CRITICAL CARE

REVIEW

Year in review 2011: *Critical Care* – cardiology

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Abstract

We review key research papers in cardiology and intensive care published during 2011 in *Critical Care* and quote related studies published in other journals whenever appropriate. Papers are grouped into the following categories: cardiovascular therapies, mechanical therapies, biomarkers, prognostic markers, hemodynamic monitoring, cardiovascular diseases, microcirculation, hypertension in critically ill patients, and miscellaneous.

Introduction

We review key research papers in intensive care cardiology published during 2011 in *Critical Care*. Related studies published in other journals are also discussed, whenever appropriate.

Cardiovascular therapies

Inotropic agents are used to increase oxygen delivery in the perioperative setting but their impact on mortality is not well defined. In a retrospective study including 1,326 cardiac surgery patients, those exposed to inotropes had, as expected, a higher unadjusted mortality rate than those patients not exposed [1]. After adjustment, inotrope exposure was still associated with increased hospital mortality and renal dysfunction. A propensity score-matched analysis yielded similar results. A limitation of this trial is that this type of analysis only takes into account measured variables, but other factors may play a role. Postoperative inotrope exposure may thus be associated with worse outcomes, but this should be tested in interventional trials.

Should nonadrenergic inotropic agents be preferred? A meta-analysis evaluated the effects of levosimendan, versus control, in patients after percutaneous or surgical cardiac revascularization [2]. The meta-analysis included 729 patients from 17 studies. Levosimendan increased the cardiac index. Compared with controls, levosimendan treatment was associated with a mortality reduction after coronary revascularization (odds ratio = 0.40, 95% confidence interval (CI) = 0.21 to 0.76) and a reduction in the length of ICU stay. An important limitation of this analysis is that most of the studies included were small sized, and that there was an important heterogeneity in dosing and time of administration of levosimendan as well as in drugs used in the control arms. This potentially beneficial effect of levosimendan should be evaluated in a large-scale randomized trial.

Another meta-analysis evaluated the renal effects of carperitide, an atrial natriuretic peptide, and nesiritide, a B-type natriuretic peptide (BNP) [3]. The systematic review included 15 studies (11 with carperitide and four with nesiritide), of which nine were included in the meta-analysis. There was no difference in mortality rates. Both drugs increased urine output, creatinine clearance and glomerular filtration rate, and reduced the use of diuretics, renal replacement therapy and length of ICU and hospital stay. Unfortunately most trials were small sized and these results should be confirmed in a larger randomized trial.

Anticoagulation during use of mechanical devices is a continuous challenge. Ranucci and colleagues retrospectively compared a conventional heparin-based anticoagulation protocol with a bivalirudin-based protocol in 21 patients submitted to extracorporeal membrane oxygenation (ECMO) after cardiac operations [4]. Patients treated with bivalirudin achieved significantly better coagulation variables. Thromboembolic complications did not differ between groups but bivalirudin patients required less blood product transfusions. Accordingly, bivalirudin appears to be an attractive alternative to conventional heparin, but this agent should be tested in a randomized trial.

Mechanical therapies

Two papers report single-center experience of using mechanical interventions. One study looked at the potential benefit of routine coronary angiography after out-of-hospital cardiac arrest (OHCA). Cronier and colleagues evaluated a series of 111 consecutive hemodynamically stable patients resuscitated from OHCA due to ventricular fibrillation and treated with mild

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therapeutic hypothermia [5]. Emergency coronary angiography was performed in most patients, regardless of the electrocardiogram pattern. Most patients (73%) had coronary heart disease, but this incidence was lower in patients <45 years old than in other groups (41% vs. 81%; $P = 0.01$). Percutaneous coronary intervention was associated with survival. These results were extended later this year in a larger database of 1,040 OHCA patients in Germany that reported similar benefits whatever the initial rhythm [6]. The potential benefits of a combination of angiography and mild therapeutic hypothermia were discussed in an accompanying editorial [7].

The other paper described the use of an intra-aortic balloon pump, ECMO and continuous-flow left ventricular assist devices in six patients with peripartum cardiomyopathy [8]. Two patients showed partial recovery and could be weaned off the intra-aortic balloon pump while four patients were implanted with a left ventricular assist device, including the ECMO patient. Three left ventricular assist device patients were successfully transplanted. Mechanical support should be considered in patients with peripartum cardiomyopathy not responding to medical therapy. The choice of the support and optimal timing of implantation is still under debate.

Biomarkers

Several studies evaluated in various settings the usefulness of biomarkers to understand pathophysiological processes, to guide therapy or to refine diagnosis.

Biomarkers as an inside to pathophysiology

Post-cardiac surgery vasoplegia frequently occurs, especially after prolonged cardiopulmonary bypass. A perioperative course of copeptin (a vasopressin precursor) and vasopressin plasma concentrations were studied in 64 consecutive patients submitted to elective cardiac surgery [9]. Patients with vasoplegia had lower vasopressin concentrations 8 hours after surgery compared with controls. Interestingly, these patients had a significantly higher copeptin plasma concentration, hyponatremia and a lower ejection fraction before cardiopulmonary bypass compared with controls. They also experienced more complex surgery. A preoperative copeptin concentration >9.43 pmol/l predicted the occurrence of postoperative vasoplegia. These results suggest that preoperative activation of the vasopressin system before surgery may induce vasopressin deficiency after surgery, through depletion of endogenous hypothalamopituitary stores.

Microvascular permeability in burn injury leads to central hypovolemia and tissue edema. In 38 consecutive patients with severe burn injury, BNP and proteinuria were used to assess evolution of microvascular permeability [10]. BNP increased from admission to day 3 and then reached a plateau. Patients with higher BNP had lower proteinuria and received less fluids than the other patients. This observation suggests that high BNP/low proteinuria can be used as a marker of microvascular permeability. Even though low permeability is associated with a better outcome, it is not clear whether these biomarkers may help to guide resuscitation.

Biomarkers as a guide for therapy

BNP and N-terminal pro-B-type natriuretic peptide (NT-proBNP) are often used to identify patients with increased hydrostatic pressure. To evaluate whether changes in BNP and NT-proBNP may help to better characterize the response to therapy, these were measured at presentation, 24 hours, 48 hours and discharge in 171 consecutive patients presenting to the emergency department with acute decompensated heart failure [11]. BNP and NT-proBNP levels were higher in nonsurvivors than in survivors at all time points (all P <0.001). Treatment reduced BNP and NT-proBNP levels in survivors by more than 50% (P <0.001), while treatment in nonsurvivors did not lower BNP and NT-proBNP levels. Evolution of these markers can be used to early assess treatment efficacy.

C-type natriuretic peptide and N-terminal pro-C-type natriuretic peptide (NT-proCNP) may reflect vascular activation in sepsis. The ability of NT-proCNP (measured at ICU admission, day 3 and day 7) to identify sepsis was evaluated in 273 critically ill patients [12]. Patients with sepsis had higher NT-proCNP levels than nonsepsis patients. NT-proCNP was strongly associated with inflammatory parameters and severity of disease. Elevated NT-proCNP levels at admission and day 3 predicted death, while NT-proCNP decline after the initial measurement was associated with reduced mortality compared with stable or increasing levels. Although interesting, this biomarker was not superior to conventional prognostic indicators.

Cell-free DNA is detected in blood in many diseases, including sepsis and pancreatitis, but also in healthy individuals. Cell-free DNA can originate from necrotic cells or apoptotic processes, but is also released by living cells. Levels of plasma cell-free DNA and their prognostic value were evaluated in 580 patients needing mechanical ventilation in 25 Finnish ICUs [13]. Blood samples were taken at study admission (day 0) and on day 2. Plasma cell-free DNA concentrations were similar at day 0 and day 2. Concentrations at admission were significantly higher in 90-day nonsurvivors than survivors, and remained an independent predictor of 90-day mortality in a multivariate logistic regression analysis. However, its clinical benefit as a prognostic marker seems to be limited given the relatively low area under the curve (AUC) (0.624, 95% CI = 0.572 to 0.676). This AUC is

indeed lower than in patients after OHCA (0.796, 95% CI = 0.701 to 0.890) [14], which was discussed in the accompanying editorial [15].

Biomarkers for diagnosis

High-sensitivity troponin has been reported to facilitate the early diagnosis of acute myocardial infarction [16]. The diagnostic performances of high-sensitivity troponin and conventional troponin for the diagnosis of acute myocardial infarction were compared in 317 consecutive patients presenting to the emergency department with chest pain suggestive of acute myocardial infarction [17]. The pretest probability of acute myocardial infarction was assessed without knowledge of troponin results. In the low to moderate pretest probability group, high-sensitivity troponin levels ≥0.014 μg/l identified acute myocardial infarction with a higher sensitivity than cardiac troponin I. As specificity of high-sensitivity troponin was lower, the AUCs were similar for high-sensitivity troponin and cardiac troponin I. Interestingly, the positive predictive value was lower for high-sensitivity troponin than for cardiac troponin I (47% vs. 78%, P <0.05) but the negative predictive value was not different (99% vs. 95%) for the entire population, with similar trends in different pretest probability subgroups. These results cast some doubts on the diagnostic accuracy of high-sensitivity troponin compared with cardiac troponin I.

Prognostic factors in cardiovascular diseases

Pulmonary embolism remains associated with significant mortality. The prognostic value of markers of right ventricular dysfunction in pulmonary embolism was evaluated in a meta-analysis that retrieved eight echocardiographic marker-based studies (n = 1,249), three computed tomography marker-based studies (n = 503) and seven natriuretic peptide-based (BNP) studies (n = 582) [18]. The presence of right ventricular dysfunction determined by echocardiography and biological markers but not by computed tomography was associated with short-term mortality in patients with pulmonary embolism without hemodynamic compromise on admission. However, the current prognostic value in clinical practice remains very limited due to insufficient pooled positive and negative likelihood ratios.

Acute heart failure is another acute life-threatening disease leading to ICU admission. A large database of 4,153 patients hospitalized with acute heart failure was used to evaluate factors associated with outcome [19]. *De novo* heart failure was seen in 58.3% of the patients. Mortality varied from 62.7% in cardiogenic shock, to 16.7% in right heart failure, to 7.1% in pulmonary edema, to 6.1% in high-output heart failure, to <2.5% in hypertensive or diastolic heart failure. Invasive ventilation and age >70 years were the most important predictive factors for mortality, with or without cardiogenic shock.

Hemodynamic monitoring

Cardiac output measurements

Analysis of the arterial pressure trace is a common way to non-invasively determine cardiac output (CO). Calibration is often required. The number of injections required at each calibration point was evaluated in 91 hemodynamically stable patients monitored by a $PiCCO_2$ device (Pulsion, Munich, Germany) [20]. At least three injections should be performed, which allows precision to drop below 10%: 8% (6 to 12%) for CO, 8% (6 to 14%) for global end-diastolic volume and 8% (7 to 14%) for extravascular lung water. These results are important, both for routine and investigational use.

The impact of vasopressor use on accuracy of pulse contour measurements of CO was evaluated in 330 data pairs of pulse contour and transpulmonary thermodilution CO measurements from 73 noncardiac surgery critically ill patients [21]. Pulse contour-derived CO was recorded immediately before calibration. Agreement between the two methods was analyzed according to norepinephrine dosage and a time interval between calibrations of up to 24 hours. Pulse contour CO had a mean bias of 0.16 l/minute with a percentage error of 38%. Bias was not affected by the norepinephrine dosage or the time elapsed between calibrations.

Some of the usually calibrated devices also have an uncalibrated version. These devices are mostly dedicated to evaluating changes in CO. The noncalibrated pulse power CO (LiDCO; LiDCO, London, UK) was compared with transpulmonary thermodilution (PiCCO; Pulsion) in 42 patients [22]. Several points were obtained before and after cardiopulmonary bypass. Before bypass, the percentage error was very high (86%). Changes in CO were not adequately tracked. This study is unfortunately limited by the acquisition of multiple (and variable) numbers of observations per patient.

There is a continuous search to develop new devices that non-invasively measure CO. An innovative technique based on measurement of spatial patterns of voltage changes distributed over the thoracic skin has been presented [23]. When applying a weak electric current over the thorax, emptying and filling of the ventricles during the cardiac cycle induce cyclic voltage changes on the thoracic skin, generating specific two-dimensional spatial patterns. Analysis of these patterns may enable measurement of changes in ventricular volume. In a pig model, CO was measured with the new device and an ultrasonic flow probe positioned around the ascending aorta. Correlation between the two methods was excellent (r = 0.978). Bias was minimal (0.114 l/minute) and limits of agreement were satisfactory

(0.55 l/minute). This device therefore appears promising but requires further validation.

New applications

A new application for transpulmonary thermodilution was proposed. Severely burned children often develop circulatory failure and increased permeability. This prospective cohort study evaluated the feasibility of transpulmonary thermodilution (PiCCO) for hemodynamic measurements in 69 severely burned children [24]. CO significantly increased from admission and was highest 3 weeks post burn. The intrathoracic blood volume index and the extravascular lung water index begin to increase at days 8 to 9 post burn, and the extravascular lung water index was significantly higher in patients who did not survive burn injury. These data indicate that the hyperdynamic state occurs 1 week post burn injury.

Echocardiography

Several articles used echocardiography to assess hemodynamic function in critically ill patients. Assessment of left ventricular function is an area of intense interest. Several echocardiographic indices for the assessment of left ventricular systolic function were compared in 50 patients with shock [25]. Transthoracic echocardiographic evaluation was obtained daily for 7 days. All measured indices were easy to obtain. The eyeball ejection fraction was the most reliable and easiest index to obtain for the evaluation of systolic function.

Transthoracic echocardiography can be used for the diagnosis of left ventricular thrombosis in the postoperative care unit [26]. Five cases were observed in 160 patients. Thrombi were observed in three of 35 patients with ischemic cardiomyopathy and in two of 21 patients with dilated cardiomyopathy. Of note, these thrombi were absent in preoperative echocardiograms. These thrombi were probably facilitated by local low-flow conditions and the postoperative procoagulant state. Clinicians should be aware of this potential postoperative complication.

Central venous oxygen saturation and lactate

Even though low central venous oxygen saturation values are associated with a poor outcome in patients with septic shock, the prognostic value of high central venous oxygen saturation values is not well determined. The relation between maximal central venous oxygen saturation levels within the first 72 hours after the onset of shock and ICU survival was evaluated in a single-center retrospective study including 152 patients in a 2-year period [27]. The maximal level of central venous oxygen saturation was higher in nonsurvivors compared with the survivors (85% (78 to 89%) vs. 79% (72 to 87%), respectively; $P = 0.009$). As the accompanying editorial commented [28], multiple causes may contribute to an increased central venous oxygen saturation, including microcirculatory alterations [29,30], decreased oxygen handling by the cells due to mitochondrial dysfunction [31], and excessive inotropic/fluid therapy.

Evolution of lactate levels over the first 24 hours may reflect adequacy of resuscitation. The prognostic value of time-weighted lactate levels was evaluated in 5,041 consecutive critically ill patients from four Australian university hospitals [32]. Both the time-weighted average lactate and the change in lactate over the first 24 hours were independently predictive of hospital mortality. The combination of both computations significantly outperformed ($P < 0.0001$) static indices of lactate concentration, such as admission lactate, maximum lactate and minimum lactate. The same group recently reported in the same database that time-weighted relative hyperlactatemia, defined as time-weighted lactate between 1 and 2 mmol/l, is also associated with a significant increase in risk of death [33]. Altogether these results show that dynamic indices of hyperlactatemia in the first 24 hours following ICU admission are associated with outcome and are superior to static measurements of blood lactate levels.

Fluid responsiveness

Optimization of fluid therapy is a topic of intense research. Cardiac filling volumes and pressures are often used to guide fluid administration. The relative value of cardiac filling volume and pressures for predicting fluid responsiveness was evaluated in 32 patients after cardiovascular surgery [34]. Regardless of the ejection fraction, baseline central venous pressure was lower in responding events. The pulmonary artery occlusion pressure was more useful than the global end-diastolic volume index for predicting fluid responsiveness when the ejection fraction was low, but when the ejection fraction is near normal the volume index is more useful than the occlusion pressure. Could filling pressures be determined on chest X-ray imaging? The vascular pedicle width is determined on chest X-ray imaging and is a non-invasive measurement of intravascular volume status. The vascular pedicle width and central venous pressure or pulmonary artery occlusion pressure were measured in 152 patients with acute lung injury [35]. This retrospective cohort is a substudy of the Fluid and Catheter Treatment Trial [36]. The vascular pedicle width correlated with the pulmonary artery occlusion pressure and central venous pressure. A vascular pedicle width ≥72 mm identified a pulmonary artery occlusion pressure ≥18 mmHg with an AUC of 0.69 ($P = 0.001$) but, admittedly, with modest sensitivity and specificity (61% for both).

Dynamic indices better predict fluid responsiveness than static indices. A closed-loop fluid-management

algorithm using a patient simulator including a pulse pressure variation output was tested in three phases [37]. In different hemorrhage scenarios, the algorithm better maintained hemodynamics compared with no management. In the second phase, compared with 20 practicing anesthesiologists for the management of a simulated hemorrhage scenario, the algorithm intervened earlier, gave more fluids and better preserved CO. The algorithm was relatively insensitive to noise and artifacts.

Dynamic indices may be limited by several factors. Respiratory variation in plethysmography, as a consequence of stroke volume variations, can non-invasively predict volume responsiveness [38]. Vasoconstriction altered this signal in 67 patients [39]. Plethysmography variability was related to pulse pressure variation in patients not receiving norepinephrine, while this relationship was lost in patients treated with norepinephrine. In the latter, plethysmography variations were unable to predict the response to fluids. The tidal volume may also affect pulse pressure variations [40]. Lakhal and colleagues observed in 65 patients with acute respiratory distress syndrome that variations in pulse pressure fail to predict fluid responsiveness [41]. The importance of the driving pressure was illustrated well [42]: pulse pressure variation adequately predicted fluid responsiveness in the subgroup of patients experiencing a respiratory variation in pulmonary artery occluded pressure >4 mmHg, reflecting large changes in pleural pressure. When these indices are ineffective, one may consider using the passive leg raising test. Interestingly, this test can be applied even in the most severe patients such as patients treated with venovenous ECMO [43]. In 17 patients, an increase in stroke volume >10% during passive leg raising predicted the response to fluids.

The increase in arterial pressure during fluid administration depends not only on the increase in CO but also on arterial tone. However, predicting whether a given patient would present increased arterial pressure before performing fluid administration remains challenging. Monge García and colleagues present an elegant method to evaluate vascular tone [44]. These authors computed dynamic arterial elastance as the slope of pulse pressure variations divided by stroke volume variations over the same respiratory cycle. In 25 preload responsive patients, dynamic arterial elastance >0.89 predicted an increase in arterial pressure in response to volume loading in preload-dependent patients with a sensitivity of 93.75% (95% CI = 69.8 to 99.8%) and a specificity of 100% (95% CI = 66.4 to 100%).

Perioperative management of high-risk surgical patients

Perioperative hemodynamic optimization is recommended in high-risk surgical patients [45]. Cecconi and colleagues extend this concept somewhat [46]. They randomized 40 patients submitted to elective total hip arthroplasty under regional anesthesia to receive either conventional hemodynamic therapy or goal-directed hemodynamic therapy (GDT). Patients randomized to the GDT group received a greater volume of intravenous fluids, more red blood cell transfusions, and more dobutamine during the intraoperative period, although control group patients received greater volumes of blood replacement postoperatively. There was an increased number of complications in the control group compared with GDT patients (100 vs. 80%; $P = 0.05$), predominantly due to a difference in minor complications. This trial is nevertheless in line with another trial in the field, using the same monitoring tool [47]. In a meta-analysis including 26 randomized trials, perioperative goal-directed therapy was also found to decrease infections, including surgical site infections (pooled odds ratio = 0.58, 95% CI = 0.46 to 0.74; P <0.0001), pneumonia (pooled odds ratio = 0.71, 95% CI = 0.55 to 0.92; $P = 0.009$), and urinary tract infections (pooled odds ratio = 0.44, 95% CI = 0.22 to 0.84; $P = 0.02$) [48].

Fluids are an important part of GDT. Cuthbertson and colleagues conducted a multicenter randomized controlled trial of fluid loading in 111 high-risk surgical patients undergoing major elective abdominal surgery (the FOCCUS study) [49]. The patients underwent preoperative fluid loading with 25 ml/kg Ringer's solution in the 6 hours before surgery and the control group had no preoperative fluid loading. Patients in the intervention group spent fewer days in hospital after surgery (mean 12.2 (standard deviation 11.5) days compared with 17.4 (20.0) days) and presented an adjusted mean difference of 5.5 days (median 2.2 days; 95% CI = −0.44 to 11.44; $P = 0.07$). There was a reduction in adverse events in the intervention group ($P = 0.048$).

However, giving fluids as a fixed amount may not be optimal. The effects of a restrictive versus conventional strategy of crystalloid administration during goal-directed therapy were tested in 88 high-risk surgical patients [50]. Patients were randomized to receive 4 ml/kg/hour (restrictive) or 12 ml/kg/hour (conventional) Ringer's lactate solution as fluid maintenance during surgery. In both groups, dobutamine and fluid challenges were administered as necessary to optimize oxygen delivery. The conventional treatment group received a significantly greater amount of fluids than the restrictive group but oxygen delivery was similar in the two groups. The restrictive group had a 52% lower rate of major postoperative complications than the conventional group ($P = 0.046$). This further illustrates that fluids should be given as needed but not using fixed amounts.

Finally, how frequently is GDT applied? Current hemodynamic management practices in patients undergoing

high-risk surgery in Europe and in the United States were evaluated in a survey among members of the American Society of Anesthesiologists and the European Society of Anaesthesiology [51]. CO is monitored by only 34% of American Society of Anesthesiologists and European Society of Anaesthesiology respondents (P = 0.49), while central venous pressure is monitored by 73% of American Society of Anesthesiologists respondents and by 84% of European Society of Anaesthesiology respondents (P <0.01). The pulmonary artery catheter is being used more frequently in the United States than in Europe in the setup of high-risk surgery (85.1% vs. 55.3%, P <0.001). These results indicate a considerable gap between clinical practices in Europe and the United States. Of note, technologies required for perioperative hemodynamic optimization were used only by one-third of responders.

Microcirculation

This year, several trials also focused on the microcirculation. The microcirculatory effects of fluids were investigated using near-infrared spectroscopy during a vascular occlusion test during 42 fluid challenges in patients undergoing major abdominal surgery [52].

Before fluids, the tissue oxygen saturation recovery slope was lower in positive fluid challenges than in negative fluid challenges (P = 0.02) while baseline tissue oxygen saturation did not differ. Volume expansion increased the tissue oxygen saturation recovery slope both in positive fluid challenges (62 ± 49%, P <0.001) and in negative fluid challenges (26 ± 34%, P = 0.04). Hence, fluid loading significantly improved the tissue oxygen saturation recovery slope, even when associated with ineffective changes in systemic hemodynamics.

The effects of vasopressin agonists on sublingual microcirculation were evaluated in 60 patients with septic shock [53]. These patients were randomized to receive continuous infusions of either terlipressin (1 μg/kg/hour), vasopressin (0.04 U/minute) or placebo (isotonic saline). Terlipressin and vasopressin decreased norepinephrine requirements at the end of the 6-hour study period. There were no differences in sublingual microcirculatory variables and systemic hemodynamics among the three study groups during the entire observation period.

Hypertension in critically ill patients

Euro-STAT is an observational study performed in 11 hospitals in seven European countries including 791 consecutive adult patients treated with intravenous antihypertensive therapy in the emergency department, perioperative unit or ICU [54]. Nitroglycerine was the most commonly used antihypertensive treatment (40% of patients), followed by urapidil (21%), clonidine (16%) and furosemide (8%). Hypotension occurred in 10% of patients.

What is the best therapy for acute hypertension? In a multicentric trial in 226 patients, nicardipine-treated patients more often reached target pressure within 30 minutes than labetalol-treated ones (91.7% vs. 82.5%, P = 0.039) [55]. Use of rescue medications did not differ between nicardipine and labetalol treatment (15.5% vs. 22.4%, P = 0.183). Nicardipine may thus more rapidly control hypertension.

Miscellaneous

Is it useful to drain pleural effusions in mechanically ventilated patients? A meta-analysis including 19 observational studies and 1,124 patients showed that effusion drainage improved the PaO_2:FiO_2 ratio by 18% [35]. Complication rates were low for pneumothorax (3.4%) and hemothorax (1.6%). Ultrasound guidance was not associated with a reduction in the risk of pneumothorax.

Abbreviations

AUC, area under the curve; BNP, B-type natriuretic peptide; CI, confidence interval; CO, cardiac output; ECMO, extracorporeal membrane oxygenation; GDT, goal-directed hemodynamic therapy; NT-proBNP, N-terminal pro-B-type natriuretic peptide; NT-proCNP; N-terminal pro-C-type natriuretic peptide; OHCA, out-of-hospital cardiac arrest; PaO_2:FiO_2, ratio of partial pressure of arterial oxygen to the fraction of inspired oxygen.

Competing interests

The authors declare that they have no competing interests.

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References

1. Shahin J, DeVarennes B, Tse CW, Amarica DA, Dial S: **The relationship between inotrope exposure, six-hour postoperative physiological variables, hospital mortality and renal dysfunction in patients undergoing cardiac surgery.** *Crit Care* 2011, **15:**R162.
2. Maharaj R, Metaxa V: **Levosimendan and mortality after coronary revascularisation: a meta-analysis of randomised controlled trials.** *Crit Care* 2011, **15:**R140.
3. Mitaka C, Kudo T, Haraguchi G, Tomita M: **Cardiovascular and renal effects of carperitide and nesiritide in cardiovascular surgery patients: a systematic review and meta-analysis.** *Crit Care* 2011, **15:**R258.
4. Ranucci M, Ballotta A, Kandil H, Isgrò G, Carlucci C, Baryshnikova E, Pistuddi V; Surgical and Clinical Outcome Research Group: **Bivalirudin-based versus conventional heparin anticoagulation for postcardiotomy extracorporeal membrane oxygenation.** *Crit Care* 2011, **15:**R275.
5. Cronier P, Vignon P, Bouferrache K, Aegerter P, Charron C, Templier F, Castro S, El Mahmoud R, Lory C, Pichon N, Dubourg O, Vieillard-Baron A: **Impact of routine percutaneous coronary intervention after out-of-hospital cardiac arrest due to ventricular fibrillation.** *Crit Care* 2011, **15:**R122.
6. Gräsner JT, Meybohm P, Caliebe A, Böttiger BW, Wnent J, Messelken M, Jantzen T, Zeng T, Strickmann B, Bohn A, Fischer H, Scholz J, Fischer M; German Resuscitation Registry Study Group: **Postresuscitation care with mild therapeutic hypothermia and coronary intervention after out-of-hospital cardiopulmonary resuscitation: a prospective registry analysis.** *Crit Care* 2011, **15:**R61.
7. Golia E, Piro M, Tubaro M: **Out-of-hospital CPR: better outcome for our patients.** *Crit Care* 2011, **15:**149.
8. Gevaert S, Van Belleghem Y, Bouchez S, Herck I, De Somer F, De Block Y, Tromp F, Vandecasteele E, Martens F, De Pauw M: **Acute and critically ill peripartum cardiomyopathy and 'bridge to' therapeutic options: a single center experience with intra-aortic balloon pump, extra corporeal membrane oxygenation and continuous-flow left ventricular assist devices.** *Crit Care* 2011, **15:**R93.

9. Colson PH, Bernard C, Struck J, Morgenthaler NG, Albat B, Guillon G: **Post cardiac surgery vasoplegia is associated with high preoperative copeptin plasma concentration.** *Crit Care* 2011, **15:**R255.
10. de Leeuw K, Nieuwenhuis MK, Niemeijer AS, Eshuis H, Beerthuizen GI, Janssen WM: **Increased B-type natriuretic peptide and decreased proteinuria might reflect decreased capillary leakage and is associated with a better outcome in patients with severe burns.** *Crit Care* 2011, **15:**R161.
11. Noveanu M, Breidthardt T, Potocki M, Reichlin T, Twerenbold R, Uthoff H, Socrates T, Arenja N, Reiter M, Meissner J, Heinisch C, Stalder S, Mueller C: **Direct comparison of serial B-type natriuretic peptide and NT-proBNP levels for prediction of short- and long-term outcome in acute decompensated heart failure.** *Crit Care* 2011, **15:**R1.
12. Koch A, Voigt S, Sanson E, Dückers H, Horn A, Zimmermann HW, Trautwein C, Tacke F: **Prognostic value of circulating amino-terminal pro-C-type natriuretic peptide in critically ill patients.** *Crit Care* 2011, **15:**R45.
13. Okkonen M, Lakkisto P, Korhonen AM, Parviai-nen I, Reinikainen M, Varpula T, Pettilä V; FINNALI Study Group: **Plasma cell-free DNA in patients needing mechanical ventilation.** *Crit Care* 2011, **15:**R196.
14. Arnalich F, Menéndez M, Lagos V, Ciria E, Quesada A, Codoceo R, Vazquez JJ, López-Collazo E, Montiel C: **Prognostic value of cell-free plasma DNA in patients with cardiac arrest outside the hospital: an observational cohort study.** *Crit Care* 2010, **14:**R47.
15. Arnalich F, Lopez-Collazo E, Montiel C: **Diagnostic potential of circulating cell-free DNA in patients needing mechanical ventilation: promises and challenges.** *Crit Care* 2011, **15:**187.
16. Keller T, Zeller T, Ojeda F, Tzikas S, Lillpopp L, Sinning C, Wild P, Genth-Zotz S, Warnholtz A, Giannitsis E, Möckel M, Bickel C, Peetz D, Lackner K, Baldus S, Münzel T, Blankenberg S: **Serial changes in highly sensitive troponin I assay and early diagnosis of myocardial infarction.** *JAMA* 2011, **306:**2684-2693.
17. Freund Y, Chenevier-Gobeaux C, Bonnet P, Claessens YE, Allo JC, Doumenc B, Leumani F, Cosson C, Riou B, Ray P: **High-sensitivity versus conventional troponin in the emergency department for the diagnosis of acute myocardial infarction.** *Crit Care* 2011, **15:**R147.
18. Coutance G, Cauderlier E, Ehtisham J, Hamon M, Hamon M: **The prognostic value of markers of right ventricular dysfunction in pulmonary embolism: a meta-analysis.** *Crit Care* 2011, **15:**R103.
19. Spinar J, Parenica J, Vitovec J, Widimsky P, Linhart A, Fedorco M, Malek F, Cihalik C, Spinarová L, Miklik R, Felsoci M, Bambuch M, Dusek L, Jarkovsky J: **Baseline characteristics and hospital mortality in the Acute Heart Failure Database (AHEAD) Main registry.** *Crit Care* 2011, **15:**R291.
20. Monnet X, Persichini R, Ktari M, Jozwiak M, Richard C, Teboul JL: **Precision of the transpulmonary thermodilution measurements.** *Crit Care* 2011, **15:**R204.
21. Gruenewald M, Meybohm P, Renner J, Broch O, Caliebe A, Weiler N, Steinfath M, Scholz J, Bein B: **Effect of norepinephrine dosage and calibration frequency on accuracy of pulse contour-derived cardiac output.** *Crit Care* 2011, **15:**R22.
22. Broch O, Renner J, Höcker J, Gruenewald M, Meybohm P, Schöttler J, Steinfath M, Bein B: **Uncalibrated pulse power analysis fails to reliably measure cardiac output in patients undergoing coronary artery bypass surgery.** *Crit Care* 2011, **15:**R76.
23. Konings MK, Grundeman PF, Goovaerts HG, Roosendaal MR, Hoefer IE, Doevendans PA, Rademakers FE, Buhre WF: **In-vivo validation of a new non-invasive continuous ventricular stroke volume monitoring system in an animal model.** *Crit Care* 2011, **15:**R165.
24. Branski LK, Herndon DN, Byrd JF, Kinsky MP, Lee JO, Fagan SP, Jeschke MG: **Transpulmonary thermodilution for hemodynamic measurements in severely burned children.** *Crit Care* 2011, **15:**R118.
25. Bergenzaun L, Gudmundsson P, Öhlin H, Düring J, Ersson A, Ihrman L, Willenheimer R, Chew MS: **Assessing left ventricular systolic function in shock: evaluation of echocardiographic parameters in intensive care.** *Crit Care* 2011, **15:**R200.
26. Saranteas T, Alevizou A, Tzoufi M, Panou F, Kostopanagiotou G: **Transthoracic echocardiography for the diagnosis of left ventricular thrombosis in the postoperative care unit.** *Crit Care* 2011, **15:**R54.
27. Textoris J, Fouché L, Wiramus S, Antonini F, Tho S, Martin C, Leone M: **High central venous oxygen saturation in the latter stages of septic shock is associated with increased mortality.** *Crit Care* 2011, **15:**R176.
28. Haase N, Perner A: **Central venous oxygen saturation in septic shock – a marker of cardiac output, microvascular shunting and/or dysoxia?** *Crit Care* 2011, **15:**184.
29. De Backer D, Creteur J, Preiser JC, Dubois MJ, Vincent JL: **Microvascular blood flow is altered in patients with sepsis.** *Am J Respir Crit Care Med* 2002, **166:**98-104.
30. Top AP, Tasker RC, Ince C: **The microcirculation of the critically ill pediatric patient.** *Crit Care* 2011, **15:**213.
31. Protti A, Singer M: **Bench-to-bedside review: potential strategies to protect or reverse mitochondrial dysfunction in sepsis-induced organ failure.** *Crit Care* 2006, **10:**228.
32. Nichol A, Bailey M, Egi M, Pettila V, French C, Stachowski E, Reade MC, Cooper DJ, Bellomo R: **Dynamic lactate indices as predictors of outcome in critically ill patients.** *Crit Care* 2011, **15:**R242.
33. Nichol AD, Egi M, Pettila V, Bellomo R, French C, Hart G, Davies A, Stachowski E, Reade MC, Bailey M, Cooper DJ: **Relative hyperlactatemia and hospital mortality in critically ill patients: a retrospective multi-centre study.** *Crit Care* 2010, **14:**R25.
34. Trof RJ, Danad I, Reilingh MW, Breukers RM, Groeneveld AB: **Cardiac filling volumes versus pressures for predicting fluid responsiveness after cardiovascular surgery: the role of systolic cardiac function.** *Crit Care* 2011, **15:**R73.
35. Goligher EC, Leis JA, Fowler RA, Pinto R, Adhikari NK, Ferguson ND: **Utility and safety of draining pleural effusions in mechanically ventilated patients: a systematic review and meta-analysis.** *Crit Care* 2011, **15:**R46.
36. National Heart, Lung, and Blood Institute Acute Respiratory Distress Syndrome (ARDS) Clinical Trials Network, Wiedemann HP, Wheeler AP, Bernard GR, Thompson BT, Hayden D, deBoisblanc B, Connors AF Jr, Hite RD, Harabin AL: **Comparison of two fluid-management strategies in acute lung injury.** *N Engl J Med* 2006, **354:**2564-2575.
37. Rinehart J, Alexander B, Le Manach Y, Hofer C, Tavernier B, Kain ZN, Cannesson M: **Evaluation of a novel closed-loop fluid-administration system based on dynamic predictors of fluid responsiveness: an in silico simulation study.** *Crit Care* 2011, **15:**R278.
38. Keller G, Cassar E, Desebbe O, Lehot JJ, Cannesson M: **Ability of pleth variability index to detect hemodynamic changes induced by passive leg raising in spontaneously breathing volunteers.** *Crit Care* 2008, **12:**R37.
39. Biais M, Cottenceau V, Petit L, Masson F, Cochard JF, Sztark F: **Impact of norepinephrine on the relationship between pleth variability index and pulse pressure variations in ICU adult patients.** *Crit Care* 2011, **15:**R168.
40. De Backer D, Heenen S, Piagnerelli M, koch M, Vincent JL: **Pulse pressure variations to predict fluid responsiveness: influence of tidal volume.** *Intensive Care Med* 2005, **31:**517-523.
41. Lakhal K, Ehrmann S, Benzekri-Lefèvre D, Runge I, Legras A, Dequin PF, Mercier E, Wolff M, Régnier B, Boulain T: **Respiratory pulse pressure variation fails to predict fluid responsiveness in acute respiratory distress syndrome.** *Crit Care* 2011, **15:**R85.
42. Muller L, Louart G, Bousquet PJ, Candela D, Zoric L, de La Coussaye JE, Jaber S, Lefrant JY: **The influence of the airway driving pressure on pulsed pressure variation as a predictor of fluid responsiveness.** *Intensive Care Med* 2010, **36:**496-503.
43. Guinot PG, Zogheib E, Detave M, Moubarak M, Hubert V, Badoux L, Bernard E, Besserve P, Caus T, Dupont H: **Passive leg raising can predict fluid responsiveness in patients placed on venovenous extracorporeal membrane oxygenation.** *Crit Care* 2011, **15:**R216.
44. Monge Garcia MI, Gil CA, Gracia RM: **Dynamic arterial elastance to predict arterial pressure response to volume loading in preload-dependent patients.** *Crit Care* 2011, **15:**R15.
45. Pearse R, Dawson D, Fawcett J, Rhodes A, Grounds M, Bennett D: **Early goal directed therapy following major surgery reduces complications and duration of hospital stay. A randomized, controlled trial.** *Crit Care* 2005, **9:**R687-R693.
46. Cecconi M, Fasano N, Langiano N, Divella M, Costa MG, Rhodes A, Della Rocca G: **Goal-directed haemodynamic therapy during elective total hip arthroplasty under regional anaesthesia.** *Crit Care* 2011, **15:**R132.
47. Mayer J, Boldt J, Mengistu A, Rohm KD, Suttner S: **Goal-directed intraoperative therapy based on autocalibrated arterial pressure waveform analysis reduces hospital stay in high-risk surgical patients: a randomized, controlled trial.** *Crit Care* 2010, **14:**R18.
48. Dalfino L, Giglio MT, Puntillo F, Marucci M, Brienza N: **Haemodynamic goal-directed therapy and postoperative infections: earlier is better. A systematic review and meta-analysis.** *Crit Care* 2011, **15:**R154.
49. Cuthbertson BH, Campbell MK, Stott SA, Elders A, Hernández R, Boyers D,

Norrie J, Kinsella J, Brittenden J, Cook J, Rae D, Cotton SC, Alcorn D, Addison J, Grant A; FOCCUS study group: **A pragmatic multi-centre randomised controlled trial of fluid loading in high-risk surgical patients undergoing major elective surgery – the FOCCUS study.** *Crit Care* 2011, **15:**R296.

50. Lobo SM, Ronchi LS, Oliveira NE, Brandão PG, Froes A, Cunrath GS, Nishiyama KG, Netinho JG, Lobo FR: **Restrictive strategy of intraoperative fluid maintenance during optimization of oxygen delivery decreases major complications after high-risk surgery.** *Crit Care* 2011, **15:**R226.
51. Cannesson M, Pestel G, Ricks C, Hoeft A, Perel A: **Hemodynamic monitoring and management in patients undergoing high risk surgery: a survey among North American and European anesthesiologists.** *Crit Care* 2011, **15:**R197.
52. Futier E, Christophe S, Robin E, Petit A, Pereira B, Desbordes J, Bazin JE, Vallet B: **Use of near-infrared spectroscopy during a vascular occlusion test to assess the microcirculatory response during fluid challenge.** *Crit Care* 2011, **15:**R214.
53. Morelli A, Donati A, Ertmer C, Rehberg S, Kampmeier T, Orecchioni A, Di Russo A, D'Egidio A, Landoni G, Lombrano MR, Botticelli L, Valentini A, Zangrillo A, Pietropaoli P, Westphal M: **Effects of vasopressinergic receptor agonists on sublingual microcirculation in norepinephrine-dependent septic shock.** *Crit Care* 2011, **15:**R217.
54. Vuylsteke A, Vincent JL, de La Garanderie DP, Anderson FA, Emery L, Wyman A, Rushton-Smith S, Gore JM; Euro-STAT Investigators: **Characteristics, practice patterns, and outcomes in patients with acute hypertension: European registry for Studying the Treatment of Acute hyperTension (Euro-STAT).** *Crit Care* 2011, **15:**R271.
55. Peacock WF, Varon J, Baumann BM, Borczuk P, Cannon CM, Chandra A, Cline DM, Diercks D, Hiestand B, Hsu A, Jois-Bilowich P, Kaminski B, Levy P, Nowak RM, Schrock JW: **CLUE: a randomized comparative effectiveness trial of IV nicardipine versus labetalol use in the emergency department.** *Crit Care* 2011, **15:**R157.

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