ICU

MANAGEMENT & PRACTICE

INTENSIVE CARE - EMERGENCY MEDICINE - ANAESTHESIOLOGY

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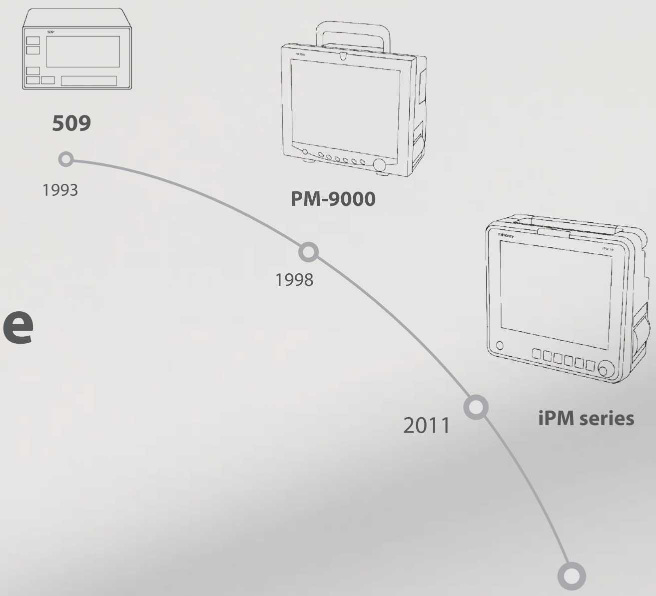
SPECIAL SUPPLEMENT
Pain Management in the ICU

Innovation

PLUS



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Innovation

The burden of critical illness is a major concern in healthcare. This burden is expected to continue to increase as our population ages. Our cover story **Innovation** highlights the growing problem of critical illness and the need to develop improved practices and implement new and advanced solutions to meet the expected challenges. Our contributors envision the ICU of the future and discuss the changing needs of critical care patients and critical care practice.

Frederic Michard, Tong J Gan and Rinaldo Bellomo highlight the importance of finding patients before they crash and discuss the recent advances and perspectives for ward monitoring with wearable sensors and smart algorithms.

Federico Gordo, Ana Abella, and Beatriz Lobo-Valbuena summarise developments in mechanical ventilation that they believe are shaping the present and will shape the future ahead.

Fernando Jose da Silva Ramos and Jorge Ibrain Figueria Salluh talk about data driven management for intensive care units and discuss the clinical and practical application of current available cloud-based data analytics to benchmark in real-time and to optimise clinical care in the ICU.

Nutrition is another important element of critical care. Pierre Singer and Liron Elia discuss technology innovations in delivering accurate nutrition and how malnutrition can be prevented by enforcing nutritional guidelines and using innovative approaches.

Juan B. Ochoa Gautier talks about the value of physicians and their contribution to the healthcare system and economic growth. He highlights the need to understand the real value of physicians and to encourage them to be creative and innovative.

Theodorus Kyprianou introduces our new Informatics and Technology section. He talks about the role of disruptive and hybrid technologies in acute care. He outlines the issues that will be the focus of this new section and how it will serve as an open forum to discuss the role technology can play in acute, emergency and intensive care medicine.

Extravascular lung water remains a useful guide for monitoring pulmonary oedema and vascular permeability in sepsis, acute respiratory distress syndrome and heart failure. Mikhail Kirov, Vsevolod Kuzkov and Lars Bjertnaes highlight the present clinical rationale for extravascular lung measurement as a key to personalisation of haemodynamic therapy.

Innovation is all about new initiatives and advanced strategies in the ICU. Claire Irwin and Sharon Parkinson discuss the Sleep Guardians, a new quality improvement initiative implemented by the Lancashire and South Cumbria Critical Care Network (LSCCCN). The role of the sleep guardian is to promote protective sleep throughout the night for patients in critical care and to ensure that all invasive nursing or medical interventions are performed before lights go out.

We also discuss another initiative - the acute kidney injury service launched at the Lancashire Teaching Hospitals NHS Foundation Trust. The goal of this initiative is to utilise the expertise and clinical knowledge of an established team of senior nurses familiar with assessing, planning, implementing and escalating the care of patients with an acute kidney injury.

In our Management section, Sethina Watson talks about communication myths of anaesthetists followed by Vishal Bakshi who discusses the role of the Physician Assistant in critical care and how they can play a leading role in the safe, efficient, value-based delivery of healthcare for the critically ill patient.

Susan East, a patient speaker at The American Thoracic Society International Conference in Washington DC, talks about one of the most burning issues in healthcare - humanising care. East, a three times ARDS survivor shares her experience as an ICU patient and highlights the need to humanise the ICU.

Our interview section features Bernd Saugel, Professor of Anesthesiology and Consultant in the Department of Anesthesiology, Center of Anesthesiology and Intensive Care Medicine, University Medical Center Hamburg-Eppendorf. Prof. Saugel is a specialist in anaesthesiology, intensive care medicine, and internal medicine. His primary field of research is the haemodynamic management of high-risk patients having surgery and critically ill patients. Prof. Saugel talks to ICU Management & Practice about future technologies and how the use of ultra-small and highly sensitive sensors can make monitoring systems wearable and wireless and how that can allow integrated monitoring.

Innovation is the key to improving patient outcomes and patient satisfaction. Embracing technology and implementing new and advanced initiatives can pave the way for the new ICU. ■

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COVER STORY

INFORMATICS AND TECHNOLOGY

SPECIAL SUPPLEMENT (pp. 33-40)

Pain Management in the ICU - Report of a live debate organised by ESICM

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INTERVIEW

I-I-I Blog

Sleep index, wakefulness can predict patient ability to breathe on their own

According to new research, critically ill patients can be more successfully weaned from a mechanical ventilator if they have higher levels of wakefulness and if both their right and left brains experience the same depth of sleep. The article titled "*Sleep and Pathological Wakefulness at Time of Liberation from Mechanical Ventilation*" is published in the American Journal of Respiratory and Critical Care Medicine.

Laurent Brochard, MD, PhD, and the co-authors of this study used polysomnography and a novel sleep index. The sleep index was developed by one of the co-authors, Magdy Younes, MD, PhD. The index has an odds ratio product (ORP) that provides a continuous digital score from 0 (very deep sleep) to 2.5 (full wakefulness). The objective was to determine whether the ORP was associated with the likelihood that a patient could be removed from mechanical ventilation.

Dr. Brochard, Director of the Critical Care Medicine Division at the University of Toronto and clinician-scientist at the Keenan Research Centre for Biomedical Science at St. Michael's Hospital in Toronto, Canada is the senior study author. He explains that patients who are under mechanical ventilation in intensive care units often suffer from severe sleep deprivation. As a result, they tend to exhibit abnormal patterns of sleep or wakefulness, which could also explain in part, the development of delirium.

Mechanical ventilation is life-saving, but it can also cause lung damage, infections, and other health problems. That is why it is important to take patients off the ventilator as soon as its medically possible. Physicians use a spontaneous breathing trial (SBT) during which a patient breathes on their own without the help of a ventilator. This is done to assess their readiness to breathe on their own. Dr. Brochard points out that in order to successfully separate the patient from the ventilator, it is necessary to get an adequate response from a number of physiological systems, which could potentially be impaired by sleep deprivation. He also notes that previous studies have linked pathological sleep with prolonged difficulties in being separated from the ventilator.

The purpose of this research was to assess whether a period of sleep and wakefulness in the hours before attempting separation from the ventilator could predict a greater level of success. To determine this, the researchers analysed data from 37 patients at three hospitals in Toronto, Canada. These patients were scheduled for an SBT and had already undergone polysomnography for 15 hours before the test. SBT was successful in 19 of the 37 patients while the breathing tube was removed in 11 others. In 8 patients, the breathing tube was not removed despite a successful SBT because other clinical factors suggested that they were not ready for extubation. The SBT was unsuccessful in 18 patients.

Study Findings

Overall, the results of the study show that:

- Classical sleep states determined by conventional sleep scoring guidelines were not associated with the success or failure of the SBT.
- Longer duration of full wakefulness was correlated with successful SBT and extubation.
- Poor correlation between sleep depth in the right and left-brain hemispheres predicts SBT failure.

ORP scores were associated with success or failure in weaning patients from the ventilator while sleep scores were not, thus suggest-

Image Credit: ATS

Wakefulness may predict if patients are able to breathe on their own.

ing that ORP scores have a better ability to distinguish different levels of sleep.

"Defining wakefulness or sleep classically necessitates detecting short-wave brain activity that typically characterises sleep and a decrease in higher frequencies that characterise wakefulness and comparing these results to clinical behaviour: does the patient look awake or asleep?" Dr. Brochard said.

Sleep deprivation produces a brainwave pattern similar to pathological wakefulness, and while the patient may appear to be clinically awake, they may, in fact, be obtunded or not fully awake. The authors of the study speculate that this state of pathological wakefulness may be the flip side of sleep deprivation.

It is thus important to understand the dissociation between the brain hemispheres. Clinicians in the ICU need to understand the cause of this dissociation, and they need to determine if the cause is sleep deprivation, the influence of sedative drugs or other medical conditions. By answering these questions, it may be possible to better manage mechanically ventilated patients in the ICU.

"We now have a monitoring tool of the brain that can help us address questions of major importance for the outcome of patients in the ICU," Dr. Brochard said. ■

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Acute pain estimation, postoperative pain resolution, opioid cessation, and recovery

Acute postoperative pain is associated with persistent postsurgical pain (PPSP). The incidence of PPSP ranges from 10 to 50% while severe, chronic pain after surgery is reported by 2 to 10% of patients. Both the severity and duration of postoperative pain are influenced by other factors including pre-existing pain.

A secondary analysis of the Stanford Accelerated Recovery Trial (START), a randomised, double-blind clinical trial, was conducted to assess the effect of perioperative use of gabapentin on postoperative pain resolution and opioid cessation. The researchers used data-mining algorithms to identify patient clusters based on the first 10 daily pain scores (reported as average, current and worst pain) after surgery. They also explored psychosocial characteristics that were associated with each cluster and determined which description best estimated the probability of 3 outcomes which included remote pain cessation, opioid cessation, and surgical recovery. The analysis was based on two hypotheses: that patient clusters predictive of poorer remote outcomes were associated with preoperative psychosocial characteristics, and that high-risk patient clusters were a superior predictor of outcomes over acute pain descriptors.

Results

A total of 371 participants (225 women and 146 men) scheduled for thoracotomy, video-assisted thoracoscopic surgery, total hip replacement, total knee replacement, mastectomy, breast lumpectomy, hand surgery, carpal tunnel surgery, knee arthroscopy, shoulder arthroplasty, or shoulder arthroscopy were included in the analysis. Of these 371 patients, 52% were partitioned into the low pain cluster, and 48% were partitioned into the high pain cluster.

Median pain duration in the high vs. low pain cluster was 92.0 vs. 40.0 days; opioid use was 39.0 vs. 12.0 days and time to patient-reported recovery was 89.0 vs. 49.0 days. Median time to pain cessation in the high vs. low-risk group was 92 days vs. 40 days. Median time to opioid cessation in the high vs. low-risk group was 39 days vs. 12 days. Median time to full recovery in the high vs. low-risk group was 89 days vs. 49 days.

Overall, the findings of this analysis show that patients categorised to each of the 3 high pain clusters had longer duration of pain and opioid use regardless of the procedure. Some preoperative characteristics that correlated with the assignment of these patients to the high-risk cluster included worse baseline pain at the future surgical site, a history of alcohol or drug abuse treatment, and randomisation to the placebo group. The analysis also showed a sex difference where women were found to be at an increased risk of categorisation to the high pain cluster.

Worst pain over the past 24 hours reported on postoperative day 10 (POD 10) was identified as a significant immediate postoperative predictor of remote pain resolution, opioid cessation, and complete surgical recovery. This measure was found to be a better predictor of all three outcomes. Its application to current clinical practice could facilitate early identification of patients requiring more-intensive, interdisciplinary, postoperative pain management as well as help decisions regarding the continuation or discontinuation of multimodal analgesia. The postoperative predictor can facilitate the identification and referral of high-risk patients through transitional pain services. ■

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Trends in epidemiology and antimicrobial resistance in intensive care units

The intensive care unit has a unique environment, mainly because it treats severe and critically ill patients who require special care. Critical care patients often require high-risk surgeries, and there is also a frequent need for invasive devices such as central or peripheral venous catheters, urinary catheters or tracheal tubes, among others. This makes these patients more susceptible to hospital-acquired infections (HAIs).

Recent data from the European Union (EU) reports that patients admitted to an ICU for more than 2 days acquired at least one HAI. These HAIs included cases of pneumonia, bloodstream infections, and urinary tract infections.

HAIs cause increased morbidity and higher treatment costs. It is estimated that HAIs result in nearly 15 million additional days of hospitalisation. More than €5.5 billion per year is spent because of HAIs. But what is even more worrisome is the fact that HAIs in an ICU environment can be life-threatening. In the EU, over 37,000 deaths each year are attributed to HAIs, and most of these deaths involve ICU patients.

Antibiotics play an important role in managing HAIs, but the problem of antibiotic resistance continues to be an issue in ICUs. Most HAIs that originate in the ICU are caused by multidrug-resistant microorganisms. The most frequent pathogens that reside in the ICU include *Escherichia coli* and members of the ESKAPE group (*Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa, and Enterobacter spp.*). Each of these microorganisms is resistant to most antibacterial agents that are commonly used in the ICUs.

The ESKAPE group, in particular, deserves special attention because of their virulence power and the fact that they have a higher level of antibiotic resistance. These pathogens are associated with high mortality rates in critically ill patients and are thus a major threat to public health.

> **strict antibiotic control measures must be implemented in all hospital settings, especially in the ICUs**

In short, antimicrobial resistance is an area of concern. There are fears that we might be returning to a pre-antibiotic era when untreatable pan-resistant microorganisms would colonise the ICU. Antibiotic options to treat the main pathogens that cause HAI have become scarce. No further development seems to be in sight since pharmaceutical companies have already announced that they are no longer investing in the development of new antibiotic drugs. Thus, the presence of highly resistant microorganisms that cause HAI is a reality that needs to be addressed.

The problem of antibiotic resistance did not occur overnight. This resistance is related to several factors including the misuse and overprescribing of antibacterial agents as well as premature treatment stops and incorrect dosages. Statistics show that in the EU from 2011-2012, hospitalised patients who received at least one antibiotic during their stay was 35% increasing to 56.5% among patients admitted to an ICU. This in itself demonstrates that there is an enhanced pressure within the ICU to prescribe antibiotics and this practice contributes to the development of antibiotic resistance.

There is a need to take urgent action to halt or mitigate the development of antibiotic resistance. Strict antibiotic control measures must be implemented in all hospital settings, especially in the ICUs. In addition, the development of new treatment alternatives to tackle these microorganisms should remain a research priority. ■

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Results of the ABATE infection trial

According to results of the ABATE infection trial, daily bathing with an antiseptic soap, plus nasal ointment for patients with prior antibiotic-resistant bacteria reduced hospital-acquired infections among patients with central venous catheters and other devices.

The ABATE infection trial included 340,000 patients from 53 hospitals. The study was led by researchers from the Harvard Pilgrim Health Care Institute, the University of California Irvine, Rush University and HCA Healthcare (HCA). The study titled "*Chlorhexidine versus Routine Bathing to Prevent Multi Drug-Resistant Organisms and All-Cause Bloodstream Infection in General Medical and Surgical Units: The ABATE Infection Cluster Randomized Trial*," is published in The Lancet.

The trial evaluated whether daily bathing with an antiseptic soap for all patients and nasal mupirocin antibiotic ointment in the nose of patients with a history of Methicillin Resistant Staphylococcus Aureus (MRSA) could potentially reduce hospital infections and antibiotic-resistant bacteria.

"Several ICU trials have shown striking reductions in infections and antibiotic-resistant bacteria using daily chlorhexidine bathing and nasal decolonisation with mupirocin. We wanted to know if patients outside the ICU could benefit from a similar decolonisation strategy," said lead author Susan S. Huang, MD, MPH, Professor of Medicine, Division of Infectious Diseases, University of California, Irvine School of Medicine.

The findings show that only patients with devices such as central venous catheters, midline catheters, and lumbar drains benefitted from this intervention, but no significant benefit was observed in other non-ICU patients. Patients with devices showed a 30% decrease in bloodstream infections and a 40% decrease in antibiotic-resistant organisms. A possible explanation for benefit in these particular patients may be because they are at a higher risk of infection. As it is, patients with devices account for more than half of all bloodstream infections in the hospital.

Senior author Richard Platt, MD, MSc, Professor, and Chair of the Department of Population Medicine at the Harvard Pilgrim Health Care Institute and Harvard Medical School points out that many hospitals have adopted antiseptic bathing for patients with devices outside the ICU even before the availability of any scientific evidence. However, findings from this trial provide additional support for this strategy, and thus it might be worthwhile to adopt the decolonisation strategy as best practice in non-ICU patients with devices to reduce bloodstream infection and antibiotic-resistant bacteria. ■

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Protecting ward patients

The case for continuous monitoring

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Finding patients before they crash might be the next major opportunity to improve patient safety. This article describes recent advances and perspectives for ward monitoring with wearable sensors and smart algorithms.

Hospital wards are dangerous. Indeed, they are where most unexpected deaths occur within institutions. In a UK national audit study, among 23,554 adult in-hospital cardiac arrests, more than half (57%) occurred on the wards and only 5% in the ICU (Nolan et al. 2014). In the large (>46,000 patients) EUSOS study done in 28 European countries, most patients (73%) who died before hospital discharge were not admitted to critical care at any stage after surgery (Pearse et al. 2012). Importantly, most patients do not suddenly deteriorate. Vital signs are often abnormal, or trending toward abnormal range, hours before cardiac arrest or ICU transfer (Churpek et al. 2012). But healthcare professionals may only suddenly notice this is happening because spot-checks are usually done on a 4-6 hours interval. Prospective observational studies conducted in a leading U.S hospital, where patients were continuously but blindly monitored, revealed that nurses who were checking vital signs every 4h missed 90% of hypoxaemic episodes and about half of hypotensive events (Sun et al. 2015; Turan et al. 2019).

Therefore, the introduction of continuous monitoring has the potential to improve quality of care in traditionally unmonitored settings (Abenstein 2010; Michard and Sessler 2018; Vincent et al. 2018). With the current rise of wearable products developed for health and fitness (e.g. smartwatches detecting arrhythmia or devices monitoring pulse oxygen saturation (SpO_2) and blood pressure (BP) when connected to a smartphone) we are about to reach an unprecedented situation: monitoring may become more intensive at home than in hospital wards so that staying at home may paradoxically be considered safer.

In this article, we summarise which physiologic variables should be monitored, which tools are currently available to do so, and discuss requirements for the future development and adoption of continuous monitoring solutions as standard of care for hospital wards.

Which variables should we monitor?

Vital signs classically spot-checked in ward patients include heart rate (HR), BP, respiratory rate (RR), SpO_2 and temperature. They all have potential value to detect clinical deterioration. Some are more sensitive than specific, like HR that may increase during many situations, including postoperative pain, circulatory shock, respiratory distress, and sepsis. Others are more specific than sensitive. For instance, SpO_2 would decrease only in case of respiratory failure, pending oxygen administration is not automatically titrated to maintain a normal SpO_2 (L'Her et al. 2017). SpO_2 has also been considered a lagging indicator in acute events of respiratory depression.

"finding patients before they rapidly deteriorate and suffer a major adverse event might be the next major opportunity to improve patient safety"

The ability of vital signs to predict clinical deterioration depends on the clinical context. During patient-controlled analgesia with opioids, rates of desaturation ($SpO_2 < 90\%$) and bradypnoea ($RR < 10$) lasting >3 min can reach 12% and 41%, respectively (Overdyk et al. 2007). In this context, monitoring respiratory variables, in particular, RR, becomes a priority. In contrast, monitoring temperature and HR would likely be more useful to detect sepsis

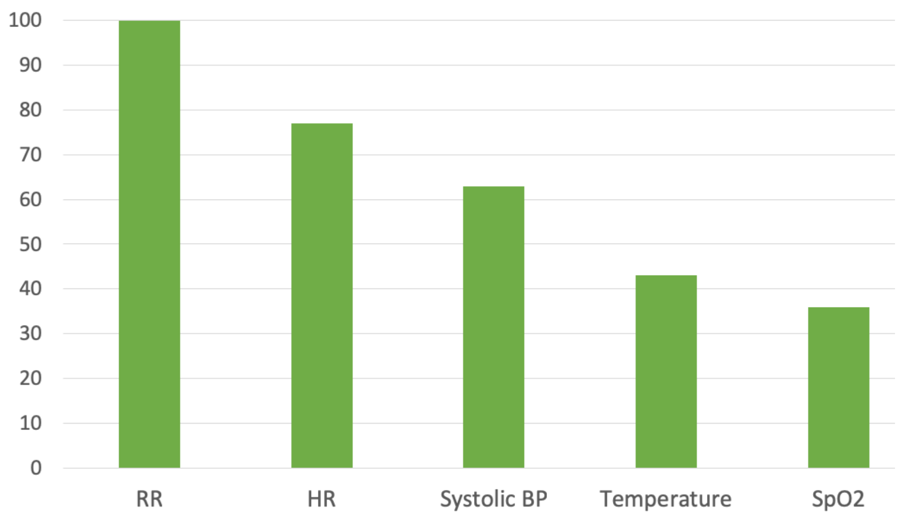


Figure 1. Importance of physiologic variables, scaled to a maximum of 100, in a random forest model developed to predict clinical deterioration on the wards.
Abbreviations: Respiratory rate, RR; heart rate, HR; blood pressure, BP; oxygen saturation, SpO_2. Original figure, with data from Churpek et al. 2016.

and prompt appropriate biological samples and treatments. A recent nationwide study (Michard et al. 2015) including >200,000 patients from >500 US hospitals showed that most common postoperative adverse events are respiratory and infectious complications, emphasising the importance of monitoring RR, SpO_2, HR and temperature.

In the general medical and surgical ward population, studies have repeatedly ranked RR, HR and systolic BP as the top 3 variables to be monitored. To predict cardiac arrest in ward patients, areas under ROC curves of 0.72, 0.68, 0.55 and 0.48 have been reported for RR, HR, systolic BP, and temperature, respectively (Churpek et al. 2012). In a recent study including >250,000 patients and using machine learning methods for predicting clinical deterioration in ward patients (Churpek et al. 2016), RR had the highest "weight" in the predictive algorithm followed by HR, systolic BP, temperature, and SpO_2 (**Figure 1**). In line with these observations, the National Institute for Health and Care Excellence in the UK stated that "RR is the best marker of a sick patient and is the first observation that will indicate a problem or deterioration in condition" (**nice.org.uk/guidance/CG50**).

Current options for continuous ward monitoring

Several methods have been proposed for the automatic estimation of RR in ward patients. They are mainly based on capnographic, acoustic, thoracic impedance and piezo-electric techniques (Michard et al. 2017). Capnographic sensors detect expired CO_2 and are the reference to measure RR in mechanically ventilated patients. In the context of ward monitoring, they are part of tethered monitoring systems sometimes poorly tolerated by spontaneously breathing patients. Acoustic sensors are better tolerated, but measurements may be influenced by speaking and swallowing (Mimoz et al. 2012). Respiration induces changes in electrical thoracic impedance that can be analysed to measure RR. Chest electrodes are classically used to quantify changes in thoracic impedance and have several advantages including ease of use and patient comfort. However, the reliability of RR measurements depends both on the number and the correct positioning of the electrodes. For patients staying in bed, a contact-free piezo electric sensor, left under the mattress, has been used with success to simultaneously monitor RR and HR (Zimlichman et al. 2012). Brown et al. (2014) monitored medico-surgical inpatients with such a system and reported a significant decrease in the number of calls for cardiac arrest.

Heart rate is classically recorded with chest adhesive electrodes. An alternative is the estimation of pulse rate from a pulse oximetry waveform. Of note, the pulse rate may differ from heart rate in case of cardiac arrhythmia and electromechanical dissociation (heart rate without pulse rate). Taenzer et al. used a tethered pulse oximeter to monitor pulse rate and SpO_2 in postoperative orthopaedic patients, many of them receiving opioids (Taenzer et al. 2010). They reported a significant decrease in the number of rescue events and transfers to ICU.

Temperature is classically spot-checked by nurses, and lately adhesive patches have been developed to continuously monitor skin temperature (Michard and Sessler 2018). A recent study showed a good agreement between temperature values from an axillary wearable sensor and reference oesophageal measurements during surgery (Pei et al. 2018). We are not aware of any evaluation conducted on the wards.

Blood pressure remains a variable difficult to measure non-invasively and continuously. Several volume clamp and tonometric methods have been developed to measure finger or radial blood pressure, respectively (Michard et al. 2018a). These systems have been designed for the operating room. Other systems, combining chest electrodes (to detect the ECG R wave) and a finger pulse oximeter (to detect a peripheral pulse), are able to predict BP from the estimation of changes in pulse wave transit time. Weller et al. used such a system to monitor BP, HR, RR and SpO_2 in neurological and neurosurgical ward patients (Weller et al. 2018). They reported a significant decrease in the number of rapid response team calls.

Further, when several variables are recorded together, they can be combined to calculate a single Early Warning Score (EWS). Several have been proposed, and they all include RR, HR, and systolic BP. Some (e.g. the NEWS and the ViEWS) integrate SpO_2 as well. The calculation of EWSs improves

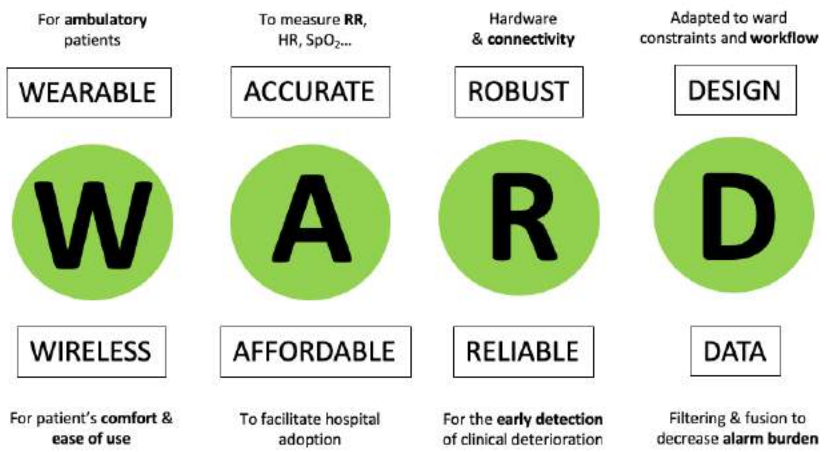


Figure 2. Requirements for future development and successful implementation of continuous ward monitoring techniques.

the prediction of adverse events (Churpek et al. 2012; Churpek et al. 2016). The use of monitoring systems that automatically calculate EWSs and alert clinicians on a pager as soon as patients deteriorate has been shown to be associated with clinical outcome benefits (Bellomo et al. 2012, Schmidt et al. 2015, Subbe et al. 2017, Heller et al. 2018). Machine learning algorithms using continuous data as input have the potential to better predict clinical deterioration and adverse events than classical EWSs (Hravnak et al. 2011).

Requirements for future developments and successful implementation

Wireless and wearable sensors

Early mobilisation is one of the key elements of enhanced recovery after surgery (ERAS) programmes. Physical movement is useful to prevent thrombotic complications and bedsores both in medical and surgical settings. Therefore, wireless and wearable sensors are highly desirable to make continuous monitoring a reality in ambulatory patients (Michard and Sessler 2018). In this respect, robust connectivity between wireless sensors, viewing, and alarming systems is a key requirement (Weenk et al. 2017). Wi-Fi or 3/4/5G connectivity would consume a lot of battery from a wearable, and unpredictable disruptions would remain a safety concern. Bluetooth and Zigbee may not be robust enough for handling wall or body mass obstruction and are not optimised for large amounts of streaming data. A wireless system ensuring robust signal quality and continuous data delivery from the patient's skin to the caring nurse, ensuring a high level of cybersecurity, low data latency, optimised battery life, and resistance to interferences from other devices in proximity would be ideal. Unfortunately, such a system remains to be invented.

> wireless and wearable sensors are highly desirable to make continuous monitoring a reality

Accuracy and false alarms

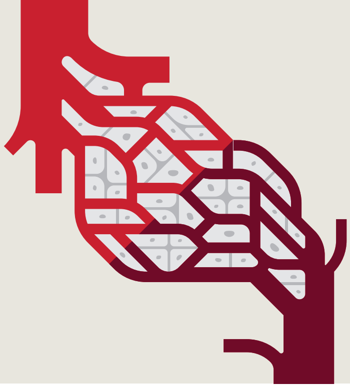
Measurement accuracy is mandatory for ensuring that any deteriorating patient is not missed. The number of wearable sensors is quickly growing, but independent validation studies done in real life conditions remain scarce (Granholm et al. 2016; Weenk et al. 2017; Subbe et al. 2018, Breteler et al. 2018). Core measurement performance is also crucial in preventing false alarms that can lead to additional workload and alarm fatigue (aka desensitisation to alarms). Different non-exclusive solutions can be envisioned. The first one is to minimise artefacts by ensuring sensors remain attached to the patient. In this regard, adhesive patches on the trunk might be preferred to finger clips or nasal sensors. Second, remaining artefacts can be filtered using smart software, such as machine learning algorithms (Chen et al. 2016). Third, both alarm thresholds and annunciation delays (the delay between when an alarm threshold has been crossed and when the alert is given) should be carefully selected (Weller et al. 2018).

Ease of use and impact on workload

Ease of use is key to clinical adoption, and monitoring systems should be made seamless and intuitive for users from minimally intrusive sensors to purposeful alarming tools. As mentioned above, the reliability of wireless connectivity should not become an issue for clinicians, and alert messages should be automatically directed to the right person, be it the nurse, the ward doctor, the rapid response team, an ICU member or a command centre, depending on the patient's condition and the local care organisation. Assuming all above conditions are met, ward monitoring should not increase workload at the hospital level, but rather redistribute it, with more adverse events managed by ward clinicians (since they are alerted earlier) and less by critical care specialists. The opportunity is also to prevent unjustified spot-checks in stable patients who remain the vast majority of ward patients. This may contribute to a decrease in nurse workload, and an improvement in patient comfort, quality of sleep and satisfaction (Michard et al. 2018b).

Affordability

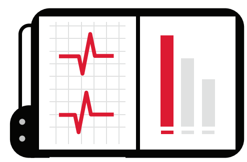
Affordability is another key determinant of hospital adoption (**Figure 2**). A fair evaluation of the return on investment has to take into account potential savings associated with a reduction in the number of ICU transfers and in hospital length of stay. Two economic evaluation studies have shown significant savings when implementing continuous monitoring solutions on the wards (Taenzer et al. 2012; Slight et al. 2014). Patient selec-



Intraoperative hypotension matters

Recent studies show associations between intraoperative hypotension and increased risk of myocardial injury (MI) and acute kidney injury (AKI) in non-cardiac surgical patients.[1,3]

Myocardial injury is the leading cause of people dying within a month after surgery.[2]



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tion with risk stratification tools may help optimise the return on investment. Machine learning algorithms could identify patients at risk of deterioration and help select those who may benefit the most from continuous monitoring techniques (Schmidt et al. 2015, Churpek et al. 2016).

Conclusion

Finding patients before they rapidly deteriorate and suffer a major adverse event might be the next major opportunity to improve patient safety (Bates and Zimlichman 2015). Thanks to recent hardware (wireless sensors) and software (data filtering and fusion, predictive analytics) innovations, it should become possible to adopt continuous ward monitoring without introducing an unmanageable nurse workload. This, beside the potential clinical benefits (faster recovery, less ICU transfers, and fewer unexpected deaths), could also lead to some logistic (more free beds for new admissions) and economic (shorter hospital stays, fewer complications) benefits. Clinical studies are needed to further investigate the clinical and economic impact of wearable and wireless sensors on medical and surgical wards, and better characterise which patients may benefit the most from these monitoring innovations.

Disclosure

Frederic Michard is the founder and managing director of MiCo, a Swiss consulting firm. Tong J Gan is the founding president of the American Society for Enhanced Recovery (ASER), the president of Perioperative Quality Initiative (POQI) and a consultant for Medtronic. Rinaldo Bellomo has been a consultant for Philips. ■

Key points

- Hospital wards are where most unexpected deaths occur within institutions
- Continuous monitoring has the potential to improve quality of care in traditionally unmonitored settings
- Wireless and wearable sensors are highly desirable to make continuous monitoring a reality in ambulatory patients
- Measurement accuracy is mandatory for ensuring that any deteriorating patient is not missed
- Ease of use is key to clinical adoption, and monitoring systems should be made seamless and intuitive for users
- Ward monitoring should not increase workload at the hospital level, but rather redistribute it, with more adverse events managed by ward clinicians and less by critical care specialists

Abbreviations

ASER	American Society for Enhanced Recovery
BP	Blood pressure
ERAS	Enhanced Recovery after Surgery
EWS	Early Warning Score
HR	Heart rate
POQI	Perioperative Quality Initiative
RR	Respiratory rate
SpO2	Pulse oxygen saturation

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Innovations in ICU ventilation

The future delivered

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In this article, we aim to summarise the developments in mechanical ventilation that we believe are shaping the present and will shape the future ahead.

Introduction

Many centuries ago, Socrates stated that "the secret of change is to focus all of your energy, not on fighting the old, but on building the new." Nowadays, we may relate his quote with the concept of innovation, which is considered the process of turning an idea into a good or service that adds value. Innovation must satisfy a specific need, involve a deliberate application of information, imagination, and initiative, and ought to include all processes by which new ideas are generated and converted into useful products. As physicians, we tend to assume regular incremental advances in technology and processes, but from time to time disruptive innovations take place.

Even though innovation entails the application of useful novel ideas, these should address our specific challenge: taking care of the patients' needs. New ideas must accept the pathophysiology, at least to a certain level, and aim to prevent further harm. We are bystanders of an exponential increase in knowledge and face complex situations with small response time. Therefore, modern technology comes to play, providing critical care with new tools that meet three major goals: improving management, making better decisions and being more effective in patient care (Pettenuzzo and Fan 2017; Schulman and Richman 2019). In the following paragraphs, some examples of these technological advances are presented.

Advanced monitoring

As healthcare professionals, we face one of our first issues: the visualisation and interpretation of the enormous quantities of patient-specific data in an extensively monitored environment.

Continuous assessment of respiratory status and optimisation of ventilator settings are one of the keystones of advanced monitoring systems, improving our understanding of the disease and the effect of therapeutic strategies (Theerawit et al. 2017; Ergan et al. 2018). Current monitors integrate several parameters at the same time, providing cleared-up information to the user.

In this context, and in order to implement the best possible medicine, clinical decision support systems (CDSS) have been born to stay. CDSS could be defined as health information technology that builds upon the foundation of an electronic health record system, granting specific, filtered and organised information (Josheroff et al. 2012; Korngiebel et al. 2017). In other words, CDSS aid to address the challenges of big data in an era of precision medicine, helping patients and clinicians to make optimal decisions. Some authors have proposed that CDSS address 5 rights: delivering the right evidence-based information, to the right people (healthcare professionals), in the right format, through the right channels and at the right time (Sirajuddin et al. 2009). From our point of view and experience, we also consider that the CDSS must fulfill a set of requirements, grouped in **Figure 1**. CDSS will mean a change in our day-to-day work, as they will be able to predict the emergence of complications and will help select the best possible treatment for each individual patient. However, these outcomes will require joint work of healthcare professionals and machine or Deep Learning systems, especially when a Blockchain Data Encryption System is fully integrated (Mandl and Manrai 2019).

Current examples of applied CDSS are outreach rapid response teams and use of early warning scores (Vincent et al. 2018). An example of the latter takes place at our department, with an ongoing project named **ICU without walls**. It consists in applying computer systems including an algorithm that monitors vital signs of patients admitted to the hospital, in order to allow an early identification of deterioration, decreasing the incidence of organ failure (including respiratory failure and need of ventilatory support), and enabling rapid targeted management (Gordo and Molina 2018). Other examples of applied CDSS are open-loop physiologic model-based decision support systems (Rees 2011; Tams et al. 2017; Karbing et al. 2018; Spadaro et al. 2018); and multimodal CDSS, which incorporate data from bedside, wireless and third-party devices, to upload the information on a platform (**Figure 2**).

In addition to ground-breaking monitoring, lung imaging techniques have experienced overwhelming progress: we currently not only base our knowledge on chest x-ray or computed tomography, but use lung ultrasound, positron emission tomography, electrical impedance tomography or magnetic resonance imaging as decision support tools. As ultrasonography is an evolving part of critical care medicine, it lends itself to innovative applications. Even though its results/images depend on the operator and the patient's characteristics (obese patients, thoracic dressings, subcutaneous emphysema), lung ultrasound may visualise pleural effusion and consolidation (alveolar consolidation, atelectasis), and has demonstrated a potential utility in several clinical conundrums: (a) during the process of recruitment manoeuvres (strong correlation between PEEP-induced lung recruitment and lung ultrasound aeration score), (b) during fluid resuscitation of ARDS patient, avoiding fluid overload (impairment correlated with

"the complexity of mechanical ventilation and of ventilators causes more than one headache to healthcare professionals; automation of ventilation settings could yield a solution"

extravascular lung water), and (c) during the process of weaning the patient from mechanical ventilatory support [including diaphragmatic ultrasound] (Mayo et al. 2016; Lui and Banauch 2017).

Conversely, electrical impedance tomography (EIT) has been a remarkable technological advance in the field of lung monitoring, and mechanical ventilation adjustments EIT may assist in (a) defining mechanical ventilation settings, (b) assess distribution of tidal volume and of end-expiratory lung volume, (c) contribute to titrate PEEP/tidal volume combinations and (d) quantify gains (recruitment) and losses (overdistention or de-recruitment), granting a more realistic evaluation of different ventilator

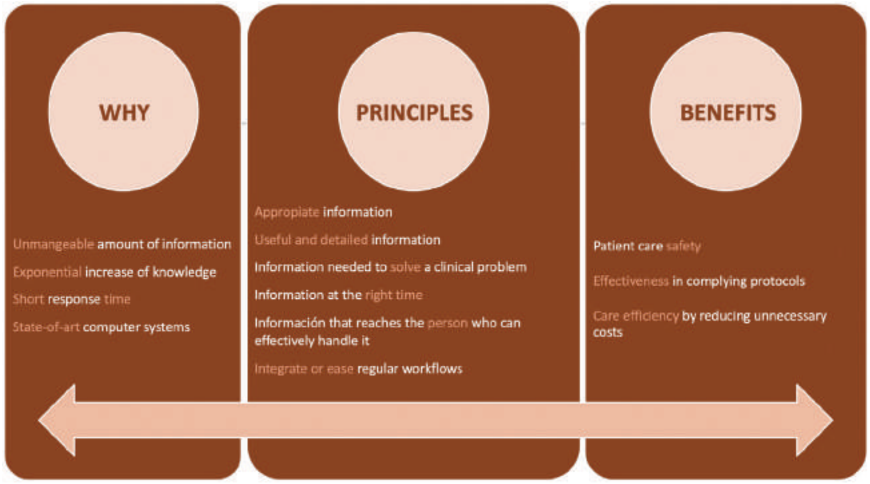

Figure 1. CDSS requirements.

Figure 2. Example of CDSS interface. Beacon Caresystem® (Mermaid Care A/S, Nørresundby, Denmark) providing real-time information and recommendations regarding ventilator settings.

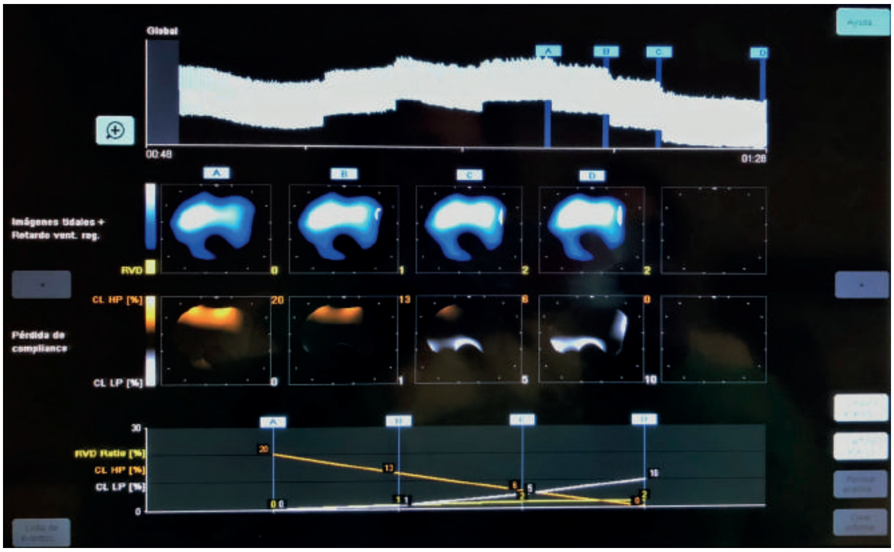

Figure 3. Pulmovista® 500 (Dräger Medical GmbH, Lündbeck, Germany). After recruitment we can observe overdistension (orange colour) and collapse (grey colour), being able to infer an optimal PEEP value.

modes or recruitment manoeuvres (Lobo et al. 2018) (**Figure 3**). EIT also contributes to the management of life-threatening lung diseases such as pneumothorax, and aids in guiding fluid management in the critical care setting. Indications for the use of EIT at the bedside are especially promising in the light of the first results, although its use on a daily basis will be the result of the clinicians' acquired experience over the years.

Ventilation strategies

Potential optimisation of ventilation bundles starts by re-evaluating the crucial components of respiratory mechanics (Bos et al. 2018). After more than half a century of modern positive-pressure ventilation, it seems that mechanical ventilation has a fairly narrow therapeutic index between the effective and damaging dose. Targets have changed from aiming normal oxygen, pH or carbon dioxide levels, to tolerating atelectasis and accepting low arterial oxygen levels and/or hypercapnia. Moreover, and as part of what could be called muscle protective ventilation strategies, a big effort has been put into preventing or shortening the use of mechanical ventilation as much as possible, besides using ventilator settings that are considered to be "lung protective."

The complexity of mechanical ventilation and of ventilators causes more than one headache to healthcare professionals. In the face of this conundrum, automation of ventilation settings could yield a solution (Rose et al. 2015; Branson 2018). Closed-loop systems have been classified into simple, physiological signal-based and explicit computerised protocols or ECP (Wysocki et al. 2014). ECP systems use multiple inputs to control one or several ventilator outputs. Some examples of automation of mechanical ventilation are: Adaptive Support Ventilation (ASV; which titrates ventilator output on a breath-to-breath basis providing a preset level of minute ventilation while minimising work of breathing), Intellivent ASV (an extension of ASV, including automated selection of FiO2 and PEEP) (Bialais et al. 2016), and SmartCarePS (control of pressure support level based on the patient's respiratory characteristics) (Rose et al. 2008). Other examples available on the market (although not totally automated) are proportional assisted ventilation plus (PAV+) and NAVA.

> "we must deepen our understanding of the principles of respiratory physiology and respiratory system mechanics"

Likewise, patient-ventilator interaction still represents a challenge for most healthcare professionals (Pham et al. 2018; Subira et al. 2018). Asynchronies cause discomfort, increase dyspnoea, may induce lung injury and prolong ventilator use. Current knowledge on asynchronies mainly comes from small physiologic or observational studies, and precise information, such as epidemiology, assessment, and management, is lacking (Gutierrez et al. 2011; Longhini et al. 2017). We must therefore, deepen our understanding of the principles of respiratory physiology and respiratory system mechanics and, as a scientific community, join forces against asynchronies. New technologies may help us in their management (predicting and preventing them), but there's still a long way to go.

The future: big data and artificial intelligence

Alongside big data techniques, new approaches such as deep machine learning and artificial neural ICU data integration are starting to become effective tools for data analysis (Lovejoy et al. 2019; Nunez Reiz 2019). Big data analysis is employed in other fields, such as marketing, banking, and logistics. But in healthcare, it depends, at least partially, on data entered by the professionals. Which information is more relevant? Have we been trained to know how to prioritise correctly?

In this new era, artificial intelligence (AI) is beginning to receive interest. In AI, data is fed into the computers, which detect and implement the rules, and continuously assess the information to re-calibrate if needed. AI could reduce the inter-clinician variability and offer other benefits, as search of complex relationships in the vast quantity of data, analyse variables to predict outcomes of interest and develop additional models that could aid healthcare professionals in extracting useful information for clinical decision making.

Ongoing examples of research in AI:

A) Neural networks for breathing-pattern recognition: machine learning algorithms that have the ability to learn input and output relationships from sets of data; being able to detect asynchronies and wean patients (Kuo et al. 2015).

B) Decision tree classification, such as the AEGLE project, for predicting risk of certain events using logistic regression models that recognise patterns of data, which are then used as inputs for a machine learning based patient-specific algorithm to evaluate the risk that a specific event or outcome (Olive and Owens 2018).

C) Development of smart alerts via machine-learning methods to avoid ever-growing evidence of alarm fatigue (Kane-Gill et al. 2017, Winters et al. 2018).

Conclusion

We are looking at a progressive shift in the intensive care standards of care. Modern ICU environment is data-rich, providing fertile soil for the development of new and more accurate technologies, where clinical decision-making is being assisted by computers that integrate and analyse recollected data. Accurate predictive models to anticipate events, better decision support tools, and greater personalisation of care are becoming a quality standard.

However, we would like to point out two concerns. Firstly, ICU data integration is the main challenge in developing effective tools for data analysis. We need big databases, such as MIMIC (Multiparameter Intelligent Monitoring in Intensive Care), that can supply our computers all possible variables (e.g. physiologic, haemodynamic and demographic variables needed to develop a CDSS for the prediction of in-hospital mortality), highlighting the importance of clinical expertise in the development of data-driven analytic models. Secondly, the introduction of new accurate tools must be prudent (Gonzalez de Molina Ortiz et al. 2018; Urner et al. 2018; Clarissa et al. 2019). Technological development must respond to the real needs of patients and clinicians. As healthcare professionals, our primary goal is the meticulous care of our patients and their families. In the face of booming technologies, we need to promote further the humanisation of intensive care. We are compelled to strive, first and foremost, proper sedation management, promote restful sleep, encourage early mobilisation, and encourage family involvement in patient care. Within ventilatory management, we ought to tackle the intrinsic problems that result in the non-application of lung protective strategies [such as low tidal volume, monitor of driving pressure, etc.] (Bellani et al. 2016). We should, therefore, focus on solving problems and seek appropriate strategies for interprofessional collaboration that bring this technological development closer. ■

Conflict of interest

Federico Gordo has performed consultancy work and formation for Medtronic and formation for Medtronic and MSD. The other authors have no competing interests.

Abbreviations

AI	Artificial Intelligence
ASV	Adaptive Support Ventilation
CDSS	Clinical Decision Support Systems
ECP	Explicit Computerised Protocols
EIT	Electrical Impedance Tomography
FiO2	Fraction Of Inspired Oxygen
ICU	Intensive Care Unit
NAVA	Neurally Adjusted Ventilatory Assist
PAV+	Proportional Assisted Ventilation Plus
PEEP	Positive End-Expiratory Pressure

Key points

- Modern technology can provide critical care with new tools that meet three major goals: improving management, making better decisions and being more effective in patient care
- Clinical decision support systems (CDSS) address 5 rights: delivering the right evidence-based information, to the right people in the right format, through the right channels and at the right time
- In addition to ground-breaking monitoring, lung imaging techniques have also experienced overwhelming progress
- Artificial Intelligence (AI) is beginning to receive interest and could reduce inter-clinician variability and offer other benefits

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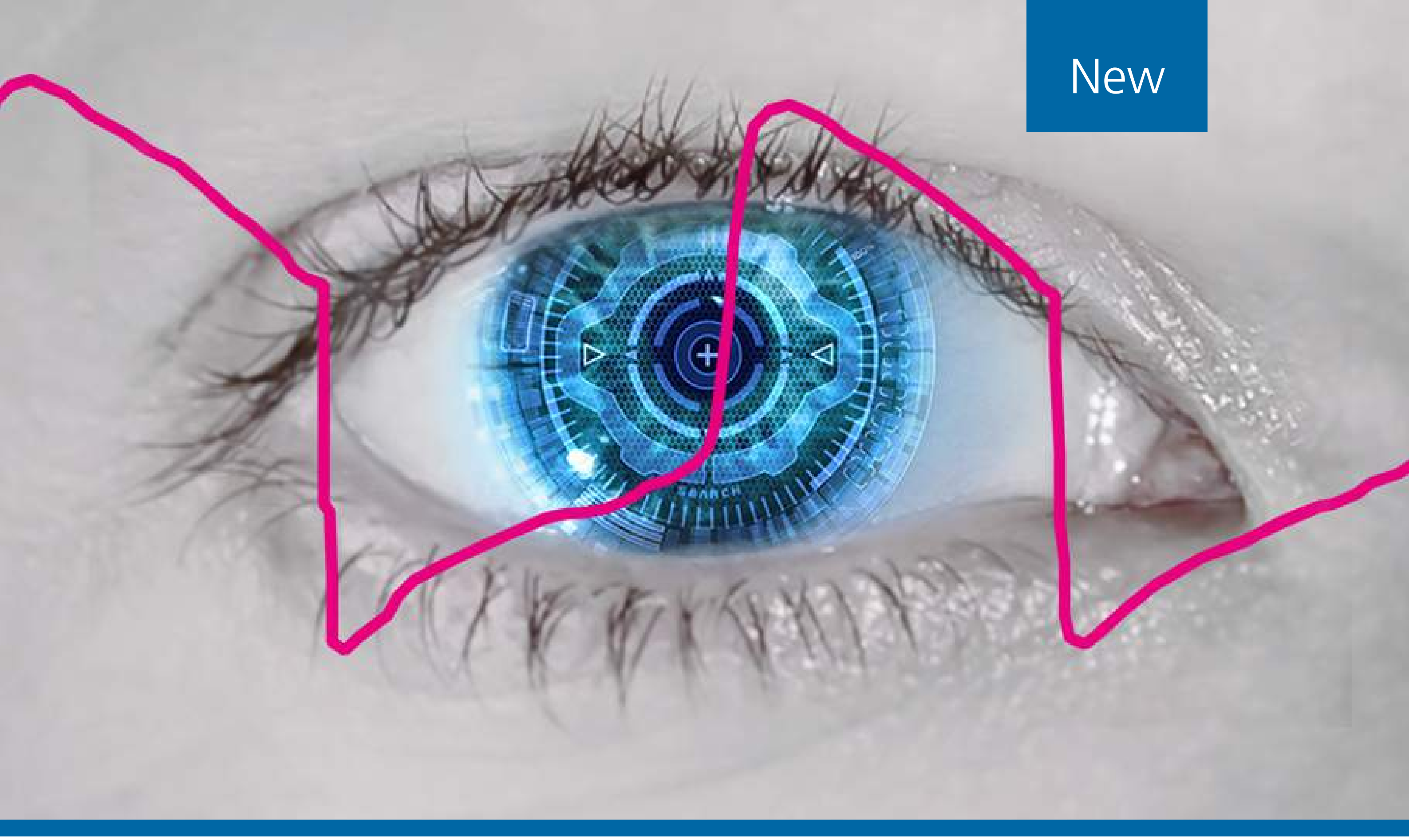
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Data-driven management for intensive care units

This article focuses on the clinical and practical application of current available cloud-based data analysis to benchmarking in real-time and to optimise clinical care in the ICU.

Introduction

The ICU is a highly technological environment where each patient data generates thousands of data-points per day. However, most of this data is usually wasted thus missing the opportunity of using this data to understand patient profile and improve outcomes. For many years intensivists have used individual patient data to monitor and follow organ failure severity and trajectory with widely used scoring systems such as the SOFA score (Ferreira et al. 2001) and aggregate ICU data using information on physiology and patients characteristics to generate severity of illness and prognostic scores such as the SAPS and APACHE scores that do not add to the management of individual patient (Salluh and Soares 2014) but can be used to evaluate global severity of illness of a population and produce estimates of efficacy of the ICU through standardised mortality rates. In recent years the fast development of electronic medical records, interoperability, connectivity with medical devices, cloud-based systems and streaming analytics brought advanced information with near-real-time analysis to the bedside aiding clinicians to manage patients based on data and to manage ICUs and their quality and performance using descriptive analysis, advanced prediction models and strategic benchmarking tools. Although not fully implemented, it is clear that the current technology allows point of care assessment of key performance indicators and is the cornerstone of data-driven management.

Data-driven management in the ICU

What kind of data improves ICU performance and patient outcomes

There is currently a plethora of data in the ICU and exploring it in-depth can be a labour-intensive task. Currently, several institutions have devoted time and resources to data-science departments in order to generate models that can help evaluate their patient population, and use of resources and outcomes. It is clear that either older methods (i.e. logistic regression, data mining techniques) or newer ones (i.e. machine learning, deep learning, super-learner algorithms) are widely available and increasingly used. A high degree of expertise, as well as access to high-quality and highly granular data through robust interoperability, is essential (Rush et al. 2018; Komorowski et al. 2018; Gehrmann et al. 2018). However, there is also data that is simpler, easier to obtain and can generate rich and very useful insights for measuring and improving quality of care and patient outcomes. With the use of core data or a minimal dataset comprised of patient characteristics (diagnosis, comorbidities), complications within the first day of ICU admission (physiologic derangements, limited lab data, use of invasive devices) and ICU related resource use and complications, robust, reliable and rich information can be easily generated.

> the emergence of Big Data and data-driven healthcare presents both tremendous opportunities as well as unprecedented challenges

Currently national registries such as the NICE registry in the Netherlands are providing ways to use actionable indicators on antibiotics, pain and transfusion management fusing the audit (adherence to best practice) measured at each ICU with a system that generates ways to improve adherence to the best current evidence in the form of "tool-boxes" (Kallen et al. 2018; Lange et al, 2017). A large real-world data project from Epimed, a cloud-based analytics for quality measurement and ICU performance (Zampieri et al. 2017) is currently implemented in more than 800 ICUs in six countries where physicians at the point of care (through computers or mobile devices) can have access to real-time information on key quality metrics (Rhodes et al. 2012), risk-adjusted outcomes and adherence to prevention of adverse events and infection and use this information as target for quality improvement initiatives.

In addition, all this information can be compared, and ICU benchmarking has made substantial progress in recent years (Salluh et al. 2018). Traditionally, benchmarking has been divided into categories of process, performance, and strategic benchmarking. It also can be performed within the same institution or as external benchmarking. For ICUs, benchmarking should use standardised measurements to allow comparison of performance between intensive care units and if

Table 1. What should we benchmark for ICUs

Domain/ Measure	Advantages	Limitations
Outcomes		
Mortality	Easy to measure, clinically relevant	Has to be risk-adjusted (SMR) with well-calibrated scores
Length of stay	Easy to measure, clinically relevant, proxy of resource use	Affected by structure, can be artificially lowered by transfers
Unplanned ICU readmissions	Easy to measure, clinically relevant, indirect marker of clinical process inside and outside ICU.	Affected by structure (e.g.- step-down units) and local policies
ICU acquired complications	Indicators of quality of care, there are validated recommended definitions, often modifiable/ preventable	Affected by case-mix, frequently under-reported, need stable definitions
Process of Care		
Adherence to best practices and process of care	Reliable surrogate of best practices, extensive EBM literature to support, can be used for audit-feedback purposes	Level of evidence varies according to the measures, effect on outcomes is variable, frequently under-reported
ICU and Hospital Organisation and Structure		
Staffing patterns	Potentially associated with outcomes, easy to measure	Should be adjusted by risk and workload
ICU structure	Can be measured within countries where there are national requirements to provide intensive care	Wide variation in national standards as well as in the definition of an ICU bed

Source: Adapted from Salluh 2017

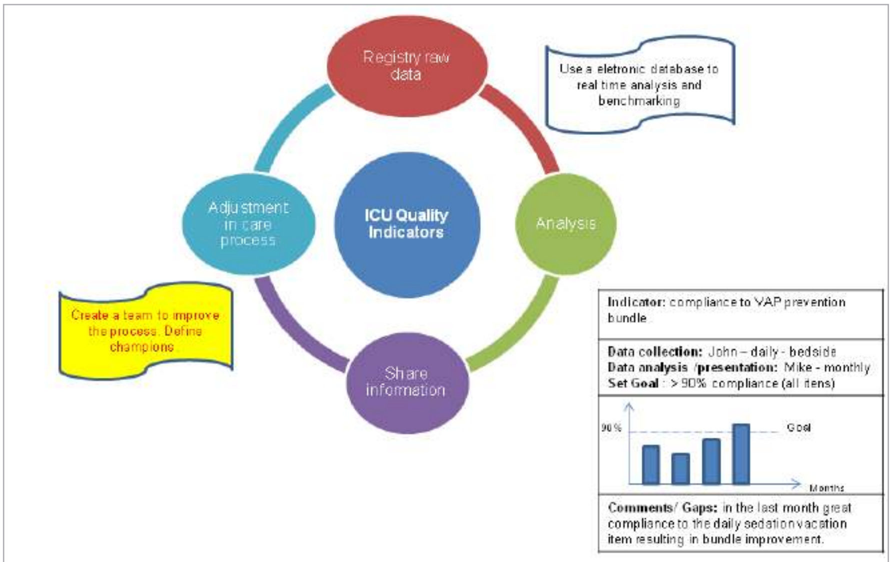

Figure 1. Practical approach to analyse and improve ICU performance

ICU - Intensive care unit, VAP - ventilator-associated pneumonia

feasible involve risk-adjusted measures such as the standardised mortality ratios that allows ICUs to compare their mortality rates with other ICUs with different profiles in a fair way. Or it could also involve risk-adjusted length of stay or resource use as a way to measure its efficiency regardless of the ICU profile (Soares et al. 2015; Rothen et al. 2007). Although imperfect, severity-adjusted mortality rates should be used preferentially associated with processes of care and compliance as they can offer an alternative approach to benchmarking, providing actionable data (**Table 1**).

How I use data to manage my ICU

Despite the worldwide adoption of electronic health records (EHR), few institutions are making full use of its entire potential using highly granular and sequential data acquired in EHR to improve the quality of care. The EHR in the ICU is a powerful source of information generated by healthcare professionals and consolidates data from patient monitoring systems, bedside equipment (i.e. infusion pumps, dialysis machines), and other hospital IT solutions. The emergence of Big Data and data-driven healthcare presents both tremendous opportunities as well as unprecedented challenges (Sanchez-Pinto 2018; Pirrachio et al. 2018). Recent studies demonstrate the potential for the use of data to reducing health care costs while improving quality of care, through the development of clinical decision support of general ICU patients and sepsis cases (Vellido et al 2018; Pirracchio et al 2018), better risk assessment and clinical profiling of ICU patients through machine learning (Vranas et al 2017) as well as identifying actionable targets for improvement of process of care in QI initiatives and registries (Soares et al 2016).

Most organisations are now in the phase of identifying patients through clinical or financial risk profiles. Urgent action is needed to improve the recognition where it is possible to have the greatest outcome with the resources available. For this purpose, the use of currently available solutions that enable predictive data analytics at the bedside can help to identify specific at-risk populations and target those individuals to optimise clinical care or improve ICU staff profile and skills.

Real-world use of analytics to evaluate the performance of my ICU

The recent progress of EHR as well as advanced Patient Data Management System (PDMS) for the ICU and cloud-based analytics allows us to apply the 40-year-old Donabedian principles in near-real time. Basically, there are three types of indicators based on Donabedian categorisation (Donabedian 1978):

1. Structure: describes the organisation, facilities, and staff. Usually describes aspects that can be improved by increasing investments.

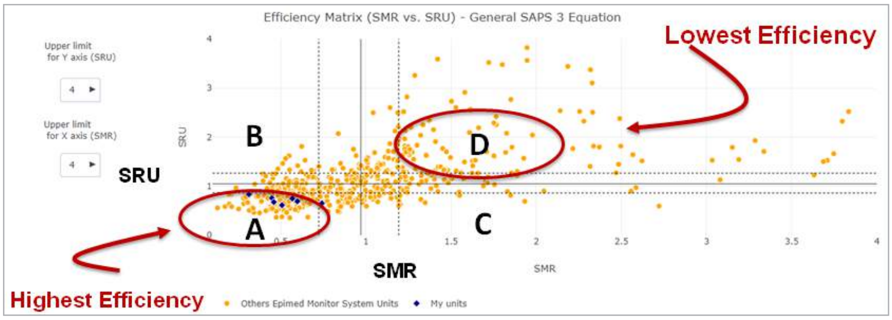

Figure 2. Efficiency matrices using SAP3 score and the SRU

A - Represents an adequte efficiency presentig both SMR and SRU lower than 1. **B** - Overachieving ICU, presents a good clinical performance but an inadequate SRU. **C** - Underacheiving ICU. In this situation, ICU presents a poor clinical performance despite an adequate resource use. **D** - Least efficient ICU presenting both SMR and SRU over 1.

SRU - Standard Resource Use, SMR - Standard Mortality Ratio, ICU - Intensive Care Unit, SAP 3 Simplified Acute Physiology Score 3.

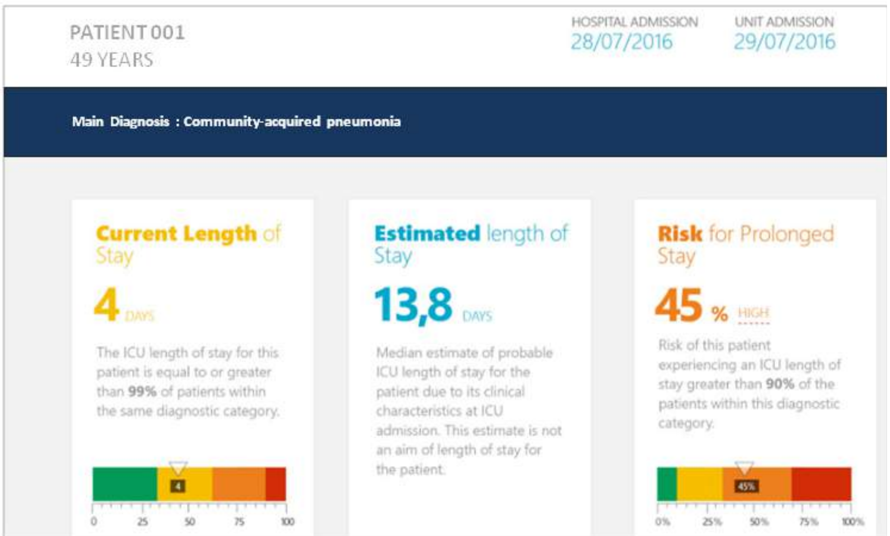

Figure 3. Epimed Monitor System® dashboard for length of stay prediction

2. Process: describes the process of care between the caregiver and the patient. Usually depends on care aspects being more easier to change.
3. Outcome: describes the outcome, frequently at the patient level. Ultimately, the indicator is more important.

The first step is to define the indicators that should be monitored. Second, guarantee the achievement and storage in a clinical database. Several examples of databases are available. Third, compare the results to other ICUs (Guidet et al. 2016).

After measurement and benchmarking, some domains will require changes. One important consideration is to evaluate the ICU results globally and for specific groups and conditions (e.g. sepsis, cardiac surgery, onco-haematological patients). Considering as an example, a mixed ICU with a poor performance for patients in mechanical ventilation (i.e. high rates of ventilator-associated pneumonia - VAP, delayed and long weaning periods, high rate of tracheotomy and longer than expected LOS) compared with other ICUs with the same characteristics. As an ICU director, the mission is to ensure the quality of data input and analyse the data. Once the problem is detected, a meeting with clinical champions in the unit must be done. The aim is to find actionable indicators and start change! It is important to share the information with the team to understand the root cause and create a plan to fix the problem. In this hypothetical case, the team concluded that high rates of VAP were related to VAP prevention bundle non-compliance, especially daily sedation vacation. As an action, a sedation protocol was developed, and its application was ensured by daily measurements with electronic checklists and a dedicated and well-trained multi-professional team. At the same time, non-invasive ventilation use could be revisited or a weaning protocol planned. A practical approach is presented in **Figure 1**.

Real-time process of measaured care

Both expert opinion and medical societies recommend that ICU LOS should be measured and compared as it represents a proxy of ICU effectiveness. Because it is easy to measure and reproducible, it is considered a good marker of resource use and is employed in a risk-adjusted way to obtain the efficiency matrices for ICU as depicted in **Figure 2** (Rothen et al. 2007). Although ICU physicians are good at predicting mortality, even experienced intensivists are unable to accurately predict LOS at admission for both those patients who will experience short and long LOS (Nassar and Caruso 2016). In the last years, several models for ICU LOS prediction have been reported. However, a recently published systematic review found that none of those models completely satisfy requirements for planning, identifying unexpected long ICU LOS, or for benchmarking purposes. The authors recommended that physicians using these models to predict ICU LOS should interpret them with caution and use them for benchmarking, but not for individual patient assessment (Verburg et al. 2017).

One important caveat about these models is that the time period between when the sample is taken, and results are generated must be shortened considerably to be used in predictive equations (Zimmerman and Kramer 2017). Recently, the Epimed Monitor System® embedded a tool that collects data on LOS and provides clinical guidance for future admissions (**Figure 3**). For each diagnostic category and from demographic information, a LOS estimate is calculated by the system in the first 24 hours from admission; however, instead of simply reporting the predicted LOS (which create a bias by "pressuring" the staff to discharge the patient from the unit), the algorithm indicates whether landmark LOS have passed (in percentiles) and provides an individualised risk of prolonged LOS (Zampieri et al. 2017). Using this management tool is

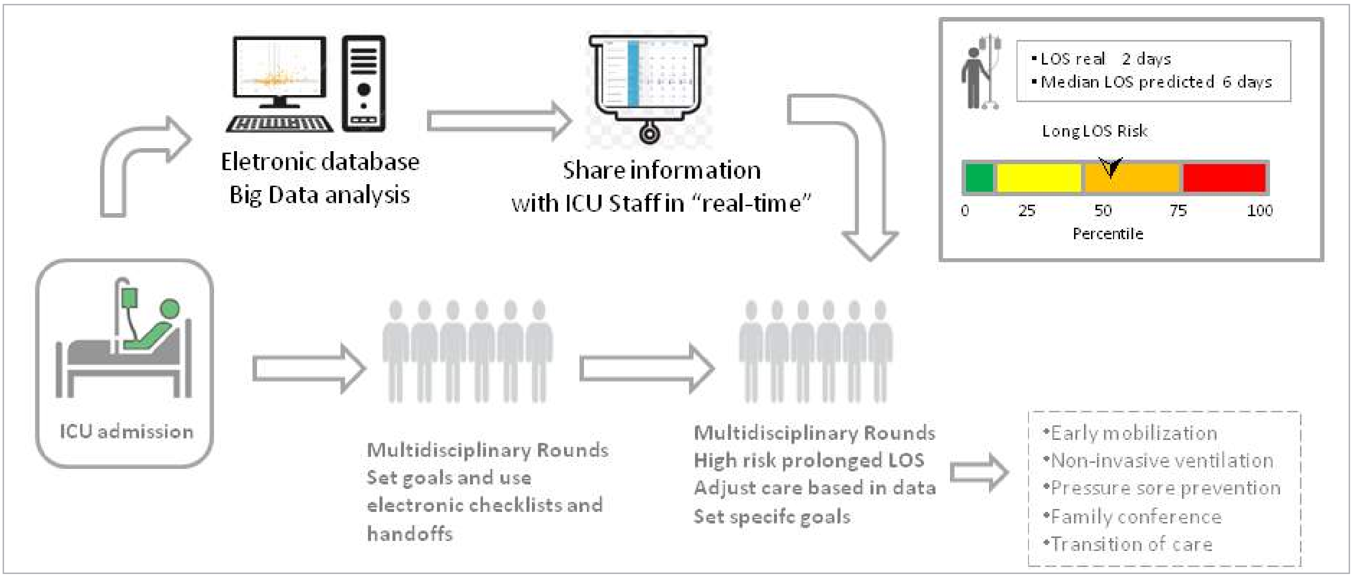

Figure 4. Real time measures of care

ICU - Intensive care unit, LOS - length of stay

possible to share the information early and in real time with all the staff involved in the care of the patient, set specific goals and predict ICU occupancy rate for the few next days.

A pragmatic model of this application tool is depicted in **Figure 4**. As an example, a 49y man was admitted in ICU and presented the diagnostic of community-acquired pneumonia. He had a history of a class II NYHA cardiac failure, hypertension, and chronic atrial fibrillation. During the first 24hs of ICU admission, the patient developed septic shock and respiratory failure being supported with vasopressors and invasive mechanical ventilation. The software predicts a median LOS of 8 days with a risk of prolonged LOS between 33-66%. This information is shared with the team during multidisciplinary clinical rounds, and each professional optimises relevant measures to improve the outcome of this patient (i.e. respiratory therapist focus on weaning process and early mobilisation, nurses in delirium prevention and family communication, a clinical pharmacist in medication reconciliation). As a manager, it is possible to use this information to negotiate with healthcare insurance.

Conclusion

Data-driven management applied to ICU allows not only an evaluation of ICU performance but has other conveniences including implementation and monitoring of clinical protocols, optimisation of patient flow, and better planning and transition of care and discharge. ■

Conflict of interest

Dr. da Silva Ramos reports no conflicts of interest. Dr. Salluh is founder and shareholder at Epimed Solutions®, the provider of a cloud-based healthcare analytics and performance evaluation software.

Abbreviations

APACHE	Acute Physiology and Chronic Health Evaluation
EHR	Electronics Health Recorder
ICU	Intensive Care Unit
LOS	Length of Stay
NICE	Netherlands Intensive Care Evaluation
NYHA	New York Heart Association
SAPS	Simplified Acute Physiology Score
SOFA	Sequential Organ Failure Assessment
VAP	Ventilator Associate Pneumonia

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CRITICAL CARE SYMPOSIUM

Technology innovations in delivering accurate nutrition

Preventing malnutrition and enforcing nutritional guidelines

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An overview of the key obstacles for the enforcement of nutritional guidelines and innovative approaches that can be used to overcome these obstacles.

Recent studies suggest that nutritional guidelines across the majority of intensive care units (ICUs) are not being implemented (Bendavid et al. 2017; Heyland et al. 2003). Lack of knowledge, no technology to support medical staff, and general noncompliance with nutritional guidelines result in higher mortality and infection complications. This review highlights the main obstacles for the enforcement of the guidelines and recommends several innovative technology approaches to overcome these obstacles, some that should be investigated and others that should be developed.

Immediate, continuous and feeding tube placement independent of x-ray for early enteral nutrition, reduced radiation and position verification

Naso-orogastric tube is recommended (Singer et al. 2018) in the majority of the cases as it is simple to be introduced and simple to be checked by x-ray. This easy access allows enteral feeding to start relatively early and in a simple way. However, enteral feeding using gastric tube access can be associated with large gastric residual volume that may minimise the use of this route (Singer et al. 2018). An alternative option is to use the duodenal or jejunal access. But this access requires the help of endoscopy or fluoroscopy or the ability to introduce these tubes at the bedside using well-trained techniques. All these accesses may increase the risk of gastrointestinal complications and lead to a loss of time to start enteral feeding and reach the target nutrition. Even if gastric feeding is chosen, delayed position verification via x-ray, due to x-ray technician priorities, may result in delayed feeding.

Not being able to perform continuous verification makes this technique outdated because the tube may migrate to the oesophagus during the feeding process and the patients may suffer from aspiration until the nurse/caregiver repositions the tube.

> **providing higher calories target than is needed has been found to be associated with increased mortality**

New technologies using tubes with end tipped video camera, guide wires or anti-retroperistaltism have been introduced with limited success. Continuous position verification technologies should be explored. The European Society for Clinical Nutrition and Metabolism (ESPEN) guidelines (Singer et al. 2018) recommend the use of post-pyloric access in case of gastric feeding intolerance. The cost-benefit of these techniques has to be demonstrated.

Indirect Calorimeter IC/REE device for calculating the patient's actual energy expenditure, initially and potentially continuously

One of the main pitfalls is the common use of predictive equations like Harris-Benedict equations for targeting energy prescription in critical illness. The equations have been demonstrated by many (Zusman et al. 2018; Tatucu-Babet et al. 2015) to be inaccurate in more than 50% of the cases, leading to under or over nutrition. In case of too low a target, patients will be underfed and, since the process is progressively increasing the rate of administration, calorie balance will reach large negative values that are associated with increased morbidity (Dvir et al. 2005).

Providing higher calories target than is needed has been found to be associated with increased mortality (Zusman et al. 2016), resulting in recommendations by ESPEN to measure energy expenditure in a rested condition [REE] (Singer et al. 2018). New easy-to-use devices have been developed to help physicians determine energy needs at the bedside (Oshima et al. 2017). These devices measure the actual resting energy expenditure related to the specific patient condition. Using REE continuously may also allow monitoring of the changes in a patient's energy consumption and amending the feeding plan accordingly to these changes. Further studies are required to confirm these findings.

Replacing the periodic total gastric evacuation with triggered reflux event

The gastric administration of enteral feeding is associated with more vomiting and reflux than parenteral nutrition (Reignier et al. 2018). The reflux and regurgitation are a factor for increasing the risks of ventilator-associated pneumonia (VAP), and there is a constant conflict between increasing feeding rate for reaching the nutritional goal and reducing feeding rate for decreasing aspiration. Therefore, clinicians are cautious in the progression of the rate of administration of enteral feeding in order to decrease the risks of reflux and vomiting and not increase the risks of VAP. Elevating the head of the bed to a half sitting position is the only demonstrated technique that reduces the incidence of VAP. The assessment of gastric function using gastric residual volume (GRV) to test periodic aspiration is clinically used, but is not useful in monitoring enteral nutrition administration (Reignier et al. 2013). For an effective result of gastric evacuation, gastric residues should be released when reflux occurs, and not in an arbitrary and pre-determined (once every 4 hours) timeframe. The use of new feeding tubes with real-time reflux detection should be examined.

Continuously calculating nutritional losses and providing feeding compensation in real time

As stated previously, the compliance to guidelines as well as to prescription rarely achieves the nutritional goal. Numerous reasons may explain this poor adherence, but the need to give the prescribed dose of enteral feeding is not perceived as the need to administer an adequate and timely antibiotic prescription. An assessment of the patient's delivered feeding efficiency should be monitored by technology methods, not manually by the nurse. Elements that should be continuously calculated are:

1. Time lost by stopping feeding, for example, related to surgical procedure, CT or MRI tests.
2. Being able to calculate and continuously compensate for all nutritional losses.

Both compensation elements should be automatically managed by the feeding pump and should be the new standard technology used in nutritional care. This would also free nurses' time.

Enforcing methodologies and guidelines through a "strict" flow and interactive help guides in the feeding platform

As mentioned before, intensivists should have more knowledge about the consequences of over- and underfeeding. A technology device assisting the medical staff and supporting adherence to the guidelines could be an important part of the decision support system. Relevant apps should be developed to support the process.

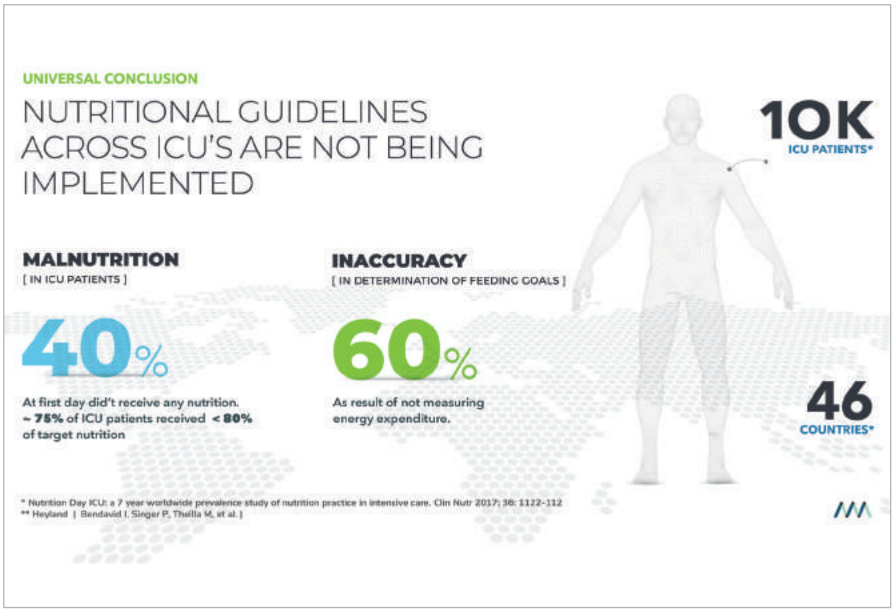
Per patient auto-calculation of 100% caloric target and the relative parenteral supplement suggestion for reaching nutritional goal

Industry products contain carbohydrates, fat, and protein in a fixed ratio. When measured, the patient's energy expenditure will never be exactly as the specific ratio of feeding formulas. In addition, evaluating datasheets of all feeding formulas in-stock to determine which one fits best to the specific patient and what are the supplement that should be added accordingly is a challenge. Classical formulas contain more carbohydrates (55%), less fat (30%) and protein (15%). If energy is targeted, as in most cases, the feed content may reach the energy target but not the protein one. Therefore, the protein deficit needs to be calculated and accounted for. If a rate of a specific product is raised to increase protein administration, according to the guidelines, a patient may be overfed in his caloric target (caloric target, per the

Reasons for malnutrition and inaccuracy of feeding

The top ten reasons why malnutrition and inaccuracy of feeding occur today include:

1. Feeding tube misplacement and delayed feeding as a result
2. Inadequacy of predictive equations to determine target energy plans
3. Routine and manual gastric residual volume evaluation to prevent reflux and aspirations
4. No feeding compensation if nutrition stopped or drained for evaluation
5. Lack of knowledge and "How to..." guidelines regarding over/under feeding and protein deficit consequences
6. No personalised feeding formula solutions
7. Massive negative energy balance post discharge and no follow-up capabilities
8. Intra-abdominal pressure not monitored
9. No nutrition audits are being performed except Nutrition Day ICU
10. Not enough tools created for metabolomics and proteomics assessment



guidelines are 30%, 50%, 70% in the first 3 days) and may have an increase in complications. Seeking 70-100% of the caloric target may be preferred (Zusman et al. 2016).

Personalised nutrition is very difficult to achieve, and only recently the industry has started to propose more balanced products to answer specific clinical requirements. Moreover, the standard of care suggests using enteral nutrition if gastric tolerance allows it. Some studies (Casaer et al. 2011) have been understood in such a way that parenteral nutrition per se may be harmful and should not be prescribed in critically ill patients or only late in the clinical course. This is despite the fact that many recent papers (Harvey et al. 2014) have shown the safety of parenteral nutrition. This reluctance to prescribe parenteral nutrition in cases of enteral nutrition failure is leading to negative caloric and nitrogen balance and may lead to impaired clinical outcomes (Dvir et al. 2005). Supplemental parenteral nutrition should be considered in any case of risk of undernutrition if enteral feeding does not reach the target after 3-7 days (Singer et al. 2018).

The optimal combination of enteral and parenteral should be personalised for the patient by technology means that can dynamically fit the formulas to the patient's measured energy needs.

reluctance to prescribe parenteral nutrition in cases of enteral nutrition failure is leading to negative caloric and nitrogen balance and may lead to impaired clinical outcomes

Artificial intelligence (AI)-powered algorithms and predictive models for managing the cumulative energy balance and the nutritional strategy

Most of the ICUs are not equipped with computerised information systems allowing calculation of daily and cumulative energy balance. This value may be missed if not evaluated daily, and the importance of keeping tight calorie balance may be disregarded. The cumulative negative energy balance may reach -10,000 kcal, thereby increasing the risks of morbidity and mortality (Dvir et al. 2005). Another substantial risk is the rehabilitation of a patient post-discharge that can be prolonged substantially (Wischmeyer and San-Millan 2015). The next generation of feeding technology will need to explore the benefits of continuous energy expenditure and use AI and prediction algorithms to handle caloric and protein deficit. Communication between ICU and post-ICU discharge units to understand nutrition regime and predictive deficit, and an app to help the patient to recover after post-hospital discharge, is needed. Using the knowledge acquired in the analysis of hospital food left uneaten by patients to evaluate the energy, protein and vitamins deficits, a similar approach could overcome the deficits in the post ICU period. Similar tools, if implemented in the critical stage, could help to ensure that a patient's nutritional plan and goals are constantly measured, monitored and achieved. Wearable data could be integrated with EHR data, including data from sensors continuously measuring physical activity and glucose level.

Continuous monitoring of intra-abdominal pressure

ESPEN (Singer et al. 2018) and WSACS- the Abdominal Compartment Society (Cheatham et al. 2009) recommend monitoring intra-abdominal pressure in patients with clinical conditions such as pancreatitis, retroperitoneal haematoma, traumatic surgery associated with severe bowel oedema, ascites, etc. (Singer et al. 2018). In the case of increased pressure, enteral feeding should be decreased, and even stopped in case of abdominal compartment syndrome. These conditions impair the administration of adequate medical nutrition therapy if parenteral nutrition is not prescribed. It would be highly desirable to have tools to continuously monitor abdominal pressure that create the necessary alerts and prediction towards Intra-Abdominal Hypertension (IAH) and Abdominal Compartment Syndrome (ACS), so that the medical staff can act accordingly.

A nutrition audit

Malnutrition assessment has not been validated in the ICU beside SGA (Detsky et al. 1984). A new malnutrition assessment based on ESPEN suggestions is now evaluated (Cederholm 2018). Because of this lack of tools, malnutrition or overfeeding is not recognised in critically ill patients, and malnutrition is not mentioned in most of the charts. Most ICUs do not perform nutrition audits except the Nutrition Day ICU (Bendavid et al. 2017), which is only done once a year. Unified cloud-based assessment platforms will enable continuous audits on a broader scale, with analytic tools that will allow clinical staff to amend their performance.

Big Data analytics on metabolomics and proteomics.

The growing fields of metabolomics and proteomics hold the potential to assess nutritional status, set appropriate adjustments of the nutrient mix, and monitor progress through the varied stages of acute illness. Recent evidence indicates that such enhanced precision may be profitably integrated into severity of illness indexes such as the sequential organ failure assessment score (SOFA score), cluster analyses, and inflammatory cytokine marker profiles to prognosticate with enhanced proficiency the outcome of life-threatening sepsis (Wischmeyer 2017). 'Big Data' analytics of relevant populations, and perhaps of the myriad points of physiologic data and laboratory variables that pertain to the individual, has only begun to show their decision support potential (Marini et al. 2019).

In summary, to improve patient safety, reduce mortality, and decrease complications and length of stay in the ICU, technology should be able to assist with the following:

1. Optimal patient feeding through a combination of real-time reflux detection and prevention.
2. Energy expenditure measurement and continuous personalised feeding formula selection.
3. Continuous monitoring of the enteral feeding delivery.
4. Calculations and continuous monitoring of supplement nutrition.
5. Automated information flow between units.

Conclusion

Medical nutrition therapy is suffering from a lack of technological support compared to respiratory or circulatory therapy. Better evaluation of energy needs, better assessment of gastrointestinal failure and of tolerance to enteral feeding, and better prevention of the complications related to this route may tremendously improve the safety and efficiency of this therapy. Technology-enabled solutions may be the answer by developing better tools, giving the physician and the nurse the ability to comply with the guidelines. Compliance with the guidelines will result in better patient safety, lower mortality, fewer complications, reduced length of stay in the ICU, and reduced overall healthcare costs. ■

Key points

- Nutritional guidelines across the majority of intensive care units (ICUs) are not being implemented
- Medical nutrition therapy is suffering from a lack of technological support compared to respiratory or circulatory therapy
- Continuous position verification technologies should be explored
- Providing higher calories above needed target has been found to be associated with increased mortality
- The use of new feeding tubes with real-time reflux detection should be examined
- An assessment of the patient's delivered feeding efficiency should be monitored by technology methods

Abbreviations

AI	Artificial intelligence
ACS	Abdominal Compartment Syndrome
EHR	Electronic Health Record
ESPEN	European Society for Clinical Nutrition and Metabolism
GRV	Gastric residual volume
IAH	Intra-Abdominal Hypertension
ICU	Intensive care units
REE	Rested energy expenditure
SOFA	Sequential organ failure assessment
VAP	Ventilator-associated pneumonia
WSACS	World Society of Abdominal Compartment Syndrome

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THE INTENSIVE CARE UNIT PAST, PRESENT AND FUTURE

WHY ICUs NEED TO INNOVATE

- To create intelligent clinical systems
- To reduce medication errors
- To improve patient safety
- To reduce incidence of hospital-acquired infections
- To improve decision-making process
- To engage patients and their families
- To improve ICU culture and teamwork

Source: Pronovost 2014

THE OLD ICU

- Small closed units
- Paternal dictatorship
- Intermittent monitoring
- More invasive monitoring
- More interventions
- Focus on protocols
- Four walls

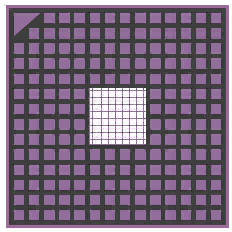
THE NEW ICU

- Larger more open ICUs
- Democratic teamwork
- Continuous monitoring
- Less invasive monitoring
- Less interventions
- Focus on checklists
- No walls

Source: Vincent and Creteur 2015

THE TELE-ICU

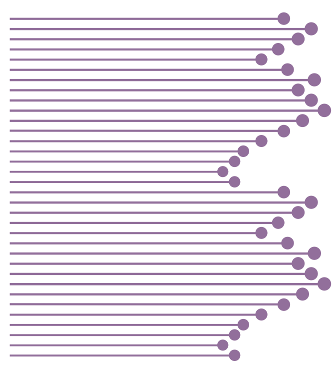
An off-site command centre which connects intensivists and critical care nurses with patients in distance ICUs through real-time audio, visual and electronic means.



Source: Kumar et al. 2013

INFECTION CONTROL THROUGH PULSED LIGHT TECHNOLOGY

- The incidence of infection in the ICU is one of the highest in the hospital.
- Approximately 20% to 28% patients in critical care acquire an infection.
- Cross-transmission from health care workers, the immediate environment, patient equipment, and poor compliance with handwashing protocols are some sources of infection in the ICU.
- One technology that could potentially be used to improve infection control in the ICU is pulsed light (PL).
- PL is a technique to decontaminate surfaces by killing microorganisms using short time pulses of an intense broad spectrum, rich in UV-C light.
- The technique used to produce flashes originates high peak power and a greater relative production of light with shorter bactericidal wavelengths.
- The technology is also known as pulsed UV light, high intensity broad-spectrum pulsed light, pulsed light and pulsed white light.



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The business of research

What is the value of physicians and their contribution to the healthcare system and economic growth? This article talks about the need to understand the real value of physicians and to encourage them to be creative and innovative as this would improve their value beyond that of daily clinical labour.

Disruptive innovations are critical for the exponential economic growth that our society enjoys (Press 2013). While anyone can innovate, physicians are particularly well-trained to create disruptive innovations. And yet, our healthcare system overwhelmingly uses physicians only as ***labour*** ignoring the real ***value*** that they can bring. Physicians are versatile, with knowledge that spans the entire breadth of the evidence development process. This includes an intimate understanding of the ***unmet needs*** (of the patient and the healthcare system), the generation of breakthrough ***mechanistic discoveries*** and demonstration of ***efficacy*** of solutions created, to the final adoption of new standards of care. The real ***value*** of physicians comes from their capacity to ***innovate.*** Denying their creativity and participation in this process ultimately hurts all. Empowering physicians to contribute beyond their day to day labour is not only good business; it is an essential endeavour for these professionals.

Introduction

Training for physicians typically takes over 10 years and is even longer (up to 15 years or more) for those training in surgical specialties. The cost to the individual is very high in the United States and abroad and frequently obligates students to obtain large loans. The social investment in training physicians also involves large investments (**rand.org/pubs/research_reports/RR324.html**). It is expected that all this training "pays off" with a **return on investment** (ROI) that can and should be measured in societal and health economic benefits. Why is medical training so long? Is it necessary? Is society getting its ROI? What is the value of the physician and her/his contribution to the health care system and economic growth? This article proposes that physicians are particularly well-trained at generating new knowledge and new innovations that will improve their value beyond that of daily clinical labour.

Measuring Value

Value in healthcare is defined as clinical outcomes [O] divided by cost [C] modified as a function by the patient experience [PE] (Moriates et al. 2015).

$$V=(O/C)\ f\ x\ PE$$

This equation can be used to determine the value that a physician brings to the healthcare system as a product of her/his labour. For the most part, physician value is measured solely in her/his capacity to improve clinical outcomes, and each patient encounter is measured (at least in the United States) as *relative value units (RVUs)*. Physicians are also key to a satisfying patient experience and in managing health economic costs, even though these two factors are rarely incorporated in measuring physician value.

> **the real value of physicians comes from their capacity to innovate**

Physician labour is essential for the sustained growth of the healthcare system, and the healthcare system itself is an essential aspect of maintaining economic growth. But physicians, as explained earlier are expensive to train and thus, it begs the question as to whether all this training (and expense) is necessary for the delivery of high-quality labour. In contrast to the training for physicians, training for other healthcare providers such as physician assistants (PA) or nurse practitioners (NP) is much shorter, typically taking less than half the time it takes to train physicians. Despite this shorter training, the technical skills developed by PA and NP enable them in many instances, to competently perform responsibilities that would otherwise be reserved for physicians. PA and NP focus on providing clinical duties such as assessing patient conditions, making diagnoses and initiating and continuing medical treatments. PA and NP, with some additional training, can intubate patients, do invasive procedures and participate in surgery. In fact, in some instances, NP and PA can perform 90% or more of the roles that a physician normally plays (Johal and Dodd 2017). These observations place us in a conundrum; the investment in physician training must generate better value than just the performance of clinical activities. Thus, it is fitting for us to determine what **value**, in addition to that of the generation of clinical revenue through daily labour, can be brought by physicians for the benefit of patients and the healthcare system.

Value and economic growth – a macro-economic perspective

The world's economy has been growing exponentially, particularly since the end of the 2nd World War. The fruits of daily labour (including

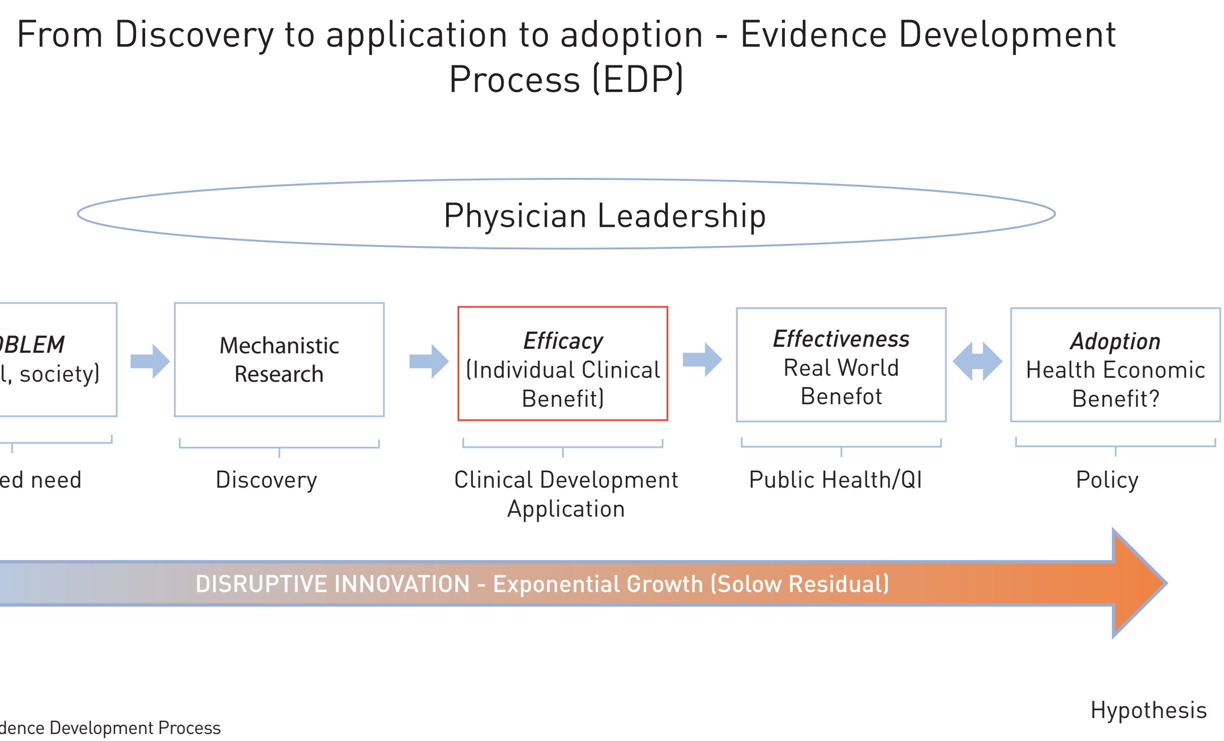

Figure 1. Evidence Development Process

physician labour) explain a sustained economic growth but fail to explain the exponential growth that we have become accustomed to. It took Robert Solow (Nobel Prize 1987) to explain that exponential growth came from the incorporation of the disruptive innovations that came from the creation of new technologies and the scientific knowledge necessary to create them (Press 2013). Disruptive innovations tend to simplify and/or improve daily living and, because of the benefits generated, are integrated into the social fabric.

Physician education involves an all-encompassing training that ranges from understanding the intricacies of the biological alterations caused by illness, the available treatments, the complexity of the healthcare system within which care of the patient is delivered, and the social environment where this takes place. It is the complexity of their training that physicians are particularly well poised to create disruptive innovations and ultimately to incorporate these into daily clinical practice.

Incorporating disruptive innovation into an evidence development process

To better understand the roles that physicians can and should play for the creation and successful implementation of disruptive innovation, it is important to understand the process by which this takes place. This is called the evidence development process (EDP), and it involves a series of steps starting with the recognition of unmet needs for the patient and the healthcare system to the successful adoption of effective solutions into healthcare practices (**Figure 1**).

Understanding unmet needs; where an unmet need is defined as a poor health outcome that increases healthcare costs and for which an effective solution has not been successfully implemented.

Discovery phase involves the identification of the mechanisms that lead to illness and the development of hypothetical solutions that are first tested in a preclinical setting.

Clinical development phase tests solutions with the demonstration of efficacy on a measurable clinical outcome at an individual level (e.g. mortality).

Traditionally, the demonstration of efficacy was enough for advocating widespread use of a solution independent of cost or any barriers preventing its adoption into clinical practice. It has become apparent thus, that two other steps in the evidence development process must be considered.

Demonstration of effectiveness comprises a phase where an evaluation of the societal value of the solution is evaluated. Health economic evaluation and analysis of cost-effectiveness are central to this phase.

Adoption; because the success of any solution created, including its demonstration of true value depends on its incorporation into daily clinical practice. Quality improvement initiatives, the generation of guidelines and the implementation of policies are all tools designed to generate widespread utilisation of technology.

Medical school uniquely prepares future physicians to engage in every aspect of the evidence development process with potential roles that reach far beyond their clinical training. Physicians, for example, intimately understand the patient unmet needs. Physicians are the main actors in their own practice and spontaneously engage in quality improvement projects to adopt new solutions to their clinical practice. Through their leadership, physicians have the capacity to engage in the creation of mechanistic discoveries, which are the foundation for the creation of disruptive innovations. Physicians happily engage in clinical development with demonstrations of efficacy as well as participating in effectiveness trials.

Encouraging physicians to participate in disruptive innovation

It is in the desire of economic growth and the betterment of the healthcare system that an effort needs to be made to create an environment where physicians are encouraged to create disruptive innovations. Society needs highly trained and skilled workers to deliver on their full potential, far beyond labour. Who knows what new disruptive innovations are lurking in the minds of physicians, just waiting for the right opportunity?

Creating a working environment that facilitates disruptive innovation

Creativity is at the core of disruptive innovations (Pink 2009). Creativity is that moment when a new radical idea, exciting in its simplicity and the harmony of its cleanliness, erupts from the mind of an individual to provide a new solution, a new paradigm that radically improves and changes our world. A significant amount of knowledge as to the environment required to stimulate creativity comes from the knowledge generated through Behavioural Economics, a discipline that incorporates psychology and neurocognitive sciences, helping us understand how day to day decisions (including economic decisions) are made. Three key elements are necessary:

1. **Time away from daily labour.** Essential in the process of creativity is allowing a "time-space" that permits an individual (or a team) to think creatively. It is customary that creative thinking is done outside of the activities of daily labour, but this needs to change. **Creative time** is an integral part of physician daily activities and needs to be protected. After all, creative thinking will result in increased **value** beyond that of clinical activities (Huettel 2014).
2. **Lack of accountability.** Measuring labour is easy; measuring the benefit of creative time is difficult. Difficulties in measuring productivity that comes from creative time is a frequent argument to state that companies can "just not afford" to invest in it. The counter argument is quite powerful, however. If disruptive innovation is what brings exponential growth, we simply need to give physicians time for creative thinking lest we miss on any disruptive innovations created. Interestingly, several companies have tested the concept of carving time for creativity. Google, for example, encourages creative time. 3M also does this. Evidence demonstrates that time for creativity has generated a large amount of growth for these companies.

> "the misuse of physicians as clinical labour robs our society of the benefits that they could bring to the patient, the healthcare system and to social-economic growth"

3. **Existential motivation.** Traditional economic theory (also called rational economic models) dismisses the importance of **altruistic existential motivations** that lead to a betterment of society with assumptions that these (existential motivations) bring no inherent **value**. Thus, the motivation of physicians to help and assist other human beings in achieving health is frequently ignored or even actively disincentivised within complex healthcare systems. Behavioural Economic Theory, however, demonstrates that, once basic needs are met, altruistic existential motivations are central to promoting creativity in human beings. Promoting, protecting and incorporating altruistic existential motivations is thus the essential "fire" that exists at the centre of the creative engine that leads to disruptive innovations.

Conclusion

Exponential economic growth comes from the incorporation of disruptive innovations into applications that generate value by simplifying and/or improving our daily living while generally reducing cost. Central to disruptive innovations is an environment that promotes creativity. Creativity demands time away from daily labour and a free environment where altruistic existential motivations provide an environment conducive to the generation of new (and often radical) paradigms. Physicians are a group of highly trained individuals, which have as their central motivation, the betterment of their patients. Based on this altruistic existential motivation along with long years of training, the physician is particularly adept at participating and providing the necessary leadership during the evidence development process that leads to the generation of disruptive innovations. The misuse of physicians exclusively as "clinical labour" robs our society of the benefits that they could bring to the patient, the healthcare system and to social-economic growth. ■

Key points

- Disruptive innovations are critical for the exponential economic growth that our society enjoys
- For the most part, physician value is measured solely in her/his capacity to improve clinical outcomes
- Physicians are particularly well poised to create disruptive innovations and ultimately to incorporate these into daily clinical practice
- Through their leadership physicians have the capacity to engage in the creation of mechanistic discoveries, which are the foundation for the creation of disruptive innovations.

Abbreviations

EDP	Evidence Development Process
NP	Nurse Practitioners
PA	Physician Assistants
ROI	Return on Investment
RUV	Relative Value Units

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MANAGEMENT & PRACTICE
SPECIAL SUPPLEMENT
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Pain Management in the ICU

Report of a Live Debate conducted on November 13th, 2018
Organised by the European Society of Intensive Care Medicine
Brussels, Belgium

Moderator
Jean-Louis Vincent
Brussels, Belgium

Speakers
Gerald Chanques
Montpellier, France

Xavier Capdevila
Montpellier, France

Supplement in collaboration with Aspen

How to manage sedation analgesia for patient-centred care in the ICU

Managing sedation analgesia for patient-centred care in the ICU

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Pain management and sedation are closely linked in the intensive care unit. In the past, clinicians were using sedative agents too liberally, often with benzodiazepines. And several issues were observed in the ICU, including the problems of delirium, weakness and prolonged ICU course.

In recent years, attempts have been made to decrease the intensity of sedation whenever possible and to put analgesia before sedation because pain control is of paramount importance. Once pain is controlled through effective analgesia, the patient can then be put on minimal or even no sedation according to the clinical team. Everybody in the critical care team must be involved and must be concerned about this.

The following is an overview of a discussion on how to manage sedation analgesia for patient-centred care in the ICU. The primary goal of this discussion is to talk about the important connection between sedation and analgesia and to find out how a balance can be achieved while ensuring deliverability of patient-centred care and humanising the patient experience in the ICU. The discussion will include input from Prof. Gerald Chanques, Intensive Care Unit, Saint Eloi University Hospital, Montpellier, France and Prof. Xavier Capdevila, Lapeyronie University Hospital, Montpellier, France. ■

Sedation and Analgesia

How to manage sedation analgesia for patient-centred care in the ICU

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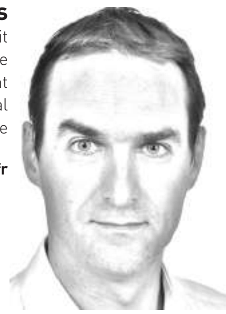

In the concept of patient-centered care, sedation and analgesia have high importance. Intensive care is sometimes invasive and very painful. Patients in the ICU are seriously ill and often suffer from anxiety, agitation, and pain. There is sometimes a need to use deep and prolonged sedation, but that can cause other issues which need to be addressed.

When deep sedation is used, the patient becomes immobile. This can lead to ICU acquired weakness as well as delirium due to the immobilisation of the brain function. Deep and prolonged sedation is associated with worse outcomes, longer duration of mechanical ventilation (MV), longer length of stay (LOS) in the ICU and the hospital, and higher rates of complications such as infections and sometimes even death. It is thus very important to limit the use of deep and prolonged sedation and to understand the use of sedation and pain targets.

Thanks to adequate control of the pain, the level of sedation can be reduced. On the other hand, if the pain is not controlled properly, there is a risk of increased agitation. It is thus very important to use valid and robust tools to assess for agitation such as the Richmond Agitation Sedation Scale (RASS). The RASS score is used to measure the agitation or sedation level and to describe a patient's level of alertness or agitation. It is mostly used in mechanically ventilated patients to avoid over and under-sedation, but it can also be used after in non-intubated patients to assess agitation and delirium as well as side effects of opioids and psychoactive drugs (coma) throughout the ICU stay.

The RASS score is the first step when administering the Confusion Assessment Method in the ICU (CAM-ICU), an effective tool to detect delirium in ICU patients. Clinicians in the ICU should be targeting a RASS score of zero or +1. Anything over +1 can become dangerous for the patient. The RASS target shall be discussed and agreed by the critical care team including nurses and physicians.

Along with definining and determing sedation targets, it is also important for the critical care team to focus on pain control. Working with a defined target and a continuous assessment of pain leads to more success in decreasing pain prevalence, pain intensity, and agitation. It enables proper and effective use of analgesics. Then sedatives can be reduced leading to a decrease in the duration of mechanical ventilation, ICU LOS, complications, and infections.

“the important thing is to measure the level of pain; that's the only way pain can be managed, and sedation can be levelled out”

Overall, there is significant evidence showing that pain measurement is associated with better outcomes. Better pain management leads to a possible decrease in the stress response. This has been shown by many sequential controlled trials and large multicentre database studies (**Figure 1**).

Analgosedation

There are two types of analgosedation. One is “analgesia-based sedation” which refers to the use of an analgesic instead of a sedative to reach the sedative goal. The other is “analgesia-first sedation” which refers to the use of an analgesic before a sedative to reach the sedative goal (**Figure 2**).

There is no defined recommendation on

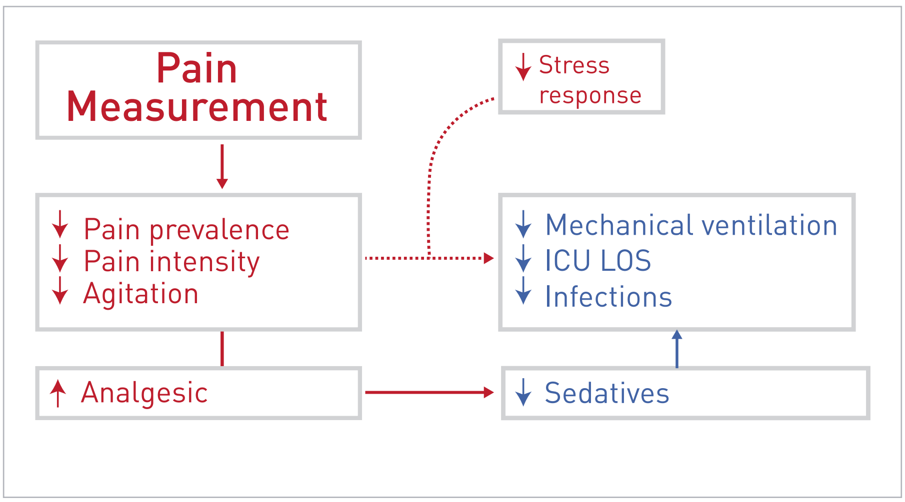

Figure 1. Impact of pain management in the ICU.

Source: Chanques et al. 2006; Robinson et al. 2008; Skrobik et al. 2010; Faust et al. 2016.

the use of opioids but generally speaking, if there is a patient who is agitated and suffering from pain, an opioid should be used instead of a sedative. By doing so, the need to use sedation will be reduced.

Measuring and managing pain

Different strategies can be used to measure pain depending on the patients. A self-reporting pain scale is generally used in patients who are able to rate their pain using a numeric rating scale (NRS) from 0 (no pain) to 10 (maximum pain) (Chanques et al. 2010). The Behavioural Pain Scales (BPS) and the Critical Pain Observational Tool (CPOT) are used on sedated patients or delirious who are unable to self-report pain scales. These two pain tools are the most validated pain tools in the world.

A study was published a few years ago that compared the use of CPOT and BPS in Critical Care (Chanques et al. 2014). Both of these tools showed the same properties. It is easy to determine whether a non-communicant patient is in pain based on their behaviour.

When the patients suffer from paralysis or are deeply sedated, the most effective way to measure pain is through electrophysiological tools, such as the Analgesia Nociception Index (ANI). This tool analyses heart rate variability. A scale of 0 to 100 is used where 100 is a perfect restful state without pain. When the ANI decreases around the 40s, it is very likely that the patient is in pain.

Pain is experienced by both surgical and medical patients. Studies show that both groups demonstrate pain prevalence and pain intensity during their ICU stay (Kress et al. 2000; Chanques et al. 2017). Surgical patients commonly report pain at the site of the surgery while medical patients often complain of back pain and pain in the limbs. Pain is thus a common occurrence in the ICU and needs to be properly managed so that sedation can be levelled out.

There are some patients in the ICU that still require sedation including those with severe ARDS as well as patients with severe brain injury. However, with proper management, treatment strategies, and the effective use of modern drugs, sedation levels can be minimised in most patients.

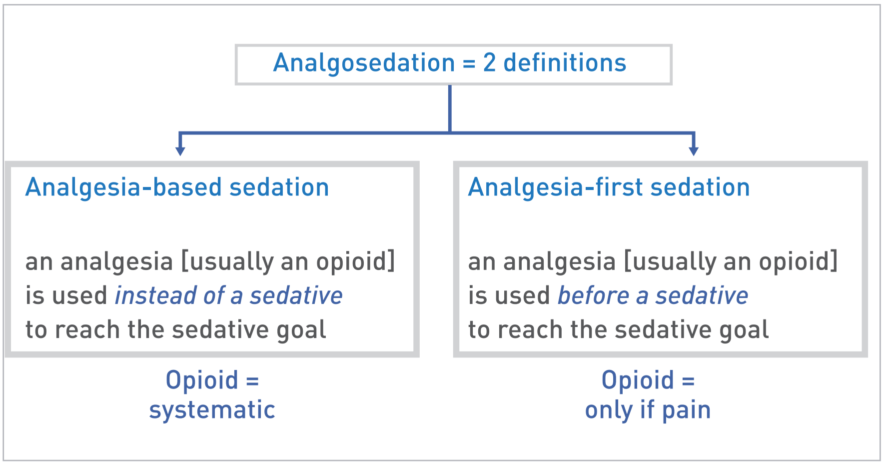

Figure 2. Types of Analgosedation.

Source: Devlln et al. 2018

> **the use of multimodal analgesia should be promoted so that opioids are not overused and the pain management effort is more effective**

Which drugs to use?

A paper published in Critical Care (Klaus et al. 2018) showed a catastrophic impact of remifentanil supply shortage on mechanical ventilation. Findings showed a very high duration of MV in patients who experienced the period of remifentanil shortage and were forced to use another drug instead (**Figure 3**). This indicates the impact that the chosen drug can have on a patient's condition and outcome.

Guidelines recommend that benzodiazepines should probably be avoided for sedation. Propofol and dexmedetomidine should be given preference. For analgesics, morphine should be avoided whenever possible as there is a risk of overdosing in patients with acute renal failure. The use of multimodal analgesia should probably be promoted so that opioids are not overused and the overall pain management effort is more effective (Devlin et al. 2018).

Using the bundled approach (ABCDEF)

The ABCDEF bundled approach to pain management is an evidence-based guide for clinicians in the ICU to enable them to optimise patient recovery and outcomes (Pandharipande et al. 2010). The ABCDEF bundle includes:

Assess, Prevent, and Manage Pain;
Both Spontaneous Awakening Trials (SAT) and Spontaneous Breathing Trials (SBT);
Choice of analgesia and sedation drugs;
Delirium: Assess, prevent, and manage;
Early mobility and exercise;
Family engagement and empowerment.

Some of the key benefits of the ABCDEF bundle include:

- Empowerment of clinicians and families
- Well-rounded patient care
- Optimal resource utilisation

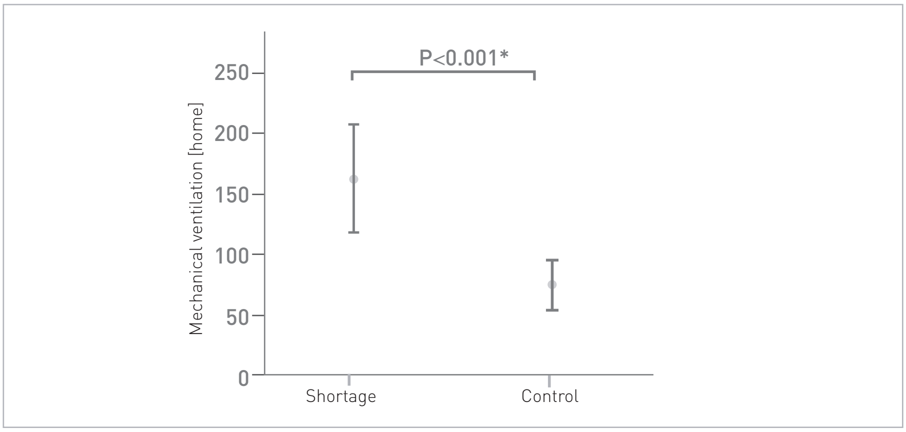

Figure 3. Impact of remfentanil shortage. Primary outcome parameter. Dot and whiskers indicate mean with 95% confidence interval. Asterisk indicates significance.
Source: Klaus et al. 2018

- Better pain control
- Improved physical recovery
- Improved mental health

The concept of eCASH

The eCASH concept is based on the premise of delivering patient-centred care without excessive sedation. The strategy can be regarded as an evolution of the Pain, Agitation and Delirium guidelines, hence the mnemonic eCASH – **Early Comfort** using **Analgesia** with a minimum of **Sedatives** and a maximum of **Humanity**. Providing effective pain relief to patients in the ICU is the first priority when implementing eCASH. This pain relief can be achieved through the use of multimodal analgesia. Sedation should be secondary to pain relief and whenever possible, should be based on drugs that can be titrated to prespecified sedation targets (Vincent et al. 2016). ■

Key Points

- Deep sedation can lead to ICU acquired weakness as well as delirium due to the immobilisation of the brain function
- Prolonged sedation is also associated with worse outcomes, longer duration of mechanical ventilation (MV), longer length of stay (LOS) and higher rates of complications
- The use of analgosedation can help manage pain as well as reduce the need for sedation
- Fixing sedation targets and measuring pain is important for more effective patient management
- The Richmond Agitation Sedation Scale (RASS) is used to measure the agitation or sedation level and to describe a patient's level of alertness or agitation
- The ABCDEF bundled approach is the key to effective pain management and improved patient outcomes

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Pain management through multimodal analgesia in the ICU

Overview and focus on regional anaesthesia

Opioid dependency is a serious problem in the ICU. Opioids are effective at providing pain relief because they reduce the perception of the pain signal. At the same time, opioids are associated with respiratory depression, cough suppression, confusion, and drowsiness. In addition, there is a risk of abuse and dependence with opioid drugs.

Despite these risks and associated side-effects, the number of opioid prescriptions continues to increase. Different formulations of opioids are now available, further increasing the risk of abuse and overdose.

The number of deaths involving opioids is consistently increasing (National Center for Health Statistics). The use of opioids in the ICU and in the post-operative period is very common. Most patients receive opioids even after simple surgeries. Opioid-related deaths are a problem in the U.S. and the opioid epidemic continues to plague the rest of the world as well (**Figure 1**).

Pain management is not just a strategy to improve patient comfort and patient outcomes, but it is also a means to reduce sedation. However, the type of drugs that are used to manage pain can make a big difference in the level of pain control that is achieved and the quality of patient outcomes that result from the usage of those drugs.

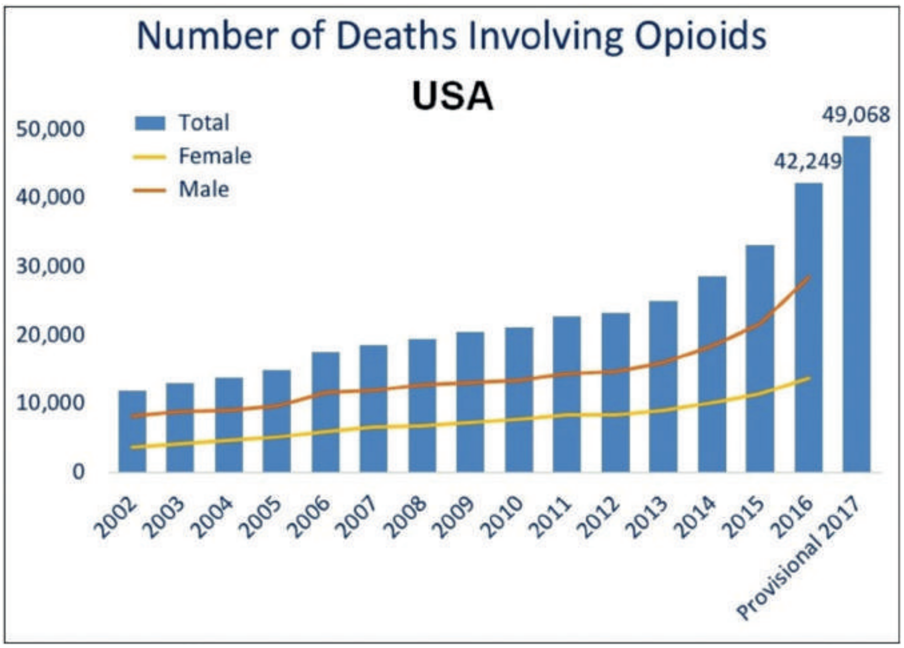

Figure 1. Opioid deaths in the US.
Source: National Center for Health Statistics, CDC Wonder

It is important to highlight some key issues that are related to drugs which are used to manage pain. For example, many patients receive opioids (such as morphine, fentanyl, sufentanil, remifentanil) in the post-operative period, even after a simple and classic surgery like total knee arthroplasty. In such patients, the use of a non-opioid drug could be a better option and could protect these patients from opioid-related side-effects.

The practice of analgosedation in the ICU, i.e. using analgesia first instead of sedation is becoming increasingly common. Results of a study published three years ago demonstrated that patients who received more fentanyl and fewer benzodiazepines, and much more dexmedetomidine, but less propofol required lower sedation (Faust et al. 2016). Thus, moving from using total sedation and some analgesics to using more analgesics accompanied by sedatives has proven to be a more effective strategy for reducing sedation. This significant change in the ICU environment is showing results in the form of reduced MV duration and reduced ICU LOS (Faust et al. 2016).

The new paradigm of pain management

It is time to focus on a new paradigm of pain management and to understand the impact of regional anaesthesia and the benefits of multimodal analgesia. Multimodal analgesia refers to a pain management strategy that combines different analgesics with different mechanisms such as opioids, NSAIDs, local

	Opioid only (n - 302)	Multimodal analgesia (n - 172)	*P*
Sedation assessment, n(%)	247 (82)	106 (62)	<.01
Sedation scale, n (%)			.11
Ramsay	98 (40)	57 (54)	
SAS	33 (13)	12 (11)	
RASS	53 (21)	17 (16)	
Other	63 (26)	20 (19)	
Deep sedation state*, n/N (%)	133/183 (73)	39/86 (45)	<.01
Sedative use, n (%)	267 (88)	103 (60)	<.01
Type of sedutive, n (%)			<.01
Propofol	41 (15)	32 (31)	
Midazolam	219 (82)	70 (68)	
Other	7 (3)	1 (1)	
Daily Dose of sedative, median (IQR)			
Propofol (mg kg-¹ 24 h-¹)	28 (10-42)	23 (7-40)	.47
Midazolam (mg kg-¹ 24 h-¹)	1.2 (0.8-2.1)	0.6 (0.4-1.3)	<.01
High dosages of sedatives ᵇ, n/N (%)	19/260 (7)	3/100 (3)	.13

Figure 2. Sedation management and sedation assessment in ICU patients according to modality of analgesia

Source: Payen et al. 2013. Image Copyright © 2013 Elsevier Inc. Reprinted with permission from Elsevier.

anaesthetics, etc. The combined use of these analgesics produces synergistic analgesia and enables clinicians to use lower total doses. This, in turn, reduces the number of side effects. Multimodal analgesia is a more rational approach to pain management and can effectively reduce postoperative pain as well as the use of opioids and sedatives (Jin and Chung 2001).

The new guidelines published in Critical Care Medicine (Devlin et al. 2018) make three primary recommendations for managing pain and balancing sedation:

1. Using multimodal analgesia in the ICU. This means that clinicians should use some opiates, and should also use adjunctive therapies such as acetaminophen or nefopam whenever possible. This can help in reducing the number of opioids.
2. Using an opiate before the sedatives, and trying to use the lowest effective dose to limit the risk of opioid addiction and dependency in patients.
3. Using light sedation in contrast to deep sedation in the critically ill, mechanically ventilated patients.

use of multimodal analgesia with non-opioid drugs and regional anaesthesia can have a positive impact on the long-term mortality in patients

Findings from a French study (Payen et al. 2013) demonstrated that the use of multimodal analgesia in mechanically ventilated critically ill patients could decrease sedation and delirium and at the same time, avoid the use of opioids and opioid-related side effects (**Figure 2**). Patients given multimodal analgesia were also more likely to have fewer organ failures and received fewer hypnotics compared to patients who received opioids alone. It is thus evident that the concept of multimodal analgesia must be promoted in the ICU.

Dexmedetomidine, an alpha 2 antagonist and a potent anxiolytic, is another important drug that should be considered within the multimodal approach to pain management (MIDEX and PRODEX) and has shown that it can limit the MV duration compared to Midazolam (Jakob et al. 2012). However, more studies are needed to prove its benefits versus its adverse events.

Regional anaesthesia: impact on patient outcomes

A study published in JAMA Surgery a few years ago demonstrated that in patients with abdominal aortic aneurysm repair, the overall mortality was different between the group using epidural analgesia and the group using classical analgosedation. Results showed that some of the complications were decreased in the epidural group. The addition of epidural analgesia to general anaesthesia was also associated with long-term survival benefit due to the reduced rates of post-operative complications (Bardia et al. 2016).

Clinical evidence shows that epidural analgesia has some effects on mortality, complications, and morbidity after surgery. The use of epidural analgesia can limit the infusion of opiates and opioid-related complications in ICU patients. The complex and mixed use of sedative agents, associated to analgesia with opiates and the use of regional anaesthesia can help improve patient rehabilitation in the postoperative period. Regional anaesthesia is associated with a composite morbidity score of pneumonia, prolonged ventilator dependency, and postoperative unplanned intubation (Popping et al. 2014).

A study published in Anesthesia and Analgesia (Malekpour et al. 2017) compared no-procedure management, i.e. sedation and opiates versus procedural management with a paravertebral blockade in patients with rib fractures. Results clearly showed differences in mortality and complications. In the patients who received regional analgesia effectively, the rehabilitation was optimised and the use of morphine decreased.

It is thus safe to conclude that the use of multimodal analgesia with non-opioid drugs and regional anaesthesia can have a positive impact on the long-term mortality in patients after big surgeries, as well as optimised pain management and decreased organ dysfunction in these patients. ■

Key Points

- While opioids are very effective at treating pain, they can also be addictive
- New guidelines make three recommendations for managing pain and balancing sedation: using multimodal analgesia; using an opiate before the sedatives; and using light sedation in contrast to deep sedation in the critically ill, mechanically ventilated patients
- Multimodal analgesia refers to a pain management strategy that combines different analgesics with different mechanisms such as opioids, NSAIDs, and local anaesthetics
- The use of regional anaesthesia can have a positive impact on the long-term mortality as well as optimised pain management in patients after big surgeries
- The addition of epidural analgesia to general anaesthesia was also associated with long-term survival benefit due to the reduced rates of post-operative complications

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Concluding Remarks

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Reducing sedation and managing and treating pain are important objectives for clinicians. The primary goal should always be to promote the comfort of the patient and to minimise pain through the proper use of multimodal analgesia. The use of opioid drugs should be avoided unless absolutely necessary; and focus should be placed on achieving pain control through combined pain management strategies. The use of the ABCDEF bundled approach, the implementation of the eCASH Concept and the effective use of epidural analgesia are all strategies that can be used to balance sedation and analgesia in the ICU.

The four take-home messages from this debate are:

- Minimise deep and prolonged sedation
- Promote comfort and analgesia
- Minimise opioids
- Promote multimodal analgesia

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The role of disruptive and hybrid technologies in acute care

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Section Editor Theodorus Kyprianou introduces the "Informatics and Technology" section of ICU Management & Practice.

It is with great pleasure that I introduce today "Informatics and Technology," an open forum to discuss the role of new, disruptive, hybrid technologies in acute, emergency and intensive care medicine. This brand-new section reflects the vivid interest of the journal's Editor-in-Chief, in exploring their role in and impact on our everyday clinical practice, teaching and research endeavours, as well as on our managerial and clinical governance decision making processes.

The whole medical specialties and health-care professions spectrum but especially acute care specialties in Europe and the world, face unequivocal challenges and at the same time enjoy unprecedented opportunities amidst the rapidly changing and transformative environment of the 4th industrial revolution (4IR): Cost of Hospital care continues to increase and in 2016, accounted for 32.4 % of the USA's annual $3.3 trillion health expenditures [of those 38 billion uncompensated!] (CDC.gov; AHA.org) and that of Intensive Care services nearly doubled between 2000 and 2010 ($56 to $108 billion) and as proportion of the Gross Domestic Product increased by 32.1% [0.54% to 0.72% of GDP] (Halpern et al. 2016). Investments in Data, Big Data, analytics and flexible combinations of Internet based tools (what many call as "Internet of things – Internet of everything!") in healthcare, is projected to grow faster than in manufacturing, financial services, or media, with a compound annual growth rate (CAGR) of 36% through 2025 (Kent 2018). Technology applications that cross the boundaries between physical, digital and biological fields (scientific fields disruption). Game changing dynamics that create opportunities for innovation from small and medium size enterprises and spin-offs and boost individual entrepreneurship outside traditional high-tech regions and countries. Globalisation of personal data and IPRs protection concepts. The following issues, briefly introduced herein set the focus of the new journal section:

> **"an open forum to discuss the role of new, disruptive, hybrid technologies in acute, emergency and intensive care medicine"**

(a) Technology enabled, tele-monitoring and remote coordination of healthcare services to acutely and critically ill patients have essentially dissolved the walls fencing traditional acute care areas in hospitals (A&E, ICUs, CCUs, HDUs, post-operative units etc). As a result, there is an ever-increasing demand for numerous forms of acute care -hospital & community based- services, hence for specialised personnel and new, complex clinical routines. At the same time, this highly stressful and complex ICU/HDU routine, demanding career and socially poor life-style, is leading to chronic fatigue/burnout, rendering acute medicine specialties/healthcare professions unattractive to the young generation.

(b) Caring for the acutely/critically ill becomes increasingly complex and encompasses multiple intra-hospital transfers and interactions with numerous medical specialties and healthcare professionals. Hence, it involves 24/7 clinical, administrative and managerial documentation and the use of new biosensors, dynamic imaging methods and ever-increasing organ-specific monitoring systems. It is worth mentioning that there has been an exponential increase of FDA licenses to new medical grade devices and software the last few years [in contrast with the stagnation -in relative terms- in developing new new drugs] (**FDA.gov**). As a result, a wealth of multiform, structured/unstructured data, clinical biosignals -numeric and waveform- and images is produced (**Figure 1**), nowadays stored and processed in expense of high storage capacity (ten times more for ICU patients than OR) but decremental cost (Burykin et al. 2011; Blum et al. 2015). However, intuitive visualisation and diagnostic/prognostic use of these data has been increasingly problematic, lacking clinical focus and mostly limited to unguided, experiential, pattern recognition and coding (Evans 2016; Islam et al. 2018; Clifton et al. 2015) (**Figure 2**).

(c) What does really lie behind these sexy names that have invaded our scientific

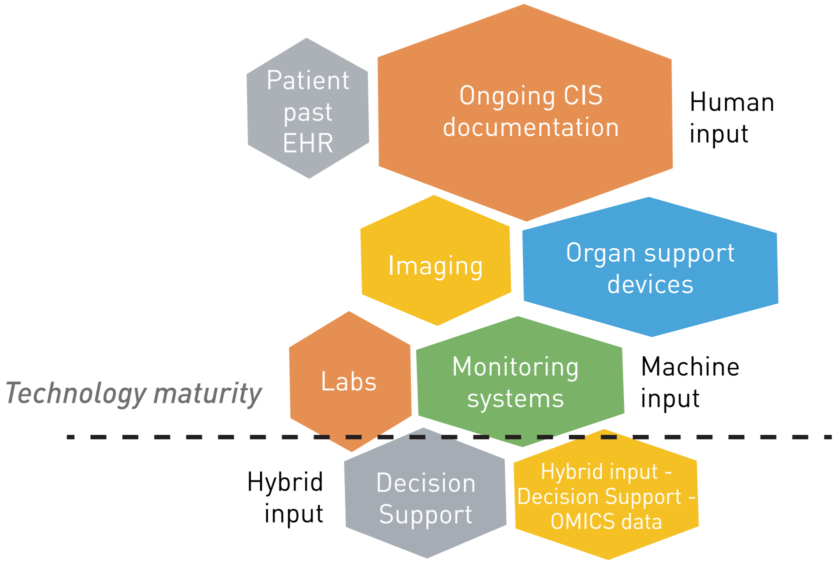

Figure 1. Data input to Clinical Information

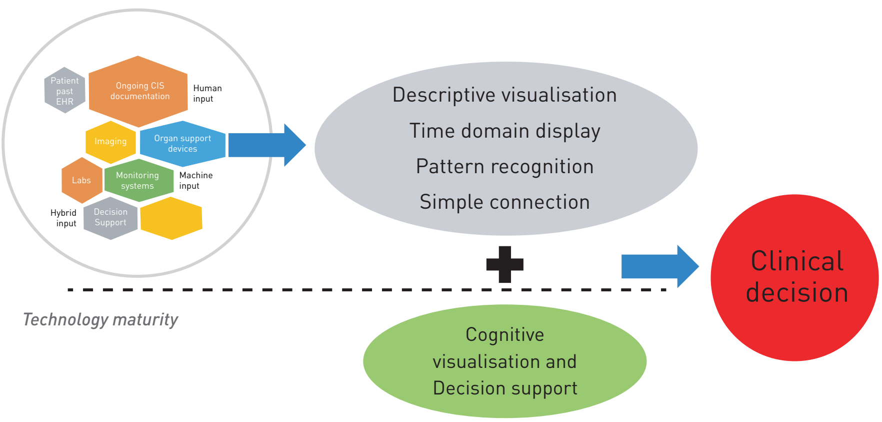

Figure 2. Data output and decision making with Clinical Information Systems

dictionary the last few years with increasing permeability? Big Data! Analytics! Artificial Intelligence! Deep Learning! Neural Networks! Python! etc (Wu et al. 2017). What is their potential role in modern healthcare systems, drug development and testing, medical devices production & software market? Are they just mathematical algorithms/IT tools behind a "black box" product built in a laptop or handheld computer for clinical decision support, or a new world of knowledge that physicians and healthcare professionals should embrace and become familiar with, if not "expert" users! What about the "virtual physician"? Do headlines in popular medicine columns like "Artificial Intelligence IBM's Watson is better at diagnosing cancer than human doctors" indicate a real threat to our profession or will this be our eternal imaginary challenge to keep us on our toes while improving performance?

(d) Failure of the vast majority of randomised studies the last decades -the gold standard of clinical experimentation- to bring positive results in complex critical illness i.e. sepsis (Ridgeon et al. 2016) and traumatic brain injury (Asehnoune et al. 2017), have increased the demand for conceptually personalised approaches to diagnosis and treatment. "Precision Medicine (National Research Council 2011)," reflecting the need to deliver the right treatment at the right time to the right group of persons (encompassing similar characteristics) in the right circumstances! High hopes have been ignited by the fact that the IR4 is bringing to the market -even not yet extensively to the bedside- a whole new spectrum of -omics tools producing more and more "personalised" data with a fraction of the cost used to entail (Martin-Sanchez et al. 2015). This is matched with the booming use of ML and AI in Healthcare and the rapid development of "middleware" toolkits which allow biomedical researchers and clinicians to easily access and use predictive analytics tools.

(e) Since the frightening figures of healthcare errors and associated mortality/morbidity have been unveiled during the last decades [3rd leading cause of death and disability in the US] (Makary et al. 2017), new processes and methods to strengthen patient safety and to prevent healthcare associated errors are becoming issues of utmost priority. Digitisation of patient records and the booming penetration of Hospital or Specialty oriented Clinical Information Systems/Patient Data management systems could help towards this direction (Prgomet et al. 2017). However, only a single-digit fraction of USA Hospitals enrolled into the first phase of digitisation of healthcare records has entered the 2nd (**HealthIT.gov**). It is becoming clear that, knowledge/experience transfer from similar successful implementations like the aviation industry as well as more sophistication and introduction of Artificial Intelligence (AI) tools is the way forward. This pathway, in turn, faces serious conceptual, ethical and financial challenges (Clifton et al. 2015).

(f) Specialty-oriented clinical information systems customised to the needs of acute medical specialties and areas like A&E, ICUs, HDUs, CCUs, ORs etc. are now increasingly being replaced (or attempted to be replaced) by hospital information systems in the name and context of better integration, interoperability and cost control. Serious controversy has been developed since this trend has been enforced by hospital authorities with -frequently- very little discussion and poor customisation process. On the other hand, the arguments for an all-encompassing HIS are solid and intuitive. It is, however, widely accepted in the scientific community, though inadequately investigated, that the usability of those systems is at least sub-optimal (Dincklage et al. 2017). The community of patients, clinicians, administrators, researchers, academics, healthcare industry management shall thus find its way to meet a number of relevant challenges: i) development of acute care specialties ontology involving clinical as well as physiology/pathophysiology and organ support terminology; ii) adoption of common standards that will allow seamless integration of data from medical diagnostic, monitoring and organ support devices; iii) consensus on minimum requirements of clinical information systems functionality; iv) development of new visualisation techniques which will improve clinical decision making with documented results. It is encouraging that quality certification standards are moving towards this direction adopting the "dialogue principles" defined in the ISO standard 9241-110 as suitability for the task, suitability for learning, suitability for individualisation, conformity with user expectations, self-descriptiveness, controllability and error tolerance (**sis.se/api/document/preview/907276/**).

(g) Clinical education at all levels and for all students and healthcare personnel involved in acute, emergency and intensive care (physicians, nurses, physiotherapists, clinical dieticians, clinical pharmacists, clinical psychologists etc) has been always a high priority, given the complexity of the working environment and the skills required. Nowadays it enters a new era, as time and physical presence boundaries are dissolving, expertise gaps can be bridged, data access is becoming increasingly easy and modelling of diseases/procedures is revolutionised with the use of internet, telemedicine and virtual/augmented reality technologies. Globalisation and free movement of healthcare personnel as well as high demand for competence standardisation and specialisation has rendered international curricula and the role of scientific societies very important, as self-paced eLearning is booming worldwide (**docebo.com**).

(h) Inter-disciplinary -as opposed to multidisciplinary- approach to challenges, came through 4IR and shall stay with us! Acute, Emergency and Intensive Care is no exception but rather a wonderful example to apply and build on this concept. It is time to think big and bring help in this particularly challenging endeavour where human lives are at stake. On top of the traditional members of the ICU team, basic lifesciences scientists, psychologists, engineers, architects and bioinformaticians should find their place to our routines. Working environment in clinical areas, especially IT HIS/EHR infrastructure is expected to facilitate and provide structured, yet flexible approaches to this interdisciplinary interaction in order to maximise its impact on patient outcomes, our ultimate target!

Welcome aboard! ■

Key points

- Acute care specialties in Europe and the world face unequivocal challenges and at the same time enjoy unprecedented opportunities amidst the rapidly changing and transformative environment of the 4th industrial revolution
- There is an ever-increasing demand for numerous forms of acute care hospital & community based- services
- Caring for the acutely/critically ill becomes increasingly complex and encompasses multiple intra-hospital transfers and interactions with numerous medical specialties and healthcare professionals
- The demand for conceptually personalised approaches to diagnosis and treatment continues to increase
- New processes and methods to strengthen patient safety and to prevent healthcare associated errors are becoming issues of utmost priority

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Extravascular lung water as a target for intensive care

The paper highlights the present clinical rationale for extravascular lung water measurement as a key to personalisation of haemodynamic therapy.

Introduction

Extravascular lung water (EVLW) remains a useful guide for monitoring pulmonary oedema (PO) and vascular permeability in sepsis, acute respiratory distress syndrome (ARDS), and heart failure (Jozwiak et al. 2015; Michard 2018). Increased EVLW is associated with a high mortality and corresponds to the severity of ARDS (Sakka et al. 2002; Jozwiak et al. 2013). In addition, EVLW has a prognostic potential in shock, cardiothoracic surgery, multiple trauma, neurocritical care, and other conditions (Jozwiak et al. 2015; Tagami et al. 2018; Brown et al. 2009).

Despite a number of limitations, EVLW measured with transpulmonary thermodilution (TPTD) has documented high correlation with *postmortem gravimetry* and other methods in both experimental and clinical settings (Michard 2018; Tagami et al. 2010; Sakka et al. 2000; Kuzkov et al. 2007; Kirov et al. 2004). Therefore, in the twenty-first century, TPTD is still referred to as a "clinical gold standard" and a reference technique for EVLW measurement despite strong competition from non-invasive methods, including lung ultrasound, bioimpedance tomography and computed tomography (Michard 2018; Anile et al. 2017; Patroniti et al. 2005).

Importantly, EVLW can serve as a guide for personalisation of haemodynamic management. Thus, critical illness resulting in shock and tissue hypoperfusion refractory to fluid resuscitation can be considered as a target for monitoring of EVLW in combination with oxygen transport and metabolic parameters (Jozwiak et al. 2015; Monnet et al. 2018). Moreover, when integrated with treatment protocols, EVLW has a potential to improve clinical outcome (Monnet et al. 2018; Mitchell et al. 1992).

Transpulmonary thermodilution for quantification of EVLW

Methodologically, TPTD calculates cardiac output (CO) according to the Stewart–Hamilton principle, based on the analysis of thermodilution curve (**Figure 1**), by applying a thermal (cold saline) indicator. Primarily the TPTD monitor calculates *intrathoracic thermal volume* and *pulmonary thermal volume* by multiplying CO with the mean transit time and the down-slope time of the curve, respectively. *Pulmonary thermal volume* consists of *pulmonary blood volume* (PBV) and EVLW, representing the largest mixing volume for the indicator. The difference between *intrathoracic* and *pulmonary thermal volumes* is *global end-diastolic volume* (GEDV) (Sakka et al. 2000; Boussat et al. 2002). Thus, the combination of CO, EVLW, and GEDV can be a useful tool for clinical assessment of the volumetric status of the patient, especially in shock and ARDS. In addition, TPTD parameters can be used to calculate *pulmonary vascular permeability index* (PVPI = EVLW/PBV), in order to differentiate cardiogenic and non-cardiogenic types of PO (Jozwiak et al. 2015; Boussat et al. 2002; Kuzkov et al. 2006). The technique is suitable for application at the bedside and integrates pulse contour analysis for continuous CO monitoring and assessment of fluid responsiveness.

The accuracy of TPTD can be influenced by diverse changes in heat conductivity of intrathoracic structures (i.e. pleural fluids or redistribution of pulmonary blood flow), and "heat leak" of the thermal indicator (myocardium and great vessels) (Jozwiak et al. 2007; Tagami et al. 2010). Additionally, inhomogeneous PO in ARDS, recirculation of indicator due to anatomical abnormalities, and other factors might compromise the accuracy of readings (Brown et al. 2009; Kirov et al. 2004; Sakka 2013). The prognostic value of EVLW is improved by indexing to predicted body weight ($EVLW_{PBW}$) (Phillips et al. 2008). Although "normal" EVLW previously was referred to as 3–7 mL/kg (Brown et al. 2009; Sakka 2013), Tagami et al. (2010) by means of postmortem gravimetry reported that normal $EVLW_{PBW}$ was 7.4±3.3 mL/kg (Tagami et al. 2010). Today, the best EVLW cut-off value for discriminating diffuse alveolar damage is 10 mL/kg (Tagami et al. 2018, Tagami et al. 2013), and values exceeding 15 mL/kg correspond to severe

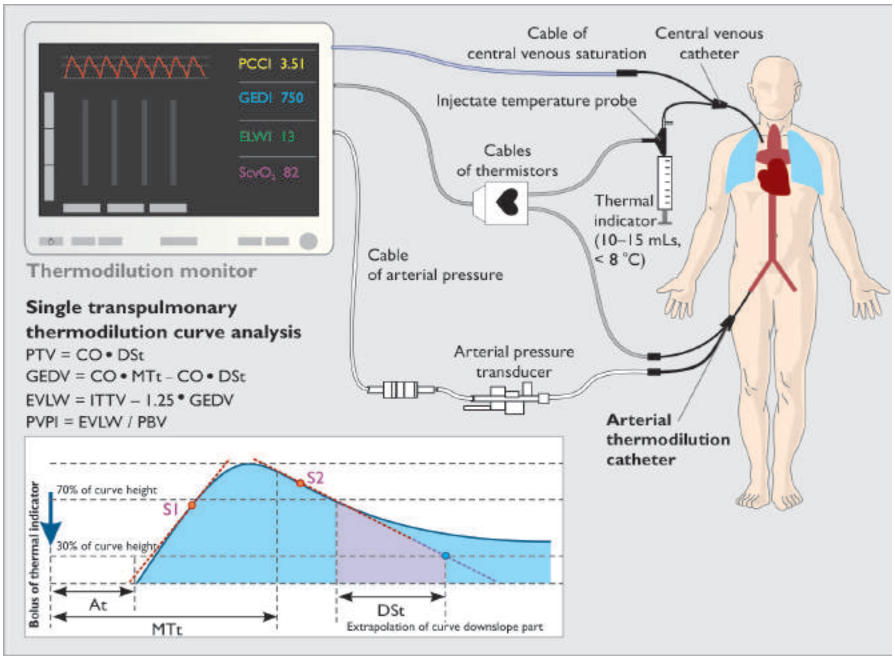

Figure 1. Methodology of transpulmonary thermodilution.

Where: MTt, indicator mean-transit time; DSt, indicator down-slope (exponential decay) time; At, appearance time; PTV, pulmonary thermal volume; CO, cardiac output; EVLW, extravascular lung water; ITTV, intrathoracic thermal volume; GEDV, global end-diastolic volume; PVPI, pulmonary vascular permeability index; PBV, pulmonary blood volume.

ARDS with increased mortality (Jozwiak et al. 2015, Michard 2018, Tagami et al. 2010). The values between 8 and 10 mL/kg can be considered as belonging to "a grey zone" (risk of ARDS) (**Figure 2**).

ARDS and hydrostatic oedema

Since PO is a hallmark of ARDS, bedside assessment of EVLW has a great potential to optimise fluid therapy and respiratory support (Jozwiak et al. 2015; Michard 2018; Sakka et al. 2002; Jozwiak et al. 2013; Tagami et al. 2018). Both EVLW and PVPI increase in non-survivors of ARDS, peaking between days 2 and 4 of the lung injury (Sakka et al. 2002; Kuzkov et al. 2006; Sakka 2013; Martin et al. 2005). In ARDS, EVLW is increased in the overwhelming majority of patients (Kuzkov et al. 2006; Le Tourneau et al. 2012). Moreover, ARDS patients with a maximum EVLW > 21 mL/kg and PVPI >3.8 have a mortality rate of approximately 70% (Jozwiak et al. 2013). In contrast, diffuse alveolar damage, which is the ultimate pathologic pattern of ARDS, was confirmed in only 45% of the patients meeting the criteria of the Berlin definition (Thille et al. 2013). Thus, $EVLW_{PBW}$ > 10 mL/kg is an important threshold of PO and remains an important candidate to be integrated into the current definition of ARDS (Jozwiak et al. 2015; Michard et al. 2012). This is also consistent with Kushimoto et al. (2013) demonstrating that ARDS severity by the Berlin definition was associated with EVLW of 14.7, 16.2, and 20.0 mL/kg in mild, moderate, and severe forms, respectively, while PVPI followed the same pattern with values of 2.6, 2.7 and 3.5.

EVLW plays an important diagnostic and prognostic role in sepsis, ARDS, circulatory shock, complicated perioperative period, and other high-risk patients

In ARDS with cardiac comorbidities, PVPI and GEDV may help to distinguish between non-cardiogenic, mixed and hydrostatic PO (Sakka et al. 2002; Tagami et al. 2018; Kushimoto et al. 2012). Recently, it has been shown that EVLW was higher in ARDS patients than in those with atelectasis or pleural effusion (Kushimoto et al. 2012). Combined with other cardiopulmonary parameters, EVLW might provide guidance for therapeutic interventions (**Figure 3**). In ARDS, these interventions can include the administration of albumin and furosemide, changes in PEEP, recruitment manoeuvres, prone positioning or discontinuation of respiratory support (Yagi et al. 2011; Cordemans et al. 2012; Toth et al. 2007; Smetkin et al. 2012; Chung et al. 2017). Thus, in patients with EVLW > 10 mL/kg, recruitment is less effective (Smetkin et al. 2012), although it may result in attenuation of PO (Chung et al. 2017), and EVLW > 11 mL/kg can serve as a predictor of unsuccessful weaning (Dres et al. 2014; Zeravik et al. 1990). Therefore, information about EVLW and other volumetric variables might support decisions associated with decreasing duration of respiratory support and shortening ICU and hospital stays (Brown et al. 2009; Mitchell et al. 1992: Dres et al. 2014; Zeravik et al. 1990). Moreover, a personalised management based on EVLW can reduce mortality in critically ill patients with increased EVLW, as compared to treatment guided by Swan-Ganz catheter (Eisenberg et al. 1987).

Monitoring of EVLW should also be used in patients with cardiogenic PO and circulatory shock (Tagami et al. 2012; Adler et al. 2013). The values of EVLW > 10 mL/kg associated with PVPI below 2.0 may indicate on prevalent hydrostatic mechanism of PO (Tagami et al. 2018; Kushimoto et al. 2012). In mild therapeutic hypothermia after cardiac arrest, a personalised approach to haemodynamic support aiming at EVLW ≤ 10 mL/kg, GEDV within 700–800 mL/m^2, stroke volume variations (SVV) < 10%, and pulse pressure variations < 10% increases fluid load and reduces the incidence of acute kidney injury (Adler et al. 2013).

Septic shock

Haemodynamic management during septic shock and ARDS also requires a personalised approach (**Figure 3**). Surviving Sepsis Campaign 2016 (Rhodes et al. 2017) recommends invasive cardiovascular monitoring,

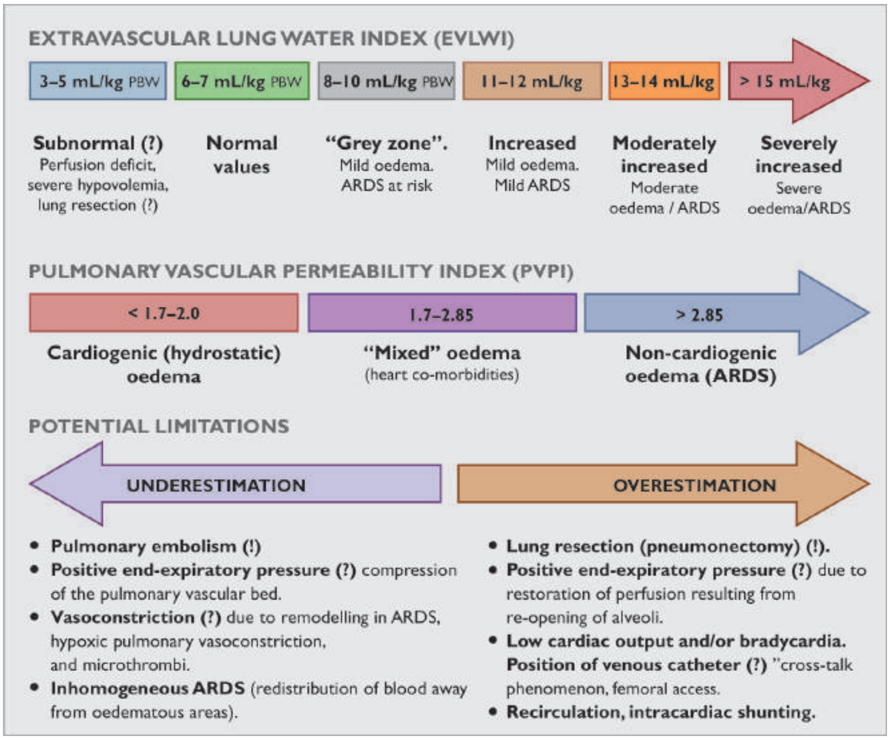

Figure 2. Clinical interpretation of extravascular lung water index and pulmonary vascular permeability index.

ARDS, acute respiratory distress syndrome; PEEP, positive end-expiratory pressure; PBW, predicted body weight.

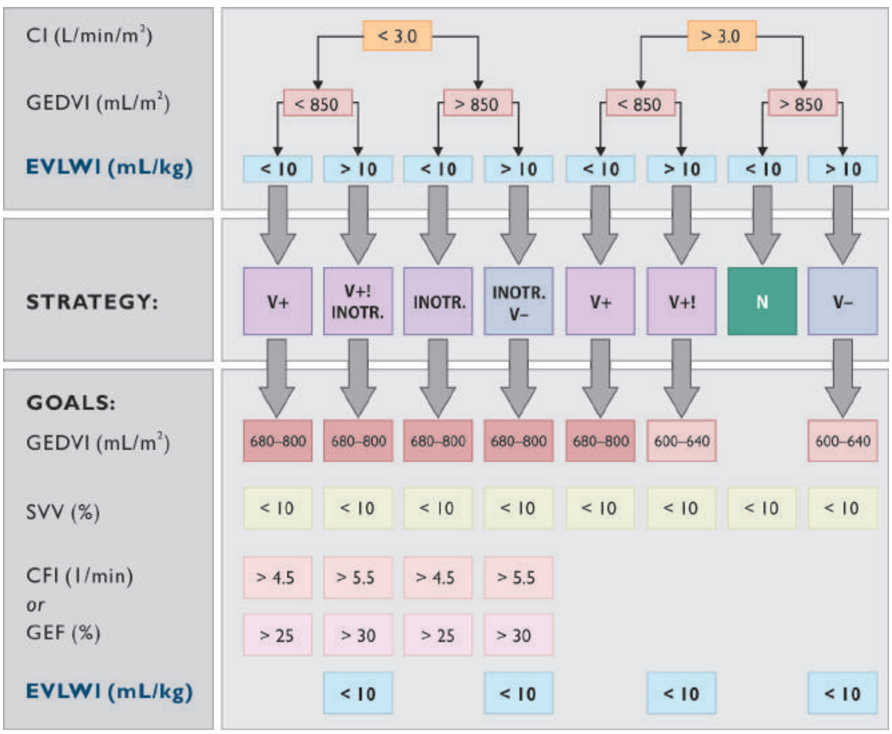

Figure 3. The proposed decision-tree of personalised haemodynamic management using thermodilution-derived parameters.

CI, cardiac index; GEDVI, global end-diastolic volume index; EVLWI, extravascular lung water index; SVV, stroke volume variation; CFI. cardiac function index; GEF, global ejection fraction.
V+, fluid load; INOTR, inotropic support, V+!, titrated volume load controlled for oxygenation and CI response; N, normal status; V–, deresuscitation.

and TPTD may increase the safety of fluid therapy, inotrope/vasopressor support, and mechanical ventilation in sepsis (Jozwiak et al. 2015; Tagami et al. 2018; Wang et al. 2016). It is well documented that in septic shock and ARDS, the combination of adequate fluid load during the first 6 hours and restrictive fluid strategy with cumulative zero net balance during at least 48–96 hrs, is associated with reduced mortality (Murphy et al. 2009; Sirvent et al. 2015). In septic shock, an increase in EVLW by more than 10% from baseline (exceeding 10 mL/kg), may be an incentive to limit fluid resuscitation (Cordemans et al. 2012; Aman et al. 2012) and implement protocols aimed at decreasing EVLW, shortening durations of mechanical ventilation and ICU stay and improving clinical outcome (Mitchell et al. 1992; Aman et al. 2012).

The accumulation of EVLW occurs before changes in blood gases and chest radiogram (Boussat et al. 2002; Kuzkov et al. 2006; Martin et al. 2005). In patients with sepsis, EVLW predicts progression to ARDS 2.6±0.3 days before they meet standard clinical criteria (Le Tourneau et al. 2012). Notably, Martin et al. (2005) showed that more than 50% of patients with sepsis without ARDS have increased EVLW, possibly representing subclinical lung injury.The increased EVLW in sepsis may be considered as an alarm signal for avoiding unnecessary and dangerous fluid load (Monnet et al. 2018; Rhodes et al. 2017). Moreover, in septic shock, the increase in EVLW, but not in central venous pressure, from day 1 to 3 is strongly associated with mortality and shows moderate correlation with lung injury score and gas exchange (Kuzkov et al. 2006).

What is beyond ARDS and sepsis?

Cardiac surgery

In uncomplicated off-pump coronary artery bypass grafting (CABG), perioperative haemodynamic management is accompanied by a decrease in EVLW after revascularisation (Smetkin et al. 2009). In on-pump CABG, patients with EVLW >12 mL/kg may require diuretics to attenuate PO, resulting in reduced need for vasopressors and inotropes and shortened respiratory support and ICU stay (Goepfert et al. 2007). In a controlled trial of combined CABG and aortic valve repair, TPTD-based goal-directed therapy (fluid load if SVV > 10% controlled with CO and EVLW and discontinuation of fluids when CO decreased or EVLW exceeded 12 mL/kg), reduced postoperative complications and length of ICU stay compared with the conventional approach (fluid therapy based on mean arterial and central venous pressures) (Goepfert et al. 2013).

Personalised therapy based on parameters of TPTD and oxygen transport can also be beneficial in high-risk patients after complex valve surgery. Compared with pulmonary arterial catheter, haemodynamic optimisation using GEDV, EVLW and oxygen delivery, improved haemodynamics and oxygen transport and reduced duration of postoperative respiratory support (Lenkin et al. 2012).

Non-cardiac surgery

Pulmonary oedema with EVLW >7 mL/kg is not an uncommon finding after major vascular surgery and can be caused by increased permeability in the absence of overt heart failure. Thus, EVLW might help to distinguish between ischaemia-reperfusion lung injury, atelectasis and cardiogenic PO (Groeneveld et al. 2006).

Monitoring of EVLW also might be useful in thoracic surgery including pulmonary resections, endarterectomy, and transplantation (Chau et al. 2014; Tran-Dinh et al. 2018; Naidu et al. 2009; Stéphan et al. 2017). Postpneumonectomy PO, most probably arising from excessive ventilation of the remaining lung, is a life-threatening complication (Kuzkov et al. 2007; Chau et al. 2014; Naidu et al. 2009). In both experimental and clinical settings, EVLW decreased immediately by 30% after pneumonectomy (Naidu et al. 2009), but increased significantly by 27% postoperatively (Kuzkov et al. 2007). After oesophageal resection, the increase in EVLW at 12 hours correlates with decreased oxygenation and lung compliance; therefore changes in EVLW represent a useful parameter for evaluation of respiratory status and prediction of pulmonary complications (Chau et al. 2014; Sato et al. 2007).

Trauma

In severe combined trauma with hypotension and hypoxemia, quantification of EVLW led to modifications of fluid and vasopressor support, resulting in lower fluid load and improved outcome (Pino–Sanchez et al. 2009). Lung water and other volumetric variables also provide guidance of fluid therapy in adults and children with severe burns involving more than 25–30% of body surface area (Wang et al. 2018,Kraft et al. 2013). Paediatric patients subjected to fluid resuscitation guided by CO, GEDV, and EVLW, had significantly lower fluid balance, better haemodynamic stability and decreased incidence of cardiac dysfunction and kidney injury compared with conventional monitoring (Kraft et al. 2013). To avoid tissue oedema in burns, the target values of GEDV and EVLW for fluid resuscitation in this category of patients probably should be adjusted to below-normal range (Wang et al. 2018; Aboelatta et al. 2013).

Table 1. Potential indications for monitoring of extravascular lung water.

Conditions	Indications
Sepsis	Prevention, diagnostics and management of ARDS Sepsis and septic shock
Acute respiratory distress syndrome	ARDS of any aetiology Pneumonia
Heart failure	Cardiogenic shock including patients after cardiac arrest Pulmonary oedema
Perioperative period	High-risk cardiac and non-cardiac surgery: coronary artery bypass grafting valve surgery major vascular surgery pneumonectomy oesophagectomy transplantation
Trauma and burns	Refractory shock Burn injury
Neurointensive care	Subarachnoid haemorrhage Neurogenic pulmonary oedema and traumatic brain injury
Subgroups of critically ill patients	Necrotising pancreatitis Abdominal compartment syndrome Multiple organ dysfunction syndrome ICU patients receiving renal replacement therapy

> **while TPTD remains a bedside "gold standard" in critically ill patients, evaluation of EVLW by using ultrasound has a great potential for further progress in other clinical scenarios**

Neurocritical care

In neurocritical care, EVLW assessment might be useful to avoid neurogenic PO (Brown et al. 2009). The evaluation of EVLW together with CO and volumetric parameters has been validated as an important tool in patients with subarachnoid haemorrhage (SAH) to prevent pulmonary complications and manage life-threatening cerebral vasospasm (Mutoh et al. 2007) Following SAH, EVLW might demonstrate a biphasic increase: a cardiogenic PO due to low cardiac contractility immediately after SAH, and most likely due to hypervolemia and systemic inflammatory response from day 7 of SAH (Obata et al. 2016). In traumatic brain injury, increased

EVLW might be associated with trauma severity and increased intracranial pressure and warrants further investigations (Lubrano et al. 2015; Chaari et al. 2015).

Other settings

Assessment of EVLW also can be proposed for personalisation of haemodynamic support in several other categories of patients, including necrotising pancreatitis (Huber et al. 2008), transplantation (Venkateswaran et al. 2013), multiple organ failure, and renal replacement therapy (Compton et al. 2007; Schmidt et al. 2016). It is important to bear in mind that the results of studies focusing on EVLW are strongly dependent on protocol and individualisation of target values (Trof et al. 2012).

Conclusions

Bedside assessment of EVLW has the potential to provide additional information regarding fluid status and to personalise therapy in a wide spectrum of ICU patients. Thus, EVLW plays an important diagnostic and prognostic role in sepsis, ARDS, circulatory shock, complicated perioperative period, and other high-risk patients, and was included into the current standards of their management (Cecconi et al. 2014). Assessment of EVLW should be an integral part of personalised resuscitation to improve outcome in patients at risk of PO with fluid restriction when EVLW exceeds 10 mL/kg. While TPTD remains a bedside "gold standard" in critically ill patients, evaluation of EVLW by using ultrasound has a great potential for further progress in other clinical scenarios. ■

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Abbreviations

ARDS	acute respiratory distress syndrome
CO	cardiac output
CABG	coronary artery bypass grafting
EVLW	extravascular lung water
GEDV	global end-diastolic volume
PBW	predicted body weight
PBV	pulmonary blood volume
PO	pulmonary oedema
PVPI	pulmonary vascular permeability index
SVV	stroke volume variations
SAH	subarachnoid haemorrhage
TPTD	transpulmonary thermodilution

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Managing delirium in the ICU with sleep guardians

Sleep guardians - a quality improvement initiative at the Lancashire and South Cumbria Critical Care Network (LSCCCN) to reduce and implement change while managing delirium in critical care patients

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Introduction

Up to 85% of critical care patients may experience some form of delirium, but it can be very easily missed (Inouye et al. 2001; Page 2008) particularly in a very busy 24 bedded General Critical Care Unit that is also the regional centre for trauma and neurosurgery. The unit admits both level 2 and 3 patients within the same clinical environment for critical care support following trauma, neurosurgical intervention, post-operative care after vascular, upper & lower gastro-intestinal, maxilla-facial or gynaecological surgery or where advanced respiratory, cardiovascular and renal support are required for the deteriorating patient.

Together with Lancashire and South Cumbria Critical Care Network (LSCCCN) as quality improvement link nurses our current aim is to reduce and implement change in regard to delirium within critical care. By focusing on improving sleep to reduce delirium we are adding to work previously conducted in our unit (Patel et al. 2014) which demonstrated sleep improvement with a multicomponent bundle.

Delirium

Delirium has been defined as an acute brain syndrome and as such should be recognised and treated as early as possible within the critical care environment (Page 2008). For patients who are suffering from delirium, any delusional thoughts or images are very real to them. In addition, unlike a dream, these images do not fade away but come and go continuously. We assess patients three times per 24 hours using the confusion assessment method (CAM-ICU) tool. Scoring patients at three different times throughout a 24 hour period enables clinicians to detect the fluctuating phases of delirium. Patients may experience hyperactive, hypoactive or mixed delirium behaviours. The CAM-ICU tool will determine whether at the time of testing the patient is either positive or negative for delirium.

> our current aim is to reduce and implement change in regard to delirium within critical care

The interventions we currently use to try and reduce adverse effects of delirium include orientating patients to their surroundings and the use of agitation mitts for those who are pulling at intravenous, arterial or central lines. If all environmental initiatives have been exhausted then medications such as dexmedetomidine or haloperidol will be administered to ensure patient safety.

Environment

The environment of the Critical Care Unit can impact on patients becoming delirious. Upon our unit, there are few windows to enable natural light onto the unit, so it is difficult to create a sense of day and night. As the building structure of our unit cannot be changed, we decided to focus on what we as nurses can do to help reduce the incidence of delirium. We felt an effective way to do this was to assist our patients in achieving a better night's sleep and feeling safe within the critical care environment.

The very nature of a close patient monitoring environment where care interventions are required around the clock impedes on establishing the difference between day and night. The need to admit patients or perform life-saving interventions at any time, day or night can and does impact on how well patients sleep at night. To compound this further is the constant alarming of monitors, ventilators and medication pumps which further impacts on a patient's ability to achieve a sleep pattern which is therapeutic.

The Sleep Guardians

Within the NHS there are 'Caldicott Guardians' and teams who 'SafeGuard' patients, so we thought why are there not 'Sleep Guardians,' to protect a patient's time to sleep, renew and repair?

The role of the Sleep Guardian upon the unit is to promote protective sleep between the hours of 2300 hours to 0700 hours. A sleep guardian can be any band of nurse, healthcare assistant, doctor or consultant. Those who are allocated the role of sleep guardian ensure throughout the night that alarms, lights and staff voices are lowered.

We are advocating that as a team where possible, any invasive nursing or medical interventions are performed before lights go out at 2300 hrs and from then on interventions are clustered to allow at least 1.5 – 2 hour periods of sleep. For those patients with a Richmond Agitation Score (RASS) of >1 eye masks and earplugs should be offered. We have worked with staff to reduce phone alarms, ventilation and bedside monitor alarms at the start of each night shift to reduce noise disturbance overnight within the bay. We have also worked with our procurement team to ensure all bins within the bays are soft-close. Furthermore, we have worked with the IT department to devise a monitor screensaver which reminds everyone to be a Sleep Guadian between the hours of 2300 –0700 hrs.

With patient safety always at the forefront of any initiative we have reinforced the 'buddy' system upon the unit. This ensures that every patient has a nominated nurse monitoring them even when their named nurse has stepped away from the bed space. Therefore, whilst alarms and lights are reduced, patient safety is still optimised.

Family/Friends

Visiting a relative or friend in Critical Care is a daunting and frightening experience for anyone. Once the patient begins to wake up and then displays behaviours associated with delirium relatives and friends feel at a loss of how to react and often express, 'this is not the usual way they behave, speak or react.' In order to help relatives and friends understand how delirium can affect patients, we have prepared a 'DREAMS NOT DELIRIUM' bedside information folder devised from guidelines set out in the LSCCCN Dreams Delirium Bundle.

Our information folder contains a 'SLEEP MENU' which asks relatives to specify how the patient would normally sleep, in terms of pattern, hours and sleep aids used. It also asks for information on what activities the patient would normally do during the day. This information then gives us the opportunity to get to know our patients' likes and dislikes whilst they may still be sedated and intubated. Once a patient begins to wake we can have the necessary aids ready, such as glasses or hearing aids to help the patient to become orientated to the Critical Care environment. Also included within the folder there is a snapshot of why we assess for delirium taken from the National Institute of Clinical Excellence Guidelines for Delirium (Delirium prevention, diagnosis, and management CG103). In addition, there is information for relatives on what delirium is, how patients become delirious and what they can do to help. A communication sheet enables patients who are intubated or have a tracheostomy to point to or spell out phrases to indicate anything they wish nurses or family members to know. Conversely, there is advice for relatives of how to speak to patients, in soft tones and to re-orientate the patient to place, date and time. To further assist with orientation we have devised orientation boards for each bed space which display where the patient is, the day, date and their named nurse. There is also a section in here for relatives and friends to display photographs and cards so that when a patient does wake they feel safer in an alien environment, knowing their loved ones are visiting by seeing the cards and pictures placed by their bed space. ■

Key points

- Up to 85% of critical care patients may experience some form of delirium, but it can be very easily missed
- The Lancashire and South Cumbria Critical Care Network (LSCCCN) is committed to reducing and implementing change in regard to delirium within critical care by focusing on improving sleep to reduce delirium
- Patients are assessed three times per 24 hours using the confusion assessment method (CAM-ICU) tool.
- The role of the Sleep Guardian upon the unit is to promote protective sleep between the hours of 2300 hours to 0700 hours.
- With patient safety always at the forefront of any initiative a buddy system has also been reinforced upon the unit

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The establishment and provision of an acute kidney injury service at a tertiary renal centre

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An overview of the acute kidney injury service launched at the Lancashire Teaching Hospitals NHS Foundation Trust

The acute kidney injury service at Lancashire Teaching Hospitals NHS Foundation Trust was launched in October 2015. Key stakeholders were identified and included in the service development from the beginning and throughout which supported the smooth introduction of the service into the hospitals. This included the Renal Directorate Clinical Director, the Consultant Nurse for critical care services, the Critical Care Outreach Team (CCOT), the Renal Pharmacist, the Information Technology (IT) Department, the Radiology Department, the Pathology and Phlebotomy services, the Quality and Effectiveness lead for the organisation, the Coding Department, and other specialist services such as the Palliative Care and Pain teams, and the Heart Failure Nurses.

In order to provide quality assurances, the service is also part of the Advancing Quality Alliance (AQuA). All stakeholders became key partners and had a significant impact on how the service was developed and implemented, especially the links with the IT and Pathology Department. Working closely with the IT and pathology departments enabled the development of robust processes to identify patients with an AKI and capture service activity.

The AKIT is a bespoke service of the CCOT. Initially, every member of the CCOT rotated into the AKI service for a period of three months to consolidate knowledge and gain experience in the management of patients with an AKI. Nowadays, the team members are allocated to either work in the CCOT or AKI service and are allocated their duties on the rota. In the beginning, the Renal Directorate Practice Educator joined the team on a part-time 12-month secondment to support service development and the professional development of the existing CCOT. This resource was invaluable to support the development of resources for ward-based education, and to strengthen partnerships within the Renal Directorate. Generating the service as an expansion of the CCOT was a deliberate decision taken to utilise the expertise and clinical knowledge of an established team of senior nurses familiar with assessing, planning, implementing and escalating the care of these patients.

generating the service as an expansion of the CCOT was a deliberate decision taken to utilise the expertise and clinical knowledge of an established team of senior nurses familiar with assessing, planning, implementing and escalating the care of these patients

The AKIT and the ward pharmacists identify patient activity from a report on all AKI 1, 2 and 3 flags generated by a search on the organisation's pathology system. The AKIT review all newly identified patients with an AKI stage 2 or 3; ensuring that NICE guidance has been completed and that there is an ongoing treatment and monitoring plan in place.

The AKI service follows up on the patients for one or two days to ensure their blood results are improving which may require further visits or simply checking the blood results remotely. For those patients whose renal function is slow to improve or does not improve, the AKIT refer them on to the renal team. The pharmacists review all patients with a new AKI in their ward areas from Monday to Friday.

The AKIT search the pathology system frequently during the day to identify any new patients in real time as blood tests are processed. The majority of patients identified as having an AKI are admitted to hospital from the community, so the majority of the AKIT's time is spent in the hospital's admission areas. One of the quality standards for patients with an AKI 3 is an early expert review. As the service operates 12 hours a day, 7 days a week; the majority of patients are reviewed within a 12-hour window following their blood results. The process for escalation of the patient with an acute kidney injury stage 3 mirrors that of the critical care outreach service but the AKIT escalates to the renal registrar or consultant on call. Good working relationships within the service facilitate daily discussion about patients to ensure best practice is implemented as soon as possible to achieve the best outcome, minimise patient deterioration and promote patient safety. The AQuA AKI patient information leaflet has been adopted locally and is given to patients reviewed by the AKIT to promote patient and carer awareness of the risk factors of AKI.

A large part of the AKIT's responsibility is to provide education for all healthcare staff in all areas. Established education sessions included in the organisation's postgraduate training programme for nurses include AKI information, recognition, and prevention. Students on renal modules at the local university also spend time with the AKIT as do trainee physician assistants, student nurses, and medical students, etc. As a tertiary renal centre, the AKI service has developed links with other hospitals in the area to support other AKI service improvements.

Recognition of acute kidney injury and appropriate coding at patient discharge are also included in the hospital discharge information letter. Ongoing recommendations following patient discharge for GPs in relation to monitoring post-AKI and patient information are also included in the hospital discharge letter for all stages of AKI.

As the service matures, we are constantly revisiting all elements to ensure we are satisfied with the service for our patients; which has created new opportunities and potential developments. For example, the service is working closely with the pre-operative team to support the development of a preoperative risk assessment tool. ■

Key points

- The acute kidney injury service (AKIT) at Lancashire Teaching Hospitals NHS Foundation Trust was launched in October 2015
- The AKIT is a bespoke service of the CCOT
- The AKIT and the ward pharmacists identify patient activity from a report on all AKI 1, 2 and 3 flags generated by a search on the organisation's pathology system
- The AKIT search the pathology system frequently during the day to identify any new patients in real time as blood tests are processed

Communication myths of anaesthetists

Vital minutes before unconsciousness

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Anaesthesia is a diverse specialty with a wide range of necessary skills, one of which is effective communication.

The myth that anaesthetists pick the specialty 'because you don't need to talk to your patients' persists. Whether said in jest or disdain this concept gains ground because, yes for much of the time, our patients are mostly 'asleep.' But this ignores the vital communication that occurs prior to anaesthesia; the communication that enables an anaesthetist to inject drugs into a total stranger. Drugs that will stop them moving, breathing or feeling pain. Gaining trust in a patient to render them unconscious and take over their vital physiology requires a very specific form of effective communication that must be tailored to that particular patient and time. Creating that private space and environment, whether it be in a hospital bay, anaesthetic room or roadside, is one of anaesthesia's greatest honours.

Anaesthetists may have less than 10 minutes in which to get to know their patient. This includes addressing their fears, experience of previous anaesthetics, assessment of medical and medication history and how that may impact their anaesthetic. Understanding how the proposed surgery may affect them and discuss the risks and benefits of different anaesthetic approaches. We need to explain and gain consent for invasive procedures that must be undertaken to get them safely through the surgery. We also discuss plans for post-operative care, pain relief, recovery expectations or address the need for intensive care. The lack-of-communication myth also ignores the patients we look after who are awake; whether having a caesarean section, hip replacement or in a chronic pain clinic. Or those patients and families we meet in intensive care or the resuscitation room of the emergency department. These loved ones to whom we may deliver life changing and devastating news.

Good communication can calm the nerves. A calmer patient can make for a safer anaesthetic. Highly anxious patients can require more drugs and can be prone to more anaesthetic critical incidents, such as laryngospasm (a sudden spasm and closure of the vocal cords making vital ventilation extremely difficult). Certainly, not all anaesthetists always communicate effectively. However, this is an essential component of our training and daily job. For recruitment into anaesthesia the following communication skills are essential, 'demonstrates clarity in written/spoken communication, and capacity to adapt language to the situation, as appropriate… Able to build rapport, listen, persuade and negotiate' (Health Education England).

> **not all anaesthetists always communicate effectively; however, this is an essential component of our training and daily job**

I'm around three to four years into my training but already I have seen and learned much about communication. I still have much to learn and no one patient or situation is the same. I know that anaesthetists communicate in many ways. We listen. We hear. We see. We sense. We smell. We touch. We observe. We reflect. We empathise. We hope with you.

Some key moments stand out. Talking a woman through an epidural needed to deliver her still born beloved child. Acknowledging fear and consoling parents whose new-born baby is being resuscitated behind the drapes. Telling a wife that her 40-year-old husband has just died of a heart attack. Among the noise and spectacle of a theatre being prepared to repair a patient's ruptured aortic aneurysm, calmly whispering reassuring last words to the patient who will never wake up again. Calming the fears of a child or parents before surgery. High fiving that brave child who allowed you to put in a cannula, after much negotiation. Looking into the eyes and saying goodbye to a parent as they leave their child in your hands for surgery, you attempt to comfort and reassure with verbal words and non-verbal body language. The frank honesty of telling someone they might not survive the anaesthetic or surgery, pausing to give them time to absorb that news. Telling a father that we have now ceased ventilation and 'life support' for his young son while we wait for death to occur and swiftly transfer them to theatre for organ retrieval. So many examples and so many poignant moments.

These are minutes of great privilege, trust, respect and empathy. Anaesthesia is an amazingly diverse specialty with a wide range of necessary skills. Communication is one of the most enjoyable aspects of the job, even if our patients are 'mostly asleep'. ■

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The role of the Physician Assistant in critical care

Physician Assistants play a leading role in the safe, efficient, value-based delivery of healthcare for the critically ill patient.

Since inception in the mid-1960s, the Physician Asssitant (PA) profession has grown to become an integral part of healthcare delivery. As the name implies, PAs were historically seen as assistants to the physician, helping with task completion and the eventual offloading of responsibilities. With the passage of time and concurrent advancement of medicine, there has been a shift towards patient-centred care models with PAs assuming the role of primary caregiver within a multidisciplinary team (Grabenkort and Ramsay 1992). The physician remains at the epicenter of this team, coordinating the overall care and overseeing the trajectory of the patient whilst in the ICU.

As early as the 1990s, physician assistants along with nurse practitioners, collectively referred to today as Advanced Practice Providers (APPs), were being incorporated into ICUs (Buchman et al. 2017). National trends and future projections in the U.S. at the time predicted a net decrease in the number of physicians going into the critical care specialty. Juxtaposed with a projected net increase in the need for critical care beds for an ageing population of the post-World War 2 born "baby-boomer" generation approaching retirement age, a gap was identified in the workforce that needed to be addressed. In 2006, the Health Resources and Services Administration report (HRSA) offered a proposal to the United States Congress to cross train the non-physician healthcare workforce in the basic components of critical care to meet the upcoming staffing needs (Kleinpell et al. 2012).

As a consequence, the roles and responsibilities of the PA within the multidisciplinary care team have evolved slowly over time, allowing for improved efficiency and delivery of critical care. Across various medical centres and academic hospitals within the United States, PAs today are considered an essential part of the 24 by 7 care delivery model for intensive care. Broadly speaking, there are three areas in which the PA functions: clinical care delivery, teaching, and academics as well as research and innovation, thereby fulfilling the tripartite mission of many major academic medical centres across the nation. This, in turn, helps to provide quality, value, and access for the focus point around which the care model was created: the critically ill patient.

> **the roles and responsibilities of the PA within the multidisciplinary care team have evolved slowly over time, allowing for improved efficiency and delivery of critical care**

With respect to current trends in clinical roles and responsibilities within intensive care units across the country, PAs are encouraged to operate at the full extent of their scope of practice, thereby engaging in the complete and comprehensive care of the patient. PAs are often at the forefront of multidisciplinary rounds with the care team, coordinating discussion, communication, and implementation of care plans with various consulting physician services, nursing, respiratory therapy, pharmacy, nutritional support, and other coordinated teams. As such, it is the expectation that the PA is up to date with current trends in pathophysiology and subsequent management of pertinent disease states. The total body, "head-to-toe" management of the patient along with the coordination of care with other disciplines by the PA under the direction of the attending physician has helped to create and define a sustainable model for safe and effective patient care delivery.

In addition to the management of pathophysiologic disease states, the PA is expected to have obtained competency in common ICU procedures, including but not limited to central venous cannulation, arterial cannulation, endotracheal intubation, thoracocentesis, and abdominal paracentesis, to name a few. Specialised intensive care units often require specialised procedures such as lumbar puncture, fibre-optic bronchoscopy, and intra-aortic balloon pump removal, to name a few. Only after having demonstrated proficiency in the aforementioned procedures according to various state regulatory authorities, hospital guidelines and physician supervision, the PA is able to perform these procedures independently with periodic review and subsequent renewal of privileges.

As a fundamental and core principle of care delivery, the physician is ultimately legally responsible for the patient. As such, the 24-hour clock within the intensive care unit has built in at least two formal times of communication between the PA and the critical care intensivist physician in the form of morning and evening rounds. At any other time, it is the expectation that the PA communicates directly with the physician for any one or more of the following reasons:

1. New admission
2. Patient demise
3. Patient is off clinical trajectory, and the physician is unaware.
4. At the request of the physician, nurse or any other member of the care delivery team.
5. If the PA has a question and needs assistance.

An example to further illustrate the roles and responsibilities of the PA is offered: A 68-year-old female is admitted to the ICU with hypotension and associated fever and chills from the emergency department. Sepsis is prioritised in the differential diagnosis, and blood, urine and sputum cultures are sent before transfer to the ICU. Upon arrival, the PA performs the requisite history and physical exam, orders the necessary diagnostic studies including labs and radiologic imaging, and initiates therapy with fluid resuscitation and appropriate antibiotic coverage. The PA then presents the patient to the covering physician, complete with an assessment and plan. After the plan is discussed, refined and confirmed, the PA establishes central venous access if indicated for vasoactive agents as needed, along with arterial cannulation for continuous blood pressure monitoring as indicated. Admission orders and documentation along with care coordination between nursing and pharmacy for implementation of the care plan are all set in motion by the PA. This information is then passed on to the PA on the next shift, ensuring the continuation of seamless care throughout the patient's ICU stay.

Involvement in teaching is another realm within which the PA takes an active role. In academic centres across the states, the ICU is often full of student learners from various disciplines. A full complement of nursing students, APP students, pharmacy students, anaesthesia students, and medical students, along with first and second-year medical interns and resident physicians rotate weeks to months at a time through the ICU. The PA is regarded as a trusted and permanent member on staff within the ICU, and helps to educate student learners and visitors on various topics ranging from relevant pathophysiology and clinical application to unit workflow, quality initiatives and operational considerations. Teaching techniques span the entire spectrum from formalised classroom teaching via lectures and presentations to informal, individual bedside instruction.

Thirdly, academic centers place notable importance on the furthering and advancement of knowledge through research initiatives. PAs are encouraged to actively participate, and clinical ladders for professional advancement within the hospital as well as within national societies are directly tied to incentives for participation in local, regional and/or national research opportunities. Collaboration between the physician and the PA, along with other members of the multidisciplinary team within critical care research initiatives have contributed significantly to the practice of evidence-based medicine.

As of 2013, the American Academy of Physician Assistants (AAPA) annual survey suggested that 2300 of the 114,000 (2.3%) PAs in the U.S. practice in critical care (Annual AAPA Survey 2014). Recent national trends have looked to further the refinement of PA application into critical care. Introduction of critical care residencies across the United States for PAs have helped provide focused and directed education for enhanced critical care thinking and practical application. Programmes range from 6 to 12 months in length, and offer condensed training in critical pathophysiologic concepts as well as procedural competencies through a mix of didactic learning and hands-on rotations through various specialty ICUs. From an operational standpoint, hiring PA graduates who have completed a critical care residency has resulted in quicker onboarding and orientation, thereby shortening the length of time to becoming a valued, productive member of the critical care team.

Current and future projections see the introduction and assimilation of PAs into the world of telemedicine, mirroring the augmentation of care delivery much like that seen within the traditional brick and mortar ICU.

The intended success of the PA within critical care has at its base a foundational support structure by physician leaders. As the Chief APP for over 140 advanced practice providers (Physician Assistants and Nurse Practitioners) in the Emory Critical Care Center, I have been afforded the opportunity to help define, design and ultimately advance the role of the PA within critical care. Together in close partnership with senior physician vision and direction, along with the funding and support from senior administrative leadership, we have been able to create, design and implement the largest critical care APP workforce in the United States. This model, in turn, offers safe, effective and sustainable delivery of healthcare to the critically ill patient population. ■

Conflict of interest

Vishal Bakshi has no conflicts of interest, financial or otherwise to disclose.

Key points

- PAs today are considered an essential part of the 24 by 7 care delivery model for intensive care
- There are three areas in which the PA functions: clinical care delivery, teaching, and academics as well as research and innovation
- PAs are often at the forefront of multidisciplinary rounds with the care team, coordinating discussion, communication, and implementation of care plans with various consulting physician services, nursing, respiratory therapy, pharmacy, nutritional support, and other coordinated teams

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The need to humanise the ICU

Susan East, a patient speaker at the ATS 2017 International Conference in Washington D. C. and a three times ARDS survivor shares her experience about her stay in the ICU.

I am Susan East, a three times ARDS survivor.

July 3, 2008, I had ARDS! I went to my primary physician on June 30, 2008 with symptoms of a sinus infection. He diagnosed me with walking pneumonia and I received a shot and a prescription for an antibiotic. Then on July 3, 2008 my daughter found me at my home, disoriented and blue. She rushed me to the emergency room. My oxygen level was 42%. I was sent immediately to the intensive care unit. I felt as though I was drowning. I was placed on BiPAP machine so that I could breathe. I never had breathing issues before, so it was extremely scary for me.

This continued for about eighteen hours. When that did not work, I was put into a medical coma and placed on a ventilator. I was like this for seven days. During this sedation period, my husband's father was diagnosed with cancer. He and my daughter were talking about it in my room. When I was taken off the vent, I asked them what type of cancer he had. They could not believe that I had heard their conversation.

In the ICU, I would only be allowed to see my family for 15 minutes, four times a day. This was very stressful for me. Once they removed my feeding tube, I was brought meal trays. I was so weak that I could not get my hand from the food to my mouth. I was scolded which made me feel that my life would never be the same.

I was very depressed and lonely. They would wake me in the middle of the night to give me a bath. I made a mental note that this needed to be changed. One night my condition worsened. I had to be placed on a ventilator again. The doctors told my family that I might need to be placed on ECMO. My family decided to move me to LSU Medical Center which was a level one trauma center.

At LSU Medical Center, I was on the ventilator but not sedated. I felt more in control of my illness. I knew I was very sick but not being so sedated helped. This allowed me more control over my decisions. They allowed my family to visit more often. That helped me a lot. The depression got better.

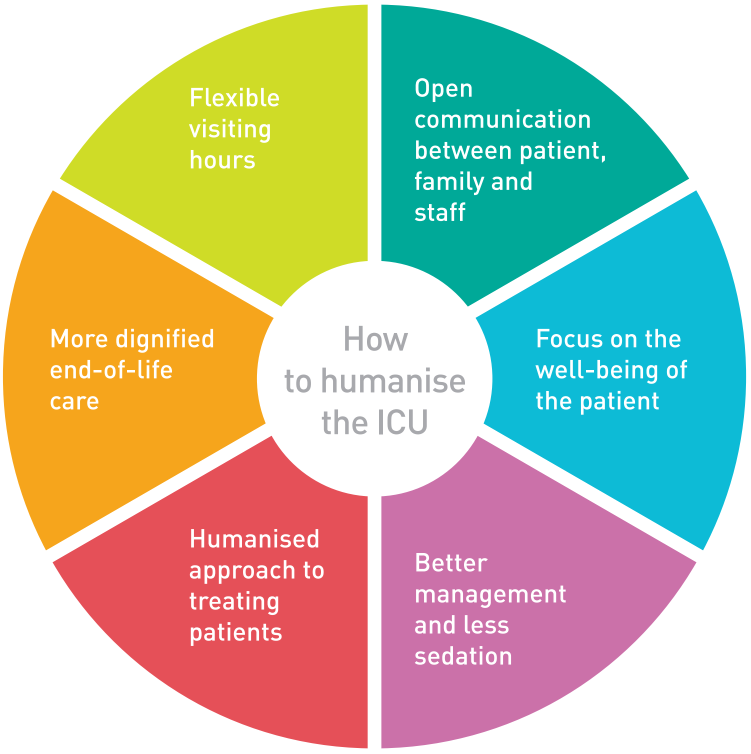
"I was so weak that I could not get my hand from the food to my mouth; I was scolded which made me feel that my life would never be the same"

I was vented a total of twenty-eight days during this illness. But at this hospital, my hair stylist could come and wash and dry my hair. My massage therapist came and massaged my arms and legs. They would bring me magazines to read, and when I was strong enough, one even brought me her laptop to surf the web. I was treated as a human being not just a patient. That made a big difference in my recovery. I was kept on a day to night schedule. This meant that everything that I needed happened during the day and I slept at night. That was a blessing. No more getting woken up at night for different things that could wait until the daytime. After forty-two days of ICU, twenty-eight days of being on a ventilator I was going to be released. To me, this was a miracle. I believed that I never would get ARDS again.

In July of 2014, I had to have another surgery. I developed ARDS again. This time I was only in the ICU for nine days and did not have to be mechanically vented. But it took a lot more out of my body. I was on BiPAP a lot longer. I truly felt that if I went on the ventilator, I would likely not be able to be weaned off it. I now only have 55% lung capacity, and I have pulmonary fibrosis. I fought so hard, and it was tough. But I made it! I felt that my body had suffered all the ARDS that it could take. I am a huge advocate for ARDS. I am so thankful for the scientists who are working so diligently to try and make a difference.

I connected with the ARDS Foundation. I was asked to be a patient speaker at the American Thoracic Society International Conference in May of 2017. The ATS wanted me to speak on "How to Humanize the ICU." I was very honoured. I felt that after surviving ARDS twice, my knowledge might help improve the communication between the patient and doctors.

What I learned from these two hospitalisations is that a patient does not need to be woken up in the middle of the night to have a bath. It is important to be careful of conversations when you are in



the room with a patient in a medicated coma. They may hear you! Flexibility in the visiting hours is very important for the patient and their family. You must consider allowing the family more time. It reduced my anxiety.

I realised that there needed to be better communication between the patient, family, and staff. I thought that if there had been a board in my room when the doctor came in, they could have left the family a note that they had been there. There needs to be a window in your ICU room so that you can realise there is a world waiting for you to be released. I was even allowed to visit with my dog once I could be wheeled outside. This was the 2008 incident. It was wonderful therapy.

Nineteen days after I spoke in Washington DC, I was on my way to Dauphin Island, AL to relax at the beach with my daughter and son-in-law. I drove six hours by myself. Once I arrived, I unpacked, and they wanted to take me out to dinner. We were gone around two hours. I was feeling normal. I had a headache, but I get them frequently. My neck was stiff, and I contributed it to driving.

When we got back to the beach house, I went to my room to unpack. My kids were out at the beach. When they came back, they found me face down and unresponsive. They are both nurse anaesthetists. They called 911 and when the paramedics arrived my blood pressure was 52/24, and my oxygen level was 48%. They called for an air medical helicopter to transport me to Mobile, AL.

I was taken to Providence Medical and placed in the ICU. I spent three weeks there; only four days were not in ICU. I was in a coma for seven days. I was ventilated again. My family was so scared for me to be on the ventilator, but the doctors told them that it was more important for me to come out of the coma. Here I was, once again in the ICU with meningitis and ARDS. Once I woke up, I realised how sick I was. I was determined to fight to recover.

After this incidence, my lung capacity was reduced to 38%. But all I could think of is how do I turn this around and make this a learning experience? I was now determined to get on par with the American Thoracic Society. And today, I am with the ARDS Foundation. I speak about my experience and how you cannot give up. I am on private message boards and help others who are suffering by giving them the knowledge that I continue to learn about ARDS. I feel that I have lived through this nightmare to help others understand that you can have a normal life after ARDS. ■

Key points

- It is important to humanise the ICU
- Communication between the patient, family, and doctors needs to be improved
- Flexibility in visiting hours is very important for the patient and their family
- Patients should be kept on a day to night schedule
- Patients should be treated with respect and dignity

Noninvasive technologies for personalised haemodynamic monitoring

Advanced haemodynamic monitoring methods

Bernd Saugel, MD, EDIC is a Professor of Anesthesiology and works as a consultant in the Department of Anesthesiology, Center of Anesthesiology and Intensive Care Medicine, University Medical Center Hamburg-Eppendorf, Hamburg, Germany. Prof. Saugel is a specialist in anaesthesiology, intensive care medicine, and internal medicine and holds a European Diploma in Intensive Care Medicine. His primary field of research is the haemodynamic management of high-risk patients having surgery and critically ill patients. Prof. Saugel is particularly interested in the concept of personalised haemodynamic management using advanced innovative haemodynamic monitoring methods in anaesthesiology and intensive care medicine.

Is noninvasive cardiac monitoring and optimisation reliable, accurate and precise enough yet?

It depends. There are numerous different technologies for continuous noninvasive monitoring of blood pressure, stroke volume/cardiac output, and derived haemodynamic variables such as pulse pressure or stroke volume variation. These technologies include bioimpedance/bioreactance, pulse wave transit time, carbon dioxide re-breathing, Doppler, pulse wave analysis, and many more (Saugel et al. 2018; Saugel et al. 2015). These technologies are based on different physical measurement principles and, therefore, have different advantages and limitations with regard to their measurement performance and applicability in clinical routine. For all technologies, different validation studies comparing the innovative test method with an established reference method showed contradicting results – depending on the patient population, clinical setting, and reference method (Joosten et al. 2017). All methods have been shown to be able to provide reliable measurements i.e. accurate and precise measurements with a good ability to indicate changes in the "true" value under study conditions. (By the way, a measurement of a haemodynamic variable is always uncertain). On the other hand, I could easily show you studies for each of the mentioned technologies showing poor agreement between these innovative methods and invasive reference methods. The challenge is to have a differentiated view on these validation studies and to exactly analyse the study protocols and study settings before drawing definite conclusions if a novel monitoring technology can be considered "reliable" or not.

What has been your clinical experience of using noninvasive monitoring methods?

In clinical practice, we started using noninvasive finger-cuff technologies that allow continuous monitoring of both blood pressure and stroke volume/cardiac output using pulse wave analysis. We don't use these technologies to replace the arterial catheter or advanced haemodynamic monitoring methods in high-risk surgical patients or critically ill patients treated in the ICU, but to monitor blood pressure continuously instead of only intermittently in low- or intermediate risk patients having surgery. However, in our University Medical Center, we still use these innovative noninvasive monitoring technologies almost exclusively in clinical studies.

What do you see as the most promising noninvasive haemodynamic monitoring technology?

My personal take on this challenging question is that –at the moment– pulse wave analysis using finger-cuff methods is the most promising approach for noninvasive monitoring of blood pressure and cardiac output in perioperative and intensive care medicine. However, the field of cardiovascular and respiratory monitoring is rapidly evolving and we, for sure, can expect that new technologies using highly innovative sensor materials will be proposed in the near future. These future technologies will use ultra-small and highly sensitive sensors to make monitoring systems "wearable and wireless" and to allow "integrated monitoring," i.e. monitoring of various cardiovascular and respiratory signals with one sensor and analysing a combination of different haemodynamic signals.

Why do you think that validation studies of noninvasive methods have shown contradictory results?

There are several reasons that might explain the contradictory results of validation studies. First, as mentioned earlier, the validation studies have been performed in very different patient populations and clinical settings (Joosten et al. 2017). It makes a huge difference if we evaluate a noninvasive test method in surgical patients having cardiac surgery or in patients treated in the ICU with septic shock. A general problem is that the patients we include in method comparison or validation studies to test these innovative technologies are usually not the patients in whom we aim to use these technologies in clinical practice; nobody would suggest using a noninvasive device in a patient having cardiac surgery. We simply use those high-risk patient populations to perform method comparison studies because –for obvious reasons– patients need to be equipped with invasive reference monitoring methods for clinical indications unrelated to the study. Last but not least, we need a consensus on how to design validation studies and –of utmost importance– how to perform statistical analyses in method comparison studies to assess "clinically acceptable agreement."

When do you expect such technologies to come into routine use in the OR and ICU?

I think that innovative noninvasive technologies for haemodynamic monitoring will come into routine use in the OR during the next 5-10 years. There will be two main indications. First, noninvasive technologies will be used for continuous blood pressure monitoring (Michard et al. 2018). Having the advantage of allowing continuous and not only intermittent blood pressure monitoring these technologies may be used as an alternative to oscillometric upper arm cuff measurements [By the way, although used as "clinical gold standard" in millions of patients throughout the world we should not ignore that oscillometry has its own limitations regarding the measurement performance and clinical applicability (Wax et al. 2011)]. With more and more data indicating that even short periods of intraoperative (and postoperative!) hypotension (i.e. low blood pressure in the perioperative period) are associated with postoperative morbidity in terms of complications and organ failure (Sessler et al. 2017; Walsh et al. 2013), there are good reasons to aim for continuous blood pressure monitoring. In some intermediate-risk patients, using these technologies will make it unnecessary to place an arterial catheter. Second, in intermediate-risk surgical patients additional noninvasively assessed haemodynamic variables such as cardiac output and dynamic cardiac preload parameters may help to titrate fluids and vasoactive agents (goal-directed haemodynamic therapy).

In high-risk surgical patients and critically ill patients treated in the ICU, however, arterial catheters and invasive advanced haemodynamic monitoring methods will still be the standard of care in the foreseeable future.

> **“ future technologies will use ultra-small and highly sensitive sensors to make monitoring systems wearable and wireless and to allow integrated monitoring ”**

In your article with Dr. Meidert, you say that the question “is whether continuous noninvasive devices need to replace the direct measurement or rather fill the monitoring gap for patients who are insufficiently monitored by intermittent measurements only." Please comment.

This statement refers to the ongoing discussion about the place continuous noninvasive monitoring technologies should have in the future.

My US colleague Robert Thiele wrote already in 2015: "It is only a matter of time until volume clamp devices [i.e. finger-cuff technologies] replace many if not the majority of arterial catheters for the continuous measurement of blood pressure, arterial respiratory variation, and even noninvasive cardiac output monitoring" (Thiele 2015). I'm not sure if this really is what we should aim for. Some patients e.g. high-risk surgical patients and critically ill patients in the ICU will have an arterial catheter anyway, not only for haemodynamic monitoring but also for arterial blood gas analysis. We should not only think about "replacing the arterial catheter"; we should think about improving the quality of care and outcome in patients who are now monitored intermittently, e.g. almost all low- and intermediate-risk surgical patients, patients undergoing diagnostic procedures such as endoscopy, patients in emergency departments and on normal wards (Wagner and Saugel 2015). I think identifying patient populations and clinical settings in which continuous monitoring instead of intermittent monitoring can help to improve the quality of care or identify haemodynamic alterations earlier is a key challenge in this field (Saugel and Scheeren 2017).

How best to personalise haemodynamic management of the perioperative patient?

In contrast to intensive care medicine, we have the unique opportunity in perioperative medicine that we can assess an individual patient's baseline haemodynamic status. This includes the patient's normal blood pressure profile, cardiac function, and metabolic status. These baseline haemodynamic variables can then be used to guide haemodynamic optimisation strategies in the intra- and postoperative period (Saugel et al. 2017).

When should advanced haemodynamic monitoring be used in shock?

In patients with circulatory shock a) if the type of shock cannot be easily identified, b) if the patient does not respond to the initial therapeutic interventions, and c) if circulatory shock is complicated by failure of other organ systems [ARDS, right heart failure, or liver failure,...](Saugel and Vincent 2018; Teboul et al. 2016).

Would you agree that routine use of the pulmonary artery catheter should be abandoned (e.g. Youssef and Whitlock 2017)?

More and more people believe that there are no routine indications for the PAC. I think that the PAC is still a valuable monitoring technique that provides important haemodynamic variables in very specific clinical problems. In patients with circulatory shock and pulmonary hypertension or circulatory shock with right heart failure, the PAC can help to titrate therapeutic interventions and to monitor the patient's response to these interventions. The same is true in certain patients having cardiac surgery in the intraoperative and postoperative phase. However, we carefully need to balance the risks and benefits of each monitoring method. The PAC is a valuable tool if used by specialists and if used only in those patients who really can benefit from haemodynamic interventions guided by PAC-derived variables (Rajaram et al. 2013).

Is noninvasive continuous monitoring within the reach of most hospitals in middle and high-income countries?

Yes, it is. Numerous methods for noninvasive haemodynamic monitoring are nowadays available. But, of course, it only makes sense to invest in any kind of monitoring if it has been shown to improve quality of care and/or patient-centred outcomes. ■

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Highlights from the I-I-I Blog (I expert, I question, I answer)

A selection from the ICU Management & Practice I-I-I blog. Have you got something to say?

Visit https://healthmanagement.org/c/icu/list/blog or contact editorial@icu-management.org

Stacey Brown

Critical Care Nurse, Canada

@simplicity4jc

From code cart to comfort cart in the ICU

"When the time has come where having the code cart with the epinephrine and defibrillator is no longer appropriate we trade it out for our end-of-life comfort cart. With donations from families and money from fundraisers we purchased a portable kitchen island. This was important for us as we didn't want the institutional look of the code carts found throughout our unit. We wanted the presence of the cart to bring peace and not anxiety.

"When a patient gets admitted into our ICU it is always with the intent to return that patient to a meaningful quality of life. When our goals shift from cure to comfort we strive to do it with compassion, grace and respect."

See more at: https://healthmanagement.org/c/icu/post/from-code-cart-to-comfort-cart-in-the-icu

Fernando Martínez-Sagasti

Head of the Medical-Surgical ICU - Hospital Clinico San Carlos, Madrid, Spain

Miguel Sanchez Garcia,

Head of Department of Intensive Care - Hospital Clinico San Carlos

Should "empiric" antibiotic therapy be considered old-fashioned?

"Over the last decade, automated diagnostic tests have been developed, which amplify resistance genes. Some of these assays require bacterial growth in blood culture bottles to allow amplification of resistance genes, a process which may take 8 hours. Other tests may even be used as a point-of-care tool, allowing the physician to test respiratory tract exudates, wound swabs or other type of samples at the bedside for potentially resistant microorganisms (PRM). Because they provide results in approximately one hour, they convert "empiric" therapy to "directed" antibiotic treatment. The purpose of this post is to discuss the need to implement this new approach to choose the most adequate antibiotic treatment from scratch."

See more at: https://healthmanagement.org/c/icu/post/should-empiric-antibiotic-therapy-be-considered-old-fashioned

Daniela Lamas

Pulmonary and Critical Care Physician - Brigham & Women's Hospital @danielalamasmd

Stories from critical care: You can stop humming now

"I hope that my readers remember Nancy Andrews, a Maine art professor who spent weeks in the intensive care unit at a Boston hospital, after a near-fatal tear in the wall of her aorta. She made it out of the ICU and though her body healed, she found herself haunted by flashbacks to horrific events that had never actually occurred. The sound of a helicopter terrified her. Nancy was ultimately diagnosed with post-traumatic stress, as a result of her critical illness. Intensive care has inadvertently created a new population of the walking wounded, and post-traumatic stress might affect up to one-in-three of those who require intubation. But Nancy Andrews thought she was alone. As critical care clinicians, we must do more to educate our patients about these possible outcomes, and to build systems that offer the screening and follow-up care they need."

See more at: https://healthmanagement.org/c/icu/post/stories-from-critical-care-you-can-stop-humming-now

AGENDA

For a full listing of events visit https://iii.hm/swz

APRIL

4-6 15th Emirates Critical Care Conference
Dubai, UAE
https://iii.hm/sx0

10-13 8th EuroELSO Congress 2019
Barcelona, Spain
https://iii.hm/sx1

11-12 16th Annual Critical Care Symposium
Manchester, UK
https://iii.hm/sx2

13-16 29th European Congress of Clinical Microbiology and Infectious Diseases - ECCMID 2019
Amsterdam, Netherlands
https://iii.hm/sx3

14-16 ESICM EuroAsia 2019
Taipei, Taiwan
https://iii.hm/sx4

18-22 6th SG-ANZICS Asia Pacific Intensive Care Forum
Singapore
https://iii.hm/sx5

25-27 4th Dubai International Conference on Infectious Diseases and Vaccination (DICID)
Dubai, UAE
https://iii.hm/sx6

MAY

1-3 7th ERAS World Congress
Liverpool, UK
https://iii.hm/sx7

8-10 30º SMART 2019 - Anaesthesia, Resuscitation & Intensive Care 2019
Milan, Italy
https://iii.hm/sx8

17-22 American Thoracic Society (ATS) Conference 2019
Texas, USA
https://iii.hm/sx9

23-24 3rd European Pediatric Resuscitation and Emergency Medicine Conference - PREM 2019
Gent, Belgium
https://iii.hm/sxa

28-29 International Course on Metabolic and Nutritional Issues in the ICU
Brussels, Belgium
https://iii.hm/sxb

28-30 37th Vicenza Course on AKI & CRRT
Vicenza, Italy
https://iii.hm/sxc

JUNE

1-3 Euroanaesthesia 2019
Vienna, Austria
https://iii.hm/sxd

3-4 6th World Congress and Exhibition on Antibiotics and Antibiotic Resistance
London, UK
https://iii.hm/sxe

6-8 ESICM LIVES Forum - AKI as a syndrome
Nice, France
https://iii.hm/sxf

8-11 42nd Annual Conference on Shock
Coronado, USA
https://iii.hm/sxg

12-15 ICEM 2019
Seoul, South Korea
https://iii.hm/sxh

20-21 Neurosciences in Intensive Care International Symposium (NICIS) 2019
Paris, France
https://iii.hm/sxi

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