Complications related to less-invasive haemodynamic monitoring‡

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Editor’s key points

- Transpulmonary thermodilution (TPTD) has been developed as an alternative to invasive haemodynamic monitoring with a pulmonary artery catheter (PAC).
- This study examined the type and incidence of complications during the insertion, use, and removal of 514 arterial catheters used for TPTD.
- The use of TPTD catheters did not increase the risk of complications when compared with the commonly used short peripheral arterial catheters or PAC.

Background. The aim of this study was to evaluate the type and incidence of complications during insertion, maintenance, and withdrawal of central arterial catheters used for transpulmonary thermodilution haemodynamic monitoring (PiCCO™).

Methods. We conducted a prospective, observational, multicentre study in 14 European intensive care units (six countries). A total of 514 consecutive patients in whom haemodynamic monitoring by PiCCO™ was indicated were studied.

Results. Five hundred and fourteen PiCCO catheters (475 in femoral, 26 in radial, nine in axillary, and four in brachial arteries) were inserted. Arterial access was obtained on the first attempt in 86.4% of the patients. Minor problems such as oozing after insertion (3.3%) or removal of the catheter (3.5%) were observed, but no episodes of serious bleeding (more than 50 ml) were recorded. Small local haematomas were observed after insertion (4.5%) and after removal (1.2%) of the catheter. These complications were not more frequent in patients with coagulation abnormalities. The incidence of site inflammation and catheter-related infection was 2% and 0.78%, respectively. Other complications such as ischaemia (0.4%), pulse loss (0.4%), or femoral artery thrombosis (0.2%) were rare, transient, and all resolved with catheter removal or embolectomy, respectively.

Conclusions. In this series of patients, central arterial catheters used for PiCCO™ monitoring were demonstrated to be a safe alternative for advanced haemodynamic monitoring.

Keywords: arteries, cannulation; complications; monitoring, cardiopulmonary

Accepted for publication: 31 October 2010

Monitoring in the intensive care unit (ICU) is regarded as essential for managing critically ill patients. However, most monitoring techniques have not been found to improve outcome per se.1 It seems reasonable to accept that monitoring devices are useful as long as they do not of themselves cause frequent significant complications and are coupled to treatments that improve outcome.2

The pulmonary artery catheter (PAC) is an established monitoring tool for cardiac output and other haemodynamic variables. However, its ‘risk-to-benefit’ ratio has become a subject of controversy over the last decade. A recent review3 showed that the use of PAC was associated with an increased risk of arrhythmias during insertion, infections and thrombotic complications during prolonged...
use (>48 h), and rarely pulmonary artery rupture and death.4,5

Transpulmonary thermodilution with integrated pulse contour analysis (PiCCO™) monitoring system (PULSION Medical System, Munich, Germany) has been developed as an alternative to haemodynamic monitoring with the PAC. This monitoring device is less invasive than the PAC because it allows the assessment of cardiopulmonary haemodynamics without contact between the catheter and the cardiopulmonary structures. PiCCO™ use requires the insertion of a generic central venous catheter and a specific arterial catheter equipped with a thermistor.6 Most commonly, the arterial catheter is inserted into the femoral artery. The brachial or axillary artery approaches serve as alternatives to the femoral route when femoral cannulation is contraindicated or not feasible (aortic-femoral bypass, femoral arteriopathy, morbid obesity, etc). The technique has also recently been validated using a long catheter (4 F, 50 cm long) placed in the radial artery with the thermistor tip located at the axillary artery level.7

Although the PiCCO™ system is promoted as a means of minimally invasive haemodynamic monitoring, data on complications on the use of PiCCO™ arterial catheters are lacking. We therefore designed a prospective observational study with the main objective of determining the type and incidence of complications during the insertion, use, and withdrawal of the arterial catheter used for PiCCO™ haemodynamic monitoring. As a secondary objective, we assessed the influence of factors that may affect complications.

Methods

This prospective observational multicentre study was conducted in 14 European ICUs from six different countries. Consecutive patients (>18 yr old) in whom a central arterial catheter was indicated for PiCCO™ monitoring were included. The study was approved by the Institutional Review Boards of participating hospitals. The use of the monitoring technique was ordered by the attending physician according to local institutional protocols. Data on complications during the insertion, monitoring period, and withdrawal of the arterial catheter were collected by senior staff.

Procedures were performed under sedation. Catheter insertion was conducted after the guidelines of the Center for Disease Control (CDC) for the prevention of intravascular catheter-related infections (CRIs).89 The skin was disinfected with standard 5% polyvidone iodine or chlorhexidine in alcohol and sterile drapes were applied around the puncture site. The puncture was performed using the cannula and dilator from the PiCCO™ catheter set. The arterial catheter was inserted using Seldinger’s technique and fixed to the skin according to the manufacturer’s instructions. The puncture site was covered with a sterile adhesive dressing.

Data collection and definitions

Patient characteristics including age, sex, weight, indication for monitoring, and indwelling time were collected. The site of puncture and the number of attempts to cannulate were also collected. Any event of oozing, bleeding (defined by a blood loss due to the puncture of more than 50 ml), and local haematoma was recorded. In a representative subgroup of patients, coagulation data immediately before insertion were obtained in four centres. Coagulation abnormalities were defined as an abnormal prothrombin (INR >1.5) and/or platelet count (<100 x 10^9 litre^-1) and/or activated partial thromboplastin time (APTT; >30 s or ratio >1.2). After cannulation, arterial pulse, temperature, and colour of the skin distal to the insertion were checked to detect limb ischaemia. When the pulse was not palpable, Doppler ultrasound was used to detect ischaemia. Pulse checking distal to the catheter site was performed daily and more frequently if ischaemia was suspected.

The management of catheters during the monitoring period followed the specific guidelines for each unit. During this period, and at least every 24 h, the puncture site was inspected to detect signs of inflammation or infection (redness, local skin changes, or serous or purulent exudate). Cultures from the puncture site, blood cultures, or both were obtained when appropriate (as per protocol). In cases of suspected or overt sepsis of any origin, swabs were taken from the puncture site, and the catheter was removed, sent for cultures, and replaced by another arterial catheter at a new site. In the absence of inflammatory signs, catheters were removed when the physician considered that PiCCO™ monitoring was no longer necessary.

Statistics

We studied the association between complications and coagulation abnormalities. We also studied the presence of inflammatory signs and positive cultures according to the site of insertion and the length of time that the catheter had been inserted. Continuous variables were expressed as mean and standard deviation (so) or median and interquartile distance and compared with the use of Student’s t-test or the Kruskal–Wallis test. Categorical variables were expressed as number and percentage and compared with the use of χ² test (or Fisher’s exact test if necessary). All the P-values were based on two-tailed tests of significance. Statistical analysis was performed with the use of STATA (StataCorp LP 2007, Stata Statistical Software: Release 10. College Station, TX, USA).

Owing to the small number of catheters inserted via axillary, brachial, and radial artery, these complications are described separately and were excluded from the general analysis.

Results

We studied 514 patients in whom a PiCCO™ arterial catheter was inserted. Table 1 shows the characteristics of patients and the main indications for haemodynamic monitoring. The median age was 61 with a standard deviation of 15 years. Arterial cannulation was performed by physicians with different degrees of experience. Four hundred and seventy-five catheters were inserted into the femoral
artery, 26 in the radial artery, four in the brachial artery, and nine in the axillary artery. Coagulation tests immediately before insertion were performed in 213 (41.4%) patients. Coagulation abnormalities were present in 84 (39.4%) of these patients. In the patients with abnormal coagulation, the mean platelet count was $54.3 \times 10^9$ litre$^{-1}$, INR was 3.4 (2.2), and APTT was 56.4 (21.6) s.

Data related to arterial access and minor problems related to insertion and removal are presented in Table 2. In 471 (92%) cases, no complications were reported during the insertion phase. Pain at the insertion site was reported in two cases. Complications were not more frequent in patients with coagulation abnormalities. No episodes of serious bleeding (more than 50 ml) were recorded.

After the catheter insertion, pulse loss was observed in one (3.8%) case after radial cannulation and in one (0.4%) case after femoral cannulation. In a further two (0.4%) cases, signs of lower limb ischaemia were observed. In these four cases, the catheter was removed without further consequences. In one patient, femoral artery thrombosis was diagnosed using Doppler ultrasound, requiring surgical embolectomy without further consequences. One case of femoral pseudoaneurysm was detected after catheter removal.

The study includes 511 successful catheter insertions that resulted in a total of 3101 catheter-days. Mean indwelling time for all catheters was 7.0 ([95% confidence interval: 6.3–7.6]) (range: 1–38) days. The mean indwelling time for catheters not used for surgical monitoring (Table 1) was 7.9 ([95% confidence interval: 7.1–8.4]) (range: 1–38) days. Catheters that showed inflammation at the insertion site were removed in all cases. Data on site inflammation are shown in Table 2.

**Discussion**

This is the first prospective observational study evaluating the complications of arterial catheters inserted for PiCCO™ haemodynamic monitoring in critically ill patients. According

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**Table 1** Patient characteristics and indications for monitoring. Data of weight and height are given as median (range) for age or mean (SD). The indications for monitoring are shown as total cases with the percentages in parentheses.

<table>
<thead>
<tr>
<th>Patient characteristics</th>
<th>Gender (M/F)</th>
<th>Age range (yr)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>Severe sepsis or septic shock</th>
<th>Unclear fluid status</th>
<th>Circulatory failure</th>
<th>Respiratory failure</th>
<th>Renal failure</th>
<th>Surgical monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (M/F)</td>
<td>328/186</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Age range (yr)</td>
<td>61 (46–76)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>75 (18)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height (cm)</td>
<td>168 (12)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>

**Table 2** Incidents during the insertion and removal of the catheters. Data are given as number of incidents and in parentheses are shown the percentages. *Successful insertion in the contralateral femoral artery was possible in 28 cases. **In four of these patients, positive blood cultures were obtained (0.78%), accounting for 0.65 and 0.26 per 1000 catheter-days.***
Peripheral arterial cannulation with short-length catheters for invasive arterial pressure monitoring is common in ICUs, with the radial artery as the preferred site, followed by the femoral artery. However, several studies have found that femoral artery pressure is more accurate and reliable than radial artery pressure monitoring.\textsuperscript{10,11}

Complications associated with femoral arterial cannulation have been reviewed in several studies.\textsuperscript{12–14} The results from these studies are shown in Table 3 and the figures are not different to those shown in the present study that used a specific arterial catheter for PICCO\textsuperscript{TM} haemodynamic monitoring.

Temporary occlusion of the femoral artery was reported in seven of the 11 studies reviewed by Scheer and colleagues\textsuperscript{13} and was reported in 10 out of 668 cannulations (1.49%). Permanent ischaemic damage was reported in only one study in three of 976 insertions (0.3%).\textsuperscript{15} Again, these figures were not different from those in the present study. Ischaemic damage is more common after radial artery cannulation being attributed to this artery having a smaller diameter than the femoral artery. The incidence of ischaemic damage ranged between 6% and 35%, with a mean of 19.7% in 831 cases from 4217 insertions from the 25 studies reviewed by Scheer and colleagues.\textsuperscript{13} However, permanent ischaemic damage was only present in less than 0.1% of radial cannulations.\textsuperscript{16} In the subgroup of 26 radial insertions from our study, only one patient showed transient pulse loss believed to be secondary to vasospasm which spontaneously recovered without catheter withdrawal. In a prospective study of 40 radial artery catheterizations, Sfeir and colleagues\textsuperscript{17} showed that 27.5% patients developed abnormal radial artery flow and 10% had absent pulses after insertion, but none had symptoms of ischaemia.

The small number of brachial and axillary artery catheters in our study precludes any conclusion on their complications. However, a prospective observational study found that axillary artery lines had a lower rate of obstruction (2.5% vs 5.5%), ischaemia (0% vs 16.5%), and thrombosis (0% vs 27.2%) than radial artery lines.\textsuperscript{18} Published cases of permanent ischaemia have pointed out the need to apply simple measures such as minimizing dressings, close observation of distal perfusion, distal continuous pulse oximetry, and placement of invasive arterial lines in the non-dominant extremity in order to prevent complications and minimize morbidity.\textsuperscript{16}

We observed one case of pseudoaneurysm formation after decannulation (0.2%) which is similar to the incidence reported by Scheer and colleagues after decannulation of the femoral (six of 2100 patients, 0.3%) and radial arteries (14 of 15 623 patients, 0.1%).\textsuperscript{13}

The incidence of infective complications such as puncture site colonization or infection (local infection or colonization (LIC)) and CRI is a very important issue for arterial catheterization. Results from different studies\textsuperscript{12–19} are summarized in Table 4. Studies that have compared the radial and femoral arteries with regard to septic complications have identified similar\textsuperscript{16} or different rates of sepsis. However, despite these differences, the CDC guidelines do not recommend a specific site for the insertion of arterial catheters in order to minimize infection risks.\textsuperscript{8} In our present study, the incidence of 0.78% of CRI was similar to that reported by Scheer and colleagues\textsuperscript{13} and Lorente and colleagues.\textsuperscript{19} It was not significantly associated with the indwelling time probably due to the small number of cases.

Most of the complications observed when using longer length arterial catheters are different from those of the PAC. Complications from the PAC have been reviewed by Hadian and Pinsk\textsuperscript{3} who analysed two major studies: the PAC-Man\textsuperscript{22} and the ESCAPE.\textsuperscript{23} Complications not related to the central venous puncture itself were ventricular arrhythmias needing treatment (3%, including one cardiac arrest), pulmonary infarction or haemorrhage (1.3% and 11% on autopsy), pulmonary artery rupture (0.3%), and less frequently perforation of the pulmonary valve, mural thrombosis, endocardial right ventricular lesions, and subendocardial haemorrhage. The death rate after right ventricular perforation or pulmonary artery perforation ranged from 50% to 100% of incidents.\textsuperscript{24} Finally, the incidence of PAC-related LIC and CRI ranged from 0.7% to 22%, clearly above the incidence found in our study.

In conclusion, the arterial catheters used for PICCO\textsuperscript{TM} monitoring are a safe alternative because they reduce or, at least, do not increase the risk of complications when

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**Table 3** Complications associated with femoral arterial cannulation reported in other studies. Data are given as percentages

<table>
<thead>
<tr>
<th>Study</th>
<th>n</th>
<th>More than one puncture</th>
<th>Catheter insertion impossible</th>
<th>Oozing</th>
<th>Small local haematomas</th>
<th>Bleeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haddad and colleagues\textsuperscript{12}</td>
<td>2318</td>
<td>18.6</td>
<td>2.3</td>
<td>2.1</td>
<td>3.3</td>
<td>0.13</td>
</tr>
<tr>
<td>Scheer and colleagues\textsuperscript{13}</td>
<td>3899</td>
<td>—</td>
<td>—</td>
<td>6.1</td>
<td>1.6</td>
<td>2.2</td>
</tr>
<tr>
<td>Frezza and Mezgebe\textsuperscript{14}</td>
<td>764</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>2.2</td>
</tr>
</tbody>
</table>

**Table 4** Incidence rates of LIC and CRI reported in other studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Type of catheter (n)</th>
<th>LIC</th>
<th>CRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haddad and colleagues\textsuperscript{12}</td>
<td>Femoral (2350)</td>
<td>18.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Scheer and colleagues\textsuperscript{13}</td>
<td>Femoral (1664)</td>
<td>0.78</td>
<td>0.44</td>
</tr>
<tr>
<td>Lorente and colleagues\textsuperscript{19}</td>
<td>Femoral (618)</td>
<td>1.78</td>
<td>1.13</td>
</tr>
<tr>
<td>Koh and colleagues\textsuperscript{20}</td>
<td>Radial (321)</td>
<td>1.78</td>
<td>0.31</td>
</tr>
<tr>
<td>Khalifa and colleagues\textsuperscript{21}</td>
<td>Femoral (61)</td>
<td>5.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Radial (234)</td>
<td>13</td>
<td>2.1</td>
<td></td>
</tr>
</tbody>
</table>
compared with the commonly used short peripheral arterial catheters or the more-invasive PAC.

Conflict of interest
The following authors are members of Pulsion’s Medical Advisory Board: F.J.B., J.L.T., M.M., J.W., M.K., E.F.-M., Zsolt Molnar, and Samir G. Sakka.

Appendix
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References
1 Osypka-Tascón GA, Cordioli RL, Vincent JL. What type of monitoring has been shown to improve outcomes in acutely ill patients? Intensive Care Med 2008; 34: 800–20
3 Hadian M, Pinsky MR. Evidence-based review of the use of the pulmonary artery catheter: impact data and complications. Crit Care 2006; 10(Suppl. 3): S8
7 Orme RM, Pigott DW, Mihm FG. Measurement of cardiac output by transpulmonary arterial thermodilution using a long radial artery catheter. A comparison with intermittent pulmonary artery thermodilution. Anaesthesia 2004; 59: 590–4