas for improvement in the ICU that they felt provided ample opportunities for creativity and impact. One facilitator was assigned to each team to

help develop these themes into broad discussion topics that began with a "How might we…?" method. This question format prompted teams to ask optimistic questions that offered maximal opportunities for new thinking. For example, the question, "How might we create an ICU that ensures dignity and respect for patients and their family members?" casts a wide net to pull in novel ideas.

The facilitator provided a short training session on brainstorming, a technique that emphasises presentation of ideas no matter how far-fetched they may seem to an open-minded audience. The advantage of brainstorming is generating a wide range of innovative ideas. Each team completed two 20-minute rounds of brainstorming to address their "How might we…?" questions. Answers were grouped by similar ideas. The teams then chose three ideas that inspired them and were, in their estimation, the most relevant and promising for designing a more ideal ICU.

Prototyping

In this last phase, teams constructed prototypes of their ideal ICU. The exercise involved synthesising concepts and using standard ICU equipment and some basic materials to create a physical product. This exercise was designed to energise and challenge the teams' creativity, enabling them to truly step outside the box and create what an ICU of the future could look like and how it could operate. Each team then presented key elements of their novel designs and prototypes and a facilitator synthesised the comments.

Results

Teams generated novel, futuristic, and challenging ideas. Some could be immediately implemented, while others required advances in technology to implement. The proposals primarily focused on changes in the physical ICU structure, workflow, technology support requirements, patient and family experiences, and operations. The goals and main concepts created by each team are briefly described below (see Table 1 for details).

Team 1 sought to use technology to deliver evidence-based care and to design patient and family-centred care processes. Their prototype included wireless technology and equipment (e.g., implantable patient monitors and treatment microsystems), and voice-activated information and communication systems to access and integrate history, physical findings, and diagnostic data.

Team 2 sought to improve situational awareness and coordination of care between providers and families. Their design centred on a wall-mounted computer display to continuously orient clinicians and family members to current and future plans for care. The system provided computerised facial identification of providers and their specific roles in care delivery, displayed reminders of required care and virtual huddles for handoffs, and had electronic location monitors to eliminate delays from tracking down staff, patients, or family members.

Team 3 focused on converting data into knowledge and action. They invented an automated head-mounted technology controlled by voice or eye blinks. Caregivers used it to access, document, and share patient data, record rounds, and complete hospital requirements (e.g., populating

Team	Description of Main Concepts
Team 1	• Everything is wireless, including the ventilator, monitors, and drug delivery systems • Voice dictation to document and access patient data on a large computer screen (removes time burden for documentation) • Patients implanted with wireless monitor to measure blood pressure, heart rate, blood gases, oxygen saturation, etc. • Patients implanted with "Pyxis pill" that contains all needed medicines, administered at will through the digestive tract • All diagnostics done interactively with an intelligent computer system, which corrects the clinician's decisions as needed (e.g., medication conflicts)
Team 2	• Visual display of where patient and staff currently are in the entire care process, including actions needed (eg medication doses or family conferences) • Visual display maintains a real-time comparative analysis of the patient's trajectory based on many variables, including some that are patient and family controlled and others that are based on chance • Face recognition that identifies staff as they enter the room and displays their health care function to familiarise patients with staff and trigger actions (e.g., cleaning room or changing ambient temperature) • Videoconferencing on tablets for handoff of patients between caregivers, termed a "virtual huddle" • Radiofrequency identification (RFID) chips to track staff, patient, and family member locations, and information used to update such activities as drug delivery, radiology tests
Team 3	• Head-mounted technology called "blinkware," controlled by caregiver voice, eye blinks, or toes • In-room displays access all patient information (e.g., consent forms, x-ray films, alerts from electronic medical record) • Blinkware system is one-stop shop for all clinician and hospital needs; document patient data, share data with research studies, and patient safety monitoring; credential clinicians, teach residents, and send feedback to manufacturers on the quality and usability of their products. • Blinkware system monitors the energy and stress level of clinicians to provide feedback for the elimination of medical errors and staff burnout
Team 4	• Conceived an artificial intelligence assistant (avatar) on computer tablet to support and advise caregivers • Using voice input method, avatar helps input orders, page colleagues for consultations, offers clinical decision-making based on real-time assessment of the patient, verifies drug doses • Avatar can also send instructional materials to family members via email or directly to their tablets by voice command to encourage greater communication and information-sharing
Team 5	• Tablet-based system to communicate information and involve family and patients, with a heads-up or eye tracking control for patients who cannot talk or use their hands • Access to patient's EMR with a natural language conversational system and hypertext to make information understandable, guidance for interpreting trends in data, and the ability of family and patient to annotate the record • Multilingual capabilities on system • Virtual tours of the ICU to orient patient and family to the processes, equipment, and staff • Information families need to survive in the local area while their loved ones are hospitalised (e.g., tours of hospital services, local hotels, restaurants and laundromats, and even movies on demand) • Disease education tailored to the patient's diagnosis, providing links to credible outside Web sites such as UpToDate® or WebMD® • Enables communication with the care team using voice-based automatic translation that instantly sends messages to the clinical team's preferred communication devices • Shows pictures of the care team with information on each person's role and personal interests in efforts to humanise the care team • Real-time help link available by voice command • Videos targeted to family members, tailored to the diagnosis of the patient, describing how they can help in patient care (e.g., oral care, ambulation) • FaceTime, Skype, or both to communicate with remote family members
Team 6	• More humanising and less hierarchical signage on doors to patient rooms • More effective signage to avoid the declining effect of current hand washing signs • Device that instantly sanitises hands after you insert them; with an RFID to track hand washing compliance and update records • Comfortable family area in the patient room, such as shelves, noise cancelling devices, plants and fountains, soft full spectrum lighting, aromatherapy, refrigerator with refreshments, a home-style headboard, cosy unique blankets, on-demand TV, control of windows, door and shades, lighting, music, white noise • Wireless black box recorder in the room that aggregates and stores all data • Computer wall display for care team and family; information organised by organ system, orders pop up instantly on the display and automatically control devices (e.g., ventilators, pumps) • Medicine cabinet in the room • Tablet-type applications replace all paper (e.g., to replace the shift change spreadsheet that some nurses share with each other), with voice-activated data entry and documentation – automation eliminated manual entry • One sensor controls all devices • Family is loaned a tablet with access to the patient's EMR
Team 7	• Interactive screen in every patient room that defaults to the patient/family screen • Screen has a patient dashboard, displaying the physician and nurse daily care plan, the family care plan, overall goals for care, patient wellbeing, smart alarms that aggregate individual alarms and detect real from false alarms, and pattern recognition-based display of sensor data; remote access to dashboard available from any mobile device • RFID technology so family members can open a web page to update their care journal, provide feedback to staff, express their thanks to the staff, or post photos • Screen has centralised communication for the care team and family, with access to photos, videos, Skype/FaceTime with family members, definitions of procedures, information on local restaurants, and other needed resources • Uses a red-yellow-green visual display to warn families about the patient's condition, using pattern recognition and clinical diagnostics rather than showing individual vital signs or other confusing measures • Clinical diagnostic system displays potential harms (e.g., a missed heparin dose to prevent a deep venous thrombosis) • A large screen on the unit displays every patient and uses a red-yellow-green coding for their condition rather than too many individual data points • RFID informs family members when their loved one's doctor is on the unit so they can find him/her for a consultation or question. It also identifies caregivers entering the room and provides relevant information about the person

Table 1. Main Concepts of an Ideal ICU Described by Teams

the patient record, clinical credentialling). This technology had a patient dashboard of key clinical indicators. Hospital administrators and supervisors could also use the technology to train providers, and, through biometrics, monitor clinician stress levels to prevent burnout, excessive fatigue, and medical errors related to these impairments.

Team 4 considered how an artificial intelligence agent might reduce caregiver anxiety. They posited that the major causes of anxiety were a sense that heroic action was frequently needed and a fear that making a mistake would harm a patient. The team conceived a voice-prompted, tablet-based, virtual personal assistant (avatar) to completely support caregiver needs (e.g., calculate medication dosages, remind caregiver about a needed intervention).

Team 5 sought to more effectively involve families in the care of their loved ones. They envisioned using tablet-based technology to improve communications between patients and their family members (offsite and in-hospital), and between patients, families and the care team. The tablet would let families and patients access their EMRs, provide lay translations of medical terminology, translate English to other languages and vice-versa, share care team information, deliver educational materials, and recommend accommodations and facilities close to the hospital.

Team 6 sought to improve the patient and family experience and foster collaboration among clinicians, family members, and patients. They modified the physical environment, creating a family area in each room with amenities that enabled families to stay for longer periods (e.g., comfortable chairs, shelves, a refrigerator, and noise-cancelling technology). They invented an instant hand sanitiser and wall displays or tablets to enhance communication, retrieve information, and control room functions (e.g., lighting). They included a voice-activated system for clinical data entry, and order entry for automated activation of devices, such as ventilators or infusion pumps.

Team 7 sought to enable collaboration in care between caregivers and family members by improving the communication of all relevant information. They envisioned a wall-mounted interactive monitor in each patient room that communicated information to the care team, patient, and family. This system contained patient and family-based applications (e.g., care journal, photo wall, understandable explanations of medical procedures) and caregiver-based applications (e.g., clinical diagnostics, daily goals, a patient dashboard of medical status). This technology allowed caregivers to remotely access a patient's medical information from any mobile device.

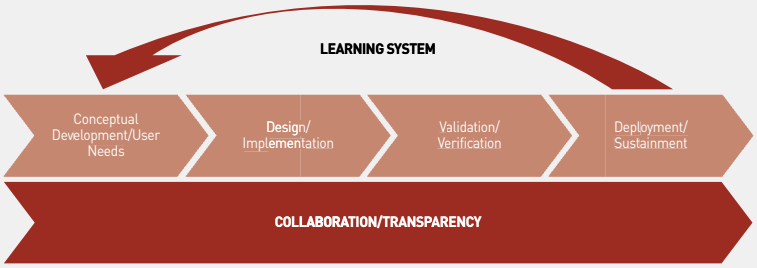

Figure 2. System Lifecycle.
Illustrates the System Lifecycle, which is a framework to understand the large body of qualitative data collected during the workshop. It represents the high-level elements of the system lifecycle that were supported by the important concepts of collaboration and transparency that participants repeatedly noted were key factors in improving patient safety.

Discussion

The workshop was undertaken to step outside current ICU medicine and invent an ICU that optimised care. We undertook this project because drastic changes are needed in current ICU systems to eliminate preventable harm, improve patient outcomes and experience, provide clinicians with better decision support tools, and reduce waste of healthcare resources. Intensive care was established to improve the health of critically ill patients, but care is more complex than 30 years ago. Studies in the ICU found an estimated 38.8 sentinel events per 100 patient ICU days, with 31% of patients experiencing multiple events (Valentin et al. 2006), and multiple complications in a single patient following abdominal aortic surgery (Pronovost et al. 2001). Multiple events in a single patient (588 events in 423 unique patient admissions) were also discovered in a retrospective study of patient admissions (Landrigan et al. 2010).

All seven teams noted how poorly the current ICU information technology meets clinicians' and patients' needs. They commented how the technology in their personal lives was far superior to the technology in their professional lives. Simply put, current approaches are inadequate to achieve our overarching goal of optimising ICU care.

The participants in this conference described seven prototypes that, if implemented, promise to substantially improve care delivery. We found common attributes among these different designs that fell into several overlapping imperatives.

1. Create intelligent clinical systems

- Use computer-based technology to automate tasks (e.g., voice dictation), improve access to all data from any device (e.g., smartphone, tablet), and establish safeguards and reminders to assist clinicians in medical care and decisions.
- Such a system would eliminate duplicate documentation and data input, improve clinical diagnostics, decrease clinician's reliance on memory, and reduce the potential for medical error.

2. Create an integrated information ecosystem

- Build an electronic platform to connect devices (e.g., ventilators, medication pumps), monitors, intelligent clinical systems (described in point 1), and the patient's EMR. The ecosystem would use wireless technology, have accurate sensors, and communicate information in real time to clinicians and patients. For example, the ecosystem would couple smart alarms to the patient's room equipment and EMR and communicate.

3. Engage the patient and family in the medical care experience

- Design a patient room with smart screens that display patient information in a timely and understandable manner, offer multilingual translations, and play instructional videos tailored to the patient's medical situation.
- Reduce clutter (e.g., wireless connection of equipment, described in point 2) and provide an area of comfort for family members. Involve the family in the patient's care (e.g., provide

Continues on page 41

PATIENT-VENTILATOR ASYNCHRONY

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Patient-ventilator asynchrony is more frequent than previously considered and correlates with unfavourable outcomes. Different forms of asynchronies may depend on various causes. When detected, asynchronies may be often corrected.

Controlled mechanical ventilation, although necessary in many instances, has side effects and complications and is therefore interrupted as soon as possible in favour of forms of partial ventilatory assistance, where the ventilator is driven by the patient's spontaneous breathing activity. With these modes both the patient and ventilator contribute to generate the ventilatory output and share the work of breathing. If, on the one hand, these modes offer clinical advantages such as reduced need for sedation, lower risk of respiratory muscles atrophy and dysfunction, and less haemodynamic impairment, on the other hand, a poor patient-ventilator interaction may lead to discomfort, agitation, increased work of breathing and worsening of gas exchange (Sassoon and Foster 2001).

Going to extremes, a poor interaction may result in asynchrony, which is when the patient and the ventilator do not work in unison. Chao et al. first suggested that patient-ventilator asynchrony could affect the outcome of weaning, the rate of failure being higher in patients with asynchrony (Chao et al. 1997). Later on, Thille et al. found that approximately one-fourth of patients receiving partial ventilatory assistance for more than 24 hours had a high incidence of asynchrony; notably, the patients with asynchronies had a prolonged duration of mechanical ventilation and, consequently, a high rate of tracheostomy (Thille et al. 2006). Recently de Wit et al. confirmed the worsened outcome of patients with asynchronies (de Wit et al. 2009). Whether asynchrony worsens a patient's outcome, or is rather a marker of severity, however, is still unclear (Sassoon 2011).

Classification and Detection

While, strictly speaking, asynchrony means absence of concurrence in time, the term is often used to indicate, in general, more a disturbance of coordination between two events normally occurring simultaneously. Relevant asynchronies are commonly considered: **1) ineffective (wasted) efforts**, also named ineffective triggering and by far the most frequent, indicating that the effort exerted by the patient is not assisted by the ventilator; it may occur during both the inspiratory and expiratory mechanical phase, and is often consequent either to a weak effort, or to the presence of intrinsic positive end-expiratory pressure (PEEPi) (Leung et al. 1997; Parthasarathy et al. 1998); **2) auto-triggering**, which means the ventilator delivers assistance without patient effort; as it occurs when variations in airway pressure and/or flow secondary to cardiac oscillations (Imanaka et al. 2000) or air-leaks (Vignaux et al. 2009) are unduly sensed as triggering efforts; **3) double-triggering**, characterised by two mechanical cycles triggered by the patient separated by a very short expiratory time (<30% of the mean inspiratory time) (Thille et al. 2006); it occurs because the mechanical breath terminates before the completion of the patient's effort, which triggers, after a brief phase of exhalation, a second mechanical breath. Additional forms of asynchrony are: **4) premature (anticipated) cycling**, indicating that the duration of the mechanical breath is shorter than the patient's own inspiration; and opposite **5) prolonged (delayed) cycling**, i.e., the mechanical breath lasts longer than the patient's effort (Vignaux et al. 2009). It is generally considered that asynchronies assume clinical relevance when their rate exceeds 10% (Colombo et al. 2008; Thille et al. 2006).

Even though algorithms for automatic recognition have been proposed (Chen et al. 2008; Mulqueeny et al. 2009; Sinderby et al. 2013), in clinical practice, asynchronies are commonly detected by visual inspection of the ventilator waveforms. Colombo et al., however, recently showed that this approach provides a gross estimate, with a relatively small influence of physician's experience, suggesting that additional signals such as oesophageal pressure or diaphragm electrical activity are necessary for proper detection (Colombo et al. 2011).

Causes of Asynchrony

Asynchronies may be secondary to multiple factors related to either the patient (mechanical properties of the respiratory system, breathing pattern, respiratory drive and effort), and/or the ventilator (mode and settings).

Ineffective triggering and delayed cycling are frequently encountered in patients with airway obstruc-

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**Compared to conventional mechanical ventilation

1. Xirouchaki N, Kondili E, Vapoidi K, et al. Proportional assist ventilation with load-adjustable gain factors in critically ill patients: comparison with pressure support. *Int Care Med.* 2008;34:2026-2034.
2. Younes, Magdy. Proportional Assist Ventilation, a New Approach to Ventilatory Support. *AM REV RESPIR DIS* 1992; 145:114-120.

tion, determining dynamic hyperinflation and PEEPi (Nava et al. 1995); while applying external PEEP may help to reduce ineffective efforts, delayed cycling may be eliminated, shortening ventilator insufflation by varying the inspiratory flow threshold to a higher value during Pressure Support (PS), or decreasing machine pre-set inspiratory time in Assist/Control (A/C). Patients with a very low respiratory system compliance undergoing PS may develop double triggering, because the inspiratory flow decays rapidly and the threshold for cycling from inspiration to expiration is reached when the patient's effort is still ongoing (Mauri et al. 2013). Decreasing the flow threshold to a lower value helps in some cases, but is ineffective in conditions of particular severity (Mauri et al. 2013).

> *"Over-assistance is probably the most common determinant of asynchrony"*

Any condition reducing the respiratory drive and/or altering the timing of breathing may determine asynchronies. When the respiratory drive is entirely suppressed and trigger sensitivity is set at a very low threshold, auto-triggering frequently occurs, consequent to activation of the mechanical assistance by non-respiratory events, such as cardiac oscillation (Imanaka et al. 2000) or air-leaks determining small fluctuations on the flow and airway pressure signals (Vignaux et al. 2009). When the drive is quite reduced, but not entirely suppressed, ineffective triggering, premature cycling and double triggering may all intervene.

Over-assistance is probably the most common determinant of asynchrony. High tidal volumes and respiratory alkalosis, secondary to excessive ventilator assistance, reduce the drive to breathe through feedback mechanisms mediated by chest wall and lung mechanoreceptors, and central and peripheral chemoreceptors, respectively. Optimising the ventilator settings to avoid over-assistance is often sufficient to reduce or even abolish patient-ventilator asynchrony. Thille et al. eliminated ineffective triggering in two-third of the cases by decreasing tidal volume and, accordingly, the preset inspiratory pressure, without observing clinically relevant increases in the patient's effort (Thille et al. 2008).

Sedatives affect the respiratory drive and/or timing through a direct effect on the brain. A pilot observational study by de Wit et al. first showed a correlation between the level of sedation and asynchrony (de Wit et al. 2009). More recently Vaschetto et al. confirmed and extended these findings in a study evaluating the effects of three levels (absent, light and deep) of sedation by propofol; they found that increasing the depth of sedation caused a reduction in respiratory drive, with minimal effects on timing, which affected breathing pattern, gas exchange, and, in the end, patient-ventilator interaction and synchrony (Vaschetto et al. 2014).

The conventional modes of partial assistance delivering a preset inspiratory pressure (PS) or volume (A/C) do not respond either breath-by-breath and intra-breath to changes in the patient's demand. New modes are now available that introduce a proportionality between patient demand and ventilator assistance and improve synchronisation between the patient's own inspiratory time and duration of ventilator applied assistance (Navalesi and Costa 2003). With Neurally Adjusted Ventilatory Assist (NAVA) and Proportional Assist Ventilatory Plus (PAV), the ventilator delivers assistance in proportion to diaphragm electrical activity and patient generated volume and flow, respectively; both modes have been shown to reduce asynchronies, irrespective of patient's respiratory mechanics, level of assistance and sedation (Colombo et al. 2008; Giannouli et al. 1999).

Non-Invasive Ventilation

Non-invasive ventilation (NIV) is increasingly used to treat patients with acute respiratory failure. Achieving a good patient-ventilator interaction is even more important during NIV, because the patient's tolerance is a crucial determinant of success and sedatives are preferentially avoided, or used at very low doses. Recent studies, however, have shown that, secondary to air-leaks and characteristics of the interface, the rate of asynchrony is quite high during NIV (Bertrand et al. 2013; Cammarota et al. 2011; Navalesi et al. 2007; Piquilloud et al. 2012; Vignaux et al. 2009). Use of ventilators specifically designed for NIV, with algorithms for air-leaks detection and compensation (Carteaux et al. 2012), reduction of the overall applied pressure (Vignaux et al. 2009), choice of the proper interface (Navalesi et al. 2007), use of a leaks-insensitive ventilatory mode (Bertrand et al. 2013; Cammarota et al. 2011; Piquilloud et al. 2012) are all helpful strategies for decreasing asynchronies during NIV.

Summary

Patient-ventilator asynchrony occurs more frequently than previously considered in patients receiving partial ventilator assistance, during both invasive and non-invasive ventilation, and correlates with unfavourable outcomes. Asynchronies are generally detected by visual inspection of ventilator waveforms, but the use of an additional signal, such as oesophageal pressure or diaphragm electrical activity, may improve their recognition. There are several types of asynchronies, which depend on multiple factors related to either the patient (mechanical properties of the respiratory system, breathing pattern, respiratory drive and effort), and/or the ventilator (mode and settings). Identifying the determinants of asynchrony often allows finding solutions to reduce or even eliminate its occurrence. ■

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GLYCAEMIC CONTROL IN THE CRITICALLY ILL: WHAT HAVE WE LEARNED SINCE NICE-SUGAR?

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Introduction

Glycaemic control of the critically ill has been a topic of considerable interest in the critical care community since the publication of a single-centre randomised controlled trial (RCT) of intensive insulin therapy (IIT) targeting euglycaemia, blood glucose (BG) 80-110 mg/dL, in a population of mechanically ventilated surgical intensive care unit (ICU) patients, 63% of whom had undergone cardiovascular surgery (Van den Berghe et al. 2003). However, the dramatic reductions in mortality and morbidity demonstrated in this investigation were not reproduced in subsequent trials (Van den Berghe et al. 2006; Brunkhorst et al. 2008; Preiser et al. 2009; Arabi et al. 2008), two of which required premature termination due to high rates of hypoglycaemia in the interventional arms (Brunkhorst et al. 2008; Preiser et al. 2009). The NICE-SUGAR trial, conducted in 42 centres, and involving an heterogeneous cohort of 6,104 patients concluded that a moderate glycaemic target, 140-180 mg/dL, achieved with a very low rate of severe hypoglycaemia, was associated with modestly lower mortality than that achieved with 'tight' control, targeting 80-110 mg/dL (NICE-SUGAR Study Investigators 2009). This study prompted the promulgation of guidelines advocating loose glycaemic targets (Dellinger et al. 2008; Moghissi et al. 2010; Ichai and Preiser 2010; Qaseem et al. 2011), and many ICUs followed suit (Kaukonen et al. 2013); interest in tight control waned.

Nevertheless, a considerable amount of new literature has expanded our understanding of factors impacting glycaemic control in the critically ill. This concise review will describe investigations appearing after the publication of the NICE-SUGAR study and focus on several key themes: the independent association of three domains of glycaemic control – hyperglycaemia, hypoglycaemia, and glucose variability (GV) – on mortality; the possible emergence of a fourth domain, glucose complexity; the relationship of diabetic status to the domains of glycaemic control; and, finally, issues relating to monitoring frequency.

The Three Domains of Glycaemic Control: Hyperglycaemia, Hypoglycaemia and Glucose Variability

Hyperglycaemia is ubiquitous in acutely and critically ill patients, due to a combination of endogenous and iatrogenic factors (Duncan et al. 2009), and the treatment of hyperglycaemia has been the focus of the interventional trials of IIT. *Hypoglycaemia* has been the unifying complication of the interventional trials. The percentage of patients who sustained at least one episode of severe hypoglyacemia, most typically defined as a single blood glucose (BG) level of < 40 mg/dL, in the RCTs of IIT published before NICE-SUGAR ranged from 5.8% (Van den Berghe 2003) to 28.6% (Van den Berghe et al. 2008), in comparison to the 6.8% of patients in the interventional arm of NICE-SUGAR who had this complication (NICE-SUGAR Study Investigators 2009). Although the authors of the first Leuven study concluded that hypoglycaemia had no discernable deleterious impact (Van den Berghe et al. 2008), prospective RCT data as well as observational investigations have since determined that hypoglycaemia is independently associated with mortality. In 2010 the Leuven investigators published a post-hoc analysis of their two RCTs of IIT, and reported an odds ratio (95% CI) for mortality associated with a single episode of severe hypoglycaemia (BG < 40 mg/dL) of 3.23 (2.25-4.64) (p<0.0001) (Meyfroidt et al. 2010). Two years later this finding was confirmed by the NICE-SUGAR investigators (NICE-SUGAR Study Investigators 2012). The odds ratio (95% CI) of mortality associated with a single episode of severe hypoglycaemia was 2.10 (1.59-2.77) (p<0.0001). In addition, a single episode of moderate hypoglycaemia (BG 41-70 mg/dL) was also found to be independently associated with death, with odds ratio (95%CI) 1.41 (1.21-1.62) (p<0.001).

> *"We have passed the era where 'one size fits all'"*

Observational data published after NICE-SUGAR corroborated the independent association of mild hypoglycaemia with mortality. In 2010 Egi et al. clearly described increasing rates of death associated with mild hypoglycaemia – BG 54-63 mg/dL – in 4,946 patients admitted to two mixed medical-surgical ICUs

in Australia (Egi et al. 2010). Similarly, an investigation including a mixed cohort of 6,240 patients from the Academic Medical Center in Amsterdam, Stamford Hospital (Stamford, CT, USA) and the GLUCONTROL RCT of IIT, reported that patients with minimum BG in the 80-110 mg/dL range had the lowest rate of death, with increasing rates of death associated with minimum BG 70-80, 55-70, 40-55 and < 40 mg/dL (Krinsley et al. 2011). For the entire cohort, a single episode of BG 40-69 mg/dL was independently associated with increased risk of death (p=0.0011).

Glucose variability (GV), the third domain of glycaemic control, was not contemplated in the design and reporting of the interventional trials of IIT. However, increased GV was reported to be independently associated with increased risk of death in observational studies published prior to NICE-SUGAR (Egi et al. 2006; Krinsley 2008), and this finding was subsequently corroborated by the Leuven investigators using data from their two interventional trials, published in 2010 (Meyfroidt et al. 2010). A robust literature has since evolved that describes the independent association of increased GV with risk of death in various settings: a mixed medical-surgical population (Hermanides et al. 2010); in relation to nutritional support (Suhaimi et al. 2010); related to therapeutic hypothermia (Cueni-Villoz et al. 2011); in 37 Dutch ICUs (Meynaar et al. 2012); in acute pancreatitis (Zuo et al. 2012); in acute myocardial infarction (Su et al. 2013); and in association with administration of total parenteral nutrition (Farrokhi et al. 2014). Moreover, increased GV may herald the development of hypoglycaemia (Kauffmann et al. 2011).

Additional work suggests that derangements in these three domains of glycaemic control have a cumulative association with death in critically ill populations. Mackenzie and coinvestigators evaluated 3,422 patients admitted to four different specialty ICUs in Birmingham, UK, and found that the odds ratio (95% CI) for mortality in patients with hypoglycaemia was 2.5 (2.0-3.1) (Mackenzie et al. 2011). The odds ratio (95% CI) for mortality in patients with hypoglycaemia and hyperglycaemia was 4.8 (3.4-6.8). Among patients who had derangements in all three domains, the odds ratio (95% CI) for mortality was even higher – 6.0 (3.9-9.2). These findings were largely corroborated in an investigation that included 101,877 patients admitted to 344 US hospitals (Omar Badawi et al. 2012).

Glucose Complexity: a Fourth Domain of Glycaemic Control in the Critically Ill?

Complex biological systems are characterised by a highly complex output; critical illness can lead to 'decomplexification' (van Hooijdonk et al. 2012). Two examples include the loss of heart rate variability or temperature complexity in the setting of severe infection. Loss of complexity in the glycaemic profile has been demonstrated as humans progress from health through metabolic syndrome to type 2 diabetes (Churruca et al. 2008). Meyfroidt et al. evaluated a measure of BG complexity, jackknifed approximate entropy, and reported that this parameter was significantly lower in non-survivors of the two Leuven investigations of IIT than in survivors (p=0.0006) (Meyfroidt et al. 2010). Two investigations using continuous glucose monitoring via subcutaneous sensors evaluated a different metric of glucose complexity – detrended fluctuation analysis – in small cohorts of critically ill patients, and corroborated the finding that glucose complexity was significantly lower in non-survivors than in survivors (Lundelin et al. 2010; Brunner et al. 2012). Curiously, in one of these studies high glucose complexity was also associated with increased mortality (Brunner 2012). Future research, in particular using monitoring technology employing higher degrees of analytic precision, will be needed to further clarify the relationship of glucose complexity to mortality, as well as to assess the effect of therapeutic interventions on this emerging domain of glycaemic control.

What About Diabetic Status?

A burgeoning literature has explored the independent association of diabetic status to mortality in the critically ill. An analysis of data from interventional trials of IIT suggested that IIT had more benefit to the non-diabetic patients in the trials (Krinsley et al. 2012). Multiple observational studies indicate that diabetes may, in fact, be independently associated with reduced risk of mortality in the critically ill. Graham and coworkers performed multivariable analysis on data from two large cohorts of patients – 36,414 patients from the Mayo Clinic system and 1.5 million patients from the University Health Consortium (Graham et al. 2010). The odds ratio (95% CI) for mortality associated with diabetes was 0.88 (0.79-0.98) (p=0.022) and 0.75 (0.74-0.76) (p<0.0001) respectively. A meta-analysis of 141 studies, using unadjusted data only, demonstrated no overall association between diabetes and mortality in populations of medical, medical-surgical, general surgical and trauma patients (Siegelaar et al. 2011). Studies involving cardiac surgery patients were the only exception to this finding; in this patient group, patients with diabetes sustained higher mortality than did those without diabetes (Siegelaar et al. 2011).

Potential mechanisms to explain a protective effect of diabetes in the critically ill may include improved nutritional or caloric substrate in obese Type 2 DM patients and adaptation to previous oxidant stress. Hyperglycaemia is ubiquitous in the critical care unit, due to relative insulin resistance, counter-regulatory hormones and iatrogenic factors, such as nutritional therapy, intravenous fluid administration and corticosteroid use, but may be injurious primarily to non-diabetics. Tolerance to the deleterious effects of hyperglycaemia may in fact be the primary mechanism protecting diabetics, and explain the 'diabetes paradox' (Krinsley and Fisher 2012). Preadmission glycaemic control in diabetics may have an important modulating effect on the relationship between glycaemic control during critical illness and mortality. Egi and colleagues evaluated the interaction of HgbA1c obtained prior to ICU admission and mean BG during ICU stay in a cohort of 415 diabetic patients admitted to two Australian ICUs (Egi et al. 2011). There was no difference in mean BG comparing survivors and non-survivors. However, patients with higher preadmission HgbA1c levels had higher mortality associated with lower mean BG levels, raising the intriguing

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possibility that aggressive correction of hyperglycaemia in patients with poor preadmission glycaemic control might contribute to adverse outcomes.

The relationship of diabetic status to the three domains of glycaemic control and mortality was explored in a recently published four-continent 9-centre observational study involving an heterogeneous population of 44,964 critically ill patients (Krinsley et al. 2013). Patients with diabetes had higher rates of mild and severe hypoglycaemia, higher GV and higher mean BG levels during ICU stay (all comparisons $p<0.001$). Nevertheless, for the entire cohort, diabetes was independently associated with decreased risk of mortality with odds ratio (95% CI) 0.92 (0.87-0.97) $p=0.003$. Among patients with diabetes there was no relationship between mean BG during ICU stay and mortality, and mean BG 80-110 mg/dL was independently associated with increased risk of mortality. Among patients without diabetes, increments of mean BG above 80 mg/dL were associated with progressively higher rates of death and the BG ranges of 80-110 mg/dL and 110-140 mg/dL were independently associated with decreased risk of death. For all patients mild as well as severe hypoglycaemia were independently associated with increased risk of mortality. For all patients increasing GV was associated with increased mortality. However, among patients with diabetes GV was not independently associated with increased risk of mortality. In contrast, among non-diabetics, GV, as reflected by coefficient of variation (CV) > 20%, was independently associated with increased risk of mortality. These findings were subsequently confirmed in a 10,320 patient study conducted in a single medical-surgical ICU (Sechterberger et al. 2013). Mean BG and high GV were independently associated with death in non-diabetics but not in diabetics, while hypoglycaemia was independently associated with death in the entire cohort.

The Importance of Measurement Frequency

Blood glucose monitoring occurred every one to four hours in the major interventional trials of IIT. The frequency of BG monitoring ranged from 2.8 to 10.6 tests per 24 hours in the 9 centres included in the large observational study referenced earlier (Krinsley et al. 2013). It is logical to infer that intermittent BG monitoring should be associated with 'missed' episodes of hyperglycaemia and hypoglycaemia. This, in fact, was demonstrated in an evaluation utilising continuous subcutaneous monitoring (Holzinger et al. 2010). A recently published investigation using a Monte Carlo mathematical simulation of patients on glycaemic control protocols modelled the relationship between monitoring frequency and metrics of glycaemic control (Boyd and Burns 2014). The model measured BG with bias varying from -20% to +20% and imprecision varying from 0% to 20% CV, and the results were used to alter insulin infusion rates based on two published insulin treatment protocols. Boyd and Burns evaluated rates of hypoglycaemia, hyperglycaemia, GV and percentage of time in target BG ranges, comparing measurement frequencies of every five and 60 minutes. They found that the impact of doubling the analytic imprecision from 5% to 10% on these measures of glycaemic control was blunted, and even reversed, when the measurement frequency increased from every 60 minutes to every five minutes. These findings have important implications for the emerging technologies that are being developed to allow continuous or near-continuous BG measurement in the critically ill. In effect, increased monitoring frequency 'trumps' a degree of analytic inaccuracy.

Conclusions: a Look Ahead

This brief review underscores the breadth of investigations that have informed our understanding of glycaemic control in the critically ill since publication of the NICE-SUGAR trial. It should be abundantly clear that current technologies, using intermittent monitoring, are not adequate to monitor and control the three domains of glycaemic control, a conclusion that was reached by a consensus group that met at the 2012 annual congress of the International Society of Intensive Care and Emergency Medicine (Finfer et al. 2013). Moreover, an era of a 'personalised' approach to glycaemic control, taking into account patient characteristics, including diabetes status and, perhaps for diabetics, preadmission glycaemic control, may determine glycaemic targets. Finally, future interventional trials should incorporate the findings of the glycaemic control studies published in the last several years in their design. We have passed the era where 'one size fits all' (Krinsley 2013). ■

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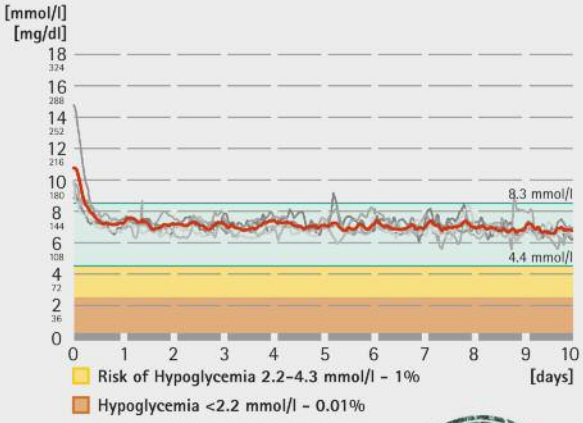

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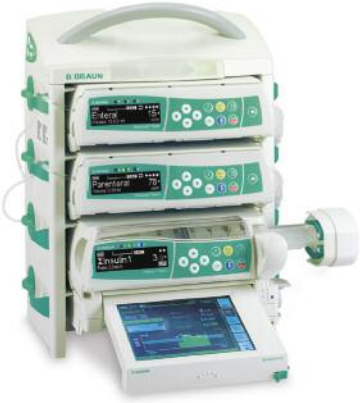

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The extra-corporeal membrane oxygenation (ECMO) retrieval team initiating ECMO in remote institutions followed by stabilisation and transfer to tertiary centres under ECMO might allow markedly improved survival to the sickest patients with refractory respiratory or cardiac failure.

Introduction

ECMO is a high risk and complex therapy that can be offered to the sickest patients with refractory respiratory or cardiac failure. It has been successfully used as a bridge to myocardial recovery, cardiac transplantation or the implantation of a ventricular assist device in patients with overt cardiac failure of various aetiologies (Bakhtiary et al. 2008; Combes et al. 2008), e.g., acute myocardial infarction (Combes et al. 2008; Chen et al. 2006), end-stage dilated cardiomyopathy (Schwarz et al. 2003), viral or toxic myocarditis (Asaumi et al. 2005; Mirabel et al. 2011), complications of cardiac surgery (Rastan et al. 2010) or cardiac arrest (Chen et al. 2008). Alternatively, the current potential indications for the use of ECMO in cases of severe acute respiratory failure (ARF) include: severe acute respiratory distress syndrome (ARDS), status asthmaticus, bridge to lung transplantation, as well as diffuse alveolar haemorrhage, pulmonary hypertensive crisis, pulmonary embolism, severe bronchopleural fistula and other forms of severe ARF (Schmidt et al. 2013; Pham et al. 2013; Noah et al. 2011; Australia and New Zealand Extracorporeal Membrane Oxygenation (ANZ ECMO) Influenza Investigators et al. 2009; Peek et al. 2009).

> *"Mobile ECMO retrieval teams for the provision of ECMO support to critically ill patients should be created as part of critical care tertiary referral networks of hospitals covering regional or national areas"*

Transfer of medically unstable patients to tertiary centres without extracorporeal support may be associated with markedly increased risks. In the CESAR trial (Peek et al. 2009) where retrieval under ECMO was not possible, 6% of the patients randomised to the ECMO group died before or during transport to the ECMO centre. Therefore, initiating ECMO in remote institutions followed by stabilisation and transfer to tertiary centres under ECMO might allow significant improved survival. The first report of a patient retrieval under ECMO was made by Cornish in 1986 (Cornish et al. 1986). Since then successful transportation of patients on cardiopulmonary support has been described for short and long distances by ambulance, helicopter, and aeroplane (Beurtheret et al. 2013; Foley et al. 2002; Forrest et al. 2011; Lebreton et al. 2012; Linden et al. 2001; Javidfar et al. 2011; Isgro et al. 2011).

ECMO Retrieval Network Organisation

A policy directive should be established at the regional or national level for critically ill patients and patients at risk of critical deterioration requiring referral and transfer to a tertiary centre. Specifically, networks of hospitals should be created around ECMO centres located in tertiary referral hospitals. Hospitals in these networks should adhere to written standardised protocols detailing criteria for both the initiation of ECMO (indications and exclusions) (Extracorporeal Life Support Organization 2010), as well as optimisation of conventional treatments to be undertaken prior to the consideration of ECMO.

In Australia, the New South Wales Critical Care Tertiary Referral Networks was established in 2006, and is currently utilised across the state to guide the process of appropriate critical care adult tertiary networking, referral and patient transfer. It has defined indications for emergent ECMO retrieval of cardiac and respiratory failure patients (NSW Health 2010), and has established the links between primary care hospitals and tertiary referral hospitals for functional clinical referral relationships. It was extensively used during the 2009 influenza A(H1N1) pandemic, and contributed to the remarkably good results obtained in that state for the treatment of the most severe forms of influenza A(H1N1)-associated ARDS (Australia and New Zealand Extracorporeal Membrane Oxygenation (ANZ ECMO) Influenza Investigators et al. 2009). Such formalised networks have also been successfully organised

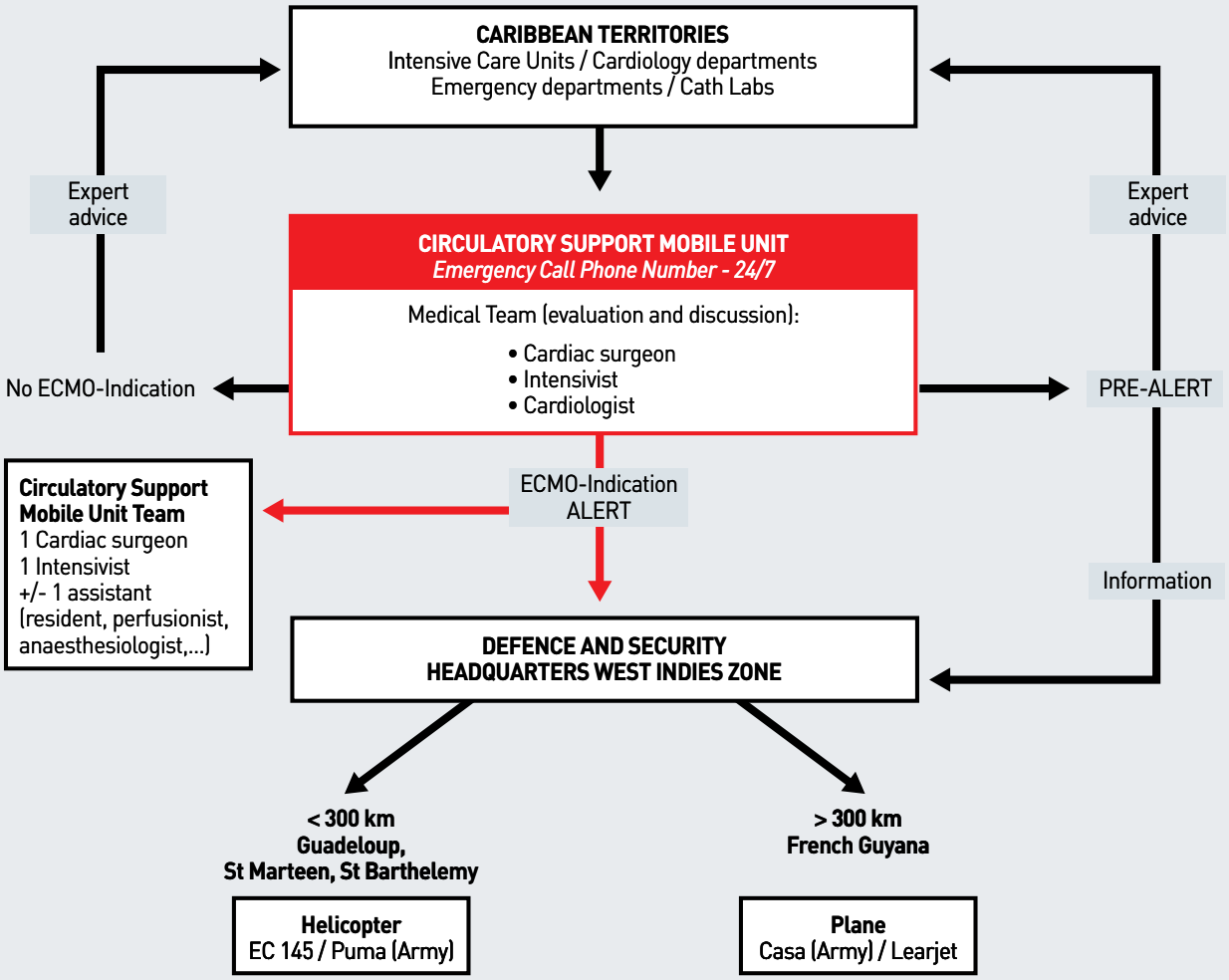

Figure 1. Airbridge Procedure for Circulatory Support in the French Carribean

in the United Kingdom (National Institute for Healthcare and Clinical Excellence 2011), Italy (Patroniti et al. 2011) and the French West Indies (Lebreton et al. 2012).

Logistics for ECMO Retrieval

The safe management of an ECMO retrieval patient requires a coordinated response by the referring and receiving hospitals, ECMO team, ambulance and the medical retrieval services. Written criteria for early notification of a patient potentially requiring referral ECMO should be available at each referral hospital, and referrals should be restricted to severe, but potentially reversible acute respiratory or cardiac failure refractory to maximal conventional therapy. Potential ECMO referrals should be discussed between physicians at the referral centre and intensivists, anaesthetists, cardiologists, cardiac surgeons and respiratory physicians at the ECMO centre (Figure 1). Telephone, email and web conference can be used to communicate and discuss patient details (such as Doppler-echocardiography, ventilator settings, blood results and imaging) and medical management.

The mobile ECMO team should be available 24 hours a day, 7 days a week, and employ experienced personnel trained in the transport of critically ill patients, insertion of ECMO cannulas, as well as circuit and patient management. All the equipment required for cannulation, circuit set-up, and transportation should be pre-packed (Figure 2) and immediately available. The team will usually include a mix of physicians, transport specialists, nurses, perfusionists or other ECMO specialists. Imaging requirements at the referring hospital should be considered and a clinician trained in echocardiography should also be considered for some transfers. Portable ultrasound equipment should also be considered. The transport to the referring hospital to bring the personnel and equipment should be as quick as possible (Figure 2). Upon arrival of the transport team at the referral hospital, the patient should be carefully re-evaluated, ECMO indication confirmed and optimal mode of mechanical support (venoarterial, venovenous, cannulation sites) determined. The choice of transport vehicle for retrieval (ambulance, helicopter, or fixed-wing aircraft) should be based on transport distance, crew and

Figure 2. The Mobile Team Prepacked ECMO Equipment and Car for Emergent Transport of the Team to Referral Hospitals

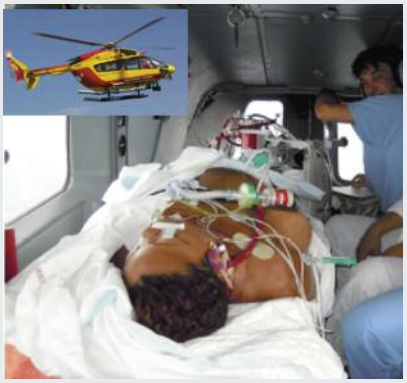

Figure 3. Helicopter Retrieval of an ECMO Patient

vehicle availability and weather (Figures 3 and 4). Miniaturised newest generation portable ECMO machines (Philipp et al. 2011) might allow easier and more rapid patient transportation, particularly in small helicopters. Transport vehicles should be equipped with adequate electrical power supply, an oxygen tank, a high performance ICU ventilator, an ICU portable monitor, infusion pumps and suction equipment.

Return on Experience

The University of Michigan Medical Centre reported the first large experience of 100 patients retrieved on bulky first generation ECMO devices in the 1990s. Of the patients, 53 were supported with venovenous bypass and 47 with venoarterial bypass. Patients were transported by ground ambulance (80%), helicopter (5%), or fixed-wing aircraft (15%). The median transport distance was 44 miles (two to 790 miles), and the median transport time was 5 hours and 30 minutes (1 hour 33 min, to 16 hours 6 min.). Complications that occurred during transport included 10 cases of electrical failure, three cases of circuit tubing leakage, and one case each of circuit rupture, membrane lung thrombosis, and membrane lung leakage. However, none of the complications occurring during transport had an adverse effect on outcome.

Our group reported more recently on a large series of 75 refractory cardiogenic shock patients who were retrieved under the newest generation venoarterial ECMO systems from hospitals without ECMO facilities throughout the Greater Paris area between 2005 and 2009. Time from phone call to circulatory support ranged from 64 to 254 minutes depending on the distance to remote centre. No technical incident or adverse event occurred during transport, except one ECMO pump dysfunction requiring temporary manual assistance. Interestingly, after adjusting for other confounding factors, in-hospital survival (37%) of these patients was not statistically different from that of 123 consecutive patients who received ECMO at our institution during the same period. Very good results have also been reported after retrievals under venovenous ECMO of patients suffering serious H1N1-induced ARDS (Forrest et al. 2011; Isgro et al. 2011; Ciapetti et al. 2011). Lastly, safe transcontinental transport of several ECMO patients referred to our centre for ventricular assist devices (VAD) implantation of heart transplantation using regular commercial flights have been performed between French Caribbean Islands, La Réunion Island and La Pitié Hospital in Paris in the last three years (Figure 4).

Figure 4. Transatlantic Transfer in a Commercial Plane to La Pitié Hospital in Paris of an ECMO Patient

Conclusion

Mobile ECMO retrieval teams for the provision of ECMO support to critically ill patients should be created as part of critical care tertiary referral networks of hospitals covering regional or national areas. A policy directive should be established within the network allowing standardisation of referral indications and adequate 24 hours a day, 7 days a week staffing, equipment and transport. This strategy might allow safe transportation under cardiopulmonary support to experienced tertiary centres and might ultimately improve survival of the sickest respiratory or cardiac failure patients initially treated in centres where ECMO is not possible. ■

Conflict of Interest Statement
Dr. Combes reports receiving lecture honoraria from Maquet Cardiovascular. He is the primary investigator of the EOLIA trial (NCT01470703) for which MAQUET provides the CardioHelp devices and ECMO cannulas.
Dr Lebreton has no conflict of interest to declare.

For full references, please send a request to **editorial@icu-management.org**

IMPLEMENTING AN ECHOCARDIOGRAPHY SERVICE IN THE INTENSIVE CARE UNIT

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Echocardiography is often an essential component in the management of a critically ill patient and setting up a service of acceptable quality requires attention to efficiency, sustainability and operator competency.

Introduction

The value of echocardiography at the bedside of a critically ill patient is well established (Cholley et al. 2006). Initially provided as an offshoot of regular radiology or cardiology ultrasound services, echocardiography in the care of the critically ill patient has increasingly been performed by critical care physicians themselves (Kaplan and Mayo, 2009). In addition to the obvious diagnostic advantages, real time echocardiography allows a greater focus on haemodynamic evaluation, thereby providing essential patient information in a more timely fashion. However, this enhancement to patient care comes with responsibilities, often unappreciated when contemplating setting up or expanding an already existent rudimentary service. Good planning will save frustration and costs compared with allowing development to occur in an ad hoc fashion.

> *"Dedicated enthusiasts have brought echocardiography from the periphery of critical care practice to what can appropriately be regarded as an essential tool in patient care"*

Components to be considered include machine selection, recording and reporting studies, archiving, interdepartmental connectivity and training. Machine availability, a major challenge in the past, is less so now with less expensive, yet more sophisticated machines, within the budget of many Intensive Care Units (ICUs). It is acknowledged that machine acquisition may still be a problem in developing countries, especially where external influences dictate who may or may not have ready access to machines on site. Often overlooked when setting up an in-house service are machine care, maintenance costs, producing quality images in well-structured examinations, recording images, archiving images and delivering reports that can be accessed in other sections of a major hospital.

Training remains a major challenge, not only in the availability of adequate educational resources, where the emphasis on practical hands-on training predominates at least for beginners, but also in assessing appropriate levels of competency. Useful guidelines and manuals dedicated to the critical care physician are becoming available (De Backer et al. 2011; McLean and Huang, 2012).

Intensive Care Medicine and Echocardiography

Echo has many advantages in the ICU with rapid application at the bedside, using either transthoracic (TTE) or transoesophageal (TOE) echocardiography for the purposes of cardiac diagnosis, haemodynamic evaluation, haemodynamic monitoring, and assistance in therapeutic procedures. Often the diagnostic information cannot be readily obtained by alternative invasive techniques, including fixed and dynamic valvular dysfunction, left ventricular diastolic dysfunction, the presence of segmental wall abnormalities in

Consideration	Specifics
1. Transducer – type, number	cardiac, lung, vascular, abdomen
2. Size/mobility	handheld, laptop size, large
3. Scanning capability	range of Doppler applications – PW/CW/colour,TDI, velocity vector tracking, 3D strain-rate
4. TOE	included in purchase package or optional?
5. Compatibility	other ultrasound machines in ICU/ED/OR
6. Image management	magnification, cineloop, annotation, display, machine storage memory
7. Maintenance	cost, support staff, sterilisation TOE probe
8. Upgrade capacity	ease and cost of future upgrade
9. Cost	what is, what is not, included in quoted price?

Table 1. Considerations in Selecting Echocardiographic Machine

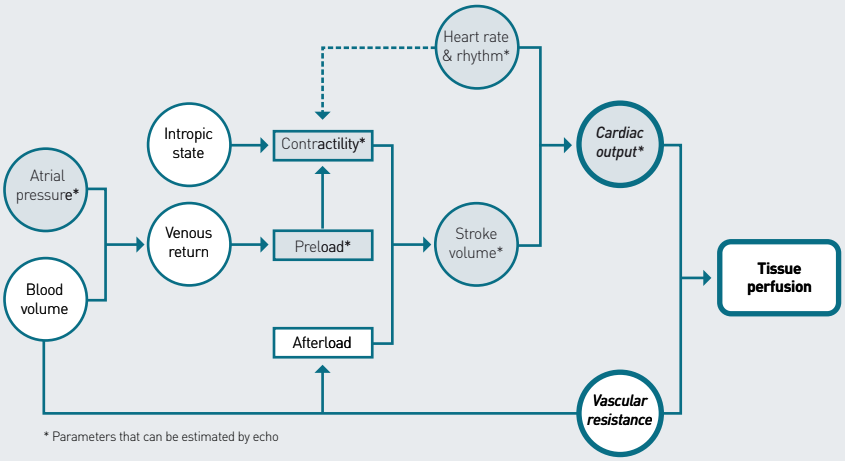


Figure 1. Haemodynamic Parameters Measured by Echocardiography

reduced left ventricular contractile dysfunction, and pericardial tamponade. Many of the underlying components contributing to circulatory status are readily assessed when haemodynamic evaluation/monitoring is the primary focus of a study (see Figure 1).

It is beyond the brief of this article to describe in detail the considerable information an experienced operator can obtain from a single or multiple studies; the benefits of critical care echo are well described elsewhere (Repesse et al. 2013; De Backer et al. 2011).

Machine Selection, Acquisition and Maintenance

A variety of ultrasound machines with cardiac capability are available, and selection should be approached in a deliberate and pragmatic manner. Often selection decisions are influenced by exposure to the same brand in another setting such as central line insertion in the operating theatre, persuasiveness of the sales representative, bias of other departments owning an echo machine, and automatically updating that particular brand. Technological advancements have created a wide range of available machines with varying capabilities over a cost range from 10,000 to 200,000 Euros. The medium range of ultrasound machines today, the size of a laptop computer, is markedly more sophisticated than a large high-end machine available 20 years ago, yet today costing one third of the larger one purchased at that time.

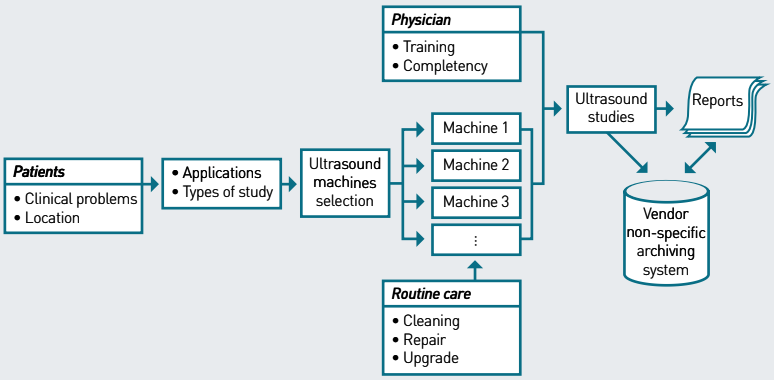


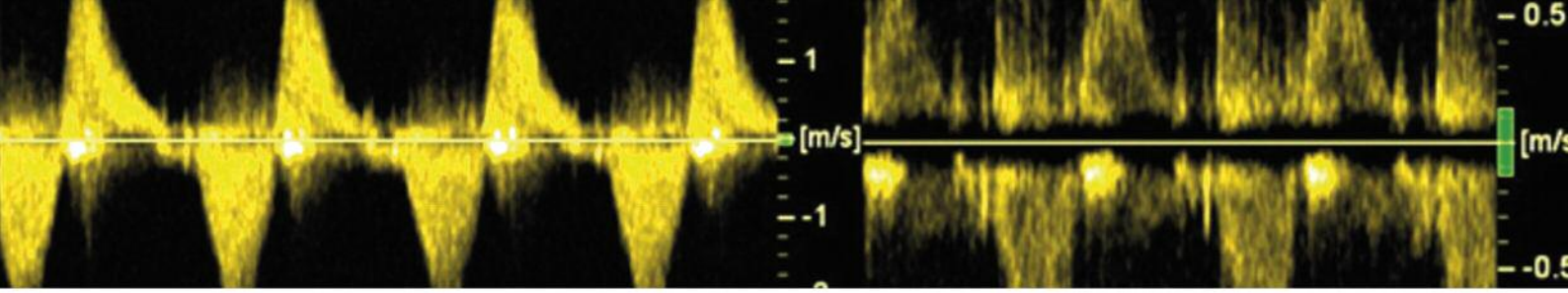
Figure 2. Image Capture, Storage and Reporting

Selection criteria should be objective, with considerations of proposed additional non-cardiac ultrasound uses of machine, software content, mobility, maintenance costs, upgrade ability, transoesophageal echocardiography (TOE) capability, and, underlying all these criteria, the cost or rather value for money. Only limited assistance is available in the literature, with comparison of machines in specific considerations or for targeted software applications (Royal College of Radiologists 2005; Wynd et al. 2009). One reason for this void is that machines are in continual evolution and an evaluation is outdated at the time of publication. Generic considerations to assist a rational approach are given in Table 1. For those engaged in newer advanced software applications like strain-rate and speckle tracking, an appreciation of intersystem agreements is important (Nelson et al. 2012; Fine et al. 2012).

Image Acquisition and Archiving

Acquiring a proper set of sequential images, with cardiac cycle timing provided by concurrent ECG monitoring should be standard practice. The practice of waving a transducer hurriedly across the chest belongs to the amateurish past. For both transthoracic echocardiography (TTE) and TOE a predetermined standard set of views should be attempted, even though it is anticipated not all will provide suitable images. Images from each view should be recorded.

Evolution from utilising echocardiography as a quick diagnostic tool to a haemodynamic assessment/monitoring one necessitates image storage for later review, post-processing, or comparison with subsequent studies. Since any machine has limited internal storage, an external archiving system is an important component to consider when developing an in-house critical care echo service. Access to a system external to the ICU, such as a hospital clinical information system, radiology or cardiology system, is preferable to setting up a stand-alone system. It is less costly and also allows access to images elsewhere in the hospital. However, this is not always possible and a stand-alone system is necessary. There are two possible approaches – that of a proprietary system, using the same supplier as the machine provider, or a 'home grown' variety. The latter is less expensive and is not so difficult where local IT assistance is available, but may not have the same post-processing ability as a proprietary sys-



International Course

Echocardiography for Hemodynamic Monitoring 2014

with videotransmissions of live cases from the ICU

Brussels, November 18-20, 2014

Course directors

Daniel De Backer (Brussels, Belgium)
Michel Slama (Amiens, France)
Antoine Vieillard-Baron (Boulogne-Billancourt, France)

Special guest speakers:

Paul Mayo (New York, USA)
Anthony McLean (Sydney, Australia)

Other Faculty members:

Laurent Bodson (Paris, France)
Chantal Dedobbeleer (Brussels, Belgium)
Jan Poelaert (Brussels, Belgium)

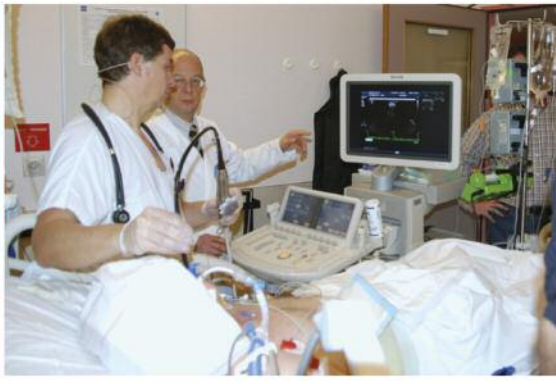
Aim:

To promote the use of echocardiography in the hemodynamic evaluation of critically ill patients.

General description:

The course will be interactive, with a lot of time devoted to questions, hands-on sessions, and discussions of live video-transmissions.

The first day will be devoted to revising the basics of echocardiography; the second and third days will describe how to use this technique to evaluate the hemodynamic status of critically ill patient.



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tem. If multiple different machines are in use then a vendor neutral platform becomes an important consideration (Strowig 2013) (see Figure 2). Reporting of studies is essential. It improves the diagnostic and analytical skills of the operator, delivers necessary information to the medical team caring for the patient, and provides a succinct record. Archiving reports is also important, and some systems store both images and reports.

Training

Dedicated enthusiasts have brought echocardiography from the periphery of critical care practice to what can appropriately be regarded as an essential tool in patient care. Introducing the practice into the ICU has by necessity developed in an ad hoc manner, dependent upon local resources, physician commitment, management support and, frequently, external political influences. Training has generally been via the apprenticeship model, resulting in a gradual increase of critical care physicians competent in the provision of around the clock bedside echo assisted patient management. Over the past two decades, training programmes to cope with the increasing demand have developed, the most notable example being established in France. To fill the training gap within the ICU setting, programmes initially came from a general ultrasound background or were cardiology based with a critical care flavour. The recognition that many aspects of echo application in the ICU setting differ substantially from those of radiology or cardiology, namely the need to rapidly assess multiple haemodynamic parameters, has led to a focus on developing specific CCE training programmes (Mayo et al. 2009). This need is further accentuated by Intensive Care training programmes around the world, making competency in basic echocardiography a mandatory component in the overall training programme.

Once the necessity of training critical care physicians in echocardiography was established, the question then arose as to what were acceptable levels of competency. Gaining experience is a continuum from the moment a doctor first places a transducer on the patient's chest, to measuring strain-rate in the right ventricular free wall. The next important step was international cooperation in determining the components required for competency in basic critical ultrasound, with a major emphasis on echocardiography. Representatives from Intensive Care bodies in Europe, Asia- Pacific, North America and South America met in Vienna in 2009, and a consensus paper was subsequently published in 2011 (Expert Round Table on Ultrasound in the ICU, 2011). This recommended that all trainee intensivists should be capable of performing a basic critical care echocardiographic study. A smaller proportion of physicians will seek to develop competency in advanced practice, with the emphasis moving from diagnosis alone, to diagnosis and haemodynamic assessment using both TTE and TOE. It is recognised that simulation techniques may enhance training, especially in TOE (Shakil et al. 2012). Recommendations on what constitutes advanced practice are now available in the literature (Narasimhan et al. 2014a; Narasimhan et al. 2014b). Some countries such as France and Australia already have training and credentialling programmes for critical care physicians in advanced practice. Although individual institutions or countries can set standards, there is considerable benefit in developing international criteria. To achieve this single objective, a gathering of expert representatives from multiple national Intensive Care bodies met to debate and identify what constitutes advanced competency in Critical Care Echocardiography. This consensus document will be published in Intensive Care Medicine early in 2014 (Vieillard-Baron 2014). Such documents do not necessarily prescribe what a particular institution or national IC training body should do, but rather provide guidelines. This may have more value in those ICUs where the Director is not au fait with echocardiography.

Summary

Echocardiography is becoming commonplace in the ICU setting, and this evolution brings with it responsibilities to provide a competent, safe, and meaningful service to the patient. The simple approach of merely obtaining an ultrasound machine and performing studies is no longer valid. It is necessary to organise a service in a rational, sustainable, efficient way and ensure doctors involved in performing the studies have demonstrated competency, either at basic or advanced levels. ■

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THE IMPORTANCE OF RESUSCITATION

AN INTERVIEW WITH DR. JERRY NOLAN

Dr. Jerry Nolan was co-editor of the European Resuscitation Council Guidelines for Resuscitation 2010. He is Consultant in Anaesthesia and Intensive Care Medicine at the Royal United Hospital, Bath in the UK. In addition he serves as Vice Chairman of the European Resuscitation Council, a Member of the Executive Committee of the Resuscitation Council (UK), Chairman of the Steering Group of the National Cardiac Arrest Audit, Council Member of the Royal College of Anaesthetists and Editor-in-Chief of the journal Resuscitation.

The updated European Resuscitation Council CPR Guidelines for Resuscitation are due in 2015. What is the latest evidence showing, and are you expecting major changes?

The evidence review process, which is quite lengthy, has only just started and there's been no discussion on the outcomes of those reviews, so it's premature to try and judge what changes might be expected. What I would say is that one area where there have been a lot of new studies is in the area of prognostication in cardiac arrest survivors. There will be some changes especially of interest to intensive care doctors and nurses in the area of prognostication for comatose survivors of cardiac arrest, in other words trying to predict those patients who are going to have a poor outcome whatever we do, and those who will potentially have a good outcome.

Is it possible to provide guidance on how long to perform resuscitation for?

This has been the subject of at least one major study (Goldenberger et al. 2012). I think the most important message is that every decision needs to be made on a case-by-case basis. There is no specific cutoff time that we could apply to every patient in every case. We do know from the work published from the American Heart Association's, Get With the Guidelines ® Resuscitation registry, which is a very large database of in-hospital resuscitation in the United States, that of those patients who achieve return of spontaneous circulation, 90% of them will have achieved this by 30 minutes. Once you get to 30 minutes the chances of survival are getting slimmer and slimmer, and only 10% more survivors will come from beyond that time. Clearly some do, and I think the most important message is that if clinicians still think there is a reversible problem, a cause of cardiac arrest they can do something about, there may well be an indication for continuing resuscitation for a lot longer. The whole process, particularly of in-hospital resuscitation, is becoming more complicated, because in many parts of the world now there is the ability to use extracorporeal cardiopulmonary resuscitation (E-CPR), where these patients are put on to bypass, which can prolong CPR for many hours whilst trying to address the underlying problem, which may be, for example, an occluded coronary artery.

Will the updated Guidelines address the issue of obesity and resuscitation?

Obviously obesity is an increasing problem across the world. There are issues around obese patients in being able to deliver effective chest compressions and, although modern defibrillators compensate for increased chest impedance, in patients with very high BMI defibrillation may be a problem. At the moment we do not have good evidence to change the way we deliver CPR in these patients.

Of particular interest to the intensive care team community is that one specific study looking at patients with poor outcomes versus body mass index (BMI), who were admitted to intensive care after cardiac arrest, surprisingly shows that those patients with higher BMI actually do better (Jain et al. 2010). I suspect that it is the low BMI patients that do particularly badly; I suspect that amongst these are patients who have lost weight or have underlying co-morbidities that probably explain why the outcome is worse. It has been shown in other areas of critical care medicine that patients with higher BMI do better, it's not just after cardiac arrest.

Do you think we have the answers yet on therapeutic hypothermia in cardiac arrest?

The short answer is clearly no. The recently published Targeted Temperature Management trial (Nielsen et al. 2013) has caused some confusion among clinicians. In that study patients were randomised to a target temperature of either 33 or 36°C, and there was no difference in their neurological outcome. I think it has left people unsure which target temperature they should be using. Some clinicians feel strongly we should shift to 36°C, others that we should stay with 33°C. I think the message that must come across from that study, and I think all experts would agree, is that we should still continue to use some form of temperature control to prevent hyperthermia in these patients. I still think we have unanswered questions about the optimal temperature and the optimum duration of temperature control. Even if we are going to use targeted temperature control at 36°C, we still don't know the best method to achieve this.

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What do you think are the biggest challenges in resuscitation currently?

I would say prognostication in post cardiac arrest patients, because I think we now recognise that we have been testing these patients far too early. Clinical examination, imaging and/or electrophysiological testing is used in an attempt to determine those who have no realistic possibility of a good outcome and therefore to enable us to withdraw active treatment. It now transpires that we have probably been too premature in those investigations and withdrawal decisions, and as time has gone on we are beginning to understand that we really need to give these patients time before we can have tests that are reliable enough to enable us to make these very difficult decisions. Patients are staying longer and longer on intensive care units as we give them time to show signs of recovery.

In hospital the biggest challenge we face today is trying to select which patients are going to benefit from our resuscitation efforts and in which patients we should not attempt cardiopulmonary resuscitation. That is a very difficult area, not least because of the ethical and potential medicolegal issues involved. But it's really important that we try to reserve these therapies for patients who have a realistic chance of returning to a good quality of life.

There has been quite a lot of progress in the technology behind defibrillators. I think we are very close to having defibrillators widely available that are capable of eliminating the chest compression artefact, so that these defibrillators will be able to analyse cardiac rhythms without interrupting chest compressions. Currently, you can't touch the patient while the defibrillator is analysing the cardiac rhythm, but we are now getting to the stage where we have the technology to filter out compression artefact. These devices are capable of reading the underlying rhythm during CPR which means that there will be virtually no pause between compressions and delivering shocks.

Looking at the Chain of Survival, where does most work remain to be done? Can more be done to teach CPR, for example?

The whole concept of the Chain of Survival is important. It's no good just trying to make one link very strong and then forgetting the others. Intensivists will tend to focus on post-resuscitation care but what happens in the first key moments after cardiac arrest is critically important. For out of hospital cardiac arrest, work has to be done at the beginning of the chain, particularly in getting the public trained and prepared to do bystander CPR. It may enable many more people to be prepared to give it a go. We know that if bystander CPR is provided the survival rate is increased by two or three times (Wissenberg et al. 2013). The study from Copenhagen is a really important study (Wissenberg et al. 2013), because it shows that if you can improve many rings of the Chain of Survival you can make an enormous difference; the improvement in their outcomes over the last 10 years is impressive. To some extent this has been shown in other communities as well. What they have done in Denmark most impressively is the increase in bystander CPR rates. They achieved that with a combination of things: for example, they have been very aggressive with their programme for teaching CPR in schools, and I think many European countries are pushing forward with that.

> *"We should still continue to use some form of temperature control"*

We've had disappointment with this in the UK, where despite a robust campaign, led by the British Heart Foundation and Resuscitation Council UK, including some support from politicians and inclusion in a debate in Parliament, we have failed to get this to be a mandatory part of the school curriculum. It's something we will keep working on.

Another thing I would single out from the Copenhagen study, which all European countries should consider, is that they mandate resuscitation training to enable you to have a driver's licence. That's a clever way of implementing bystander CPR and they are to be congratulated.

The other initiative from a European perspective is the European Resuscitation Council's Restart a Heart Day (http://www.restartaheart.eu), which is the 16th October each year. The idea is to try and educate and focus people's minds on the importance of CPR, particularly engaging members of the European Parliament, for example, by lobbying for training on CPR in schools.

This interview will appear in an issue on Organisation and Design of the ICU. Could you briefly explain the reasons for and benefits of rapid response teams and cardiac arrest centres?

The rapid response team comes back to prevention of cardiac arrest. The principle of rapid response teams is to have systems in place to identify a patient who is at risk of cardiac arrest and of deteriorating, and having in place a system, which can alert the appropriate people, who then can come along and treat them effectively and stop them from having a cardiac arrest in the first place. It may be that that is the time a 'do not attempt cardiopulmonary resuscitation' decision is made with the patient and their family. The idea is to dramatically reduce the incidence of unexpected cardiac arrests in hospital. There is some evidence that that has already happened. That's how we will start to see much higher survival rates, simply by targeting those that will benefit most and preventing others from having an arrest in the first place.

Cardiac arrest centres are really developing by default, because we are now recognising that many of these out of hospital cardiac arrest patients benefit from early cardiac catheterisation and percutaneous coronary intervention. These patients need to be taken to a centre that has a 24/7 cardiac catheter lab that can provide the best treatment. Of course not all hospitals have that facility, so we're already beginning to see, certainly in the UK and I'm sure in many European countries as well, a situation where the cardiac arrest patient is taken to a hospital with a 24/7 cardiac cath lab and not necessarily the nearest hospital. Intensive care clinicians and neurologists join with the cardiologists in treating these patients. As more and more of these patients are bypassing local hospitals, we effectively build up a cardiac arrest centre network. It is clearly happening, it is just a question of how fast it is implemented internationally.

What should be the priorities for further research into resuscitation?

Prognostication is really important. There is a lot going on there, but I think there's a lot more

to be done. I think we need to be getting research to provide evidence for clinical guidelines that can help clinicians and families make very difficult decisions, It is important for patients and for healthcare systems; we should not invest a lot of resources in patients who, sadly, have no chance of quality survival.

Other areas of research that I think should be priorities include pre-hospital airway management in cardiac arrest. That's a whole area that's never been properly studied, so we don't know, even now, whether tracheal intubation or some form of supraglottic airway is the best way to initially manage the airway during cardiac arrest.

The third area, which I hope will be the subject of research, is to determine once and for all whether adrenaline benefits patients in cardiac arrest. I hope we will be doing a very large placebo-controlled trial of adrenaline vs. placebo for out-of-hospital cardiac arrest in the UK fairly soon. It has been the standard drug for resuscitation for decades, and this is largely on the basis of animal data with virtually no high quality human clinical data.

Some observational studies have suggested that adrenaline given during cardiac arrest actually makes long-term neurological outcomes worse. There have been recent observational studies. It is important to go back to the drawing board and have a very large placebo-controlled trial. I hope that that such a study will get underway soon.

There are many ethical and medicolegal issues around discussing resuscitation with families. Could you comment on these?

I think this is an extremely challenging area, possibly one of the most difficult that I face in my clinical work as an intensive care consultant today. I think that we should be clear about the objectives. Firstly, we should not be offering treatment to patients that will not work, so if we have patients who are sadly coming to the end of their lives, trying to resuscitate them with what is really quite aggressive treatment potentially needing to be followed up with long term intensive care afterwards, should be done only when the patients have a chance of surviving with good quality of life. However, deciding when that time has come is very difficult, and deciding when patients have very little or no chance of survival is not necessarily that easy. So if there is a situation where it is a question of the likely quality of life after a resuscitation attempt, we should discuss what treatment is appropriate, either with the patient if they are well enough, or with the family to try and determine what the patient's views would be. These are the principles in theory. How this is applied in practice in increasingly busy hospitals, with clinicians that are under enormous pressures, is very difficult. I don't think there will ever be easy answers. Of course there are different cultural aspects as well, and inevitably it will be different in every country across the world.

What are your views on family presence during CPR?

The results of the randomised controlled study of family presence during prehospital resuscitation of adults were very interesting (Jabre et al. 2013) and align with the experience we have of parental presence during the resuscitation of children. If relatives were very keen to be present during the resuscitation of an adult, I would be comfortable with that, not least because I'm already used to this when resuscitating children. So far, in my experience, it is uncommon for adult relatives to request to be present during resuscitation. ■

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HOW A CRITICAL CARE NETWORK IMPLEMENTED LEAN METHODOLOGY

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A Network Lean Methodology Approach improves the cost-effectiveness of, and reduces the wastage in, critical care delivery.

What is Lean Methodology?

Lean methodology (LM) was originally developed by Toyota, and has since been adopted throughout British industry under various names, including Total Quality Management and Total Preventative Maintenance. It can be defined as a process of identifying the least wasteful way to provide value in order to produce better, safer and more cost-effective results without unnecessary delay.

Cost pressures and the worldwide economic downturn have driven the widespread implementation of lean methodology across the UK National Health Service (NHS). In this context the main aims are to:

- Get things right first time, thus improving quality and lowering costs;
- Empower staff to motivate them to sustain results;
- Make high quality evidence-based decisions;
- Improve flow to eliminate waste and reduce delays;
- Produce rapid results using workplace learning.

The Cheshire & Mersey Critical Care Network

The Cheshire & Mersey Critical Care Network (CMCCN) was first established in 2001 as part of the NHS Modernisation Agency programme. The CMCCN oversees the critical care units in 12 NHS acute hospital Trusts throughout the Cheshire and Mersey region in the North West of England. Over time the roles of the CMCCN have expanded to include contingency planning, commissioning, performance management, peer review and expert guidance amongst others; however a core function of the CMCCN has always been service improvement, overseen by the CMCCN Clinical Effectiveness Group. The principles of LM are particularly relevant to service improvement in critical care practice.

How Critical Care Medicine Can Use Lean Methodology

Critical care provides care for our very sickest patients and relies on the round-the-clock availability of a highly skilled multiprofessional team. It is a high-cost, low-volume, demand-led service, which is essential to hospitals with core services such as major elective surgery and emergency admissions. Although critical care in the UK represents only approximately 1% of acute beds, each unit employs a large number of direct care and indirect care professional staff, amounting to 1,500 individuals in the CMCCN. A collaborative approach to safe, equitable, efficient and effective critical care service is consistent with the principles of LM to ultimately improve patient experience and outcomes as well as reduce inequalities. However, for some patients in critical care, an improved outcome may be a well-managed and dignified death.

How the Cheshire & Mersey Critical Care Network Developed a Lean Approach Strategy

Patients are admitted to critical care when organ support is required, and can therefore present from any clinical pathway. The CMCCN supports all of its trusts to manage the critical care pathway, including end-of-life care. This is achieved through a clear strategic focus on agreed strategy, priorities and regular reviews of measures to quantify progress.

The CMCCN Clinical Group is the key expert body, which manages both critical care-related issues and developments across Cheshire & Mersey. The Clinical Group's membership comprises multiprofessional clinical leaders from all hospitals across the Network.

The CMCCN acts in a facilitative clinical governance capacity to ensure that safe practice is in place in all of the Network's constituent units. When compliance with agreed standards is not being achieved the CMCCN alerts the relevant organisations involved to effect change. The CMCCN Medical Lead plays a key role in this process by ensuring that provider organisations comply with current national and local policy. The end result is that patients can be assured that only safe and effective services are actually commissioned.

The CMCCN supports Trusts and commissioners in prioritising critical care service developments and their associated financial consequences, in line with agreed strategy and priorities on a Network basis. The CMCCN advises on the need for additional investment or disinvestment, as well as identifying areas where efficiency might be further improved:

- Through the Clinical Group, new and updated clinical pathways are discussed and may result in modernisation and improved efficiency (as an example the collaboration with

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laboratory services to improve access to investigation results at specific times to meet clinical need).

- The CMCCN is leading a work programme to identify opportunities to enhance patient recovery, to reduce length of stay, to ensure that safe clinical pathways are delivered consistently, contributing towards a reduction in patient length of stay and therefore costs. A similar project is planned for critical care follow-up services.
- The CMCCN supports the development of pathways that maximise the utilisation of resources and teams that are already available. An example is that in developing an approach to psychological support, the Network has ensured that work is directly linked to developments around improving access to psychological therapies.
- The Network has achieved agreement from all constituent units to use standardised drug concentrations, thus reducing clinical risk and cost.
- The CMCCN is committed to ensure that critical care services deliver quality and innovation as well as productivity. As a result the Network was the first nationally to have a rehabilitation strategy and to address the long term future of education and training of the multiprofessional critical care workforce.

Examples of Lean Methodology in Action across the CMCCN

1. Long Term Learning Aligned with the Patient Journey

In 2008 the CMCCN carried out a wide-ranging review of education and training for non-medical critical care professionals. The results demonstrated that training was fragmented with no clear standards or transferability across the Network or beyond. This was shared nationally, and similar issues were identified across the country. This resulted in the CMCCN carrying out a project to identify the competencies required to meet patient needs, including the underpinning scientific knowledge base where appropriate, to ensure a safe and efficient service in the long term.

This project has informed the national development of an education programme to support the education and training of critical care nursing staff, utilising learning packages that can be delivered in ways that suit the needs of the workplace.

Each of the CMCCN units has a Practice Educator in post whose role is to facilitate learning and to support mentors. The CMCCN Practice Educator Task Group provides vital peer support across the Network, and has been the vehicle through which the project has been implemented across the Network. The Practice Educators also act as external assessors to other units across the Network to ensure that the project is implemented in a consistent fashion.

2. Service Improvement

The CMCCN employs a team of service improvement leads (SIL) so that one individual is employed for one day each week in each of the 12 critical care units. The SIL's primary role is to initiate, coordinate and report on local multiprofessional service improvement projects. Over 300 service improvement projects have been undertaken across Cheshire and Mersey including the:

- Introduction of patient diaries;
- Introduction of care bundles;
- Bereavement follow-up;
- Introduction of nurse-led weaning;
- Introduction of new observation charts;
- Identifying opportunities for waste reduction and cost savings;
- Publication of a CMCCN Service Improvement Newsletter.

The SILs also collate safety incidents data from each unit, which is then analysed at Network level and any lessons learnt are shared across the Network. The CMCCN Pharmacy Group has identified considerable savings in drug budgets, and the group's recommendations have been implemented across Cheshire and Mersey.

3. Delayed Discharge

Delayed discharge from critical care units is a major problem across the UK. Delayed discharges result in a number of undesirable outcomes including delayed admission and capacity transfers to critical care units in other hospitals. One of the CMCCN's units introduced a delayed discharge task group consisting of doctors, nurses and bed managers to ensure that patients were discharged within four hours of the discharge decision. This resulted in the bed managers giving higher priority to critical care discharges and also greater planning for more complex discharges. This project successfully reduced capacity transfers and delayed admission, resulting in more efficient throughput and a better patient and relative experience.

4. Handover

The need for a high quality handover when a patient is discharged from critical care to the general ward is well recognised. One unit redesigned its handover form into a concise multiprofessional single sheet handover form resulting in more efficient and more clinically relevant handovers.

5. Data Collection

Not uncommonly the collection of Critical Care Minimum Dataset System information (organ failure-based activity data) is undertaken by non-clinical administrative staff. One unit introduced mandatory input from a senior clinician on a daily basis resulting in increased data accuracy and reduced need to review the data retrospectively.

6. Guideline Implementation

The CMCCN Neurosurgical Centre's unit considered its brain injury management guideline to be used inconsistently. The centre's unit, with the assistance of the CMCCN, developed a safety-based project in collaboration with other members of the CMCCN to design an online modular learning package for the use of doctors and nurses. This resulted in more efficient teaching, more timely decision making, reduced length of stay and improved patient experience.

Conclusion

The need to demonstrate value for money is greater today than it has ever been. We believe that a Network-wide Lean Approach shares learning more rapidly and improves quality indicators more effectively as well as justifying the underlying costs of running a Network. ■

Continues from page 17

oral care, help with mobility). This last point will increase engagement and reduce the sense of hopelessness felt when a loved one is critically ill (Hibbard and Greene 2013). Such involvement will also reduce the burden on caregivers.

4. **Use technology to improve communications**

- One key recommendation was the use of technology to allow everyone involved in care – patient, family, and care team – to communicate with each other as easily and often as possible.

Future Directions

Workshop participants compiled a list of key elements or actions to start designing a more ideal ICU, including always partnering with patients and families to co-create the design. Table 2 outlines future directions and provides a list of design principles for the next generation ICU. The main principles that should govern future ICU designers are to meet the needs of patients and clinicians, actively engage family members in care, employ technology to reduce workload and improve quality of care, provide continuous feedback to patients, families, and providers, and be humble and respectful by learning and improving care delivery. The group agreed to meet again to conduct a similar exercise to review the prototypes they developed, review progress, and brainstorm additional ideas.

We will use the systems lifecycle framework shown in Figure 2 as our work continues to design the ideal ICU. Throughout this work, collaboration and transparency are essential features of this framework. This manuscript informs the conceptual development and user's needs. Future work with the transdisciplinary team will complete the system lifecycle and design the ideal ICU.

Collaboration and Transparency:
- Define a set of patient safety requirements for intensive care units (ICUs)
- Share the group's vision of what ICUs could be like and encourage leaders of major vendors to collaborate in getting there
- Encourage hospitals to sign a pledge insisting that vendors in the ICU marketplace provide products that really work in the ways we have described
- Interchange of data among devices used in ICUs, enabling devices to intelligently and safely control each other
- Establish open standards for data sharing among electronic medical records (EMRs) and equipment in ICUs
- Establish a neutral collaborative space for joint activities, experiments in connectivity, new technology testing, etc.

Conceptual Development and User Needs:
- Write a white paper on the future of ICUs and the need for a system based on an open information sharing platform
- Invent and deploy intelligent technology systems that convert data into meaningful information and trigger automated actions to prevent harm
- Maintain face-to-face communications between nurses, doctors, patients and families; use technology as an enabling platform, but never a replacement for in-person communication
- Make information technology (IT) systems more human-centred with greater control by patients and staff
- Allow caregivers to customise the information they receive from technology systems to suit how they think and best utilise information (visual, auditory, etc.)
- Employ more visualisation technologies to improve timely and accurate communication among all stakeholders
- Provide patients that cannot talk or use hands with an eye tracking or other technology to communicate
- Overall, a greater sense of control by patients and families will lead to better outcomes
- Develop technology that enables patients to control their physical environment
- Develop proactive technology systems that use prediction models, best clinical evidence, and expert practice to assist in clinical decision making
- Create a more humane and flexible ICU environment to allow individuals to express their own needs and preferences

Design and Implementation:
- Automated data entry whenever possible to reduce hand written errors and lag times
- Develop a central data system; data should be collected once, go to one place, and be distributed wherever it is needed
- Build an intuitive EMR that incorporates clinical diagnostics and has greater intelligence to assist with and reduce the clinician's work
- Decouple displays from devices (e.g., pumps and respirators) to reduce complexity and make devices accessible as internet appliances
- Use IT applications, such as Siri (Apple's intelligent personal assistant and knowledge navigator) to connect to medical devices and the EMR during clinical care; clinicians are often frustrated with having to look down or away from patients when using an EMR

Validation and Verification:
- Involve patients, families, and relevant health professionals in the design of future ICUs
- Pilot test a customised information system that provides useful information, displays the trajectory of care and patient condition, and is context appropriate for family or clinical team members. The system should contain an accurate and real-time record of care delivered by all caregivers including family members

Deployment and Sustainment:
- More effective use of space in the ICU. For example, rounds could be done at the bedside and not clog up the hallway. The care team should be able to gather around one electronic document rather than have multiple people use multiple computers during rounds.

Learning System:
- Hospitals should have a programme that empowers ICUs to learn and practise design thinking and be able to prototype new approaches themselves
- We should learn from and build upon the lessons of the EMR implementations to make more effective and efficient use of technology
- We should conduct an inventory of what has already happened in areas similar to our prototype ideas and draw upon enabling technologies–humans remain the best aggregators and interpreters of clinical data and need to be continually involved to improve the systems, which include technologies, care processes, and physical environments

Table 2. Design Principles for the Next Generation Intensive Care Unit

Conclusion

In summary, our innovation process helped workshop participants identify ways in which an ICU can be redesigned to eliminate patient harm, optimise the patient and family's experience and outcomes, and reduce wastefulness. This process, which is deeply rooted in the needs of all stakeholders, could be widely applied in healthcare to move from a health system where clinician heroism is the safety net to one in which the net relies on safe, innovative design. ■

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COLLEGE OF INTENSIVE CARE MEDICINE TRAINING IN THE ANTIPODES

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The College of Intensive Care Medicine provides the training and certification of ICM specialists in Australia and New Zealand. After an extensive review and revision of its training programme, the College has launched the new curriculum effective from 2014. By improving the quality of ICM training the quality of intensive care delivered to our patients may be improved.

Intensive care services for the 28 million residents of Australia and New Zealand (ANZ) are provided largely in public hospitals, and access to intensive care admission has no direct financial cost to the patient. While very limited private intensive care services are available in New Zealand, confined largely to elective post-operative care, Australia has a more developed private system, funding for which comes from both private insurance and the state funded Medicare system. Intensive Care organisation is based upon 'closed' units in which the Intensive Care Medicine (ICM) specialist takes responsibility for the patient care for the duration of the ICU stay, with support and consultation with specialists of other disciplines. This article's focus is upon ICM training in the ANZ health systems.

The intensive care medical community in ANZ is served by two non-competing bi-national organisations, the Australian and New Zealand Intensive Care Society (ANZICS) and the College of Intensive Care Medicine (CICM) of Australia and New Zealand. Both work co-operatively towards improving ICM, and, while there is considerable role overlap, the College takes responsibility for the training, certification and continuing professional development of ICM specialists.

Historically, two distinct ICM training pathways existed in ANZ, the training requirements of the Royal Australasian College of Physicians (RACP) differing from that required by the Australian and New Zealand College of Anaesthesia (ANZCA). The foundation in 2002 by the RACP and ANZCA of a Joint Faculty of Intensive Care Medicine (JFICM) produced a single structure and a unified pathway for general ICM training. This subsequently allowed the formation of a stand-alone College in 2009, an international first for ICM (van Heerden 2009). In 2010 CICM took over the function of JFICM. There are currently 939 CICM Fellows and over 650 trainees, with an average annual output of 60 new Fellows. About 80% of new fellows are employed in ICM and 70% of these are practising full time ICM (Venkatesh and Freebairn 2013).

The ICM training programme, from its inception to the formation of the college, was an iterative process, with introduction of the formal project, regular formal in-training assessment, basic and advanced training, and the requirement to complete a series of formal clinical assessments prior to the examination over the last two decades. In 2011 the CICM underwent an accreditation conducted jointly by the Australian Medical Council and the Medical Council of New Zealand (College of Intensive Care Medicine 2011). Their recommendations provided impetus for a comprehensive review of the training processes CICM employed, and to map the curriculum to the various assessment processes. Recognition that while the total duration of training was unchanged, work hour restrictions were limiting clinical exposure, and the desire to employ more robust educational techniques than a simple apprenticeship model with experiential learning and a high stakes examination were also incentives for the review (Van der Vleuten and Schuwirth 2005). In 2014 a new curriculum was launched by CICM (College of Intensive Care Medicine 2014). Simultaneously, the CICM has introduced a criterion based trainee selection process, and changes to the primary examination exemptions. As CICM policy is not to disadvantage trainees, trainees enrolled prior to 2014 will continue their prescribed training.

The new CICM training is a minimum six year programme, starting once 12 months of general hospital experience is completed. It includes 42 months in specific ICU training, divided into three stages: Foundation Training of 6 months; Core Training of 24 months (after first part Examination) and the final Transition Year of 12 months. One year of both anaesthesia and one year of medicine, divided into 'acute' medical and 'longitudinal care' components are also required.

The 103 CICM accredited core-training hospitals are regularly inspected and assessed for training quality and case mix by CICM. The programme aims to produce high quality specialists with a broad range of general ICM experience. To help achieve this, trainees will need three months rural hospital experience and at least six months paediatric exposure, clinical placements in ICU, where the case mix includes sufficient trauma, cardiothoracic and neurosurgery ICM, and a transition year aimed towards developing the non-clinical characteristics of a medical specialist and to promote clinical autonomy.

Generally, all core intensive care training needs to be prospectively approved. Trainees can, and are encouraged to, undertake simultaneous supervised dual training in CICM and another specialty, rather than rely upon retrospective recognition of prior learning.

In addition to the time based training requirements, the trainees must complete a suite of prescribed online learning packages with associated assessments, and several face-to-face courses. (e.g. echocardiography). These courses have a described curriculum, allowing multiple course providers to develop courses with appropriate content that can be accredited for training. For example, the BASIC course meets the criteria for, and is accredited as a 'foundation course' for CICM; this does not prevent another provider developing an alternative course that would meet the described objectives (Douglas et al. 2010).

The first dedicated Intensive Care examination in the world was possibly the 'Fellowship Examination' conducted by the Section of Intensive Care of the Faculty of Anaesthetists of the Royal Australasian College of Surgeons in 1979 (Harrison and Clarke 1993). This body eventually evolved to become the CICM. At that time ICM practice was barely twenty years old, and practitioners were providing most ICU, with no formal ICM training, on a part-time basis. The principal advocate of the examination was the late Professor G.A. (Don) Harrison, who considered formal assessment of the many specific skills and areas of knowledge required to practise as an intensive care specialist essential for the foundation of ICM as a separate specialty (Harrison and Clarke 1993; Lee et al. 2009). The presence of organised high stakes exit examination stimulated the development of the ICM training programme. Today, the longevity of the examination and common training pathway for ICM means that the majority of ANZ ICM physicians has passed the examination (Lee et al. 2009).

> *"The new CICM training is a minimum six year programme, starting once 12 months of general hospital experience is completed"*

The ICM primary examination, which assesses the basic science components of ICM practice, was first held in 2007. Trainees enrolled prior to 2014 could claim a primary exemption by completion of one of a number of other ANZ Colleges' examinations. However, marked differences exist in syllabus content and the breadth and depth of these other examinations, compared with the CICM Primary. New CICM trainees will therefore need to complete the CICM Primary examination, or complete fellowship of another approved acute specialty college.

The examination remains crucial to identify trainees' level of understanding and core knowledge, and as an audit of the other programme assessment processes. Examination is a powerful driver of learning, but the examination can become all encompassing. Formative assessments that offer feedback are also a major positive influence on learning (Norcini and Burch 2007). Instead of relying solely upon a high stakes examination, a more comprehensive assessment programme utilising multiple complementary methods has been devised, including clinical competency assessments for specific procedures (e.g. percutaneous tracheostomy) and eight for-

mal observed clinical encounters, to assess trainees' ability to conduct clinical assessments and formulate management plans. Trainee progression (from novice to fellowship level) in the seven domains of medical practice, based upon the CanMeds Framework, is evaluated using a web-based in-training evaluation report (Royal College of Physicians and Surgeons of Canada 2005). Feedback is provided during each attachment through regular formative and summative interviews with college appointed supervisors of training. The aim is to encourage trainee behaviour consistent with good ICM practice, rather than focus activities on 'passing the exam'.

While the CICM training programme is accredited to produce ICM specialists for the ANZ health work force, a large proportion of CICM trainees are overseas graduates. Over half of the candidates presenting to the CICM Fellowship examination are international medical graduates (Lee et al. 2009). These doctors come to ANZ with the intention of undertaking ICM training, or having been appointed to one of the previously abundant ICU service positions, enjoyed ICM practice and entered the training scheme. Post fellowship many stay, but over 20% of CICM Fellows currently practise outside Australia (Freebairn 2013). The drive by the ANZ governments for medical workforce self-sufficiency has increased graduate numbers from local medical schools. Placement in ANZ hospitals of these new doctors has dramatically decreased the training opportunities for overseas doctors. The CICM remains committed to providing comprehensive training in Hong Kong, and training for more limited periods in CICM accredited hospitals in Singapore, India, United Kingdom, Ireland and Canada.

While the new Curriculum is implemented there is no doubt that the CICM programme will require 'tweaking' to ensure its currency and relevance to clinical practice. Within the current framework courses, assessments and online packages can all be adjusted as required. The ANZ ICM pioneers were the vanguard of robust ICM training systems. We hope that these refinements, aimed at improving the standard of ICM consultant practice, will further add to the quality of intensive care delivered to our patients. ■

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INTENSIVE CARE REGISTRIES IN AUSTRALIA & NEW ZEALAND

This year there will be over 160,000 patients admitted to Intensive Care Units (ICUs) in Australia and New Zealand. More than 90% will leave hospital alive. Two out of every five patients will be cared for in large university affiliated tertiary referral hospitals. The most common patient will be a 68 year old man, weighing 85 kg who will be admitted after coronary artery bypass surgery and will survive to return home. Not only do we know this but we also know how much his chances of survival will vary depending on which hospital he is admitted to!

Our ability to make projections like this is due to comprehensive data collected by The Australian and New Zealand Intensive Care Society (ANZICS) Centre for Outcome and Resource Evaluation (CORE), which runs the Intensive Care registries in Australia and New Zealand.

Why Have an Intensive Care Registry?

In all fields of medicine it is important to monitor the care given to patients. Without adequate monitoring and appropriate feedback, 'dysfunctional' systems may arise and put lives at risk through provision of unsafe or sub-standard healthcare. Numerous publications have highlighted the adverse consequences of failure to monitor outcomes or appropriately feedback and act on findings (Spiegelhalter et al. 2003; Pilcher et al. 2010; Mid Staffordshire NHS Foundation Trust Public Inquiry 2013).

In recognition of this, clinical registries have

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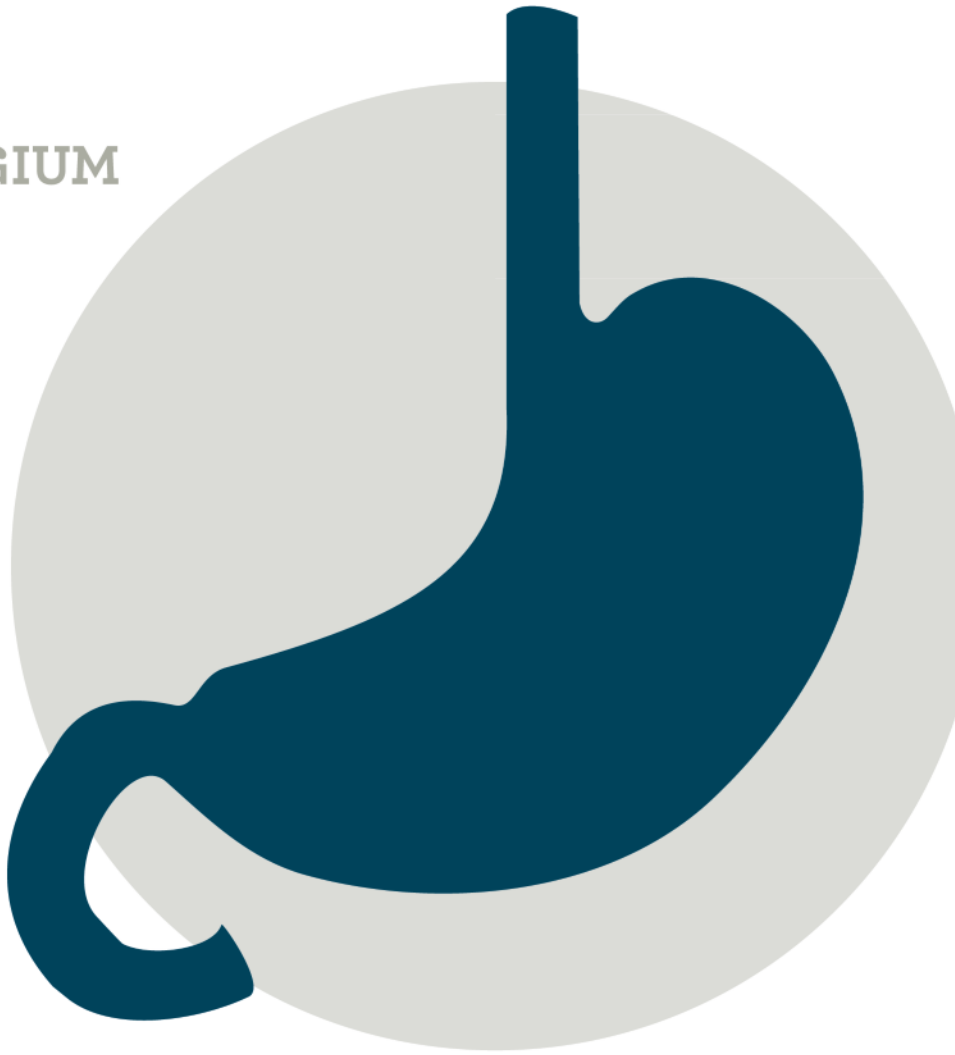

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become more common in recent years. Many countries already have well established organisations collecting clinical information from ICUs and providing comparative reports to submitting sites. Registry organisations in the United Kingdom, the Netherlands and Scandinavia have a long history of collecting clinical information, using severity of illness scores to risk adjust mortality outcomes and providing benchmarking reports to submitting ICUs. Within Australia and New Zealand these activities are run by ANZICS CORE.

A Little Bit of History

The publication of severity of illness scoring systems in the 1980s paved the way for appropriate comparison of mortality outcomes between ICUs. In the early nineties, Australia and New Zealand ICUs began collecting information on patient outcomes and severity of illness using software developed by a small band of highly driven clinician enthusiasts (Stow et al. 2006). From the outset a bi-national approach was undertaken with intention to benchmark outcomes across both Australia and New Zealand. Participation rapidly grew over the 1990s. Over the 2000s with further support from the clinical community, improved infrastructure and more secure funding, individual Intensive Care databases were consolidated under a single organisational banner, which is now ANZICS CORE.

CORE presently houses a dataset of over 1.5 million patient records with a further 130,000 added each year and sees international contributions from Hong Kong, India and hopefully soon Fiji. Submission of data within Australia remains voluntary, but high levels of support from the clinical community have led to over 90% of ICUs in Australia and approximately 50% in New Zealand contributing data. Non-contributing ICUs are predominantly private ICUs, which require individual contractual agreements, or small rural units where resources for data collection are limited.

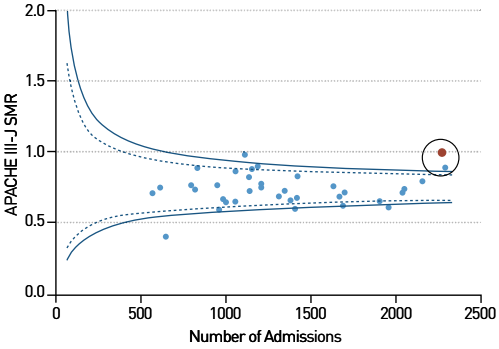
What Does ANZICS CORE Actually Do?

ANZICS CORE collects de-identified data on diagnoses, severity of illness and outcomes from adult and paediatric ICUs. CORE also surveys ICUs annually to determine bed numbers, staffing and resources. In addition to data collected directly from units, information from jurisdictional infection control bodies on rates of central line associated bloodstream infections are collected. Online reports are created quarterly and made available to submitting ICUs and to regional health departments. These reports benchmark ICU mortality outcomes against similar hospital types using internationally validated scoring systems (Acute Physiology and Chronic Health Evaluation (APACHE) III for adults, Paediatric Index of Mortality (PIM) 2 for children). Additional information is also provided on factors such as patient demographics, length of stay, readmission rates, after-hours discharges, provision of venous thrombo-embolism prophylaxis and exit block.

If an ICU appears to have worse mortality outcomes than its peer group, then a structured "Outlier Analysis" is undertaken and fed back to the hospital and to the regional department of health who determine any action required. In about half the cases, data quality and case mix issues appear to be the strongest factors contributing to the ICU's outlier status……..but not always! An example is given below:

Case Study from 2011 – An Outlier ICU?

This ICU had a higher standardised mortality ratio (observed deaths / predicted deaths derived from the APACHE III scoring system) than other similar units. The ICU Director, hospital administration and local jurisidictional committee were informed and further analyses were confidentially undertaken.



Initial analysis showed:

- An on-site audit had demonstrated accurate data collection
- The data was of high quality with a high level of completeness
- Case mix was similar to other peer group hospitals

Further analysis indicated that this ICU (compared to its peer group) had:

- Higher levels of after-hours discharge from the ICU
- Higher occupancy
- Higher nursing vacancy
- Lower medical and nursing staffing levels.

It was likely that these factors contributed to the poor mortality outcomes at this hospital.

A formal report was put together jointly by staff at ANZICS CORE and experienced clinicians who form the Outlier Working Group. This was provided to the unit Director and to the local jurisdictional governance body.

What Does ANZICS CORE Actually Do?

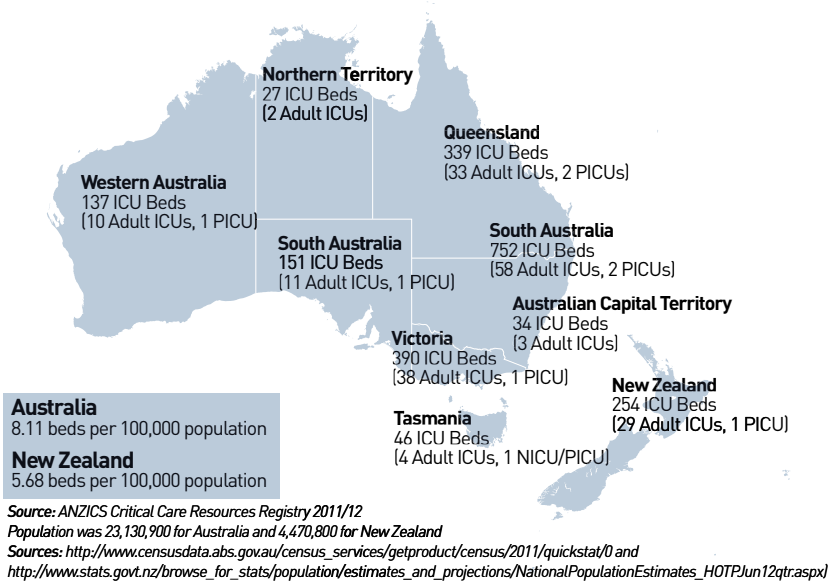
ANZICS CORE comprises ten staff located in Melbourne and Brisbane (exclusively funded by the State Health Departments) who work with three intensive care physicians, to manage education, audit, data submission, software support, data-

bases and provision of online reports for all contributing units. Data quality is ensured through automated validation rules, regular training workshops and on-site audits. ANZICS CORE provides free data collection software to all contributing units. This is essentially the same software built by the "founding" clinicians in the 1990s but with several renovations. Most ICUs do not have to pay to contribute data or receive reports, but the costs of data collection are born by the ICUs themselves.

What Else Can Registry Data Tell Us About Intensive Care Medicine in Australia?

Although the primary purpose of the registry is to monitor mortality outcomes of ICUs, the data finds many other uses. It allows us to paint a picture of resources available and outcomes achieved in ICUs throughout Australia and New Zealand (Figure 1). It can also be used for research. However it is worth noting that financial support from health departments comes with the expectation that 'their money' is spent on monitoring the healthcare system, not funding the growth of someone's personal publication list! Thus, when research with data is undertaken, it is self-funded by interested clinicians. This requires careful data governance and oversight of publication processes to ensure the appropriate use of data. This is achieved through close collaboration with organisations such as the Australian and New Zealand Intensive Care Research Centre at Monash University and The George Institute in Sydney.

ANZICS CORE data has facilitated development of performance indicators such as 'after-hours discharge from ICU' (Pilcher et al. 2007) and 'provision of venous-thromboembolism prophylaxis in the first 24 hours ICU admission' (Ho et al. 2011); has led to development of statistical methods for monitoring outcomes, identifying variation and describing trends (Pilcher et al. 2010; Kasza et al. 2013); has provided physiological rationale for randomised trials (e.g. following the finding that high body temperatures are associated with improved survival in patients with infections (Young et al. 2012)) and has resulted in the development of new severity of illness models (Paul et al. 2013; Straney et al. 2013) tailored to Australian and New Zealand practice.



Source: ANZICS Critical Care Resources Registry 2011/12
Population was 23,130,900 for Australia and 4,470,800 for New Zealand
Sources: http://www.censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/0 and http://www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/NationalPopulationEstimates_HOTPJun12qtr.aspx)

Figure 1. A profile of All ICUs Across Australia and New Zealand

The Future for Intensive Care in Australia and the ANZICS CORE Registries

Future aims include ensuring coverage of all ICUs, increasing linkages with other registry groups locally and internationally, matching our services to the developing needs of the speciality, integration with clinical information systems and developing registry methodologies to perform large, cost effective and well powered clinical studies. In addition, as mortality outcomes continue to improve, it will become increasingly important to determine functional outcomes and long-term survival (Figure 2).

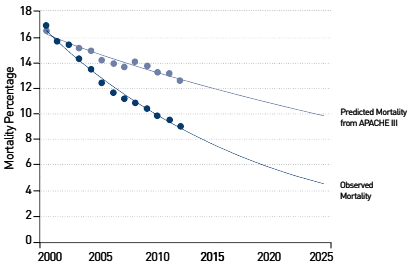


Figure 2. Observed and Predicted Mortality (Derived from APACHE III) 2000-2012 with Extrapolated Trend until 2025

Although we may know whether the 68 year old 85 kg man admitted after cardiac surgery in 2014 survives to leave hospital alive, to truly understand if we are providing effective care to critically ill we will need to know how well he can walk, talk and care for himself and what his chances are of being alive are five, ten or more years later. These are the future challenges for the ANZICS CORE registries and Intensive Care medicine in Australia and New Zealand. ■

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AGENDA

APRIL

3-5 The 10th Emirates Critical Care Conference
Dubai, United Arab Emirates
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MAY

4-7 PICC 2014 - 7th World Congress on Pediatric Intensive and Critical Care
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www2.kenes.com/picc2014/pages/home.aspx

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22-24 ECMO & Euro ELSO 2014
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31-3 Euroanaesthesia 2014
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3-4 Metabolic and Nutritional Issues in the ICU
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www.intensive.org

5-6 4th Paris International Conference on Intensive Care
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12-14 SESAM 2014
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6-9 ESPEN
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27-1 27th ESICM LIVES 2014 Annual Congress
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