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Tourniquet pressure settings based on limb occlusion pressure determination or arterial occlusion pressure estimation in total knee arthroplasty? A prospective, randomized, double blind trial

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ABSTRACT

Objective: The aim of this study was to compare the limb occlusion pressure (LOP) determination and arterial occlusion pressure (AOP) estimation methods for tourniquet pressure setting in adult patients undergoing knee arthroplasty under combined spinal-epidural anesthesia.
Methods: Ninety-three patients were randomized into two groups. Pneumatic tourniquet inflation pressures were adjusted based either on LOP determination or AOP estimation in Group 1 (46 patients, 38 female and 8 male; mean age: 67.71 ± 9.17) and Group 2 (47 patients, 40 female and 7 male; mean age: 70.31 ± 8.27), respectively. Initial and maximal systolic blood pressures, LOP/AOP levels, required time to estimate AOP/determinate LOP and set the cuff pressure, initial and maximal tourniquet pressures and tourniquet time were recorded. The effectiveness of the tourniquet was assessed by the orthopedic surgeons using a Likert scale.
Results: Initial and maximal systolic blood pressures, determined LOP, estimated AOP, duration of tourniquet and the performance of the tourniquet were not different between groups. However, the initial (182.44 ± 14.59 mm Hg vs. 200.69 ± 15.55 mm Hg) and maximal tourniquet pressures (186.91 ± 12.91 mm Hg vs. 200.69 ± 15.55 mm Hg) were significantly lower, the time required to estimate AOP and set the tourniquet cuff pressure was significantly less (23.91 ± 4.77 s vs. 178.81 ± 25.46 s) in Group II ($p = 0.000$). No complications that could be related to the tourniquet were observed during or after surgery.
Conclusion: Tourniquet inflation pressure setting based on AOP estimation method provides a bloodless surgical field that is comparable to that of LOP determination method with lower pneumatic inflation pressure and less required time for cuff pressure adjustment in adult patients undergoing total knee arthroplasty under combined spinal epidural anesthesia.

Introduction

Pneumatic tourniquets which are widely used in extremity surgery may lead to soft tissue damage including the skin, vessels, muscles, and nerves due to unnecessarily excessive inflation pressure.[1–4] Therefore, the use of the lowest effective tourniquet inflation pressure which provides a bloodless surgical field is recommended.[5–15] However, there is still a lack of standard practice regarding optimal inflation pressures.[16–19]

Limb occlusion pressure (LOP) and arterial occlusion pressure (AOP) are the terms that mean the lowest tourniquet pressure required to cease the arterial blood flow into the extremity distal to

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the cuff. LOP can be determined manually or automatically by slow cuff inflation to pulse cessation with a diagnostic equipment such as Doppler flowmeter or pulse oximeter.[20–24] AOP can be estimated by a formula using patient's systolic blood pressure (SBP) and tissue padding coefficient (K_{TP}) values (AOP = [SBP + 10]/K_{TP}).[25–27] In both methods, addition of a safety margin to LOP or AOP is recommended for potential hemodynamic fluctuations during surgery. Setting the tourniquet pressure on the basis of LOP or AOP allows to use a personalized tourniquet pressure in each individual patient and has been shown to be useful in optimizing tourniquet cuff pressures.[20–27] However, we were unable to find a study which compared the LOP determination and AOP estimation based tourniquet pressure settings in extremity surgery.

The aim of the present study was to compare the practices of individualized tourniquet pressure settings based on LOP determination and AOP estimation methods in terms of LOP and AOP levels, required time to set the tourniquet pressures, tourniquet pressures and their effectiveness in adult patients scheduled for total knee arthroplasty (TKA) under combined spinal epidural anesthesia (CSEA).

Methods

After, ethical approval (Ethical Committee Number: KA13/96), informed consent was obtained from 100 patients scheduled for total knee arthroplasty with the pneumatic tourniquet under CSEA. Exclusion criteria were age outside the range of 18–85 years, American Society of Anesthesiology (ASA) physical status $\geq$ 3, peripheral claudication, severe anemia, any contraindication to regional anesthesia, previous adverse reactions to medications used in the study, and inability to provide informed consent. The gender, age, ASA status, weight and height of the patients, circumference of the lower extremity were recorded.

In the operating room, an 18-gauge intravenous catheter was inserted in the arm; and 0.9% NaCl solution was administered. Supplemental oxygen (3 L/min) via a face mask was administered during the procedure. All patients were continuously monitored for heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), oxygen saturation (SpO_2), and respiratory rate (RR) during the surgical procedure. CSEA was performed in the sitting position via L3-4 interspace with 0.5% hyperbaric bupivacaine, followed by placement of an epidural catheter. The patients were turned to supine position and it was confirmed that the sensory block level reached at least T_{10}. Then, the patients were randomly assigned to one of two study groups. Randomization was provided using a computer-generated randomization list including 100 patients. Surgical procedure and anesthetic management were performed by the same surgical and anesthesia teams respectively. The attending anesthesiologist was aware of the allocated group, but the data analyst, surgeon and the patients were blinded to group allocation.

In Group I, the tourniquet cuff was placed around the thigh with the distal edge 15 cm proximal to the proximal pole of the patella. To determine the LOP, a pulse oximetry probe was applied to the toe at the side of the operation and the tourniquet was inflated slowly until the arterial pulsations disappeared on the monitor. This pressure was recorded as LOP and the tourniquet was deflated. The time required for the determination process was recorded. Following exsanguination of the limb with an Esmarch bandage, the tourniquet cuff was inflated to the pressure according to the guidelines of the Association of Perioperative Registered Nurses (AORN) which recommends that a safety margin of 40 mmHg should be added for AOP below 130 mmHg, 60 mmHg for AOP between 131 mmHg and 190 mmHg, and 80 mmHg for AOP above 190 mmHg for adult patients.[24]

In Group II, the thigh circumference was measured 20 cm proximal to the superior pole of the patella with the knee in extension using a tape measure. Then the tourniquet cuff was placed around the thigh with the distal edge 15 cm proximal to the proximal pole of the patella. To determine the appropriate tourniquet inflation pressure, AOP estimation formula was used. The calculation (AOP = [SBP+10]/K_{TP}) was made using initial SBP and tissue padding coefficient (K_{TP}) values from a list, according to limb circumferences of the patient (Table 1).[25] After calculation of AOP, tourniquet pressure (TP) was determined by adding a safety margin of 20 mmHg to AOP (TP = AOP + 20 mm Hg). The time required for the measurement of extremity circumference and calculation process was recorded. Following exsanguination of the limb with an Esmarch bandage, the tourniquet cuff was inflated to the predetermined setting in all patients. During the tourniquet period, TP was manually raised 10 mmHg in response to each 10 mmHg increment in SBP.

Primary outcome measures were initial and maximal SBP, LOP and AOP levels, initial and maximal tourniquet pressures, required time to estimate AOP and determinate LOP and set the cuff pressure and tourniquet time. Secondary outcome measure was tourniquet performance determined by the quality of bloodless operative field. The orthopedic surgeon who was blinded to group allocation rated the performance of the tourniquet using a 4-point scale [1 (Excellent) = No blood in the surgical field, 2 (Good) = Some blood in the surgical field but no interference with surgery, 3 (Fair) = Blood in the surgical field but no significant interference with surgery, 4 (Poor) = Blood in the surgical field obscures the view] at the beginning, in the middle, and at the end of the surgical procedure. All patients were examined on the day after surgery for signs of any complications, such as skin damage, nerve palsies, or vascular occlusion that could be associated with the use of a tourniquet. The patients were also asked whether or not they felt pain, burning, coldness, numbness, or paresthesia on their feet by a blind investigator.

The t test was used for continuous data. The $\chi 2$ test was used for comparison of categorical data. A P value of less than 0.05 was

Table 1
Tissue padding coefficients based on limb circumferences.[28]

Extremity Circumferences (cm)	Estimated K_{TP}
20	0.91
21	0.90
22	0.89
23	0.88
24	0.87
25	0.86
26 to 27	0.85
28	0.84
29	0.83
30 to 31	0.82
32 to 33	0.81
34	0.80
35 to 36	0.79
37 to 38	0.78
39 to 40	0.77
41 to 43	0.76
44 to 45	0.75
46 to 48	0.74
49 to 51	0.73
52 to 54	0.72
55 to 57	0.71
58 to 60	0.70
61 to 64	0.69
65 to 68	0.68
69 to 73	0.67
74 to 75	0.66

K_{TP} = Tissue padding coefficient.

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