Review

Year in review 2006: *Critical Care* - cardiology

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Abstract

This review summarizes key research papers published in the fields of cardiology and intensive care during 2006 in *Critical Care* and, where relevant, in other journals within the field. The papers have been grouped into categories: haemodynamic monitoring, vascular access in intensive care, microvascular assessment and manipulation, and impact of metabolic acidosis on outcome.

Haemodynamic monitoring

Successful use of central venous oxygen saturation ($ScvO_2$) in the management of early sepsis [1] has led to interest in the use of this variable in high-risk patients who are undergoing major surgery, in whom the concept of goal-directed therapy is well established [2-4]. The collaborative study group on perioperative $ScvO_2$ monitoring has conducted a multicentre pilot study to assess the incidence of low $ScvO_2$ in high-risk surgical patients and its impact on outcome in terms of postoperative complications. Takala and coworkers [5] included all patients satisfying two or more of the criteria proposed by Shoemaker and coworkers [2], who were undergoing major surgery, defined as an intra-abdominal or retroperitoneal procedure with an expected duration of at least 90 min. In the 60 patients studied, low perioperative $ScvO_2$ was associated with a greater risk for complications, with a mean value of 73% for discriminating between patients who did and those who did not develop complications (72% sensitivity and 61% specificity). This is in close agreement with values observed in healthy volunteers [6] and, more importantly, with the 8-hour postoperative mean $ScvO_2$ of 75% seen in the complication-free patients in the optimization study conducted by Pearse and coworkers [7].

The group was successful in establishing grounds for an interventional trial with $ScvO_2$ as a therapeutic goal, within the context of other physiological targets, in perioperative settings in which a value of 75% is targeted with intravenous fluids and inotropes. Until such a study has been completed, use of this physiological variable in the perioperative setting should be considered with care [8].

Sander and colleagues [9] were first to report the wide discrepancy between cardiac output measured using new arterial waveform analysis hardware that is claimed not to require any calibration [10,11] (Flotrac sensor and Vigileo monitor; Edwards Lifesciences, Irvine, CA, USA) and cardiac output measured using the intermittent thermodilution technique via a pulmonary artery floatation catheter (PAFC). Thirty patients undergoing coronary artery bypass graft surgery with a preoperative ejection fraction in excess of 40% were studied. Cardiac output was measured using PAFC intermittent thermodilution and transpulmonary thermodilution using PiCCO (PULSION Medical Systems AG, Munich, Germany) [12,13], in addition to the noncalibrated arterial waveform analysis device under scrutiny. Readings were taken after induction, 15 min after sternotomy, 1 hour after admission to the intensive care unit, and after 6 hours. The percentage error between PAFC intermittent thermodilution and the new device varied from 36% 1 hour postoperatively to 70% before cardiopulmonary bypass, which are higher than the acceptable limits [14]. Subsequent studies [15,16] reaffirmed the findings reported by Sander and colleagues, and further developments on this cardiac output monitor are required before it can be implemented into clinical practice.

Cannesson and colleagues [17] described a technique that relies on stroke area (left ventricular end-diastolic area - left ventricular systolic area) variability, as measured using automated border detection with trans-oesophageal echocardiography (TOE) [18,19]. This was tested on 20 patients scheduled for coronary artery bypass grafting, in which stroke area variability and cardiac output were measured after the onset of anaesthesia and mechanical ventilation, and reassessed after a passive leg raise (PLR) manoeuvre. A positive response to the latter was defined as an increase in cardiac

OR = odds ratio; PAFC = pulmonary artery floatation catheter; PLR = passive leg raise; $ScvO_2$ = central venous oxygen saturation; TOE = trans-oesophageal echocardiography.

output of 15%, as calculated using velocity time integral obtained by TOE from the long-axis transgastric view. Stroke area variability, as hypothesized by the authors, can be used to predict fluid responsiveness, and the value of 16% was found to have a sensitivity of 92% and specificity of 83%.

The fact that the study patients had preserved cardiac function and were mechanically ventilated with tidal volumes of 10 ml/kg limits the applicability of this trial to the wider population of intensive care patients. The accuracy of automated border detection is limited in the presence of myocardial dysfunction [20]. Also, stroke area variability may not be as good a predictor of fluid responsiveness when a lung protective ventilatory strategy is adopted (low tidal volume and high positive end-expiratory pressure) [20,21].

Cannesson and colleagues [17] also highlighted the importance of pulse pressure variability, which was measured in patients before and after the PLR manoeuvre. Their findings indicate that this variable is a good predictor of fluid responsiveness in this group of patients, exhibiting no signficant difference from stroke area variability, as measured using TOE with automatic border detection. This is in accordance with previous work conducted in this field [22]. However, Heenen and coworkers [23] demonstrated the limitations of pulse pressure variability when they studied 21 patients with spontaneous breathing through a mask or on pressure support mode. All patients recruited had arterial and central venous catheters placed, in addition to cardiac output monitoring. Baseline haemodynamic variables were noted before and after fluid loading, which was administered on the clinical basis of arterial hypotension, tachycardia, or oliguria. A 15% increase in cardiac output was considered a positive response, and this was observed in nine patients out of 21. Baseline pulse pressure variability was not significantly different between responders and nonresponders, and interestingly static indices such as pulmonary artery occlusion pressure and right atrial pressure had better predictive value.

On the same theme of fluid responsiveness, Lafanchère and colleagues [24] looked into the effect of PLR manoeuvre on descending aortic blood flow, left ventricular ejection time and pulse pressure variation in 22 mechanically ventilated patients with circulatory failure. Their findings show that a PLR-induced increase in descending aorta flow by 8% predicts fluid responsiveness with a sensitivity of 90% and specificity of 83%, whereas baseline pulse pressure variation of more than 12% is 70% sensitive and 92% specific. Left ventricular ejection time compared poorly with these variables in terms of predicting fluid responsiveness, which is in accordance with the findings of previous studies [25]. This technique of combining PLR with descending aortic blood flow measurements shows promise in patients with spontaneous breathing activity, according to Monnet and coworkers [26], who found other indices such as pulse pressure variability to predict fluid responsiveness poorly.

Critical Care devoted a supplement to the contentious issue of the use (or misuse) of PAFCs in the intensive care unit. The introductory editorial [27] briefly discusses all of the important studies done in this field, and alerts the reader to the fact that the safety and efficacy of this haemodynamic monitoring tool is coherently linked to operator interpretation of the results and subsequent therapeutic interventions based on this interpretation. Detailed reviews covering specific aspects of the applications of pulmonary artery catheters follow [28-30], and the supplement draws to a close with an evidence-based critique of the impact data and complications in relation to pulmonary artery catheters by Hadian and Pinsky [31]. The authors here conclude, after carefully examining all the relevant data, that 'routine use of pulmonary artery catheters should be discontinued unless coupled to a defined treatment protocol of proven efficacy.'

Vascular access in intensive care

Central to peripheral arterial pressure variation is a well recognized phenomenon [32] in which it is thought that distal pulse amplification results in increased systolic and decreased diastolic pressure in the peripheral circulation, as compared with central measurements, but no difference in mean pressure [32,33]. Blood pressure in intensive care patients is conventionally monitored continuously using invasive radial artery catheters connected to a transduction system to allow for rapid detection of any fluctuations and titration of vasoactive therapy. Because mean arterial pressure is targeted in this context, radial artery cannulation is thought to provide a rationale and practical estimate of central pressure. However, a clinically significant difference was recognized at the termination of hypothermic cardiopulmonary bypass, in which radial artery pressures underestimated central pressures [34-36]. Further work followed, which showed that in patients on high doses of noradrenaline (norepinephrine), systolic and mean arterial pressures were lower in the radial artery than in the femoral artery, which may lead to excessive administration of vasoactive drugs [37].

Mignini and colleagues [38] revisited this issue by simultaneously collecting radial and femoral artery waveforms from 55 medical and surgical patients, and analyzed the data using the Bland and Altman method [39]. The authors identified no difference between the two methods in measuring arterial pressure, regardless of the use of vasoactive drugs; these findings are in contrast to those reported by Dorman and coworkers [37]. This discrepancy may be related to the latter group using longer femoral catheters (30 cm versus 16 cm) and the different statistical methodology used.

Lorente and colleagues [40] conducted an observational study looking into arterial catheter-related infections in relation to the site of cannulation. A total of 2,949 arterial catheters were inserted under full sterile barrier precautions and catheter dressing was changed daily. Incidences of catheter-related local and bloodstream infection were 0.68%

and 0.59%, respectively, which is significantly less than reported elsewhere [41]. The femoral artery catheters carried the greatest risk for catheter-related local (odds ratio [OR] 1.5; $P = 0.01$) and bloodstream infections (OR 1.9; $P = 0.09$) compared with radial artery lines. Although previous work did not identify a significant difference in the incidence of arterial catheter-related infections in relation to the access site [42], these findings are consistent with many studies concerning central venous catheter-related infections, including recent work reported by the same group [43]. It is worth noting the different population characteristics between the patients who had radial artery catheters and patients who had femoral artery catheters, despite the similar Acute Physiology and Chronic Health Evaluation II score; 43.2% of the group were post-cardiac surgery and 12.7% were trauma admissions, as opposed to 14.6% post-cardiac surgery and 22.5% trauma admissions in the femoral artery group. This difference may well have had an impact on the likelihood of developing catheter-related infections because it certainly had a statistically significant effect on the median length of stay in intensive care, which was 10 days in patients who had femoral artery catheters as compared with 3 days in patients who had radial artery catheters ($P < 0.001$). In addition, the unit in which this study was conducted used povidone iodine solution to disinfect the insertion site, as opposed to the currently recommended chlorhexidine-based solutions [44,45], and applied occlusive rather than semi-permeable dressing [46]. These factors may have influenced the results, considering the high density of bacterial flora in the femoral region.

Whether ultrasound-guided central venous access should be part of routine practice remains an issue of considerable debate [47-50], but this argument has been virtually resolved in the critical care setting owing to the elegant work of Karakitsos and colleagues [51]. Their trial involved 900 mechanically ventilated critical care patients, who were randomly assigned either to insertion of a central line using the landmark method or to real-time ultrasound guidance. The investigators found the success rate in the latter group to be 100%, the average time required to access the vein was shorter (17 ± 17 s versus 44 ± 95 s) and fewer attempts were required (1.1 ± 0.6 attempts versus 2.6 ± 2.9 attempts). There was a major impact on the incidences of complications ($P < 0.001$), specifically carotid puncture (1.1% versus 10.6%), haematoma formation (0.4% versus 8.4%), haemothorax (0% versus 1.7%), pneumothorax (0% versus 2.4%) and even central venous catheter bloodstream infection (10.4% versus 16%). These findings clearly put beyond doubt the superiority of ultrasound-guided central venous access, which should be considered as a standard of care in our intensive care units.

Microvascular assessment and manipulation

Buise and coworkers [52] studied the effect of nitroglycerin on microvascular blood flow, as measured by laser Doppler flowmetry, in patients undergoing oesophagectomy. The basis of this work was the relatively frequent anastomotic breakdown that occurs in this group of patients, which may be related to tissue hypoxia of the reconstructed gastric tube [53], and previous work conducted by the same group showing a significant improvement in microvascular blood flow when topical nitroglycerin was applied to the gastric fundus where the future gastric tube is to be reconstructed [54]. Thirty-two patients undergoing oesophagectomy were randomly assigned, in a double-blinded fashion, to receive intravenous nitroglycerin or saline during gastric tube construction, and microvascular blood flow and haemoglobin concentration and its oxygen saturation were monitored at the gastric tube fundus. The findings showed no differences in these microvascular variables between the study groups. It is of note that patients who received intravenous nitroglycerin maintained a higher heart rate throughout the procedure. Also, considering that both groups had a standardized amount of fluid intraoperatively, the difference in heart rate between the two groups can be a compensatory mechanism for the reduction in cardiac output as a result of nitroglycerin-mediated venodilatation [55,56]. This might have led to compromised microvascular flow. Alternatively, the intravenous dose required may be greater than was used in this study.

Metabolic acidosis and outcome

Gunnerson and colleagues [57] examined the impact of different causes of acidosis on outcome. They retrospectively examined intensive care patients whose physicians had requested a lactate level measurement based on clinical suspicion. A total of 548 patients had a standard base excess of below -2 mEq/l; these patients had a mortality rate of 45%, as compared with 25% for those without metabolic acidosis ($P < 0.001$). The cause of the acidosis had a bearing on outcome; lactic acidosis, which was the commonest (44%), also had the highest associated mortality of 56%, as compared with 39% and 29% for strong ion gap and hyperchloraemic acidosis, respectively. The latter associated mortality was not statistically significant from that in the nonacidotic group, which is somewhat reassuring because hyperchloraemic acidosis is commonly observed in intensive care practice as a consequence of intravenous fluid therapy. Another important finding was the association of elevated plasma phosphate with high mortality (OR 1.2; $P < 0.0001$). A further finding of note from this paper was the lack of association between worsening base deficit and mortality when the underlying cause of metabolic acidosis was accounted for.

Conclusion

This review covers a disparate group of subjects ranging from technology for measuring cardiac output to methodology for minimizing the risks associated with insertion of central venous lines. It also covers the assessment of fluid responsiveness both in ventilated and in spontaneously breathing patients, microcirculatory flow in major surgery and the predictive ability of metabolic acidosis.

This wide spectrum of subject matter nicely illustrates the eclectic nature of the cardiological section of *Critical Care*. It also confirms the wide ranging research interests of the intensive care community. We hope that these interests will continue and expand.

Competing interests

The authors declare that they have no competing interests.

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