Pulmonary Artery Versus Central Venous Catheter Monitoring in the Outcome of Patients Undergoing Bilateral Total Knee Replacement

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Abstract Bilateral total knee replacement (BTKR) has been associated with a higher incidence of fat embolism (FES) compared to single knee replacement. Consequently, intraoperative monitoring with a pulmonary artery catheter (PAC) has been recommended. This study compares clinical outcome in BTKR patients monitored with central venous pressure versus PAC. A retrospective chart review of 249 consecutive patients undergoing BTKR, 132 of whom had PAC insertion versus 117 who had central line insertion, over a 1-year period were included in the study. Their medical records were reviewed for co-morbidities, baseline characteristics, and type of intraoperative monitoring. Need and duration for postoperative monitoring in the postoperative care, length of hospital stay (LOHS), signs of fat embolism, development of arrhythmias, and respiratory failure were all outcome measures. A total of four patients (1.6%) had FES as per Schonfeld criteria. One of these patients died within 48 h of surgery. They all had PAC monitoring intraoperatively. Pulmonary artery pressure (PAP) remained unchanged during surgery which raises doubt as to the clinical utility and advisability of the use of

PAC's in this setting. There was no statistically significant difference in cardiac or pulmonary complications, or LOHS between the two groups. Central venous pressure monitoring appears to be sufficient in patients undergoing BTKR.

Introduction

Bilateral total knee replacement (BTKR) has been associated with a higher incidence of fat embolism syndrome (FES) compared to single total knee replacement [1–3]. Since an increase in pulmonary arterial pressure (PAP) is an early sign of FES, it has been recommended that patients undergoing BTKR be monitored with a pulmonary artery catheter (PAC) to detect any elevation in PAP suggestive of FES prior to proceeding with surgery on second knee [4]. Being a major orthopedic hospital, this became our standard of monitoring for BTKR. However, subsequent studies questioned the utility of a PAC in monitoring the surgical patient [5, 6]. In light of these studies, the use of this type of monitoring became less frequent at our hospital. During this period, at the discretion of the anesthesiologist, some patients received a PAC while others had CVP alone for intraoperative monitoring. The assumption was that CVP monitoring would be as useful as PAC in the setting of BTKR. The purpose of this study is to verify that assumption by addressing the following questions. Was there a difference in the ability to detect FES intraoperatively when CVP monitoring was used as opposed to PAC monitoring during bilateral total knee replacement? Furthermore, does CVP monitoring provide sufficient similar information which might help prevent the development of arrhythmia or respiratory failure after bilateral TKR to make PAC monitoring unnecessary during BTKR?

Materials and methods

In this retrospective study, all consecutive patients who had BTKR during the year 2001, were identified from the

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Ethical Board Review statement: the hospital institutional review board approved this human study and the study was performed according to ethical principles of research.

Level III: Retrospective Case Controlled Study.

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hospital data base. All patients had epidural or combined spinal epidural anesthesia except for one patient who had general anesthesia because of previous back surgery with spinal fusion. In addition to standard monitors, all patients received a radial arterial line along with either a PAC or a CVP line placed at the discretion of the anesthesiologist. A CVP or PAC was used to monitor central pressures throughout surgery, especially upon tourniquet deflation of the first knee prior to inflating the tourniquet on the second knee. A rise in central pressure upon release of the first tourniquet, suggestive of FES, would result in cancellation of surgery on the second knee.

A total of 249 patients had BTKR performed at our institution over a 1-year period. One hundred seventeen patients had CVP inserted compared to 132 patients who had PAC insertion. The group with PAC monitoring was older, but otherwise similar in terms of ASA status and BMI (Table 1). There was a higher incidence of hypertension in the PAC group, but the incidence of previous MI, abnormal stress test or echocardiogram, peripheral vascular disease, and pulmonary disease were similar in both groups (Table 2).

After IRB approval, medical records were reviewed for co-morbidities, baseline characteristics, type of intraoperative and postoperative monitoring and complications. Evidence of the development of FES, the primary outcome variable, was sought. Schonfeld's criteria were used to define signs of the development of FES. These included the appearance of petechiae, diffuse alveolar infiltrates on chest radiograph, hypoxemia, confusion, fever, tachypnea, or tachycardia [7]. In addition, other outcomes scrutinized included the development of arrhythmias, respiratory failure (hypoxemia requiring $>50\%$ FIO_2 by face mask) the duration of postoperative monitoring in the post-anesthesia care unit (PACU) and length of hospital stay.

Differences in the rates of occurrence of FES between the two groups as well as the appearance of other complications

Table 2 Patient co-morbidities

Significant History	CVP n (%)	PAC n (%)	p value ^a
HTN	48 (41%)	72 (54.5%)	0.03
Previous MI	2 (1.7%)	5 (3.8%)	0.45
(+) Stress Test	6 (5.1%)	7 (5.3%)	0.96
CABG	2 (1.7%)	2 (1.5%)	0.90
Angioplasty	3 (2.6%)	5 (3.8%)	0.58
Arrhythmia	12 (10.3%)	8 (6.1%)	0.24
Abnormal Echo	9 (7.7%)	16 (12.1%)	0.25
PVD	0	3 (2.3%)	0.25
Pulmonary Disease	6 (5.1%)	16 (12.1%)	0.07
Pulmonary HTN	2 (1.7%)	0	0.13

HTN Hypertension, MI myocardial infarction, CABG coronary artery bypass graft, PVD peripheral vascular disease

^aStatistical analysis was done with chi-square

was analyzed by chi-square and the unpaired *t*-test and corrected for multiple comparisons. Significance was set at $p=0.05$.

Results

There was no difference in the incidence of the development of the signs of FES, arrhythmias, myocardial infarct, pulmonary embolism, or respiratory failure between groups (Table 3). Length of hospital stay as well as the time required for observation in a monitored setting was not affected by CVP or PAC placement (Table 4). Four patients from the PAC group developed FES (1.6%), one of whom died. This patient had an uneventful intraoperative course. The PAP remained normal (25/8 mmHg) throughout the surgery even after tourniquet release on the second knee. Several hours postoperatively, PAP increased to 35/20 mmHg while the patient became obtunded, unresponsive to commands and hypoxemic with diffuse alveolar infil-

Table 1 Patient demographics

	CVP (n=117)	PAC (n=132)	p value
Gender (n)			0.87 ^a
Female	81	89	
Male	36	43	
Age (years)	64.5±9.2	67.0±8.4	0.02 ^b
Height (cm)	165±11	166±10	0.33 ^b
Weight (kg)	85±19	88±19	0.11 ^b
ASA Status			0.16 ^b
1	7	5	
2	80	74	
3	27	47	
BMI	31±7	32±7	0.19 ^b
Tourniquet time (min)			
First side	53±15	53±16	0.89 ^b
Second side	50±17	51±14	0.72 ^b

BMI Body mass index

^aStatistical analysis was done with chi-square

^bStatistical analysis was done with unpaired *t*-test

Table 3 Patient outcomes

	CVP n (%)	PAC n (%)	p value ^a
Arrhythmia	0	1 (0.76%)	0.35
Tachycardia HR >100	5 (4.3%)	6 (4.5%)	0.99
Signs of FES	0	4 (3.0%)	0.58
Death	0	1 (0.76%)	0.90
MI	1 (0.85%)	3 (2.3%)	0.62
PE	0	2 (1.5%)	0.49
Fluid boluses ^b	15 (12.8%)	20 (15.2%)	0.06
Respiratory failure	2 (1.7%)	1 (0.76%)	0.60
Atrial fibrillation	3 (2.6%)	5 (3.8%)	0.72

Signs of FES include: petechiae (5 pt) diffuse alveolar infiltrates (4 pt.), $\text{PaO}_2 < 70$ (3 pt), confusion (1 pt), fever $>100.4^\circ\text{F}$ (1 pt), $\text{RR} > 30$ (1 pt.), $\text{HR} > 120$ (1 pt.). Diagnosis of FES was indicated by a Schonfeld Index score > 5

FES Fat embolism syndrome, MI myocardial infarction, PE pulmonary embolus

^aStatistical analysis was done with chi-square

^bGuided by CVP or PAC reading in PACU

Table 4 Use of CVP/PAC and length of care

	CVP (<i>n</i> =116)	PAC (<i>n</i> =127)	<i>p</i> value ^a
Length of stay in PACU (hours)	21.0±5.6	23.0±14.8	0.12
Length of stay in SDU (days)	2.9±16.2	2.0±9.3	0.56
Length of stay in Hospital (days)	6.6±2.8	6.2±1.8	0.19

^a Statistical analysis was done with unpaired *t*-test

trates on chest radiograph requiring mechanical ventilation. The patient subsequently died within 48 h of surgery. The three other patients who had Schonfeld score greater than 5 survived but had no alterations in the PAP intraoperatively. Subset analysis of these patients did not reveal any statistically significant difference in baseline clinical characteristics from the rest of the group. None of the patients from CVP group developed FES. No alteration in CVP was noted intraoperatively.

Three patients scheduled for BTKR only had one total knee replacement performed. The first was found to have elevated PAP upon PAC insertion (70/30 mmHg). The decision was made at the time not to proceed with the second total knee replacement. This patient did not have an echocardiogram performed preoperatively. The intraoperative and postoperative courses for this patient were uneventful. The second patient while, under general anesthesia, developed hypoxemia (oxygen saturation 80%) with low-end tidal CO₂ (from 40 to 12 mmHg) upon release of the tourniquet after cementing the prosthesis on the first side. PAP increased from 38/18 mmHg to 50/28 mmHg while pulmonary capillary wedge pressure remained at 12 mmHg. Consequently, only one knee was operated on. The postoperative course was uneventful. The patient subsequently returned 4 months later to have the other total knee replacement without sequelae. The third patient had the other knee aborted due to a decision made by the surgical team.

Discussion

This retrospective, case-controlled study was undertaken to review our experience and to address the controversies regarding the use of PAC catheter in the surgical patient. This study's conclusions are limited by the fact that this was a retrospective review but the size of the cohorts was considerable lending credence to the power of the study. Being retrospective, one of the study's limitations is PVR was not calculated. Since PAP is a major determinant of PVR, any change in PAP would implicate a similar change in PVR with an unchanged cardiac output. A previous study in a group of patients undergoing total knee replacement was able to show both an increase in PAP (and PVR) in patients with significant emboli as identified by echocardiography [8].

In this patient population, the use of a PAC did not enhance the ability to predict the postoperative development

of cardiac or pulmonary complications, length of PACU or hospital stay. The one patient who died was in the PAC group. Although he went on to develop fulminant FES, no changes in PAP were noted intraoperatively arguing against the ability of intraoperative PAC monitoring to predict the postoperative development of FES. Two patients from the PAC group had only one total knee replacement because of medical reasons; one patient was found to have baseline pulmonary hypertension upon insertion of PAC which precluded operating on the second knee in fear that right ventricular failure might occur from further rise in PAP. The other patient was noted to have elevated PAP with other signs consistent with FES at the time of tourniquet release following completion of one knee. In view of the clinical scenario (hypoxemia, low-end tidal CO₂), very suggestive of FES, the surgery on the second knee would probably have been aborted even in the absence of a rise in PAP. Three other patients with Schonfeld score greater than 5, which would qualify them as having fat embolism syndrome, had PAC monitoring which failed to show any change in PAP. Dorr et al., in a group of 79 patients undergoing BTKR recommended that an increase in PVR above 200 dyne/s/cm³, or a doubling of PVR should lead to cancellation of the second knee [9]. Of note is that none of the patients with such findings went on to develop FES. Although PAP was measured, the values were not reported. Central venous pressure was not recorded.

Other studies looking at the use of PAC in the perioperative period have questioned its use. In a prospective observational study, a three-fold increase in major postoperative cardiac events in patients with PAC monitoring undergoing non-cardiac surgery was found. Hospital length of stay was also increased [10]. Additional studies have also shown increased survival in higher risk surgical patients undergoing goal-directed therapy with PAC compared to controls [11, 12]. However, in a larger prospective randomized study comparing the use of CVP vs. PAC with goal-directed therapy, in high-risk surgical patients, no difference in mortality between groups was noted [13]. In this study, the use of PAC did not alter outcome or help predict the development of FES. Both the PAC and CVP groups were similar in characteristics except for an older population in the PAC group. Co-morbidities did not differ except for a higher incidence of hypertension in the PAC group. Two of the patients from the CVP group had mild pulmonary hypertension which was not confirmed by right heart catheterization. Of note, sensitivity, and specificity of Doppler echocardiography in diagnosing pulmonary hypertension has varied from 85–97% and 55–77% [14, 15]. Although no benefits were seen with PAC use, no additional harm was detected. Of note, in our patient population, the PAC is usually removed within 48 h of surgery preventing any complication which may arise from prolonged use.

This study adds evidence to the growing body of literature that monitoring with a CVP catheter is sufficient in patients undergoing BTKR. In view of the higher cost of PAC, and potential morbidity, PAC should not be used routinely in patients undergoing BTKR.

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