ICU MANAGEMENT

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THE PAEDIATRIC PATIENT

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Within any given hospital, the critically ill are among those patients requiring the highest level of specialised care and resources; but as it is increasingly noted, there are growing sub-populations of patients who require even more specialised care, equipment and protocols. In past issues of ICU Management, we have focused on many of these distinctive groups—from the management of obese patients to the expanding number of elderly in our units.

In this edition of ICU Management, we delve into another uniquely special patient: The Paediatic Patient. As the mindset surrounding this patient group has morphed from the simplified treatment of "small adults" into a more complex physiology of care, so too does the need for more vigorous studies and subsequent guidelines covering the management of this precious, yet precarious population.

Beginning with an economic evaluation, Prof. Regier from Seattle, Washington examines the use of therapeutic hypothermia for perinatal hypoxic ischaemic encephalopathy, while Dr. Mehta teams up with paediatric critical care dietitian Heather Skillman to discuss optimal nutrition therapy in the PICU. Dr. Webb, a Paediatric Cardiologist and her colleague Kaliope Berdusis from Children's Memorial Hospital in Chicago, Illinois describe how they run an optimised telecardiology service in their institution.

Rounding out our cover story and within our new "Advances in Mechanical Ventilation" section we have an overview of haemodynamic monitoring and management in children from Prof. Cannesson, who has a background in paediatrics. We also feature a brief article written by consultant anaesthetists Tim Cook and Nicholas Woodall, which outlines findings relevant to intensive care from NAP4, a UK audit project from the Royal College of Anaesthetists and Difficult Airway Society.

In the features, there is an interesting article on the clinical implications of patterns of CRP-ratio response to antibiotics from Drs. Coelho, Póvoa (Portugal) and Salluh (Brazil), as well as a discussion of the management of abdominal compartment syndrome in medical patients by Drs. Smith and Cheatham (Orlando, US).

Technology is once again our focus in the management section, where we highlight an electronic prescription system that is designed and implemented by ICU clinicians in a bid to utilise IT to reduce medication errors and improve patient safety.

In Viewpoints, Managing Editor Sherry Scharff visits Prof. Saïd Hachimi-Idrissi, Head of the Paediatric Intensive Care Unit at of the University Hospital of Brussels and this issue features an excerpt of their in depth conversation on the staffing the PICU, and other management dilemmas.

We then head to Spain for a look at intensive care in the country as well as a description of how an outbreak of linezolid-resistant staphylococcus aureus was effectively controlled in a Madrid ICU.

As the strains on resources within our units steadily increase, so do the expectations of our patients, and their families—within our growing specialised patient populations. Be it elderly, obese or paediatric patients, we must mobilise our teams to respond to their specific needs and requirements and to continue to share our experiences—both successes and challenges with our colleagues throughout the critical care field.

Jean-Louis Vincent

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RESEARCH NEWS

New Procedure to Make Brain Surgery Safer

To increase patient safety in clinical practice and minimise risks and damage that may arise during surgery, computer support and digital medical imaging are key technologies. Before brain operations, neurosurgeons can now evaluate patient-specific surgical risks, achieve increased safety, and avoid unacceptable risks.

Brain interventions must be planned so that the neurosurgeon can access and remove the tumour without causing unnecessary damage. The Fraunhofer MEVIS Institute for Medical Image Computing in Bremen, Germany has pioneered a procedure that analyses uncertainty in patient-specific images, modeling, and reconstruction and incorporates this information into reconstructions of patient data. This procedure allows safety margins around nerve tracts in the brain to be more accurately determined. In addition, the reliability of the reconstructed data is calculated to supply the surgeon with accurate information concerning nerve tract locations, paths, and intersections and to construct safety margins around the nerve fiber tracts. By integrating errors in measurement, reconstruction, and modeling, the exact locations of tracts in a space-occupying tumour are calculated. This gives the neurosurgeon a reliable prognosis concerning where the incision in the brain should be made and which safety margins should be chosen to avoid harming nerve tracts and irreversibly damaging important functional areas. Before an intervention, the surgeon can evaluate patient-specific risks. These software assistants will be refined and implemented for neuronavigation in future operations, providing the surgeon with updated information during surgery that can be compared to planning data.

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RESEARCH NEWS

Remove Children's Catheters as Soon as Possible to Prevent Bloodstream Infections

Hospitals can reduce the risk of life-threatening bloodstream infections in children with peripherally inserted central venous catheters by assessing daily the patient's progress and removing the device as early as possible, according to a new Johns Hopkins Children's Center study published online in the journal Clinical Infectious Diseases. The study, believed to be the largest one to date of its kind in paediatric patients, analysed predictors of catheter-related bloodstream infections among 1,800 children treated at Hopkins over six years. The children cumulatively underwent more than 2,590 catheter insertions, which resulted in a total of 116 infections. One potent predictor of infection was length of use, the researchers found. Children whose devices remained in for three weeks or longer were 53 percent more likely to get a bloodstream infection, compared with those with shorter catheter times. Children who got the catheters to receive IV nutrition were more than twice as likely to get an infection as children who had the devices placed for other reasons. A peripherally inserted central venous catheter, or "PICC" line, is a tube inserted into a peripheral blood vessel, usually in the arm, and threaded toward major blood vessels near the lungs and heart. The catheter serves as a temporary portal for medications, food, fluids and blood draws. However, with prolonged use, the line can become contaminated and give dangerous bacteria entry into a patient's blood stream. The findings of the study underscore the need for a tailored approach to each patient while at the same time following standard infection prevention guidelines, the investigators say.

"Clinicians should evaluate each patient's condition daily and weigh the risk of leaving the device in against the risk of removing it by asking a simple question 'Does this child need a central line for another day?'" says senior author Aaron Milstone, M.D., M.H.S., an infectious disease specialist at Hopkins Children's. No matter the length of PICC use, the researchers say, the first line of defense against bloodstream infections should always be simple precautions that include rigorous hand-washing before handling the line, regularly changing the dressing that covers the PICC line, and periodically changing the tubes and caps attached to it.

"Even when clinicians follow meticulously basic rules of catheter insertion and maintenance, the risk of infection is never zero," Milstone said. "Reducing the time a child has a PICC is one extra step to minimise that risk." When researchers compared patients in intensive care with those on regular units, they found an 80 percent higher risk of bloodstream infections among children in intensive care. However, the study showed that more than 30 percent of all infections occurred in children outside of the intensive-care unit, a finding that underscores the need for vigilant monitoring of all children with PICC lines. About one-fifth (22 percent) of infections occurred after patients left the hospital, the researchers found, a finding that points to the importance of educating both parents and home-based caregivers on ways to prevent infections at home.

Sonali Advani, Nicholas G. Reich, Arnab Sengupta, Leslie Gosey, and Aaron M. Milstone. Central Line–Associated Bloodstream Infection in Hospitalised Children with Peripherally Inserted Central Venous Catheters: Extending Risk Analyses Outside the Intensive Care Unit Clin Infect Dis.. Clinical Infectious Diseases, March 30, 2011 DOI: 10.1093/cid/cir145

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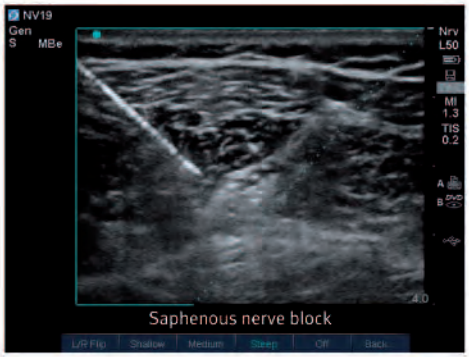

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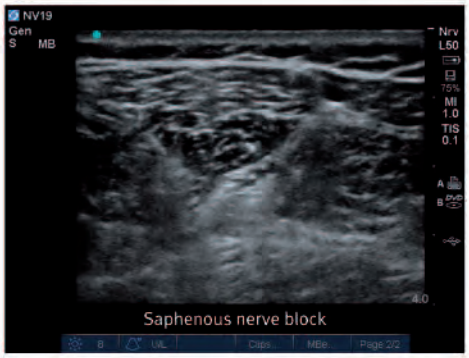

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ECONOMIC EVALUATIONS OF THERAPEUTIC HYPOTHERMIA FOR PERINATAL HYPOXIC ISCHAEMIC ENCEPHALOPATHY

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Therapeutic hypothermia reduces the risk of death and neurological impairment in children with hypoxic ischaemic encephalopathy. The article reviews the published literature examining the cost effectiveness of therapeutic hypothermia to treat neonatal encephalopathy.

Introduction

Neonatal encephalopathy is a major cause of death and neurodevelopmental impairment worldwide. New medical interventions are urgently needed to improve the survival and health outcomes of affected children. A recent meta-analysis suggests that reducing a child's body temperature 3-5˚C below normal produces a statistically significant reduction in mortality and major neurodevelopmental disability at 18 months of age (risk ratio 0.81; 95% confidence interval [CI] 0.71-0.93) (Edwards et al. 2010). The cost of therapeutic hypothermia, however, is greater than standard care; it is thus important to evaluate the cost and health effectiveness trade-offs of this intervention before widespread implementation. This article begins by providing a brief overview of economic evaluation methods for informing healthcare management decisions, which is followed by a review of the clinical efficacy and cost effectiveness of therapeutic hypothermia to treat neonatal encephalopathy.

Economic Evaluation of Health Technologies

There are four main types of economic evaluation:

- cost-minimisation;
- cost effectiveness;
- cost-utility; and
- cost-benefit.

Each approach measures the cost of a health intervention in monetary units, but the methods differ with respect to characterising health outcomes. Cost-minimisation analysis assumes there is no difference in health outcomes and solely examines the cost implications of competing clinical management strategies.

Cost effectiveness analysis (CEA) characterises the health effectiveness of competing interventions in naturalistic units, such as the number of deaths prevented. The effectiveness outcome can also account for the duration of time spent in a health state. For example, the disability free life year (DFLY) statistic has been used in CEAs examining interventions in young children (Petrou et al. 2006). The primary outcome in CEA is typically the incremental cost effectiveness ratio (ICER), which has incremental cost (ΔC, Δ intervention minus standard care) in the numerator and the incremental effectiveness (ΔE) in the denominator.

Cost-utility analysis (CUA) values the effectiveness of the competing strategies using the microeconomic concept of utility, which can be valued using the standard gamble or time trade off techniques (Torrance et al. 1972), or via an 'off-the-shelf' multi-attribute utility instrument (see, for example, Torrance et al. 1995). Utility weights are anchored on 0 (death) and 1 (perfect health), and health states worse than death are also possible. A widely applied summary effectiveness metric is the quality adjusted life year (QALY), which is calculated by multiplying the utility weight of a health state by the amount of time spent in that state. The primary endpoint in CUA is $\Delta C/\Delta QALY$.

The final approach is cost benefit analysis (CBA). CBA quantifies both costs and consequences in monetary terms. Estimating the value of a health effectiveness gain in monetary units can be achieved directly using contingent valuation techniques or by monetising benefit using respondents' preferences for alternative courses of action using conjoint analysis (see, for example, Regier et al. 2010 a). The primary outcome of CBA is net-benefit: Incremental cost subtracted from incremental benefit.

Regardless of approach, it is recommended that the statistical uncertainty surrounding each input parameter and primary outcome is reported (Briggs et al. 2006). When applying decision-analytic modelling techniques, a popular method to estimate confidence intervals (CIs) is to assign each parameter an empirical distribution; Monte Carlo simulation techniques are then used to propagate parameter uncertainty throughout the model (Briggs et al. 2006). The Monte Carlo replications provide incremental cost and effect pairs that inform 95% CI around primary outcomes and decision uncertainty. Decision uncertainty is communicated using the cost effectiveness acceptability curve (CEAC), which cumulatively plots the percentage of ICER draws that are

cost effective at different thresholds of willingness to pay for an effectiveness gain (van Hout et al. 1994).

Efficacy of Hypothermia for Neonatal Rescue

Four large randomised controlled trials (RCTs) characterise the efficacy of therapeutic hypothermia for perinatal asphyxial encephalopathy. The CoolCap RCT (Gluckman et al. 2005) examined intensive care and selective head cooling for 72 hours (n=116) against intensive care alone (n=118). The primary outcome was severe disability or mortality. The former was defined as one of: gross motor function classification score (GMFCS) between 3-5, Bayley mental development index score of (MDI)<70 or bilateral cortical visual impairment at 18 months of age. The reduction in the risk of mortality and disability in the cooling arm was 0.61 (95% CI 0.34-1.09). The NICHD RCT (Shankaran et al. 2005) studied intensive care plus total body cooling for 72 hours (n=102) or intensive care without cooling (n=106). The primary outcome was death or moderate-severe disability, where moderate disability was defined as having one of: MDI 70 to 84, GMFCS of 2, hearing deficit with amplification or a seizure disorder; severe disability was defined as: <70 on the Bayley MDI, GMFCS 3-5, or bilateral blindness or deafness at 18 months of age. The NICHD showed a statistically significant reduction in death or disability in the cooling arm (risk ratio 0.72, 95% CI 0.54-0.95). TOBY (Azzopardi et al. 2009) randomised encephalopathic infants to either intensive care plus total body cooling for 72 hours (n=163) or intensive care alone (n=162). The primary outcome was the combined 18-month outcome of mortality or severe neurodevelopmental disability defined as: MDI<70, GMFCS 3-5, or bilateral cortical visual impairment with no useful vision. The relative risk reduction in the cooling arm was 0.86 (95% CI 0.68 -1.07). A recently published RCT, the ICE trial (Jacobs et al. 2011), examined whole body cooling (n=110) against standard care (n=111) in tertiary and non-tertiary care centres. The primary outcome was death or sensorineural disability at 2 years of age defined as: Cerebral palsy, GMFCS 2-5, MDI<70, Bayley psychomotor development index score (PDI) <70, Bayley motor composite index score of <70, Bayley cognitive scale score <70, Bayley languages composite scale score <70, or blindness or deafness. The risk ratio for death or disability in the cooling arm was 0.77 [95% CI 0.62-0.98].

Cost Effectiveness Models of Neonatal Therapeutic Hypothermia

Two studies (Gray et al. 2008; Regier et al. 2010 b) have quantified the economic implications of therapeutic hypothermia for neonatal encephalopathy. Gray et al. (2008) examined the lifetime cost and utility differences of selective head cooling (SHC) for multiple scenarios that differed on the availability of abnormal amplitude integrated EEG (aEEG) screening or SHC. Each centre was defined by the level of care they could provide as defined by the American Academy of Paediatrics (Stark 2004). Clinical outcomes were obtained from the CoolCap RCT, and an ad hoc health state utility value of 0.67 was used if the child had neurodevelopmental impairment. If an infant had neurodevelopmental impairment, it was assumed they continued in that state throughout their life. Costs and long-term mortality rates were obtained from secondary data sources. A lifetime time horizon was used in the model. The primary outcome was $\Delta C/\Delta QALY$. Costs were reported in 2006 US dollars. Monte Carlo simulation for selected inputs was employed to characterise statistical uncertainty.

In the UK setting, Regier et al. (2010 b) used decision analytic modelling to synthesise clinical outcomes on mortality and morbidity from the TOBY, NICHD and CoolCap trials. Resource utilisation was directly obtained from prospectively collected data in the TOBY trial, which obviated the need to model the ability of a centre to offer aEEG or cooling. Three health states were modelled: Survival without neurological abnormality, survival with neurological abnormality, or death. Survival without neurological abnormality was defined as MDI>84, PDI>84, no neuromotor impairment, normal vision and hearing. The primary outcome of the economic evaluation was the $\Delta C/\Delta DFLY$. The DFLY endpoint was calculated such that children without neurological abnormality were assigned a health state value of 1 for each disability-free year of survival (and 0 otherwise). The time horizon of the baseline model was the first 18 months after birth. In sensitivity analyses, the time horizon was extended to 18 years and children could transition between neurodevelopmental health states (Mangham et al. 2009). Costs and effects were discounted at a rate of 3.5% per year and were valued at 2006-2007 prices. Probabilistic sensitivity analysis using Monte Carlo simulation techniques was conducted.

Measurement and Valuation of Resource Utilisation and Costs

Gray et al. (2008) obtained information on resource utilisation and costs from published literature and administrative databases. This limited their evaluation because the model was unable to discriminate neonatal length of stay by level of ICU care. Unit costs were obtained using cost-to-charge ratios calculated from Medicare and Medicaid Services Hospital Cost reports. The costs of acquiring the cooling equipment and the aEEG machine were obtained using market prices. These costs were amortised over 5 years and were distributed evenly across cooled infants. The indirect long-term costs of developmental impairment were incorporated via the costs associated with cerebral palsy as published by US Centre for Disease Control and Prevention (CDC 2004). Societal costs associated with productivity losses from premature mortality or inability to work were included, as were the costs of special education and out-of-pocket expenses for caregivers.

Regier et al. (2010 b) benefited from resource utilisation data collected alongside TOBY. This included micro-level information on the personnel required during transport to/from a cooling hospital, and the personnel required throughout the hospital stay. Further, the number of days in each level of neonatal care as defined by the British Association of Perinatal Medicine (BAPM 1992) was reported, as was the estimates on hospital readmissions, outpatient hospital visits, and the

use of other healthcare services at 6, 12, and 18 months post initial discharge. Unit costs were attached to resource utilisation using data from the National Health Service Reference Costs database and the British National Formulary. The market costs of acquiring the aEEG machine and the total body cooling system were annuitised over 5 years. The non-capital variable costs of cooling were informed via telephone interviews. The cost of aEEG and cooling were incorporated into the model by dividing the equivalent annual cost of the machines by the number of infants per year that received cooling in the TOBY RCT centres. Societal costs were not included in the model.

Results from the Economic Models

Gray et al. (2008) reported that cooling resulted in lower lifetime costs and greater QALYs in each of the scenarios examined. The degree of cost savings and QALYs gained differed little between the assumed scenarios. The average cost in the usual care arm was US $2,133 per birth and was between $2,066 and $2,084 per birth in the SHC scenarios. The estimated mean cost savings in the cooling strategy ranged from $49 to $67; the QALYs gained in each scenario were between 0.0066 and 0.0088. The authors did not report 95% CI's, but the percentage of ΔC and ΔQALY replications that were jointly cost saving and more effective was between 68% and 73%, depending on the scenario. The percentage of ICERs that were expected to be below a willingness to pay threshold of $50,000 per QALY ranged between 88% and 92%.

The economic model by Regier et al. (2010 b) found that cooling resulted in an incremental cost of (UK) £3,787 (95% CI: -2,516-12,360) in the first 18 months after birth. The percentage of Monte Carlo replications that resulted in expected cost savings was 15%. For effectiveness, cooling resulted in a statistically significant DFLY gain of 0.19 (95% CI: 0.07-0.31). The ICER was £19,931 per DFLY gained in the baseline analysis. The CEAC suggested the probability of cost effectiveness was 69% at a willingness to pay for a DFLY gain of £30,000. The scenario analyses found that when the time horizon of the model was extended to 18 years, the incremental cost was £1,847 (95% CI: -4,494-10,303) and the incremental effectiveness was 1.30 DFLYs gained (95% CI: 0.51-2.15). There was a 99% probability that cooling is cost effective when at a willingness to pay threshold of £20,000.

Conclusion

New, expensive technologies have propelled the expenditure of scarce healthcare resources into the spotlight over the past 40 years. Adopting interventions that 'bend the cost curve' and improve health outcomes is the new mantra, and decision makers are thus increasingly turning to healthcare economic evaluation to inform optimal management strategies. The economic cost and consequences of therapeutic hypothermia to treat perinatal asphyxial encephalopathy has been examined from the UK and US perspectives; the evidence surrounding the cost effectiveness of therapeutic hypothermia is uncertain over the short-term, but seems favourable when a longer-term perspective is adopted.

In the UK, Regier et al. (2010 b) state that the cost effectiveness of therapeutic hypothermia is 'finely balanced' when the analysis is restricted to 18 months after birth. Their conservative conclusion was influenced by the considerable decision uncertainty surrounding the cost and effects of therapeutic hypothermia over the short term. Over the medium and long-term, both Gray et al. (2008) and Regier et al. (2010 b) find that therapeutic hypothermia is likely to be cost effective at acceptable willingness to pay thresholds. Gray et al. (2008) further predicted that the majority of the cost replications were jointly cost saving and more effective, irrespective of the scenario examined.

Conclusions surrounding the cost effectiveness of therapeutic hypothermia over the medium- and long-term should be treated with caution because the data used to project outcomes beyond the RCTs was not prospectively collected for that purpose. Long-term panel data examining the long-term costs, effectiveness, and change in demand for cooling services should be prospectively collected to better inform the likely economic impact of therapeutic hypothermia. Nonetheless, existing cost effectiveness models can, in part, inform local decisions on the likely economic impact of implementation, and current evidence suggests that therapeutic hypothermia is likely to be cost effective and may result in reduced costs and better health outcomes for encephalopathic infants over the long-term. ■

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OPTIMAL NUTRITION THERAPY IN THE PAEDIATRIC INTENSIVE CARE UNIT

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A significant proportion of infants and children admitted to the paediatric intensive care unit (PICU) are malnourished, and further deterioration of nutrition status has been observed during the course of critical illness. The prevalence of obesity is also rising in the PICU, and is associated with higher rates of complications, increased length of stay, and loss of muscle tissue in this population (Bailey 2010). Optimal nutrition therapy for critically ill infants and children is essential to meet both macronutrient and micronutrient requirements, and to preserve lean body mass during critical illness.

Goals of Optimal Nutrition Therapy

Nutrition screening is recommended on admission to the PICU to identify patients who are malnourished or at risk for nutritional deterioration or complications (Mehta and Compher 2009). At-risk individuals must be promptly assessed by a dedicated PICU dietitian for assessment of nutrient requirement, and monitored for nutritional deterioration during their hospital stay (Skillman and Wischmeyer 2008).

Prescription of appropriate energy and protein goals is the next step to achieving optimal nutrition therapy for PICU patients. Critical illness and injury significantly alter energy and protein requirements and may limit the potential for growth until after resolution of the insult. The physiologic stress response is characterised by reprioritisation of hepatic protein synthesis to increase acute phase proteins (C-Reactive Protein) and reduce transport proteins (prealbumin and albumin). While attempts to attenuate protein breakdown during this phase are largely unsuccessful, adequate protein intake may avoid net negative protein balance. Indirect calorimetry (IC) is the most accurate method to determine energy requirements in the PICU (Mehta and Compher 2009). Energy expenditure measured by IC varied from 60-130% of energy expenditure predicted by standard equations in mechanically ventilated children (Coss-Bu et al. 2001). Energy intake goals matching basal metabolic rate (BMR) equations based on healthy children may cause overfeeding in some critically ill children (Mehta, Bechard et al. 2010). On the other hand, those with severe burn injuries or neurologic injury may require up to 175% of predicted BMR and may be underfed (Prelack et al. 2007).

Thus, critically ill children are at risk for both underfeeding and overfeeding. Prolonged inadequate intake can exacerbate malnutrition, cause loss of lean body mass, and increase infection rates in the PICU, whereas overfeeding can induce hypercarbia, hyperglycemia, and lipogenesis (Skillman and Wischmeyer 2008). It is essential to frequently monitor the cumulative balance between intake and actual requirement of energy and protein, adjust the nutrition prescription, and implement strategies to prevent complications from underfeeding and overfeeding (Hulst et al. 2006).

After accurate estimation or measurement of energy requirement, enteral nutrition (EN) should be initiated within 24-48 hours from admission in haemodynamically stable patients with a functioning gastrointestinal (GI) tract, and increased to meet estimated or measured energy and protein goals within the next 24 hours. Initiation of early EN can reduce caloric deficits, improve protein retention, and is generally well tolerated. EN should be postponed until after resolution of haemodynamic instability, GI bleeding, ischaemia, and ileus. Parenteral nutrition (PN) may be initiated if a delay in EN initiation is anticipated (Duggan et al. 2002), or to supplement inadequate enteral feeding.

Thus, overall goals for optimal nutrition therapy in the PICU include:

a) Screening for at- risk and malnourished patients;
b) Accurate assessment of energy and protein requirements during illness course;
c) Prescription of energy and protein based on accurate assessment or measurements;
d) Monitoring cumulative energy and protein balances;
e) Use of EN where feasible with the aim of early initiation; and
f) Prudent use of PN where necessary.

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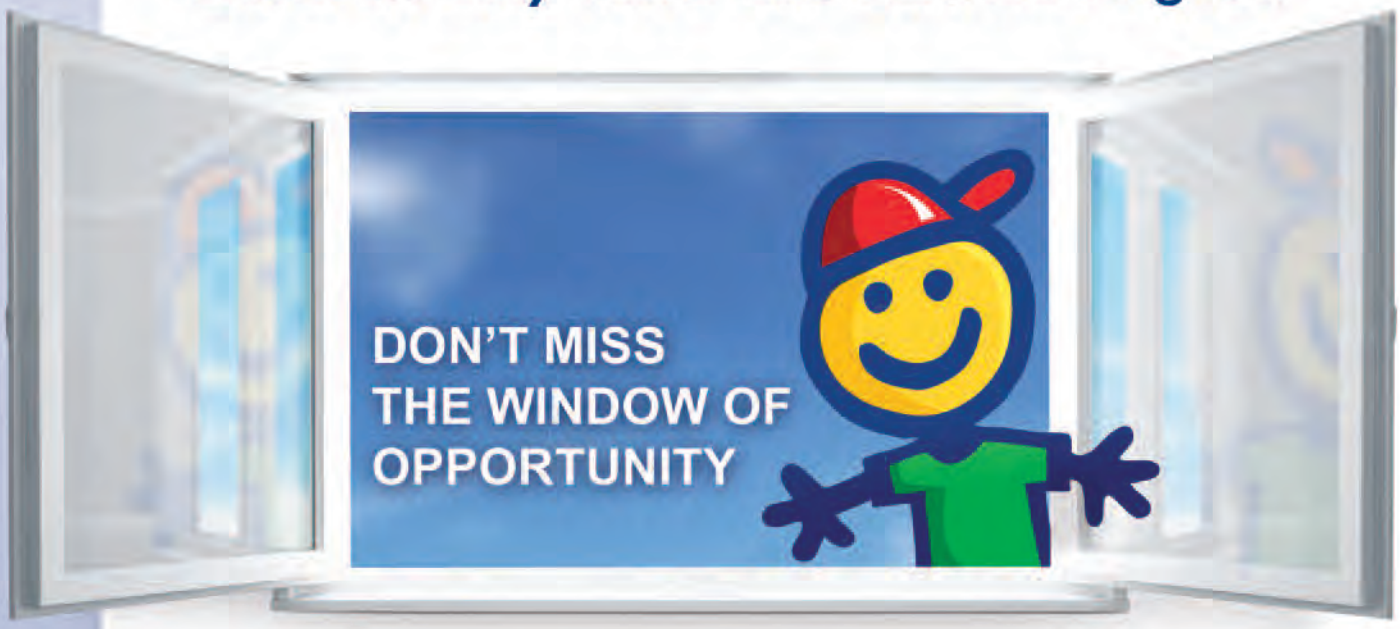

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*Medium Chain Triglycerides

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1. Khoshoo V et al. Incidence of Gastroesophageal Reflux with Whey and Casein-Based Formulas in Infants and in Children with Severe Neurological Impairment. *J Ped Gastroent Nutr.* 1996, 22:48-55. **2.** Fried MD et al. Decrease in gastric emptying time and episodes of regurgitation in children with spastic quadriplegia fed a whey-based formula. *J Ped.* 1992,120:569-572. **3.** Khoshoo V and Brown S. Gastric emptying of two whey-based formulas of different energy density and its clinical implication in children with volume intolerance. *Eur J Clin Nutr.* 2002, 56:1-3. **4.** R.H.Rolandelli, J.R. Ullrich. Lipids and Enteral Nutrition. Enteral and tube feeding. J.L. Rombeau, R.H. Rolandelli. W.B. Saunders Company, *Clinical Nutrition:* 1997. **5.** Roberfroid M.B. & Delzenne N.M. Dietary Fructans. *Annu Rev Nutr.* 1998, 18:117-43. **6.** Gibson G.R. & Roberfroid M.B. Dietary modulation of the human colonic micro-biota: introducing the concept of prebiotics. *J Nutr.* 1995, 125(6):1401-12. **7.** Van den Heuvel, E.G.H.M. et al. Oligofructose stimulates calcium absorption in adolescents. *Am J clin Nutr.* 1999, 69:544-8. **8.** Kolida et al. Prebiotic effects of inulin and oligofructose. *British Journal of Nutrition.* 2002, 87(Suppl. 2):S193–S197.

Future studies in the paediatric population will be needed to clarify the role of individual nutrients in modifying the stress response. Until then, this concept of immunonutrition remains experimental in critically ill children.

Challenges to Optimal Enteral Nutrition

Early EN is preferred in patients with a functioning GI system. However, the goal to establish and maintain EN intake in the PICU is often in direct competition with other interventions, and opportunities to initiate or sustain enteral feeding can be overlooked.

EN is typically withheld from critically ill children with ongoing fluid resuscitation and escalating vasoactive medication support (Petrillo-Albarano et al. 2006). In two observational studies, approximately 30% of children receiving cardiovascular medications experienced GI complications with EN (López-Herce et al. 2008). However, fully resuscitated patients with signs of adequate tissue perfusion, oxygenation, and stable or decreasing need for vasoactive medications should be considered for cautious initiation of EN (Cresci and Cúe 2008).

cardiac intensive care unit (Lambe et al. 2007). Concentrated intravenous solutions and enteral formulas may be administered as tolerated to critically ill infants and children to meet the EN goal despite fluid restriction (Hulst et al. 2006).

There is currently no uniform definition of feeding intolerance in the PICU. The threshold of elevated gastric residual volumes (GRVs), as an indicator of feeding intolerance in critically ill children has not been rigorously studied. EN should not be discontinued solely due to increased GRVs, unless accompanied by other overt signs of intolerance such as severe abdominal distention, reflux, vomiting, or aspiration. For children with intolerance to gastric feeding, sufficient evidence to support use of prokinetics is lacking, but a trial of postpyloric EN is appropriate. Abdominal distention in response to the delivery of EN can be classified objectively with baseline and serial measurements and examinations of abdominal girth. Significant abdominal distention that is concerning for an acute abdomen, or which impairs respiratory function may require cessation of enteral feeding. In general, a uniform definition of intolerance

> *"Adherence to EN guidelines in the PICU has been shown to increase the delivery of early EN, reduce energy deficits, decrease the time to reach goal, and improve feeding tolerance."*

The success of early and sustained enteral feeding depends on availability of local expertise to access the GI tract. Early EN via the gastric route can be easier and quicker to establish, and requires less expertise for placement compared to the postpyloric route. Although postpyloric EN has not been shown to reduce tracheal aspiration of gastric contents in critically ill children (Meert et al. 2004), it may be considered for patients at high risk of aspiration or with intolerance to gastric feeding.

Fluid restriction often impedes the ability to reach the EN goal, especially in the and step-wise practical management of the above factors will help minimise unnecessary interruptions to EN and allow safe and uniform bedside practice.

Procedural feeding interruptions are a significant barrier to optimal nutrition in the PICU (Mehta, McAleer et al. 2010). It is important for the healthcare team to determine the duration of fast needed for the specific intervention to avoid unnecessary cessation of EN. Following the procedure, EN should be resumed at the previously tolerated rate. Some children may be able

Continued on page 29

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GUIDELINES FOR RUNNING AN OPTIMISED TELECARDIOLOGY SERVICE

How We Do It

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For paediatric cardiologists, telecardiology has become a valuable tool in diagnosing and triaging newborns with suspected congenital heart disease at remote hospital nurseries. The tele-echocardiography programme developed over 15 years ago at Children's Memorial Hospital, Chicago, IL, has spawned similar programmes both in the United States and internationally. The continued success of this type of service has relied on several key points:

- Access of both hub and outreach sites to stable, low-cost telecommunications services and videoconferencing equipment;
- Easy to use technology for all hospital personnel participating in the programme;
- Appropriate echocardiography equipment;
- The commitment to training by outreach sites; and
- Continuous customer improvements.

A community hospital with 2,000 live births may need the tele-echocardiography service only 150 times per year. Hospital administration commonly resists purchase of complex technology with high capital and operational costs, which requires subsequent ongoing equipment upgrades. Therefore, the price point needs to be affordable and at a break-even point within the first few years.

Developing the Service

In 1994, the diagnosis of congenital heart disease was made in several inefficient ways, which prolonged the time to diagnosis:

- Transport of the patient to the paediatric hospital;
- Paediatric cardiologist or paediatric sonographer travel to the patient; and
- Echocardiogram sent to the paediatric cardiologist for interpretation.

> *"Telecardiology resulted in decreased time to diagnosis, shorter ICU and hospital stay, and cost savings due to better ability to accurately triage the need for ambulance transport."*

In addition, sonographers who perform the studies at outreach sites are unfamiliar with specific paediatric scanning techniques and they have limited knowledge of congenital heart disease. Tele-echocardiography decreases the time to diagnosis and allows necessary life-saving treatment and better management of critically ill patients.

The concept of bedside real-time videoconferencing at an affordable cost and with off-the shelf technology was pioneered at Children's Memorial through regional access to Integrated Service Digital Network (ISDN) telephone lines. The partnership with area hospitals was built on a 24/7 service model between cardiac sonographers, the paediatric cardiologist, and the referring physicians managing the patients. A critical component has always been the training of the remote hospital sonographers in techniques of paediatric cardiac scanning. This training is more than simple memorisation of the various types of congenital heart disease. It includes thorough interrogation of normal cardiac and abdominal situs with assessment of intra- and extra-cardiac connections using a segmental approach. This same scanning protocol continues to be used today.

Customer Service

Key components of the success of this service include easy to use equipment as well as the important relationships, which are developed between the hub and the outreach hospitals. With a pre-arranged page during the day or on-call, the tele-echo is scheduled. Then the performance of a tele-echo during off hours involves the remote site sonographer taking the ultrasound system with the attached self-contained videoconferencing unit to the patient's bedside. No additional outreach hospital staff sup-

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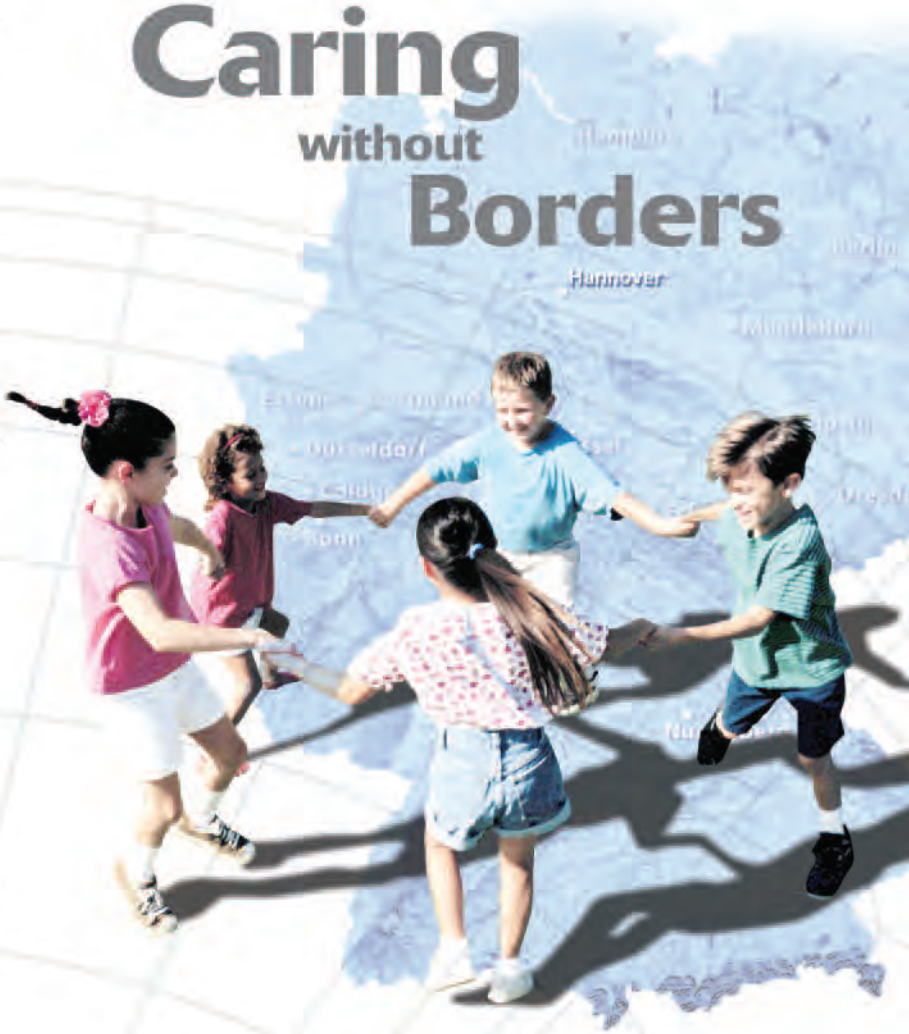

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port is needed. The sonographer dials the Children's Memorial Hospital paediatric cardiologist on-call at her home unit. After confirming the medical information, the echocardiogram is begun, with ongoing dialogue between the cardiologist and the sonographer to ensure that proper views are obtained. Severe heart disease is usually evident within the first few minutes. A complete study can be finished within 30 minutes. Using the results of the echocardiogram, management decisions are made by the referring neonatologist and the parents receive immediate feedback. A neonatal intensive care unit and a paediatric cardiologist may be many miles apart, yet, timely cardiac diagnosis is accomplished within 45 minutes of the sonographer arriving at the child's bedside, and appropriate treatment can be started.

Training for Success

While in many parts of the world the echocardiogram is performed by physicians, in the US, the cardiac sonographers perform the transthoracic echoes. These skilled allied health personnel complete training and sit for examinations through the American Registry of Diagnostic Medical Sonography. The pass rate on these rigorous examinations for both physics and paediatric echocardiography is about 60%. It is also recommended that sonographers have ongoing exposure to at least 400 patients a year in order to maintain their skills. Since sonographers at our partner sites are usually skilled in adult echocardiography, but not in paediatric echocardiography, we provide specific on-site training in the mastery of our scanning protocol. Only those sonographers who have successfully completed this training may participate in tele-echocardiography and the on-call service. The videoconferencing provides the needed supervision.

Measuring the Benefits

A multi-institutional study sponsored by the American Society of Echocardiography demonstrated that telecardiology resulted in decreased time to diagnosis, shorter ICU and hospital stay, and cost savings due to better ability to accurately triage the need for ambulance transport. In addition, therapy could be very specifically tailored to the individual needs of each infant. More than 1,000 cases were assessed in this study and the most significant success of telecardiology has been the lives saved due to the immediate diagnosis and interventional management. Since inception of the telecardiology programme at Children's Memorial Hospital, more than 12,000 telecardiology studies have been done.

Some patients diagnosed using this technology have had critical heart disease requiring immediate medical therapy and ambulance or helicopter transport to the hub tertiary care hospital. Such was the case with baby Matthew, who was being discharged from the normal newborn nursery when a heart murmur was heard. A tele-echocardiogram was done and critical pulmonary stenosis was discovered. Matthew required administration of the life saving medication, prostaglandin, and he was transported to Children's Memorial Hospital where his severely narrowed pulmonary valve was opened surgically. Matthew is now a normal 15-year old boy with no symptoms of heart disease. Had telemedicine not been available, Matthew may have died as a newborn infant due to insufficient blood flow to his lungs.

Telecardiology also enables the paediatric cardiologist to triage patients for different types of inpatient or outpatient care depending on the cardiac abnormality. In another case, a pair of twins was born to a mother at an outreach hospital. One twin was normal, but the other twin was a "blue baby". Telecardiology demonstrated that this baby had abnormal return of the venous blood from his lungs to the heart. Instead of returning to the left side of the heart, the pulmonary venous flow returned to the right side of his heart, causing him to have abnormally low oxygen levels in his blood. Because this baby was very small, an immediate operation would have been very risky.

Using tele-echocardiography, the paediatric cardiologist determined that it was safe for this baby to stay in the ICU at the outreach hospital so that he could feed and grow bigger. When the baby was the appropriate weight, he was transferred electively to Children's Memorial Hospital for repair of his anomalous pulmonary venous return. This management decision was also tremendously advantageous for the baby twins and their parents. Both babies remained in the same nursery and the parents were able to bond with both of them. Had one twin been transferred too early, the parents would have been required to split their time between two hospitals. Due to transportation difficulties, the parents would have had difficulty bonding with the twin with heart disease.

Finally, telecardiology is very effective in defining cases of mild heart disease, which can be very easily managed in an outpatient setting. For instance, if a small hole between the upper or lower chambers of the heart is found, the baby may be discharged with the mother and scheduled for routine follow up in an outpatient paediatric cardiology clinic. Prior to the advent of telecardiology, these babies may have been unnecessarily transported to the hub hospital for diagnosis or their discharge may have been delayed while waiting for an echocardiogram to be interpreted.

Conclusions

In summary, telecardiology is a life saving technology for infants with congenital heart disease. With a modicum of outreach sonographer training and real time interaction between the sonographer and the hub hospital paediatric cardiologist, congenital heart disease can be diagnosed or ruled out. Time to diagnosis is decreased, improving the infant's chances of survival if heart disease is present, and expeditiously allaying parental anxiety if the heart is normal. Unnecessary costly transports and prolonged hospital stays are avoided. Since the distance between hub and spoke hospitals is irrelevant, telemedicine technology may also be an important solution to the diagnosis of congenital heart disease in remote parts of the globe without access to paediatric cardiology expertise. Thus, using this simple technology, outcomes for patients with congenital heart disease can be significantly improved not only locally but also throughout the world. ■

HAEMODYNAMIC MONITORING AND MANAGEMENT IN CHILDREN

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During the past 20 years, intensivists and anaesthesiologists have faced tremendous changes in the way haemodynamic monitoring and management is performed in adult patients. The use of the pulmonary artery catheter has dramatically decreased, leaving a strong reliance on less or non-invasive technologies that mainly rely on transpulmonary thermodilution, pulse contour analysis, bioimpedance-bioreactance, and Doppler technologies. Functional haemodynamic monitoring, which focuses on the effects of stress on a particular haemodynamic parameter rather than on the haemodynamic parameter itself, has dramatically increased. Moreover, haemodynamic management has been strongly impacted by the concept of "Goal Directed Therapy" related to the optimisation of parameters such as cardiac output, venous oxygen saturation, and dynamic parameters of fluid responsiveness (pulse pressure variation, stroke volume variation, or plethysmographic waveform variation)(Rivers et al. 2001; Hamilton et al. 2010; Cannesson 2010).

Despite the numerous improvements observed in the adult patients, haemodynamic monitoring in children remains poorly investigated. This population presents specific characteristics that make the implementation of haemodynamic monitoring technologies challenging. First, the paediatric population includes a wide spectrum of age, size, and weight. Second, the most commonly used technologies in adults are not yet designed for children. Third, vascular access in children (especially in infants and neonates) can be challenging and most haemodynamic monitors are not designed for this population. Fourth, the cardiovascular physiology observed in children (especially in the paediatric cardiac intensive care unit) makes implementation of technologies using thermodilution extremely difficult. And finally, because the haemodynamic data recorded in children are significantly lower than those measured in adults (cardiac output), the accuracy of these haemodynamic monitors is constantly challenged.

However, despite these potential difficulties, clinicians still have the opportunity to use and implement haemodynamic technologies in the paediatric patient. Because certain technologies are available in this setting, it is more likely that protocols for specific haemodynamic goals will be developed in the near future.

Basic Cardiovascular Physiology Applied to the Clinical Setting

As described by Arthur Guyton in his textbook of medical physiology, one of the main goals of the circulation is to bring oxygen to the body tissues. To be achieved, this goal requires two physiological objectives: An adequate perfusion pressure in order to force the blood into the capillaries of the organs, and an adequate flow to deliver oxygen to the tissues (Guyton and Hall 2006). Interestingly, if arterial pressure is monitored everyday in the intensive care unit and in the anaesthesiology setting, cardiac output is rarely monitored. However, arterial pressure does not provide any relevant information regarding cardiac output. The relationship between these two parameters is complicated and far from being linear. Consequently, there is a need for cardiac output monitoring technologies in these settings.

Invasive Arterial Pressure Monitoring

In children, a few specifics have to be kept in mind regarding invasive arterial pressure measurements. First, because heart rate is much higher than in adults and because arterial pressure is lower, measuring this parameter requires high fidelity tracings. Second, because the vascular compliance is higher in kids than in adults, invasive arterial pressure readings are impacted: Systolic arterial pressure has a tendency to be lower while diastolic arterial pressure has a tendency to be higher. Finally, the most reliable arterial pressure parameter measured invasive-

ly in children under six years old is the mean arterial pressure.

Cardiac Output Monitoring

Cardiac output is the product of stroke volume and heart rate. Stroke volume in children (as well as in adults) depends on ventricular contractility, preload, and afterload. In neonates and infants, there is a very low reserve of contractility because of the immaturity of the cardiac muscle. Consequently, the ventricles are very sensitive to acute changes in afterload. Another consequence of this immaturity is that the adjunction of inotrope has very little effects on the ventricular contractility. Consequently, the most efficient way to increase cardiac output in this setting is to increase heart rate. The immature heart is thus chronotrope dependent.

Several devices have potential to be used for cardiac output monitoring in children (See Table 1).

Thermodilution

– Pulmonary artery catheter

The pulmonary artery catheter remains the gold standard for cardiac output monitoring in adults. It relies on thermodilution and on the Stewart Hamilton principle. It's a highly invasive method with very few remaining indications in the paediatric critical care setting (mostly paediatric cardiac transplantation). The minimum size limit for the use of the pulmonary artery catheter in children is 3 to 5 kgs. However, the correct positioning of this catheter in children under 10 kgs of body weight is particularly challenging, even in trained hands. The main advantages of this technique in the paediatric setting is the accuracy of the device, and its ability to allow for SvO2 and pulmonary artery pressure monitoring in children.

Transpulmonary thermodilution

Currently, two distinct devices allow for transpulmonary thermodilution: The PiCCO system (Cecchetti et al. 2003; Fakler et al. 2007) and the EV1000. The PiCCO system has been tested in several paediatric clinical studies with positive results. The system requires a dedicated femoral arterial line and a central venous catheter placed in the superior vena cava territory. This system has been validated against the aortic flow probe in paediatric animal models, and against the Fick method, and the pulmonary artery catheter in human paediatric studies that displayed positive results (McLuckie et al. 1996; Bajorat et al. 2006; Pauli et al. 2002). The major advantage of this technique is that it also allows for continuous cardiac output monitoring using pulse contour analysis. The pulse contour analysis method is calibrated against the transpulmonary thermodilution data and is accurate enough in the absence of acute changes in systemic vascular resistances. Moreover, this technique provides additional important haemodynamic information such as pulse pressure variation, stroke volume variation, global end diastolic volume, and extra vascular lung water (Lemson et al. 2009). Consequently, this system can be qualified as an advanced haemodynamic monitoring device. In term of size, the device is designed for any weight. However, most studies have focused on children weighing more than 3 – 5 kgs.

Lithium dilution

The LiDCO device offers the lithium dilution technique. This system only requires an arterial line and has no size limit. One must keep in mind that Lithium injection presents a few contra indications: lithium therapy (exceptional in children) and neuromuscular blockade. This system has been tested and validated in several paediatric clinical studies with positive results (Kurita et al. 1997; Linton et al. 2000).

Ultrasound techniques

Several ultrasound techniques have been developed and are available. The most widely recognised and most accurate is the transthoracic echocardiography. Transoesophageal echocardiography is also feasible, especially in the operating rooms, and the size limit for this technique is around 3 – 5 kgs; however, there is no size limit for transthoracic echocardiography. This technique is very well validated and is an extremely reliable tool for measuring cardiac output and also for evaluating left and right ventricular functions, valves, and other cardiac structures and functions. It's a completely non-invasive technique. The main limitation is related to the relative complexity of performing a comprehensive and reliable exam. Echocardiography requires an extensive training and presents evident in-

Method	Technique	Invasiveness	Continuity	Technical difficulty	Accuracy	Size Limit
Thermal	Pulmonary artery	High	Intermittent	High	High	5 - 10 kgs
	Transpulmonary Thermodilution	High	Intermittent	Medium	High	3 kgs
Lithium	LiDCO	Medium	Intermittent	Low	High	None
Ultrasound	Echocardiography	Low	Intermittent	High	High	None
	Esophageal Doppler	Low	Continuous	Medium	High	3 kgs
Pulse contour analysis	PiCCO	High	Contiunous	Medium	Medium	3 kgs
Electrical	Bioimpedance/ Bioreactance	Low	Continuous	Low	Low	None

Table 1. Cardiac Output Monitoring Solutions in Children

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ter and intra observer variability. Moreover, echocardiography cannot be considered as a continuous haemodynamic monitor but rather as an intermittent monitoring that is able to provide the most comprehensive cardiac evaluation.

Other ultrasound techniques are represented by the oesophageal Doppler and by the USCOM device. The USCOM device allows recording aortic flow through a suprasternal Doppler technique and is completely non invasive (Knirsch et al. 2008). Both have been validated in paediatric human studies. The oesophageal Doppler allows for continuous monitoring while the USCOM device is an intermittent monitor. Both of these devices require some expertise and training before use. However, just to make note, both of these devices only measure the flow in the descending aorta.

Other cardiac output monitoring techniques

Several other cardiac output monitoring technologies, especially non-invasive technologies, are now available. Electrical techniques such has bioimpedance and bioreactance have been developed initially in adults and then in children. These techniques are not yet completely validated but surely represent an interesting future.

Also, ultrasound dilution techniques have been described recently. These systems allow for continuous cardiac output monitoring in the intensive care unit. They rely on an extracorporeal system and on ultrasound dilution measurements. They are not fully validated yet, but the preliminary studies show interesting results. These systems could potentially be able to monitor cardiac output in patients with intracardiac shunts and/or abnormalities, which is not feasible with most thermodilution techniques.

Dynamic Parameters of Fluid Responsiveness in Children

Dynamic parameters of fluid responsiveness allow for accurate prediction of fluid responsiveness (i.e. they predict the effects of volume expansion on cardiac output). In patients under mechanical ventilation and general anaesthesia, the most popular dynamic parameters are either derived from the arterial pressure waveform (pulse pressure variation, stroke volume variation) or from the plethysmographic waveform (respiratory variation in the plethysmographic waveform amplitude). These parameters have been tested in several clinical studies in adults and have consistently been demonstrated as the best predictors of fluid responsiveness (and superior to central venous pressure or wedge pressure). Only a few studies have been performed in children so far and most of them seem to demonstrate that stroke volume variation is a strong predictor of fluid responsiveness (with a threshold value between 10 and 15 percent), while peripheral parameters such as pulse pressure variation and plethysmographic waveform variation fail to predict fluid responsiveness in this setting (Durand et al. 2008; Pereira de Souza Neto

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An eight-part television series on BBC One (aired originally in May 2010) followed the remarkable work of the mobile intensive care teams dedicated to taking critically ill children to the UK's specialist hospitals.

Cameras followed the highly specialised CATS team as they travelled by road, plane and helicopter to stabilise and safely transfer young patients to specialist hospitals including the world-renowned Great Ormond Street Hospital for Children, St Mary's Hospital and Royal Brompton Hospital in London.

The series reveals the extraordinary skills of some of the country's top paediatric consultants and nurses: Dr. Mary Montgomery, Dr. Daniel Lutman and Dr. "Ram" Ramnarayan, the full-time CATS Consultants; Dr. Andy Petros, Clinical Director of CATS and one of the UK's leading children medicine figures; and Lynn Shields and Mark Clement, two of the most highly qualified CATS nurses who are authorised to take the lead on retrieval missions – a rare qualification held by less than 10 nurses in Europe.

With a close focus on the key characters from the retrieval team we witness each story from their perspective: from the emergency call to the CATS HQ in London, the retrieval mission against the clock, the critical issues faced by the medical staff, the attention at the specialist hospital, to the rehabilitation; and finally the resolution of the story as the family return home. Whether it's a child with suspected meningitis, a cardiac problem, a mystery fit, a newborn with respiratory illnesses, or even a transplant patient there is no mission impossible for CATS.

"Moving a seriously ill child is high risk but is sometimes the only option. Our people must combine top medical expertise with the ability to provide emotional support to the parents involved in the emergency operation" said CATS Clinical Director Dr Andy Petros. Each episode intercuts several poignant cases with key elements common to all: the outstanding skills and care of the CATS teams; the often astonishing bravery of the children; and the families' reaction to the unfolding events.

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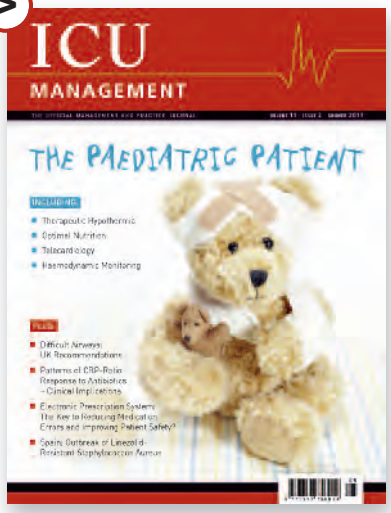

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et al. 2011; Renner et al. 2011). The most convincing explanation is that arterial compliance in children is so high that even if respiratory variations in stroke volume are important, the respiratory variations in arterial pressure are absorbed and then fail to predict fluid responsiveness. As a consequence, only stroke volume variation can be considered as a good predictor of fluid responsiveness in children. Just to make note, only stroke volume variation obtained using echocardiography has been found to be predictive. Stroke volume variation derived from the arterial pressure waveform may be impacted by arterial compliance and thus, may be inaccurate.

Central Venous Oxygenation (SvO2)

Central venous oxygenation depends on cardiac output, haemoglobin, SaO2, and oxygen consumption. Consequently, SvO2 is a synthetic parameter that provides a global view on haemodynamic. Recently, central venous catheters allowing for ScvO2 monitoring (venous oxygenation from the superior vena cava) have been developed for children (Liakopoulos et al. 2007). This device has been tested against co oximetry with very good results. The use of these parameters has also been tested with positive results in an outcome study that focused on children with septic shock, following the methodology of the Rivers study conducted in adults. In addition, SvO2 monitoring in children with congenital heart disease and intra cardiac shunts allows for measuring the ratio between the pulmonary flow and the systemic flow ($Qp/Qs=[SaO2 - SvO2]/[SvpO2 - SaO2]$) where SvpO2 is the oxygen saturation in the pulmonary vein and is considered to be 100 percent.

Integration of the Haemodynamic Parameters Together in the Paediatric Setting

As in adults, haemodynamic monitoring and management in children cannot only rely on arterial pressure. There is a need for cardiac output and oxygenation parameters monitoring. Depending on the setting (anaesthesiology, intensive care unit), the choice of the haemodynamic monitoring solution will be different. Low risk situations will more likely require non-invasive technologies while high-risk situations will require a more in-depth understanding of the physiology, and consequently will need more invasive solutions. Cardiac output should be used more often in the management of these patients because arterial pressure alone does not provide the full picture. In addition, ScvO2 monitoring can help in driving the resuscitation more efficiently. In the future, it is more likely that regional haemodynamic monitors will progressively appear. Today, some systems that rely on Near Infrared Spectroscopy have been proposed for monitoring regional oxygenation with encouraging results (cerebral, hepatic, or renal). It is more likely that the future of haemodynamic monitoring in children will involve more accurate and less invasive technologies as well as more integrative approaches using different parameters (from global haemodynamic parameters to regional haemodynamic parameters). ■

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NAP4: THE 4TH NATIONAL AUDIT PROJECT OF THE ROYAL COLLEGE OF ANAESTHETISTS AND DIFFICULT AIRWAY SOCIETY

Findings Relevant to Intensive Care

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It is increasingly recognised that major airway events, including those with poor outcome, may occur on Intensive Care Units (ICUs). NAP4 (the 4th National audit project of the Royal College of Anaesthetists and Difficult Airway Society) examined major complications of airway management in NHS hospitals in the UK for a period of one year, during anaesthesia, in ICU or in the Emergency Department (ED). Events were defined as 'A complication of airway management that led to death, brain damage, the need for an emergency surgical airway (needle, cannula, open cricothyroidotomy or tracheostomy), unanticipated ICU admission or prolongation of ICU admission'.

A registry of these major airway management complications was established. Appropriate ethical and regulatory clearance was achieved. The process of notification, submission and case review were carefully controlled to ensure high quality data acquisition, data management and maintenance of patient, clinician and institutional confidentiality.

An expert review panel examined each submitted clinical report. The panel incorporated representatives from all specialties involved in the project. Case review was a structured process. Contributory or causative factors were identified. The degree of harm caused was formally graded. Airway management was classified as good, poor or mixed.

Details are reported in the original papers (Cook et al. 2011a, b) and in a full report (Cook et al. 2011c), which includes several chapters dedicated to ICU and complications of tracheostomy. This article a portion of data from ICU.

NAP4 and ICU

Overall there were 184 cases: 133 from anaesthesia, and 15 from the ED. There were 36 reported events from ICU (20% of all reports to NAP4): 18 resulted in death and four in persistent neurological injury (combined rate 61%). Fourteen percent of anaesthesia cases and 33% in the ED led to death or brain damage.

Seventeen ICU events (47%) occurred in obese patients.

There were four cases of unrecognised oesophageal intubation, resulting in three deaths. Capnography was not used.

Ten events involved failed intubation (including re-intubation after inadvertent extubation), resulting in five deaths. Of these ten patients only six patients had a Supraglottic Airway device (SAD) used in an attempt to rescue the airway. Five events deteriorated to CICV.

Eighteen cases involved accidental airway displacement: 14 of a tracheostomy (seven deaths and four patients with brain damage) and four of a tracheal tube (no deaths). Capnography was not in use in 13 of these cases and in five, its use was unclear. Obesity was prominent in both groups but particularly with tracheostomy cases. Airway rescue with a SAD was attempted in only four of these patients.

There were 12 attempts at placement of an emergency surgical airway (33% of all ICU cases) of which three completely failed (25%): Four died and one suffered brain damage as a result of the event. Three were in obese patients. Five cannula cricothyroidotomies were attempted, three failed. Seven tracheostomies were performed (two after cricothyroidotomy) and in at least six the airway was rescued.

Two cases described failed placement during planned tracheostomy: One surgical and one percutaneous.

The most frequent causal and contributory factors, were patient-related (e.g. obesity, recognised difficult airway) (69% of cases), followed by education and training (58%), judgement (50%), equipment and resource (36%) and communication (31%). Positive factors were identified in 54%.

Case Review

Nearly half of reported events (46%) occurred outside 'office hours' when the first medical attendant was a trainee who

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We look forward to seeing you in Brussels in January!

would not necessarily have advanced airway skills: 31% of anaesthesia events occurred 'out of hours'.

Unrecognised Oesophageal Intubation

There were four cases, of unrecognised oesophageal intubation, leading to two deaths and perhaps contributing to a third. Two intubations were performed by relatively junior trainees and later proved to be straightforward. Both were performed without capnography. In a third case, an unintubated, obese patient suffered a cardiac arrest in the CT scanner. Laryngoscopy was difficult and intubation required two attempts and the use of a bougie. Tracheal tube position was checked by observation and auscultation, but capnography was not used. Resuscitation was unsuccessful. After death, fibreoptic bronchoscopy identified the tracheal tube in the oesophagus.

Failed Intubation

There were ten cases of failed intubation or re-intubation after accidental extubation. Several patients with anticipated difficult airways, had intubation delayed until the patient was in extremis, exacerbating an already difficult problem. In others potential difficulty was not recognised. When difficulty was recognised failure to establish a back-up plan in patients at risk of difficult intubation was observed. Finally, some plans were established but equipment or skilled staff were not available to carry the plan out when difficulty arose.

Case 1

A young cachetic patient with myopathy developed respiratory failure secondary to pneumonia. The patient deteriorated further in the middle of the night: by this time on 100% oxygen with non-invasive ventilation intubation was imperative and two trainee doctors attended. Intubation failed and ventilation with a laryngeal mask was inadequate. The reporter commented that a ProSeal LMA was not available. Attempted cricothyroidotomy by the trainees failed and the patient died.

Case 2

A patient with a known difficult airway needed re-intubation because of respiratory distress in the early hours of the morning. Fibreoptic intubation was required but this was not available on the ICU and the appropriately skilled doctor was at home. It took an hour for suitable equipment and staff to be assembled. During this time oxygenation was barely maintained by trainees performing airway manoeuvres. Attempted fibreoptic intubation failed and emergency tracheostomy was performed.

Rescue techniques failed frequently. Although most difficult airway algorithms include cannula cricothyroidotomy as part of the management of the 'can't intubate, can't ventilate' (CICV) scenario, in this group of patients, the failure rate was high.

Case 3

A patient with grade 3 laryngoscopy and multiple co-morbidities developed oozing after prolonged carotid endarterectomy. Before ICU admission the patient had a bradycardic arrest briefly managed with an i-gel.

The patient was sent to ICU for monitoring and in the middle of the night had an asystolic arrest. Prolonged attempts to establish an airway using an i-gel, laryngeal mask ILMA and intubation all failed. Needle cricothyroidotomy and a surgical tracheostomy failed and the patient died. The local reporter commented that a ProSeal LMA was not available.

Accidental Extubation

Inadvertent displacement of a tracheostomy occurred in 14 patients (leading to half of all cases of death and brain damage on ICU) and of a tracheal tube in four (no deaths). Displacement occurred most frequently on movement or during routine care. Capnography was rarely used. The method of fixation of tracheostomies was not consistent. Often, patients whose tracheostomies became displaced were obese, implying that tracheostomy tubes are not always long enough or of appropriate design for such patient's anatomy. Standard tracheal tube displacement occurred in several patients when they and either coughed or attempted self-extubation when waking during a sedation hold. There was a lack of a systematic approach to management of these events: Extubation plans and training were judged lacking. In several cases recognition of extubation was markedly delayed, even until cardiac arrest.

Tracheostomies and tracheal tubes become dislodged at all times of day or night and attending staff did not always have the knowledge to deal with the problem in a measured way. Attendance by only junior trainees was common in out-of-hours cases. Routine rescue techniques (e.g. placement of a SAD) were not always used during management of the airway event. Staff reporting these incidents did not always know what airway equipment or manoeuvres were (e.g. BURP, Combitube), suggesting a deficiency of training in advanced airway skills.

Case 4

An obese patient had a difficulty emergency tracheostomy placed by an ENT surgeon to manage supraglottic airway obstruction. While on ICU, during turning in the middle of the night, the tracheostomy became displaced. Capnography was not in use. Surgical emphysema developed, and the patient could not be intubated or ventilated by the attending registrar. ENT and ICU consultants arrived promptly and replaced the tracheostomy over a bougie at second attempt. The patient suffered hypoxic brain injury.

Problems During Transfer

Three patients suffered adverse events directly related to transfer to or from the ICU: All died or sustained brain damage.

Case 5

A neonate with dysmorphic features was intubated at sixth attempt and

transferred to a neonatal unit. While a non-invasive investigation was being performed the tracheal tube fell out when the head was moved; despite the attempts by a consultant neonatologist, intensivist and anaesthetist, a tracheal tube could not be re-inserted and the airway was rescued with a laryngeal mask. The patient was transferred to theatre for an emergency tracheostomy but the laryngeal mask was displaced during transfer, the airway could not be re-established and the patient died.

Discussion

Methodological considerations (Cook et al. 2011a) suggest that up to 75% of relevant anaesthesia events may not have been reported to the project: As ICU had considerably less local reporters it is possible that even more events may have been missed. Despite this, reports from ICU account for a disproportionate number of adverse airway incidents, with ICU the source of one fifth of all events and more than half of all cases of death or brain damage. Events on ICU were more likely than those in anaesthesia to lead to permanent harm, including death.

During anaesthesia there were 19 reports of airway complications leading to death or brain damage from 2.9 million anaesthetics. In ICU using NHS Hospital Episode Statistics (HES) data we estimate 48,000 patients received advanced respiratory report and there were 22 reports of death or brain damage. This represents a 60- to 70-fold higher incidence of such events in ICU compared to anaesthesia. Even though there is possible error in this calculation it reinforces the message that airway complications occurring on ICU are an important problem.

The cases raise concerns that junior staff (particularly trainees without anaesthetic backgrounds) without the experience or skills to deal with airway complications, are resident as the only medical staff on ICUs out-of-hours.

Reporters noted a lack of equipment on several occasions. Reviewers noted that the breadth of equipment used to manage airway compromise was considerably narrower than in theatres. Rescue techniques were not always used when indicated and when used, failed more often in ICU than anaesthesia; these factors may be related.

A major concern was lack of anticipation and planning for difficult cases. Planning has several phases:

- Recognition of potential difficulty;
- Formation of a strategy (plan A, B, C, etc.);
- Confirmation that the equipment to perform these plans is immediately available;

- Confirmation that appropriately skilled and experienced staff are immediately available; and
- Communication of these plans at staff handovers.

Finally, and perhaps most importantly, although continuous capnography is a standard of care in the operating theatre (AAGBI 2007) it has not been widely adopted in ICU. Failure to use capnography likely contributed to 17 cases of death or brain damage, as a result of failure or delay in recognising displaced or misplaced airway devices. This included three oesophageal intubations and 14 tube displacements, accounting for 77% of ICU deaths. Use of capnography would likely have prevented or reduced the extent of patient harm in these cases.

> *"Failure to use capnography likely contributed to 17 cases of death or brain damage, as a result of failure or delay in recognising displaced or misplaced airway devices."*

Recommendations

- **Capnography**
  Capnography should be used for all intubations and for all patients with tracheostomies or tracheal tubes who are being mechanically ventilated in ICU. Staff should be appropriately trained in its use and interpretation, especially identification of airway obstruction or displacement.
- **Airway Equipment**
  Difficult airway trolleys including a flexible fibrescope must be available in all ICUs and their contents should be familiar to staff.
- **Intubation Planning**
  An intubation checklist (equipment, drugs, personnel, preparation, etc.) should be available and should include strategies for dealing with difficult intubation and the 'can't intubate, can't ventilate' situation.
- **Back-up plans**
  Algorithms must be available for the management of accidental tracheostomy and tracheal tube displacement. These should identify the necessary equipment and skills for carrying out the plan.
- **Cricothyroidotomy**
  Training in needle cricothyroidotomy and emergency tracheostomy is required for intensivists.
- **Staffing**
  Trainee medical staff should be proficient in simple emergency airway management. Appropriate senior staff with advanced airway skills also need to be available at all times.
- **Patient Movement and Transfer**
  Moving patients within the ICU or for transfer may cause airway complications. Staff should be trained to prevent, recognise and manage such complications.
- **Education/Training**
  Intensive care trainees need airway training, including basic airway management and knowledge of appropriate algorithms. All intensive care unit staff should be familiar with interpretation of capnography waveforms. Airway complications should be audited and discussed at morbidity and mortality meetings with learning points implemented.
- **Tracheostomy Tube Design**
  There is a need to consider re-design of tracheostomy tubes for obese patients to reduce the risk of displacement complications. Senior organisations and manufacturers should address this need.
- **Teamwork**
  Working together as a team and involvement of senior staff are vital in the successful management of airway problems in the ICU. Communication between teams is, and will remain, a vital part of safety. ■

NOTE: The project made numerous recommendations as a result of the above findings. These are available in full in the original publication (Cook et al. 2011b) and in the project report (Cook et al. 2011c) chapters 9 and 15. They are not reproduced here in full detail, but summarised.

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Continued from page 12

to tolerate an increased EN infusion rate to compensate for the period of fasting.

Role of Enteral Nutrition Guidelines

Despite renewed interest in the role of optimal feeding during critical illness, a variety of challenges to reaching nutrition goals remain in the PICU. Failure to prioritise nutrition as a therapy during critical illness, absence of uniform feeding guidelines, and scarcity of studies examining the impact of nutritional deficiencies and interventions on clinical outcomes are probably responsible for heterogeneity in practice and suboptimal nutrition delivery in the PICU. Standardised guidelines based on evidence and/or consensus may help to minimise wide variability in feeding practices and allow a systematic approach to illuminating gaps in bedside practice and conducting clinical research. Adherence to EN guidelines in the PICU has been shown to increase the delivery of early EN, reduce energy deficits (Meyer et al. 2009; Tume et al. 2010), decrease the time to reach goal, and improve feeding tolerance (Petrillo-Albarano et al. 2006).

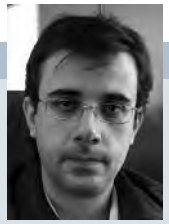
Role of the Dietitian and Nutrition Support Team in the PICU

A dietitian with knowledge of nutrition requirements and consequences of critical illness is an essential member of the multidisciplinary PICU team. The PICU dietitian identifies patients with existing or impending nutritional deficiencies, assesses accurate energy and protein needs, selects an appropriate enteral formula, monitors nutritional adequacy, and works with the healthcare team to optimise nutrition therapy. Participation in quality improvement initiatives is a fundamental component of the PICU dietitian's role, which can advance patient care and enhance relationships within the PICU team. Nutrition support teams may offer an added impact on achieving optimal nutrition therapy for critically ill children. Establishment of a nutrition support team in one PICU led to an increased use of EN, decreased use of PN, and improved clinical outcomes (Gurgueira et al. 2005).

Conclusion

There are multiple barriers to adequate nutrition in the PICU. Critically ill children are at risk for underfeeding and overfeeding, and must be monitored for cumulative energy and protein imbalance. The goals of optimal nutrition therapy in the PICU include timely nutrition assessment, accurate prescription of energy and protein goals, and early initiation and maintenance of EN to achieve nutrition requirements. A multidisciplinary approach prioritising optimal nutrition, monitoring nutrient intake and nutritional status, with uniform evidence-based practice can help attain nutrition goals in the PICU and may improve clinical outcomes in critically ill children. ■

PATTERNS OF CRP-RATIO RESPONSE TO ANTIBIOTICS – CLINICAL IMPLICATIONS



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Patterns of CRP-Ratio Response to Antibiotics – An Innovative Concept

After prescription of antibiotics, the evaluation of the patient clinical response as well as the assessment of resolution of the infection relies on the monitoring of the same criteria used for clinical diagnosis. Therefore, following data such as temperature, heart rate, respiratory rate, blood pressure, white cell count, and tracheobronchial secretions and chest x-rays is mandatory in an infection like pneumonia (Dennesen et al. 2001; Vidaur et al. 2005). However, chest x-rays, which are fundamental for the diagnosis of pneumonia, have a limited role in the evaluation of clinical response to antibiotics, since an initial deterioration is often expectable and there is commonly a delay in the radiologic improvement. Besides, drugs frequently used in ICU can influence almost all clinical resolution criteria such as steroids, antipyretics or beta-blockers. Consequently, the reliance on those markers may not only result in an inaccurate diagnosis of sepsis but also makes the evaluation of the response to therapy often misleading. To overcome these limitations, physicians frequently use serum biomarkers to assist in their clinical decision making process namely in the assessment of response to antibiotic therapy. C-reactive protein (CRP) is one of these biomarkers and probably the most widely used (Póvoa 2002).

We have shown in different types of infections in critically ill patients, namely ventilator associated pneumonia (VAP), bloodstream infections (BSI), community-acquired pneumonia (CAP), that the course CRP after prescription of antibiotics correlates with clinical course and prognosis (Póvoa et al. 2005). It is possible to monitor absolute CRP changes over time, however we think that the use of relative CRP variations (CRP-ratio) are more informative, since CRP has a first order elimination kinetics. This concept is easily understandable with the following example: an absolute 5 mg/dl decrease in CRP concentration has a different interpretation if the previous level is 50 mg/dl or 10 mg/dl; in the first case CRP concentration dropped 10% in the second CRP decreased 50%. As a result, we have defined the new concept of CRP-ratio has the ratio of each day CRP concentration in relation to day 0 (D0) level to assess the dynamic changes of CRP instead of its absolute values. A sharp decrease in CRP-ratio is a surrogate marker of infection resolution whereas a persistently elevated or an increasing CRP-ratio suggests that infection is refractory to therapy (Póvoa et al. 2005).

Using this concept, CRP-ratio, we introduced another new hypothesis with the definition of four individual patterns of CRP-ratio response to antibiotic therapy:

1. **Fast response pattern** when the CRP-ratio at D4 of antibiotic therapy was < 0.4 relative to D0 CRP concentration;
2. **Slow response pattern** characterised by a continuous and slow decrease of CRP ratio;
3. **Nonresponse pattern** when the CRP-ratio remained always ≥ 0.8 of D0 CRP concentration; and
4. **Biphasic response pattern** characterised by an initial CRP-ratio decrease to levels < 0.8, followed by a secondary rise to values ≥ 0.8 D0 CRP concentration.

We also showed, in different infections, that these patterns of CRP-ratio response presented a good correlation with the individual clinical course, patient outcome and also with the adequacy of antibiotic therapy.

Patterns of CRP-Ratio Response – Clinical Course and Patient Outcome

Several studies from different groups have confirmed that serial measurements of CRP are useful in the evaluation of clinical course and patient outcome.

In a cohort of severe CAP patients requiring ICU admission (N=53), our group found that CRP-ratio showed a significant and steady decrease in survivors, whereas in nonsurvivors it remained elevated. In survivors, by D3, the CRP-ratio had decreased by almost 50% from the admission CRP concentration. We found that a D3 CRP-ratio > 0.5 was a marker of poor outcome, with a sensitivity of 0.91 and a specificity of 0.55, and was associated with the diagnosis of non-resolving severe CAP (Coelho et al. 2008). Besides, the CRP-ratio patterns of response to antibiotics were closely correlated with outcome: 76% of patients with fast and slow response patterns survived, whereas the combined mortality rate of the patients with the nonresponse and biphasic response patterns was 75% (Coelho et al. 2007). We showed similar results in a study with VAP (N=47). All patients with fast and slow response patterns survived, whereas those showing a nonresponse and a biphasic response pattern exhibited a mortality rate of 78% and 75%, respectively.

In BSI, CRP-ratio course was also helpful to predict outcome. In another study by our group (N=44), the time-dependent analysis of CRP-ratio, assessed on a daily basis, from D0 to D7, showed a steady and significant decrease in survivors, whereas it remained almost unchanged (or even increased) in nonsurvivors (Póvoa 2005). Those values were already divergent after 24hrs of therapy and become significantly different from D2 onwards. Of the 26 patients with CRP-ratio patterns of fast or slow response, only 2 died, whereas 16 out of 18 patients, with a nonresponse or a biphasic pattern, died. In other words, our group showed that this innovative concept, the patterns of CRP-ratio response to antibiotics, showed a good correlation with individual clinical course in different infectious situations. Those with fast and slow response patterns present a much better prognosis than those with nonresponse or biphasic response pattern.

Seligman et al. analysed 75 VAP patients showing that the decrease of CRP at D4 of antibiotic therapy was predictive of survival, with an odds ratio (OR) of 7.4 (95%CI: 1.58-34.73, p=0.01). In this study, D4 CRP-ratio was also found to be predictive of survival. In survivors, D4 CRP-ratio was 0.68 whereas in nonsurvivors remained almost unchanged, 0.88.

More recently, in the largest cohort multiple centre observational study assessing biomarkers conducted in 17 Portuguese intensive care units (UCI), a total of 891 patients with community acquired sepsis (CAS) were included and were followed-up during the first five ICU days. In this large study daily CRP-ratio after antibiotic prescription was useful, as early as D3, in discriminating CAS patients with good and bad outcomes. A patient with an average decrease of the CRP-ratio of 0.1 per day had 32% more chances of surviving when compared to a patient with the same SAPS II score and the same severity

Author	Infection Type	N	ICU Mortality	CRP-ratio D3/D4		
				Survivors	Nonsurvivors	p
Póvoa 2005	VAP	47	27.7	0.6	1.0	←0.001
Póvoa 2005	BSI	44	40.9	0.6	0.9	0.03
Coelho 2007	CAP	53	24.5	0.5	0.7	←0.001
Lisboa 2008	VAP	42	16	0.7	1.4	←0.01
Bruns 2008	CAP	289	20*	0.6	0.8	←0.001
Póvoa 2010	CAS	891	38#	0.7	0.9	←0.001
Moreno 2010	NP	64	37.5#	0.8	1.2	0.04

*VAP: ventilator-associated pneumonia; BSI: bloodstream infection; CAP: community-acquired pneumonia; CAS: community-acquired sepsis; NP: nosocomial pneumonia; CRP: C-reactive protein; D3: day 3; D4: day 4; ICU: intensive care unit. *: 28th day mortality; #: hospital mortality*

Table 1. CRP-ratio as a marker of prognosis

of sepsis but with no decrease of the CRP (CRP-ratio per each 1% change, adjusted OR =1.03, 95% confidence interval: 1.02 - 1.04, p<0.001). Besides, patterns of CRP-ratio response to antibiotics presented a marked correlation with hospital mortality with patients with a nonresponse pattern having a 2.5 times higher probability of dying in comparison with patients with fast response (adjusted OR = 2.5, 95% confidence interval: 1.6 – 4.0, p<0.001) (Póvoa et al. 2010). Slow responders showed a non-significant increase on the odds of mortality in comparison with the fast responders (adjusted OR = 1.5, 95% confidence interval: 0.9 – 2.5, p=0.124). By D3, median CRP-ratio (5th and 95th percentiles) was 0.81 (0.40, 1.30), 0.95 (0.62, 1.48) and 1.22 (0.70, 6.64) in patients with fast response, slow response, nonresponse patterns respectively (p<0.001).

In all these studies, the patterns of CRP-ratio response allowed the early identification, between D3 and D4, of patients with poor response to antibiotics and consequently with poor prognosis (Table 1). Thus, the recognition of the patterns of CRP-ratio in clinical practice may significantly influence the clinical decision making process. In patients with persistently elevated or rising CRP-ratio, that is nonresponse or biphasic response patterns, an aggressive diagnostic and therapeutic approach should be attempted in order to prevent further clinical deterioration and to diagnose potential infectious complications related or not to the primary infection, like an empyema, an acalculous cholecystitis, appendicitis or a catheter-related bloodstream infection in the case of a pneumonia.

> *"These results demonstrate that CRP-ratio can be an important marker in the early identification of patients who had initial inadequate antibiotic therapy."*

In opposition, patients with consistent CRP-ratio decrease, patterns of fast and slow response, usually have an adequate antibiotic therapy, resolution of infection and good prognosis. As a result, these patterns could be used in conjunction with the clinical evaluation to tailor the duration of antibiotic therapy.

Patterns of CRP-Ratio Response and Adequacy of Antibiotic Therapy

The impact of initial adequacy of antibiotic therapy on mortality has been repeatedly demonstrated and in addition a late antibiotic escalation, from inadequate to adequate antimicrobials seems to have little impact on survival (Iregui et al. 2002).

In a population of 68 VAP patients, Lisboa et al. found a good correlation between the bacterial burden (measured by quantitative tracheal aspirates) and CRP levels. In addition, in patients with adequate antibiotic therapy, CRP-ratio by D4 fall to 0.58±0.32 while, in patients with inadequate therapy, CRP-ratio eventually rise to 1.36±1.11. Besides, authors found a correlation between bacterial load in serial tracheal aspirates, CRP-ratio and the adequacy of antibiotic therapy. By day 4 of antibiotic therapy, patients with adequate antibiotics showed a fall in the bacterial load and CRP-ratio (D4 CRP-ratio – 0.58) whereas in those with inadequate therapy was the opposite, bacterial load remained elevated as well as CRP-ratio (D4 CRP-ratio – 1.36, p<0.05). As a result, we could speculate that patients with adequate antibiotic therapy are those with a fall in the microbiological burden and consequently with a decrease in the inflammatory response. Consequently, the fall of CRP-ratio could be a surrogate marker of this response with a good correlation between

CRP-ratio and the change in microbiological burden. In patients with inadequate antibiotic therapy we would expect an opposite behaviour. The authors concluded that serum CRP-ratio variation was a quick and objective surrogate for bacterial burden and inflammation. Besides the authors found in this study, a strong association between CRP-ratio and survival was perceived (CRP-ratio: 0.68 ± 0.39 in survivors and 1.35 ± 1.33 in nonsurvivors) (Lisboa et al. 2008).

Bruns et al., in a cohort of 137 patients with severe CAP found that patients treated with inappropriate empirical antibiotics had significantly slower normalisation of CRP levels measured in the first three days and in the first week of hospitalisation. In multivariate analysis a decline of <0.6 in CRP-ratio levels in three days and a decline of <0.9 in CRP-ratio levels in seven days were both associated with an increased risk of having received inappropriate empirical antibiotic treatment (Bruns et al. 2008).

In a cohort of 47 patients with microbiological documented VAP (Póvoa et al. 2005), those with initially adequate antibiotic therapy exhibited a better outcome than did those with initially inadequate therapy. The overall mortality rate was 18.4% in the 38 patients with adequate antibiotics and 66.7% in the nine patients with inadequate antibiotic therapy. Also, patients who initially received adequate antibiotics showed a significant CRP-ratio decrease (0.6 at D4) in comparison with those with inadequate therapy (>1.0 at D4, $p<0.001$). In this study, all patients with a pattern of fast response received adequate therapy, as well as 85% of the patients with a slow response. Conversely, 44% of the patients showing a nonresponse pattern and 25% with a pattern of biphasic response received inadequate antibiotic therapy. In other words, the patterns of CRP-ratio response are also markedly influenced by the adequacy of empiric antibiotic therapy.

We found similar results in a cohort of 44 patients with BSI. In this study the mortality was significantly higher among patients initially treated with inadequate therapy (76.9% vs 25.8%, $p=0.002$). Patients who initially received adequate therapy had a marked CRP-ratio decrease, compared with patients who initially received inadequate therapy (Póvoa et al. 2005).

Altogether, these results demonstrate that CRP-ratio can be an important marker in the early identification of patients who had initial inadequate antibiotic therapy. The recognition of the individual pattern of CRP-ratio response to antibiotic therapy reflects not only the infection response but in addition is useful in the assessment of the adequacy of antibiotic therapy. Consequently, this innovative concept, patterns of CRP-ratio response, seems to be a crucial tool in the decision to modify early the antibiotic treatment in patients with patterns of non-response or a biphasic response, or allow the shortening of antibiotic treatment in patients with rapid-response pattern.

Conclusion

This innovative concept, introduced by our group in 2005, has been repeatedly confirmed by different groups, in different countries and in different infections. The relative changes of CRP, CRP-ratio, as well as the patterns of response show a good correlation with clinical outcome, mortality and the adequacy of antibiotic therapy.

We suggest that in patients showing the patterns of nonresponse and biphasic response, with these easily available and inexpensive tools, we should follow an aggressive diagnostic and therapeutic approach to prevent further clinical worsening trying to change the associated ominous prognosis. Also, the identification of fast and slow CRP-ratio patterns of response may help to reduce the length of antibiotic therapy, as well as to reduce the risks of emergence of resistant strains and costs of medication. ■

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ABDOMINAL COMPARTMENT SYNDROME IN THE MEDICAL PATIENT

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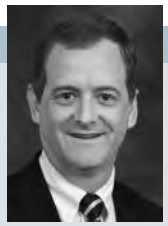

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Intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS) have been well-described in trauma, surgical, and burn patients, but occur with similar frequency in medical patients. The mortality of IAH/ACS in critically ill medical patients is significantly greater than that of surgical patients. This may be a result of pre-existing comorbid conditions that limit the medical patient's ability to successfully respond to critical illness. Early recognition of IAH/ACS and application of multi-modality therapy to correct organ dysfunction and failure significantly improves survival in such patients.

Introduction

Intra-abdominal hypertension (IAH) and abdominal compartment syndrome (ACS) have been increasingly recognised in the surgical literature over the past two decades. The management of this spectrum of disease has changed significantly as well. The majority of the scientific literature published on IAH/ACS deals with trauma, surgical and burn patient populations (Offner et al. 2001; Cheatham and Safcsak 2010; Raeburn et al. 2001). IAH/ACS is not specific to these patient populations, however, and this article will briefly review the published data regarding IAH/ACS in the medical patient.

Definitions

Normal intra-abdominal pressure (IAP) is slightly negative or near 0 mmHg. Normal physiologic elevation of IAP can occur in hospitalised patients with ranges of up to 5-7 mmHg. Pathologic elevation of IAP occurs in critically ill medical and surgical patients. The World Society of the Abdominal Compartment Syndrome (WSACS) recommends serial IAP monitoring for patients with risk factors for IAH/ACS (Cheatham et al. 2007). IAP is easily determined using intravesicular pressure measurements via an indwelling urinary catheter and a bedside pressure transducer. IAH is defined as an IAP ≥ 12 mmHg. Impaired organ perfusion begins with IAP elevations of 12-15 mmHg. A precipitous decrease in splanchnic blood flow occurs with IAP's increasing above 20-30mmHg. ACS is defined as sustained elevation of IAP > 20 mmHg with new onset organ dysfunction or failure. Signs of ACS include metabolic acidosis, hypotension, oliguria, elevated peak airway pressures, refractory hypercarbia and hypoxemia, and elevated intracranial pressure. ACS is classified as primary, secondary, or recurrent. Primary ACS is associated with injury or disease within the abdomino-pelvic region and is typically seen in surgical patients. Secondary ACS involves processes outside of this region, such as capillary leak syndrome, multisystem organ failure, and sepsis, making it the most common form of ACS encountered in medical patients. Secondary ACS is more gradual and insidious in onset as compared to the more dramatic primary ACS. The development of secondary ACS in the medical patient population can be easily missed if recommended IAP screening does not occur. Recurrent ACS occurs when IAH-induced organ failure recurs in patients who have already been treated for ACS. Prompt recognition and treatment of IAH/ACS is imperative to reduce morbidity and mortality. Untreated ACS has a mortality of up to 100%.

> *"A high index of suspicion for elevated IAP and a low threshold for measuring IAP are essential in these patients."*

Medical Causes of IAH/ACS

The disease processes that are associated with "medical" IAH/ACS do not inherently suggest to practitioners that IAH/ACS is also present; hence the need for serial IAP measurements. Common medical causes include pneumonia, bacteremia, sepsis, acute renal failure, pancreatitis, acidosis, coagulopathy, poly-transfusion, hypothermia, liver dysfunction/failure, acute respiratory failure, and aggressive mechanical ventilatory support, especially with high positive end-expiratory pressures. A high index of suspicion for elevated IAP and a low threshold for measuring IAP are essential in these patients.

Prevalence

An epidemiologic study by Malbrain et al. in 2005, enrolled 265 consecutive mixed intensive care unit (ICU) patients to evaluate the incidence of IAH/ACS. The reported mean IAP was 10 ± 5 mmHg for all measured IAPs. Upon ICU admission, 32% of patients had an IAP ≥ 12 mmHg and 4.2% patients had ACS. The prevalence of ACS in patients with IAH was 12.9%. Seventy-three patients (27.5%) died. The demographics of nonsurvivors included significant differences in age (older patients fared worse), higher mean IAP, SAPS II, APACHE II, and SOFA score at admission. Development of IAH during the ICU stay was identified as an independent predictor of mortality. Medical admission to the ICU was associated with a higher risk of death (Odds Ratio 2.5 [95% confidence interval (CI) 1.2-5.6; p= 0.01]). The mortality rate for medical patients was 40.3%, emergency surgery patients 36.4%, trauma patients 8.7%, and elective surgery patients 6.7%. A recent study by Cheatham et al. confirmed that medical patients have a significantly higher mortality following IAH/ACS (67%) compared to surgical patients (trauma 28%, emergency surgery 44%, and burns 45%; p<0.0001) (Cheatham et al. 2011).

Cothren et al. reviewed cases of secondary ACS (SACS) over a seven-year period (Cothren et al. 2007). Fifty-four patients developed SACS, 41 of which were post-injury patients and 13 medical patients. There were no significant differences in demographics between the two groups. The authors did find differences in transfusion requirements with the post-injury patients requiring more packed red blood cells (14.5 ± 2.0 units vs. 3.7 ± 1.8 units; p<0.05). Medical patients had a significantly increased time to abdominal decompression (21.0 ± 3.6 hours vs. 6.5 ± 1.9 hours; p<0.05). There was also a trend in increased use of vasoactive medications in medical patients (54% vs. 34% of patients; p=NS). The number of medical patients who had primary fascial closure was significantly less (54% vs. 83%; p<0.05). Multiple organ failure was significantly higher in medical patients (62% vs. 57%; p<0.05). There was a strong trend towards increased mortality in the medical group (54% vs. 34%; p=NS).

Medical and surgical patients with septic shock were studied by Reguiera et al. in 2008. The goal of the study was to serially collect IAP's and monitor for the development of IAH/ACS. There were 81 consecutive patients enrolled. The most common diagnoses included intra-abdominal infection (44.5%), pneumonia (27%), urinary tract infections (8.6%), soft tissue infections (8.6%), obstetric infections (4%), and oncologic infections (6%). The incidence of IAH was lower in medical patients than surgical patients (73% vs. 92%; p<0.009). Maximal IAPs were higher in non-survivors (survivors 17.2 ± 5.3, vs. non-survivors 19.9 ± 5.6 mmHg; p< 0.04). Septic shock patients required more frequent mechanical ventilation and higher doses of vasoactive medications. These patients also had significantly lower abdominal perfusion pressures (APP), higher arterial lactate levels, and higher creatinine levels when IAH was present. The incidence of IAH was 82% in this septic shock patient population. The mean reported incidence of IAH in a mixed ICU population approaches 60% (Malbrain et al. 2004). As mentioned previously, Reguiera found that medical patients with septic shock had a 73% incidence of IAH and a 21% incidence of ACS (Cothren et al. 2007). This is higher than the IAH incidence of 54.4% and ACS incidence of 2% reported in medical patients by Malbrain et al.

"A recent study by Cheatham et al. confirmed that medical patients have a significantly higher mortality following IAH/ACS (67%) compared to surgical patients (trauma 28%, emergency surgery 44%, and burns 45%; p<0.0001)."

These differences can be explained due to the predisposing nature of septic shock. These patients present commonly with bacteremia, hypotension (leading to decreased APP), massive fluid resuscitation, acidosis, coagulopathy, intra-abdominal infections, need for aggressive mechanical ventilation, ileus, and interstitial oedema due to capillary leak syndrome. All of these entities can contribute to increased volume within the abdomen and decreased abdominal compliance thereby raising IAP.

Intensivist Awareness

Early recognition of IAH/ACS is extremely important to improving survival in the critically ill, especially patients with septic shock. A survey performed by Kimball et al. was sent to 4,538 Society of Critical Care Medicine (SCCM) members of which 35.7% (1,622) responded (Kimball et al. 2006). A ten-item questionnaire addressing ICU type, training, and management of IAH/ACS was used

to determine national trends in knowledge of and treatment for ACS. Surgical intensivists managed the majority of ACS cases (47% managed 4-10 cases, and 16% managed >10 cases). 25% of medical and paediatric intensivists reported never having seen a case of ACS. Respondents agreed that intravesicular pressure measurements were needed to assess for IAH/ACS. Only 2% percent of surgical intensivists were unaware of the procedure for intravesicular pressure measurement as compared with 24% ($p<0.001$) of paediatric and 23% ($p<0.001$) of medical intensivists. 33% of paediatric intensivists and 19.6% of medical intensivists ($p<0.001$ for both groups) indicated they would never use abdominal decompression as a treatment for ACS compared with 3.6% of surgical intensivists. The authors concluded that a significant gap exists between the medical and surgical intensivist communities with regard to the awareness of and management methods for IAH/ACS.

Discussion

Critically ill medical and surgical patients clearly differ in the contributing factors that result in their illnesses. Patients in the trauma/surgical spectrum usually lack the significant comorbidities that are common in medical patients. The need for trauma/surgical ICU admission is typically because of acute injury or surgical disease in a patient that is often otherwise healthy. The organ systems of these patients are usually normal at baseline prior to the traumatic event. As a result, they usually possess significant physiologic reserve that allows them to respond to their critical injury / illness. Medical ICU patients differ in that their acute injury process (infection, myocardial infarction, sepsis, etc…) is commonly compounded by the presence of multiple comorbidities (cardiac, pulmonary, renal, endocrine, etc…). As their baseline health status is less optimal, they may not be able to respond to critical illness as well. This may explain the significant increases in IAH/ACS mortality witnessed in medical patients. The compounding effects of intestinal, renal, pulmonary, and cardiac dysfunction brought about by ACS in the medical patient may lead to a worse prognosis when compared to a young, healthy trauma or emergency surgery patient with previously normal physiologic reserve. Given the under-recognition, high prevalence, and significant morbidity and mortality of IAH/ACS in the medical patient population, additional education regarding the detrimental impact of IAH/ACS in medical ICU patients is mandatory.

> *"Development of IAH during the ICU stay was identified as an independent predictor of mortality."*

Conclusion

A multi-modality approach towards the treatment of IAH/ACS has been demonstrated to significantly improve patient survival following IAH/ACS in both medical and surgical patients (Cheatham and Safcsak 2010). Such an approach is certainly within the scope of practice of most intensivists. It is imperative, however, that medical patients developing IAH refractory to these less invasive measures receive timely evaluation by a surgeon familiar with IAH/ACS and management of the open abdomen. This practice should improve outcomes by enabling patients to receive early abdominal decompression, which leads to decreased rates of organ failure and mortality as well as earlier primary fascial closure. In this fashion, we can significantly improve upon the previously poor survival rates encountered in the medical ICU population who develops IAH/ACS. ■

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The Multi-Organ Effects of a Vicious Cycle
What Happens to the Body's Organs?
Intra-Abdominal Pressure and Intra-Abdominal Hypertension

Intra-Abdominal Pressure

Most critically ill patients have a significant systemic inflammatory response (SIRS) that triggers the release of cytokines leading to capillary permeability and interstitial edema. Abdominal viscera are particularly vulnerable as tissue edema worsens with the third spacing of resuscitative fluid. As visceral edema worsens intra-abdominal pressure (IAP) increases. As IAP increases perfusion to abdominal organs decreases resulting in compromise to visceral blood flow and tissue ischemia. Tissue ischemia then perpetuates further cytokine release and worsening systemic inflammation thus initiating the *vicious cycle*.

Intra-Abdominal Hypertension

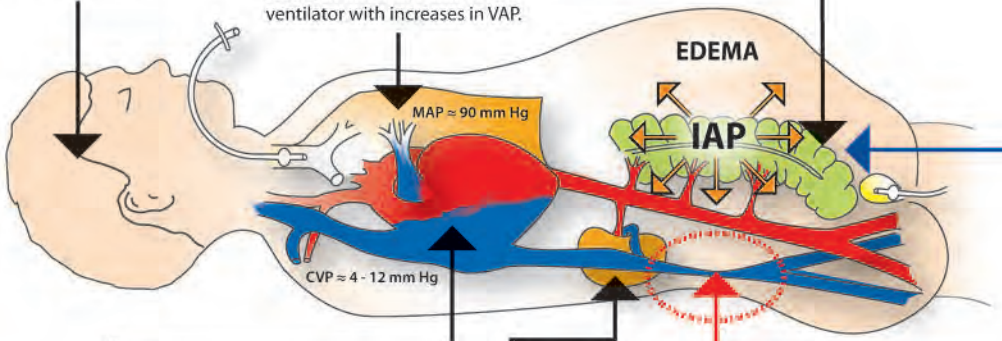
Intra-Abdominal Hypertension (IAH) is defined as Intra-Abdominal Pressure (IAP) above 12 mm Hg [1]. At which point significant tissue perfusion problems arise, which can lead to early organ dysfunction. An IAP level over 20 mm Hg typically causes organ failure and is called Abdominal Compartment Syndrome [1].

Fluid resuscitation for critical illness → Total body fluid third spacing/edema → Elevated intra-abdominal pressure due to bowel edema → Vena cava compression

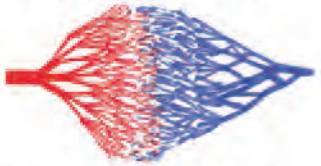
Brain: IAP elevation can directly contribute to ICP elevation.

Lungs: IAP pushes diaphragms into chest, raising intrathoracic pressure causing an increase in barotrauma, hypercarbia and hypoxemia. This results in increased time on the ventilator with increases in VAP.

Intestines: IAP compromises intestinal blood flow resulting in ischemia, necrosis and multisystem organ failure.



Impact of IAH on capillary blood flow to abdominal organs:



If IAP exceeds 15 to 20 mm Hg capillary blood flow is dramatically reduced, leading to anaerobic metabolism, increased cytokine production and exacerbation of capillary permeability (worsening bowel edema). At IAP levels approaching 20 mm Hg venous return to the heart is impaired reducing cardiac output. Decreases in systemic blood flow (CO) compounds the insult of direct tissue ischemia perpetuating the *vicious cycle*.

Heart: Cardiac monitoring, including CVP and PCWP, are artificially elevated by IAP making them difficult to interpret in the IAH setting.

Kidneys: Reduced kidney perfusion and urine production results in inability to mobilize fluids and increased rates of renal insufficiency/failure.

Vena Cava Compression: IAP greater than 8-12 mm Hg results in reduced blood flow to the heart (preload).

Multi-system organ dysfunction/failure ← Reduced blood flow to organs ← Reduced cardiac output ← Reduced blood flow to heart (preload)

[1] Results from the International Conference of Experts on Intra-abdominal Hypertension and Abdominal Compartment Syndrome. II. Recommendations Intensive Care Medicine 2007

"The Multi-Organ Effects of a Vicious Cycle" diagram above combined with intra-abdominal hypertension assessment and medical management algorithms is available as a free educational poster. **Please contact AbViser Medical, LLC at +1-801-281-3000 or email vharder@abviser.com for a free copy.**

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Patient safety in the healthcare sector has improved significantly with the appropriate use of information technology. However, there is increasing evidence that insufficient involvement of users in the design process can result in systems that fail to achieve their full potential. This case study describes one approach taken to user engagement in the design and implementation of an electronic prescribing and administration system.

Design of Healthcare Systems

Healthcare systems frequently involve multidisciplinary users working in busy and stressful environments. In these complex work environments, where safety is critical, divergence between the way in which users work and the technologies that support them can have unintended consequences and cause inefficiencies.

One approach to gaining an understanding about the users and their workflow is ethnography. Ethnography has been used to observe clinicians and their work practices (Harper et al. 1997). Rapid design prototyping is another approach that can be used to generate insights into what a solution may be. Whilst ethnography provides an understanding to users work practices, prototyping puts users in touch with the design through tangible artifacts and has been associated with successful implementation of healthcare systems (Parle and Lassere 2008). Rapid prototyping allows stakeholders to be engaged in the design process and allows a collaborative solution to be produced. "Including all points of view makes it more likely that traditional assumptions about problems and expected solutions will be challenged and possibly overturned" (Nemeth 2004). However the success of rapid prototyping does rely on the engagement of appropriate stakeholders.

User involvement presents users with an opportunity to contribute to the design and develop their understanding of the problem, in addition to providing designers with an understanding of the users' work and how the system could be designed to enhance current practice.

Participatory design is a recommended form of user involvement. This approach involves the user, actively participating as a member of the design team, to help ensure that the designed product meets their needs. Gulliksen et al. (2003) encourage active participation with representative users actively participating, early and continuously throughout the entire development process and system lifecycle.

User involvement is not always a straightforward task. Wilson et al. (1997) provided an insight into the particular challenges of adopting a collaborative approach. Obstacles to the process ranged from gaining access to the users, organising and motivating ongoing user involvement and facilitating contributions to the design.

Developing an Electronic Prescribing System

An electronic prescribing and administration system was designed to actively reduce prescribing errors and be highly usable. The development of the electronic prescribing and administration system was based on the lifecycle model for interaction design (Preece et al. 2002). This user-centred lifecycle involves four basic activities, which inform one another and are repeated continuously throughout the cycle.

A key characteristic in the process is the ongoing involvement of users (Preece et al. 2002).

Authentic User Participation

Fundamental to the success of a system, is the quality and experience of the user participation,

with hands-on user experience being a prerequisite for real user participation (Bødker and Grønbæk 1997). Thus, in this project it was important to explicitly involve users throughout the whole process, to maintain engagement and motivation and to allow effective participation.

A project team was formed at the outset, consisting of clinicians from Ninewells Hospital, Dundee and a group from the School of Computing, University of Dundee. The team comprised two consultants in anaesthesia and intensive care, the principal clinical pharmacist for critical care, the intensive care specialist liaison nurse, a nursing education specialist, a professor of interactive systems design, a professor of assistive systems and healthcare computing and a PhD computing student. Some of the individuals on the team changed during the three-year period but the professional composition was unaffected.

Maintaining Engagement

The established team was involved throughout the design, development and implementation of the system. During the three-year period, a total of forty-eight official meetings were held.

The meetings were organised to reinforce the participatory design approach. The frequency of the meetings ranged between fortnightly and monthly. Agendas were circulated in advance of the meetings with a reminder of actions from the last meeting. It was important that the meetings kept to the allocated times, all items on the agenda were addressed within the designated time and that any unresolved items were carried forward to the next meeting. The agendas and chairing were well received by the team as they allowed the meetings to be kept to time, structured and thus potentially more productive. All of the meetings were held at the hospital and were scheduled for either one or two hours accumulating a total of 227 hours of user participation.

The Participatory Approach

Activities of the participatory design approach included field studies and evolutionary prototyping. It was firstly important for the computing side of the team to gain an understanding of the intensive care environment and the way in which the different user groups worked and interacted with one another in ICU. To supplement surveys of prescription non-compliance, an ethnographic approach was adopted, where users were directly observed in the ICU with the observer granted permission to interrupt users at any time, to ask questions and converse about their work. In total, three official observations were undertaken at different times of the day; one session was at the shift change which was also the time when most medications are administered, the other two sessions occurred at random between 9 am and 5 pm. Observing the interaction between doctors, nurses and pharmacist in the ICU provided an insight into how the system could be designed to support their work practices and allowed questions to be raised about the basic assumptions that were taken for granted by the users.

Site visits to two UK hospitals that used electronic prescribing were also undertaken to gain an understanding of current systems and to learn from practioners' experiences of using them.

Evolutionary prototyping, in which the system is presented to the end users in a series of iterative prototypes, each of which gradually adds functionality, was employed. The design began as a set of paper-based prototypes that quickly enabled a visualisation of the system providing a basis for agreeing the requirements. These paper prototypes led to the development of the evolutionary software prototype. To sustain engagement and enthusiasm, regular meetings to evaluate the evolving prototype were held with the interdisciplinary team. The typical structure of these meetings was a walk-through of the prototype, with particular emphasis on recent amendments, followed by a managed discussion during which the users identified improvements and agreed recommendations for changes to the interface, to support best practice.

Adopting a process that allowed authentic user participation ensured the evolving system focused on the clinicians' requirements and allowed them to actively contribute to the design decisions.

The participatory approach also provided the computing members of the team with an improved understanding of the users' practice.

Evaluation

The electronic prescribing and administration system was evaluated on 16 different patients over a five month period; 15 paper charts and 16 electronic charts were viewed and assessed. The system was used at one bed for 76% of the time by 15 doctors, 46 nurses and the critical care pharmacist. The prescription charts, both electronic and paper, were compared for impact on prescribing errors. It was found that the overall level of prescription compliance when using the electronic system was significantly higher (91.67%) compared to the paper system (46.73%). A sample of clinicians who had used the systems were interviewed to gather their views. The sample comprised 9 doctors, 10 nurses and a pharmacist. Overall, the electronic system was preferred.

Conclusion

Authentic user participation not only involved the users in the design, development and implementation but was also used to elicit knowledge about the healthcare domain and work processes. Evolutionary prototyping was used to overcome difficulties with users envisioning their needs. The tangible product was used to elicit and validate requirements.

The authentic user participation was over a sustained period of time. Sustained engagement provided clinicians with a period of time to reflect and consider different problems and situations that are encountered in their work environment and the way in which the electronic system could/would be able to accommodate. Another advantage was the trust that emerged over time between the clinicians and computing members of the team; this meant that the clinicians felt comfortable to disclose their experience of non-compliances. This allowed a further understanding of the types of non-compliances that occurred and allowed a further exploration of ways in which the system could prevent future occurrences.

Extensive user involvement can cause users to lose motivation and the process can become counter intuitive. Wilson et al. (1997) highlighted that involving users in an effective way is a

Continued on page 43

TREATING THE PATIENT AND THEIR FAMILIES

AN INTERVIEW WITH **PROFESSOR SAID HACHIMI-IDRISSI**

For this special issue of ICU Management, Professor Saïd Hachimi-Idrissi, Head of the Paediatric Intensive Care Unit at the University Hospital of Brussels (UZ Brussels) took Managing Editor Sherry Scharff on a tour of the unit and sat down to talk about the challenges of managing paediatric patients, maintaining staff levels and avoiding burnout.

Could you take me through a standard day?

I start at 8 am and go directly to the ICU, consulting in all the units, but mainly in the paediatric wing. As a professor, I generally teach in the afternoon and evening, some days until 10 pm. Most of the courses are in intensive care medicine, and paediatric critical care and emergency medicine.

We have five ICU departments; in each department, we have six beds. One of these units is dedicated to paediatrics; one for trauma, another for cardiac care; a separate unit for cardiac surgery and a general ICU. There is an additional ICU, which we call the haematological unit that is used for burns and transplantations. Within these units, the physicians move fluidly, supervising cases based on their specific areas of expertise. We have surgeons who come to work with us from across Belgium, and in trauma and cerebral resuscitation we are doing work, which is very well respected. Another area of strength within our units is our work with ventilation techniques. In fact we were the first to work with the NAVA system in children. In the future I hope we will expand and improve further in the areas of abdominal surgery and also orthopaedic surgery.

What are the main differences in treating critically ill children vs. adults?

The approach in treating the same disease in a child is completely different than in an adult. From the very basics; that means communicating with children, withdrawing information from them… the approach must be different. Moreover, sometimes we are lucky that we have the additional information provided by the mother and father or family accompanying the child; but often this requires yet more effort on behalf of the physician, as we must approach the parents differently as well, often needing to ease anxieties in addition to retrieving information. True, we must reassure the kids, but reassure the adults that come with them as well. In fact, I would venture to say that 50 percent of the treatment that we provide in the paediatric ICU is directed at the family- from parents to grandparents, sometimes two sets even; one from each side of the family… We have to treat them all! Needless to say, it can get a bit crazy.

The second thing that is quite important for treating children, that means in contrast with adults- is that we often think they are more resilient than they indeed are. Frequently we are working with very little information about the condition from the children, and we must rely primarily on observation. The symptoms for so many conditions are the same: fever, feeling of being unwell, vomiting, diarrhoea, etc., however, sometimes there are additional symptoms, but they are misunderstood by the physician and these can be fatal. So while children can be very strong and resilient, if we are not able to make the diagnosis very quickly and indeed very accurately, we can lose the kids in less than one hour.

With children especially, we have to anticipate and prevent all the most common complications that may occur, and if those complications occur, we are behind and we might lose the patient. We must always be thinking in terms of preventative treatment; working three steps ahead.

Do you have to deal with cultural differences in treating patients?

Brussels is a cosmopolitan city. There are different backgrounds, religions, colours, languages and so on. When I was a student, we had no training on how to manage patients from different cultures, but now we have training programmes and there are lessons in the first year of medicine. The root of this is the knowledge that communication is very important in medicine and sadly this is often where we fail. We have to make sure we are attempting to communicate, and have the best approach for each patient/family. The second part related to cultural differences, is that we must be aware of the important cultural issues, so that we can take advantage of this knowledge, and offer the most suitable treatments and/or explain to patients the treatments in a way that helps them accept the course of action. For example, there is a predominant belief in most faiths that God will ultimately decide fate. My approach is often in the manner of "I am here, as a tool, with my treatments to help God" to cure their child. In most cases, the family can see and appreciate this way of thinking and accept the treat-

ment; but we must respect the differing cultural feelings and approach them individually. We must use every tool at our disposal, integrate every member of the team in the process of treating our patients and families- and key to this is the nurses. Without them we can do nothing!

Staff. What are your greatest challenges in managing staff?

In the paediatric unit, we are lacking nurses. We need more, but unfortunately finding nurses who are specialised in working in a paediatric ICU is difficult. Most nurses find it an emotionally draining and often frustrating area to work in. This can be due in part to the fact that many nurses are of the age where they themselves have young children, and they are mindful that they too could be treated in the ICU. Some nurses have an understandable problem coping with that. The other real concern with working in an emotional and stressful department such as the PICU, is that the average rate of burnout is six or seven years.

We try to target that threat of burnout by keeping staff informed, well-educated… we encourage empathy for the patients, dedication to helping them recover but also acknowledgement of the difficulties of their tasks. Keeping staff attuned to professional development is also key in keeping them committed to remaining in their roles, and maintaining respect for the work they do.

At the moment, we have the equivalent of 16 full time people working in the unit. Some of these are half time workers- so for one full time staff member, we may have two people working 50 percent of the hours. Of course, it is preferred that we have staff who are working at least 80 percent, and this works well for our nurses who are over 50 years old, and can take one or two days off additionally a month, to recuperate. We do this in order to keep them. In addition to the 16 full time staff, there is a resident and a physiotherapist as well as a part time psychologist and part time social nurse.

Do you favour long or shorter shifts in your unit?

We have three main shifts: before 7 am – 3 pm; 2 pm – 8 pm; 7 pm – 7am.

Of course, there is some overlap for handover between shifts, but it is always preferred that the shifts remain long (twelve hours) to keep consistent care in the unit. Unfortunately, this does not suit most nurses, who are usually of the age of having young children at home and keeping them from 8 am until 8 pm causes them a lot of frustration and subsequently, creates a problem in the ICU.

In terms of availability, we look to nurses in their 50's and 60's, who no longer have young children at home to work these twelve hour shifts… of course, many are not keen to work such long shifts for a number of years.

As a manager, it is important that you respect the sacrifices that workers make in order to be dedicated to their position, and you try to provide a good example. Often, this means you must sacrifice your own "free time" for the greater good before you can ask others to do the same.

> *"The ICU is not a factory….We are not manufacturing a product, we are providing an important social service and have a public impact: Our mission is to care and cure."*

I think all the staff are doing a very good job. Sure, we struggle with balancing everyone's private issues with the needs of the department, but in the end, I think most people are happy and the unit runs efficiently and effectively as a result. What more can you ask for?

Did you have some training in management?

No, I rely on my own instincts when it comes to working with people. There are a number of managers working within the hospital these days—but how can I say this diplomatically? Forget diplomacy… Hospital managers are focused on results, as we are, of patients and staff. However, their focus is with regards to how many minutes we should spend with each patient, the cost of each treatment and the amount of time staff should have off in relation to how long they have worked. There is a real element of empathy missing here, which is crucial on both sides for an important department like an ICU to run smoothly. The ICU is not a factory: We do not produce X number of bottles of water, for example, per hour with Y number of workers for such a cost. There are too many outside variables. While it is true that medicine has a business aspect to it, i.e., we must be mindful of the costs of treatments, equipment and staff and indeed, make sure we have the funds to cover it all; we are not manufacturing a product, we are providing an important social service and have a public impact: Our mission is to care and cure. This is considerably quite different from the owners, managers and workers of a manufacturing company. ■

INTENSIVE CARE MEDICINE IN SPAIN

Adapted from:
Spanish Society of Intensive and Critical Care Medicine and Coronary Units

GENERAL REPORT – 2010

Statistics:

Total Population (mid-year)
45 929 476 (2009)

Life expectancy at birth, in years
81.52 (2008)

Life expectancy at birth, in years, male
78.35 (2008)

Life expectancy at birth, in years, female
84.67 (2008)

Estimated infant mortality per 1000 live births (World Health Report)
4 (2008)

Infant deaths per 1000 live births
3.35 (2008)

Hospital beds per 100000
322.27 (2008)

Physicians per 100000
354.02 (2009)

In-patient care admissions per 100
11.59 (2008)

Total health expenditure as % of gross domestic product (GDP), WHO estimates
8.70 (2008)

Sources:
European Health for All database (HFA-DB)
www.euro.who.int

In Spain, the first units for critically ill patients, which appeared during the 1970s, were managed by anaesthetists, internists and, to a lesser extent, by cardiologists and pneumologists. The need for continuous and specific care of these critically ill patients represented the basis and origin of the specialty known as Intensive Care Medicine. The training of medical specialists (Resident Physicians [Médicos Internos y Residentes, MIR]) was legally regulated in 1978; Intensive Care Medicine was one of the recognised medical specialties. The legal framework only considered primary specialties, and there were no options for supra- or sub- specialities. The official MIR training programme (5 years), clearly defined two periods: An initial period comprising basic medical specialties, and a specific training period in Intensive Care Medicine (ICM). In 1979, the first MIR generation started its specialised training in Intensive Care Medicine – receiving the official title in 1984.

Background

In 1973, 31% of physicians working in Spanish services of intensive care medicine were specialists in internal medicine, 25% in cardiology, 16% in anaesthesiology and 9% in different areas, mainly respiratory diseases and surgery. The remaining 19% of professionals had started their work directly in the services of intensive care medicine without having passed through any other specialty.

The Spanish Society of Intensive Care Medicine and Coronary Units (Sociedad Española de Medicina Intensiva y Unidades Coronarias) was founded in 1974, five years after the creation of the first intensive care unit in Spain. Thereafter, the name of the society was changed by the Spanish Society of Intensive and Critical Care Medicine and Coronary Units (Sociedad Española de Medicina Intensiva Crítica y Unidades Coronarias, SEMICYUC), being the name by which it is still known today. Of Note: The first issue of Medicina Intensiva, the official journal of SEMICYUC, appeared in 1976. The National Cardiopulmonary Resuscitation Plan (Plan Nacional de Resucitación Cardio-Pulmonar), which was created in 1985 in the setting of the SEMICYUC.

Current Situation

The Spanish model of ICM has been positive for a number of reasons. From the healthcare perspective, the polyvalent model has been shown to be efficient, as recognised by the majority of healthcare managers because in daily practice a single specialist is able to carry out multiple tasks, extending beyond the limits of the services of intensive care medicine. As an example, intensivists play an important role in the national organ donation and transplantation programme, since in most hospitals the transplant programme coordinator is an intensivist physician.

The efficiency of the polyvalent model in the second-level hospitals has allowed intensivists to assume specific responsibilities, such as permanent pacemaker implantation or secondary risk transportation. Mention should also be made of the extension of intensivist activities to the field of emergencies, implemented in the Autonomous Community of Andalucía and also in isolated hospital centres in the rest of the country, with very positive results.

Programmes of Quality and Safety

In 2005, the scientific society published a set of quality indicators for key processes in the care of critically ill pa-

tients. A total of 120 quality indicators covering all areas and aspects of ICM were established. Twenty of these indicators were considered important enough to recommend their monitoring in all ICUs, with the other indicators depending on the case-mix of each individual ICU. The dimensions monitored with greatest frequency are safety and effectiveness. A prospective, observational, cohort study was carried out at 80 centres over a 3-month period. Compliance with five essential indicators in all patients meeting the criteria established in the quality indicators manual was monitored. Although in many hospitals the degree of compliance was high, there is still room for improvement in most of the indicators monitored. Recently, a map of 27 indicators to measure the quality of care given to patients with acute coronary syndrome attended in the pre- and hospital areas was published.

At the present time, the SEMICYUC is participating in the safety task force led by the European Society of Intensive Care Medicine (ESCIM) in the development a set of quality and safety indicators.

The SEMICYUC sponsored by the Quality Office of the Ministry of Health and Social Policy, undertook the "The Safety and Risk in Critical Patients" (SYREC) study to assess the incidence of adverse events and non-harm events, classify them, and evaluate their impact and the extent to which these events can be avoided. The probability of suffering at least one safety-related event for the only fact of being admitted to an ICU is 62%. On the day of study, 1.22 events were reported for each patient admitted to the ICU. The rate of events in our study was 5.89 per 100 patients and hour. The SYREC study showed a high individual risk for events in critically ill patients. Most events were related to medication, equipment and devices, nursing care, accidental withdrawal of catheters and other devices, or artificial airways and mechanical ventilation. Although in many cases, events did not result in harm to the patient, a significant percentage caused harm and a few were even related to the patient's death. Most events, however, were considered avoidable.

The SYREC Project has also developed a national training plan about safety and risk of the critical patient. This training programme aims to improve the safety culture in all ICUs and to facilitate training in this area for many professionals involved in the care of severely ill patients. Another important aspect of the project is the implementation of a voluntary and anonymous reporting system to identify adverse events and no-harm events.

Structures and Workforce

At the present time, around 257 services of ICM are included in the census, with a total of about 3500 beds and a mean of 12–18 beds per service (range 8–40). University-affiliated hospitals account for the largest number of intensive care beds. A total of 240,000 patients are annually attended, and the mortality rate is approximately 11%. University-affiliated hospitals accounted for the largest number of ICU beds. The majority (90%) of the services of intensive care medicine belong to the public healthcare system. The type of patients attended in these services is polyvalent, including medical, surgical, trauma and coronary patients. Only in large cities such as Madrid and Barcelona are the coronary units independent of the services of ICM. In some Autonomous Communities such as Andalucía, Emergency Departments are directly dependent upon the services of ICM.

A minority of Spanish critical care beds are dependent upon the services of Anaesthesiology. Although most the services of ICM in Spain are directed by specialists in intensive care medicine, approximately 6% of the critical care beds, the great majority of them devoted to post-surgical care, are run under the responsibility of specialists in Anaesthesiology.

In most hospitals, medical staff of the services of ICM is hierarchically structured into different professional categories: Head of service, chief of unit and attending physician. The number and professional category of the staff members vary according to the number of beds in the service and to the hospital ownership. The nursing personnel, which may or may not have specific training in critical care medicine, is an important part of the staff of the services of intensive care medicine. Nursing staff usually includes one nurse for every 2–3 intensive beds, with a distribution of three daily shifts. The nursing personnel are directed by a supervisor who in turn is dependent upon nursing management, and sometimes upon the head of the service of intensive care medicine. Furthermore, all services of ICM have additional personnel, such as administrative personnel, clinical assistants and specialised technicians. ■

For the original report including references, please visit **http://ebicm.esicm.org**

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complex issue, with factors such as user demotivation preventing the users from contributing effectively. However, in this study, by careful management of the process and the team, achieved through the regular meetings, the users remained engaged and enthusiastic throughout the design and development process.

The organisation of the team and their management were also important aspects of the process, as was the make up of the team with a representative sample of users. Their systematic involvement throughout the design, development and implementation of the system provided greater opportunity for the users to influence the design, increasing their sense of ownership of the system.

Future Work

The approach taken to create a usable electronic prescribing and administration system, that enhanced compliance with the medical prescribing process, may be capable of wider application in other healthcare application areas. Funding has been secured, in collaboration with NHS Tayside and Knowledge Transfer Partnership to take an authentic participatory approach to the design and development of a system for the surgical high dependency unit. The system will enable real-time data to be entered on certain healthcare processes, the environment in which these processes are occurring, and the outcomes from these processes whilst providing real-time feedback on this information to enable early intervention if a problem is identified. ■

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

CONTROL OF AN OUTBREAK WITH LINEZOLID-RESISTANT STAPHYLOCOCCUS AUREUS IN A SPANISH INTENSIVE CARE DEPARTMENT

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A 12-patient outbreak with linezolid-resistant Staphylococcus aureus (LRSA) developed in our intensive care department. A combination of interventions, in close collaboration with the microbiology and the preventive medicine services, were effective in controlling the outbreak within two months.

Introduction

Linezolid resistance was first reported in 2001 in a clinical isolate of S. aureus in the USA (Tsiodras et al. 2001), although it still is very uncommon in surveillance programmes (Cuevas et al. 2008; Jones et al. 2008; Jones et al. 2009). Nonetheless, linezolid and methicillin-resistant Staphylococcus aureus (LRSA) is increasingly being identified as a colonising and infecting microorganism agent both in ambulatory and hospitalised patients. At the time of writing this manuscript, 77 strains/cases of colonised and/or infected patients have been published, mostly in the years 2009, 2010 and 2011. The importance of this development resides both in the fact that MRSA is a frequent aetiology of severe, mainly respiratory tract and bloodstream, healthcare-associated and ICU infections (Alvarez-Lerma et al. 2007; Klevens et al. 2007) and that therapeutic options for severe MRSA infections are limited. Linezolid has a favourable safety profile in short-term administration, provides multi-drug resistant Gram-positive coverage and has proven to be an effective antimicrobial tool. An additional and recent factor driving its use is the rising concern about the decreasing effectiveness of vancomycin (Haque et al. 2010; Soriano et al. 2008). Linezolid is therefore widely employed as empiric and directed therapy, both in critically ill patients in ICUs, as well as in hospitalised or ambulatory patients. Antimicrobial activity of linezolid is due to protein synthesis inhibition by binding to the domain V of the 23S rRNA of the 50S subunit of bacterial ribosomes (Diekema and Jones 2001). The reported principle mechanisms of linezolid resistance documented in human isolates of S. aureus are mutations in the domain V of the 23S ribosomal RNA and, more recently, the existence of a plasmidic cfr gene (Long et al. 2006; Morales et al. 2010) encoding a methyl-transferase which modifies the binding site of linezolid on the bacterial 23S rRNA. In April 2008, we were alerted by the Microbiology Service about a positive blood culture growing LRSA and 4 weeks later, at the third isolate identified in a third patient, an LRSA outbreak was officially declared in our Intensive Care Department (Sanchez Garcia et al. 2010); to our knowledge, this was the first LRSA outbreak to be reported.

Outbreak

Our centre is a referral tertiary-care university teaching hospital in Madrid. The Intensive Care Department consists of three closed dedicated ICUs with a high mean bed occupancy rate. The outbreak involved 12 patients and the predominant clone was transmitted to the three ICUs (Figure 1) causing primary bacteraemia in three patients and ventilator-associated pneumonia in six. Affected patients had been in intensive care for approximately one month at LRSA index culture, half of them required vasopressor support and all were mechanically ventilated. 11 of the 12 patients had linezolid-susceptible MRSA prior to the de-

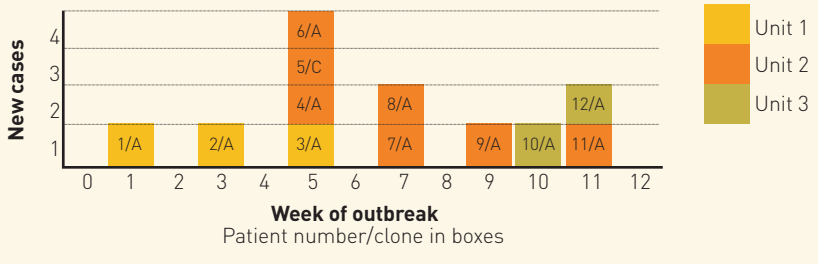

Figure 1. Spread of index cultures for LRSA over the duration of the outbreak by intensive care unit.

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tection of LRSA and had received a relatively short period of a median of 7.5 days of linezolid therapy. Infections with LRSA were treated with vancomycin and tigecycline. Hospital mortality was 50%, with one death possibly related to infection with LRSA.

Management Measures

The short duration of two months of this outbreak suggests that an effective combination of control measures was in place. Some of these measures are routinely implemented in our department and tend to limit the spread of resistant bacteria, while other, more specific interventions, were instituted upon identification of LRSA.

Disinfection

Extensive cleaning and disinfection of the patient area and equipment is daily practice in our units and it is also performed after discharge of a patient. Actually, investigation of environmental spread of LRSA resulted in negative cultures in 90 of 91 randomly selected surfaces (bedside equipment, furniture, clinical devices and the nursing station).

Prevention / Collaboration

Immediate communication of identification of bacterial multi-drug resistance (MDR) to the attending physicians and the preventive medicine service is of utmost importance for the swift implementation of the strict barrier precautions issued by the preventivists. The MRSA protocol reinforces hand washing and the use of gloves, masks and disposable gowns for patient contact, daily 4% chlorhexidine body wash, and five days of intranasal mupirocin ointment in nasal carriers.

Isolation

Specific measures implemented during this LRSA and other MDR bacterial outbreaks start with immediate placement of patients in isolation rooms under strict barrier precautions, as detailed above, until three consecutive negative weekly surveillance samples are documented. If more than two cases occur simultaneously, they are cohorted and nursed in a separate four bed ICU area.

Use of Linezolid

An important characteristic of the management of this outbreak, which should be pointed out is that the prescription of linezolid by intensivists was not restricted in any way or, much less, prohibited. Daily updates of the outbreak data were provided and discussed on clinical rounds with the attending intensivists in each unit and linezolid was reserved for documented respiratory tract and complicated skin and soft tissue infections caused by linezolid–susceptible microorganisms to take advantage of the excellent efficacy and safety profile of linezolid in selected cases. As a result, an immediate, marked, approximately 8-fold, reduction of linezolid use occurred within few weeks (Figure 2), which after definitive control of the outbreak has settled at approximately 40 to 50% of prior usage. The reduction of linezolid pressure in the ICU environment seemed a logical outbreak control measure to implement, as it is apparently, the most specific risk factor for the development of linezolid resistance. Of note is, however, that linezolid was administered to outpatients for months (Gales et al. 2006; Hentschke et al. 2008) and even years (Meka et al. 2004b; Roberts et al. 2006) before it induced mutations leading to resistance in MRSA, while inpatients had received linezolid therapy for much shorter periods of time (Kola et al. 2007; Meka et al. 2004a; Paterson et al. 2003; Peeters and Sarria 2005; Tsiodras et al. 2001; Wilson et al. 2003). Also, strains of LRSA with resistance mediated by the cfr gene, which doesn't seem to be directly induced by the presence of linezolid, are detected after relatively short durations of therapy. Cfr-mediated linezolid resistance was shown in an LRSA isolate after only two doses in the first Colombian isolate (Toh et al. 2007), without prior exposure in the US strain (Mendes et al. 2008) and after a median of 7.5 days of linezolid therapy in our outbreak. Therefore, although LRSA strains with the cfr gene may emerge due to a survival advantage in the presence of linezolid, other, yet unknown, risk factors may contribute to the emergence of LRSA. It may be speculated that cross-resistance, transmission of the plasmid from an undetected LRSA patient, or transferral of the cfr plasmid from an undetected linezolid-resistant microorganism, like coagulase-negative staphylococci, may be the mechanisms of acquisition of resistance. This implies that further studies are needed in order to identify additional effective outbreak control measures or the prevention of emergence of LRSA.

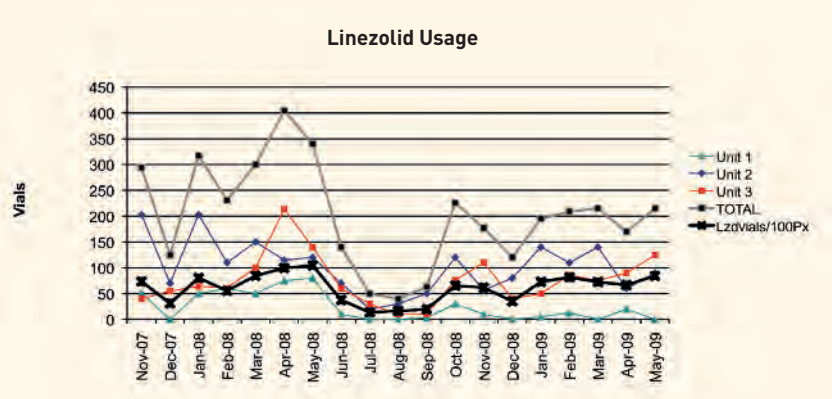

Figure 2. Linezolid (Lzd) usage in 600 mg vials per ICU, total usage, and per 100 admissions (Px).

Conclusion

Finally, the characteristics and interventions which specifically may have facilitated the rapid control of the outbreak that occurred at our institution were the absence of stable exogenous reservoirs on the hands of ICU staff and environment, with only five patients harbouring LRSA in their GI tract, and the strict barrier precautions, respectively. In conclusion, the efficient rapid control of an outbreak with LRSA in the ICU department was attained by a combination of control measures mainly consisting of barrier precautions, environmental cleaning and reduction of linezolid use. ■

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

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www.espen.org

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1–5 24th ESICM LIVES Annual Congress
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14–15 ERC Resuscitation 2011
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www.erc.edu

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