American Journal of Emergency Medicine 32 (2014) 629–633

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Original Contribution

Clinical evaluation compared to the pulse indicator continuous cardiac output system in the hemodynamic assessment of critically ill patients☆,☆☆

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ARTICLE INFO

Article history:
Received 10 January 2014
Received in revised form 30 January 2014
Accepted 16 March 2014

ABSTRACT

Objective: The objective was to assess the effects of pulse indicator continuous cardiac output catheterization on the management of critically ill patients and the alteration of therapy in intensive care units.
Methods: One hundred thirty-two patients with primary physiological abnormalities of hypotension or hypoxemia were evaluated. Prior to catheterization, physicians were asked to complete a questionnaire that collected information regarding predictions of the ranges of several hemodynamic variables and plans for therapy. After catheterization, each chart was reviewed by a panel of intensive care attending physicians to determine the possibility of altering the therapy.
Results: Overall correct classification of the key variables ranged from 46.0% to 65.4%. Catheterization results prompted alterations in therapy for 45.5% of patients. The fellows were less accurate in predicting hemodynamic values for patients whose diagnoses were unknown, and the primary abnormality was hypotension. There was significant difference in the physicians' abilities to predict the hemodynamics for the subgroups with and without acute myocardial infarction. When the patients were divided into 3 subgroups by Acute Physiology and Chronic Health Evaluation II and Sepsis-related Organ Failure Assessment scores, the fellows had the most difficulty predicting the variables of the moderately ill patients in the middle subgroup, which led to the greatest percentage of therapy alterations for this subgroup; and this difference was significant.
Conclusions: The hemodynamic variables obtained from pulse indicator continuous cardiac output catheterization improved the accuracy of bedside evaluations and led to alterations in therapeutic plans, particularly among the moderately ill patients with hypotension or unknown diagnoses.

1. Introduction

The optimal management of cardiopulmonary physiological disorders among critically ill patients requires an accurate assessment of hemodynamic status. The introduction of pulmonary artery catheterization (PAC) in the 1970s led to an extreme expansion of the field of hemodynamic monitoring [1,2]. Pulmonary artery catheterization has been proven to always be superior to careful clinical evaluation including physical examination, laboratory examination, and chest roentgenogram in terms of determining hemodynamic status; and it has been shown that the measurements obtained by PAC often prompt changes in therapy [3–9].

However, controversies regarding the overuse of PAC for hemodynamic monitoring exist [10–12]. The effect of PAC on the improvement of patient outcomes is still debated, and the assistance that PAC provides is partially offset by the high associated risk of serious complications and mortality. Recently, a variety of advanced hemodynamic monitoring techniques that are safer and less invasive have been generally used in clinical settings as substitutes for PAC. Among these techniques, the pulse indicator continuous cardiac output (PiCCO) system has been extensively extremely used and provides accurate assessments of constant and dynamic hemodynamic statuses, provides aid in the determination of immediate and subsequent therapies, and correlates well with PAC measurements [13–17].

Despite the widespread use of the PiCCO system, there are few data documenting the superiority of this system in the assessment of hemodynamic status over that of careful clinical evaluation; and the information obtained from PiCCO alters the management of critically ill patients. Our study was designed to prospectively appraise whether PiCCO provides additional useful information beyond that obtained by careful clinical evaluation. Additionally, we evaluated the frequency with which the results of PiCCO resulted in alteration of planned therapies.

2. Methods

2.1. Study site and patients

This prospective evaluation of PiCCO catheterization was performed in the intensive care unit (ICU) of the China-Japan Friendship

☆ Conflict of interest: The authors have no potential conflicts of interest to disclose.
☆☆ Financial support: This study was not supported by any foundation.
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http://dx.doi.org/10.1016/j.ajem.2014.03.023
0735-6757/

Hospital between February 2008 and June 2013. One hundred eighty-three consecutive patients with primary physiological abnormalities of hypotension or hypoxemia were entered into this study. After the exclusion of patients with insufficient data, the data from 132 remaining patients were analyzed. *Hypotension* was defined as a systolic blood pressure (SBP) less than 90 mm Hg or a decrease in SBP of greater than 40 mm Hg compared to baseline. *Hypoxemia* represented impaired oxygenation and was defined as Pao_2/Fio_2 less than or equal to 300. Patients meeting the following exclusion criteria were excluded: (1) younger than 18 years; (2) contraindications to catheterization, including concomitant infection and arterial grafting; (3) history of hemorrhagic shock; (4) moribund state or inability to obtain informed consent; and (5) conditions likely to render the PiCCO measurements inaccurate, including large aortic aneurysms, intracardiac shunts, and significant mitral/tricuspid regurgitation [18].

2.2. Experimental protocols

A 5F thermistor-tipped catheter (Pulsiocath PV2015L20, PiCCO plus; Pulsion Medical Systems, Munich, Germany) was inserted into the femoral artery of the patient. A double-lumen central venous catheter was inserted into the internal jugular vein or subclavian vein. Three central venous injections of 15-mL boluses of cold isotonic saline were injected within 7 seconds, PiCCO was measured at each of these time points, and the values analyzed were the average of these 3 consecutive measurements. All operations were performed according to this procedure by ICU physicians under the supervision of fellows, and all catheter positions were confirmed via standard portable chest radiograph.

2.3. Data collection

Prior to the insertion of the PiCCO catheter, the team of ICU physicians, which consisted of a critical care attending physician, a critical care fellow, and a resident, was required to complete a questionnaire. The questionnaire collected information from the ICU physician team regarding the purpose of catheterization (diagnostic or monitoring), the primary physiological abnormality of the patient (hypotension or hypoxemia), and the major clinical indication for PiCCO (septic shock, acute respiratory distress syndrome [ARDS], acute myocardial infarction [AMI], congestive heart failure, hypovolemic shock, pulmonary edema, pancreatitis, pulmonary embolism, etc). The physician team was then asked to predict the ranges of the key hemodynamic variables of cardiac index (CI), global end-diastolic index (GEDI), systemic vascular resistance index (SVRI), and extravascular lung water index (EVLWI) asked on all previous clinical information (Table 1).

Additionally, the ICU team was also asked to indicate a plan for therapy based on the predicted hemodynamic profile by selecting a plan from the list of potential therapeutic options presented in Table 2.

After catheterization and the first measurement of the hemodynamic variables, a review panel composed of 2 critical care attending physicians reevaluated the hemodynamic data to determine whether alterations to the predicted therapy plan should be made.

Major changes in therapy were defined as changes in the type of therapy (ie, changes in volume management from fluid expansion to restriction, changes in vasoactive agents from constrictors to dilators, and the initiation of an inotropic drug), and *minor changes* were defined as differences within a single type of therapy (ie, the usage of diuretic drugs vs continuous renal replacement therapy for the fluid restriction or the use of dopamine vs norepinephrine for vessel constriction). The absence of alterations in anticipated therapy was defined by the absence of adjustments in treatment, and simple alterations in drug dosages (eg, a change in dobutamine dose from 8 to 12 μg/[kg min] or a change fluid infusion from 300 to 400 mL/h) were not interpreted as alterations in therapy.

Table 1
Definition of ranges

	CI (L/[min m^2])	GEDI (mL/m^2)	SVRI (dyn·s·cm^{-5}·m^2)	EVLWI (mL/kg)
Low	<3	<680	<1200	≤7
Medium	3-5	680-800	1200-2000	8-12
High	>5	>800	>2000	≥13

Table 2
Therapeutic options

	Major options	Minor options
Volume management	Fluid expansion	Crystalloid infusion
		Colloid infusion
	Fluid balance	
	Fluid restriction	Diuretic drugs
		Hemodialysis
		Continuous renal replacement therapy
Vasoactive medication	Constrictor	Dopamine
		Norepinephrine
	Dilator	Sodium nitroprusside
		Nitroglycerin
		Urapidil
		Nicardipine
		Diltiazem
Inotropic agent	Inotropic drug	Cedilanid
		Dobutamine
		Mirinone

2.4. Statistical analyses

Statistical analyses were performed with SPSS 17.0 software (SPSS Inc, Chicago, IL). The data are presented as the means ± the standard deviations. χ^2 tests were used to compare qualitative data, and the Fisher exact probability test was used for small sample sizes as appropriate. *t* tests were used to compare quantitative data. All *P* values at or below .05 were considered statistically significant.

3. Results

3.1. Characteristics of the patients at baseline

One hundred thirty-two patients were entered into the study and underwent PiCCO catheterization. Cases of repeated catheterizations were excluded because the prior results may have influenced the later predictions. The sample included 76 men (57.6%) and 56 women (42.4%) with a mean age of 63.4 years (range, 24-89 years). Eighty-three patients had hypotension, and these patients had significantly lower SBPs and higher heart rates, higher Pao_2/Fio_2 ratios, and higher lactate concentrations than did the remaining 49 patients who had hypoxemia (Table 3).

3.2. Complications of catheterization

Serious complications and problems occurring during insertion were uncommon. The incidence of hemorrhage from the femoral arterial puncture site was 6.8% (9/132). These hemorrhages were reduced or stopped by compression and were predominately observed in the patients with coagulation problems. Ventricular (premature ventricular contractions) and atrial arrhythmias were observed in 5 patients (3.8%) at the time of cold saline injection, and these arrhythmias recovered within 10 seconds without requiring antiarrhythmic therapy.

3.3. Overall predictions of hemodynamic variables

There were 396 sets of predictions of CI, GEDI, SVRI, and EVLWI for the 132 patients. The accuracies of the physicians' predictions of the 4 hemodynamic variables are indicated in Fig. 1. The physicians were