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Original Research Article

Limb occlusion pressure as a tool to optimize the tourniquet pressure in total knee arthroplasty without compromising the creation of a bloodless surgical field

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ABSTRACT

Introduction: Pneumatic tourniquet is utilized in orthopedic surgery to create a bloodless field. Limb Occlusion Pressure (LOP) is the minimum pressure required at a specific time and location to halt arterial blood flow distal to the cuff.

Aim and Objective: The purpose of this study is calculation of the minimum possible tourniquet pressure using LOP to significantly reduce tourniquet pressure in Total knee arthroplasty surgery without compromising the creation of a bloodless surgical field.

Materials and Methods: This study included 200 patients who underwent primary total knee arthroplasty. Tourniquet pressure was set based on Limb occlusion pressure measured just before the surgery. After the surgery, surgeon was asked to rate the quality of the bloodless field on a visual analog scale, and look for post-operative complications like, tourniquet site pain, injury to skin, redness, blisters, flaring, neurological symptoms. tourniquet palsy and chemical burns.

Results: The average LOP was 163.65mmHg and average tourniquet pressure was 221.15mmHg. The minimum tourniquet pressure we used was 140mmHg. The quality of bloodless field was excellent in 88% patients. 6 patients (3%) had redness at the skin and 5 patient had tourniquet site pain. None of the patients had chemical burns, injury to skin, blisters or tourniquet palsy.

Conclusion: This new tourniquet technique based on Limb occlusion pressure (LOP), is an effective device for maintaining a bloodless surgical field in orthopedic limb surgery. By reducing tourniquet pressure, this method lowers the frequency and severity of pressure-related complications. The LOP estimation method is simple, quick, and effective, making it feasible for broader clinical use. It ensures safer, personalized cuff pressures for tourniquet applications in limb surgery.

1. Introduction

The pneumatic tourniquet, first introduced by Harvey Cushing in 1904, is commonly utilized in orthopedic surgery to create a bloodless field, thereby improving visibility and reducing surgical time.[1,2] Over the past thirty years, significant advancements have been made in tourniquet technology, enhancing their safety, efficacy, and reliability. This progress has led the US Food and Drug Administration to classify pneumatic tourniquets as Class I medical devices, indicating minimal risk of harm when used properly.[3]

Traditionally, tourniquet pressure has been set using one of two methods. The fixed pressure method standardizes the pressure to 250 mmHg for the upper limb and 350 mmHg for the lower limb. The alternative method sets the pressure to 100 mmHg above the patient's systolic blood pressure for upper limb surgeries and 150 mmHg above systolic pressure for lower limb surgeries, typically resulting in pressures around 230 mmHg and 280 mmHg, respectively.[4]

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In the early 1980s, James A. McEwan developed the modern pneumatic tourniquet, which includes an inflatable cuff, a compressed gas source, and a microprocessor-controlled pressure regulator that maintains cuff pressure within 1% of the set pressure.[5] Despite these advancements, patient-related issues such as tourniquet site pain, tourniquet palsy, and chemical burns remain common.[6]

Efforts have been made to determine the minimum necessary pressure to avoid these complications.[7] Limb occlusion pressure (LOP) is a concept that defines the minimum pressure required at a specific time and location to halt arterial blood flow distal to the cuff.[8] LOP can be measured just before surgery using an automated photoplethysmographic sensor connected to the tourniquet apparatus. This method considers variables such as cuff type and width, application tightness, fit, and the patient's soft tissue and vessel characteristics, potentially leading to more optimal cuff pressure settings.[9]

The purpose of this study is calculation of the minimum possible tourniquet pressure using LOP to significantly reduce tourniquet pressure in Total knee arthroplasty surgery without compromising the creation of a bloodless surgical field.

2. Materials and Methods

2.1. Inclusion criteria

Patients undergoing a primary total knee arthroplasty were considered eligible for inclusion.[10]

2.2. Exclusion criteria

Pre-existing vascular conditions, poor skin condition at the site of tourniquet and other conditions which are contradictory for use of tourniquet were excluded.

2.3. Procedure

Intraoperative increase in blood pressure following one side TKR, where LOP cannot be taken into consideration for the contralateral side. Total knee replacement done under general anaesthesia, as there is less peripheral vasodialatation compared to spinal anaesthesia resulting in higher LOP.

This study was conducted at Aster CMI Hospital, Hebbal, Bengaluru from August 2022 to May 2024 in patients who had underwent primary total knee arthroplasty. All cases were operated by same operating team and the tourniquet machine we used is Dual port ATS 4000 automatic tourniquet (Zimmer) (Figure 1).

Patient given spinal anaesthesia. Skin over proximal thigh where we apply lower limb tourniquet cuff protected with 1 layer of stockinette and 3 layers of cast padding (Figure 2). The tourniquet cuff was placed around the thigh with the distal edge at least 15 cm proximal to the proximal pole of the patella. Fluid impermeable non adhesive layer put over the distal edge of the tourniquet to prevent seepage of povidine iodine to prevent chemical burns.

To determine the LOP, a photoplethysmographic sensor was applied to the 2nd toe at the side of the operation and the tourniquet was inflated with incriments of 10 mmHg from baseline systolic blood pressure until the arterial pulsations disappeared on the monitor. Then reduce pressure by 5-10 mmHg to look for reappearance of arterial pulsations to obtain the most accurate pressure This pressure was recorded as LOP and the tourniquet was deflated. Following exsanguination of the limb with an Esmarch bandage, the tourniquet cuff was inflated to the pressure according to the standard protocols. An additional safety margin of pressure is added to the measured limb occlusion pressure to account for physiologic variations and other changes that may be anticipated to occur normally over the duration of a

Figure 1: Dual port ATS 4000 automatic tourniquet (Zimmer)

Figure 2: Tourniquet cuff, stockinette and cast padding

surgical procedure, which recommends that a safety margin of 40mmHg should be added for LOP below 130 mmHg, 60 mmHg for LOP between 131mmHg and 190mmHg and 80mmHg for LOP above 190mmHg for adult patients.[11]

After the surgery was completed, the surgeon was asked to rate the quality of the bloodless field on a visual analog scale (VAS), with

1. For acceptable bloodless field (Excellent)
2. For some blood in operating field but no obstruction to surgery (good)
3. For blood in operating field but insignificant obstruction to surgery (fair)
4. For blood in surgical field and significant obstruction to surgery (poor)

After putting subcutaneous layer stitches, deflate the tourniquet to allow reperfusion before skin staples were placed. The surgeon also look for post-operative complications like, tourniquet site pain, injury to skin, redness, blisters, flaring , neurological symptoms. tourniquet palsy and chemical burns.

3. Results

In our study 200 patients were recruited. All patients were operated under spinal anaesthesia. The study group contained 47 (23.5%) male patients and 153 (76.5%) female patients (Figure 3). The age of the patients varied from 48 years to 86 years old. The mean age of the recruited patients was 65.46 years. The average LOP was 163.65mmHg and average tourniquet pressure was 221.15mmHg (Figure 4).

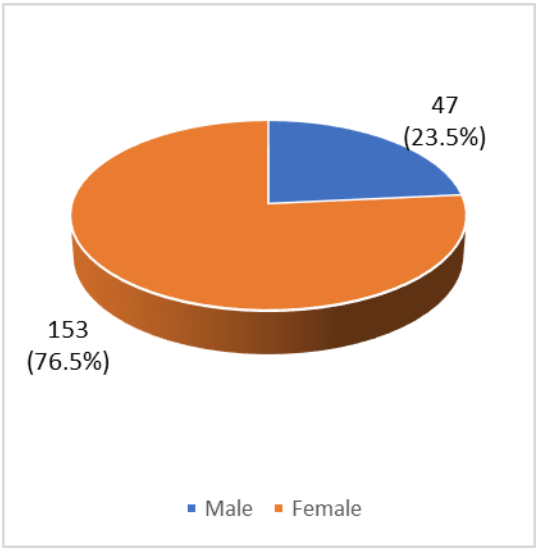

Figure 3: Sex ratio

The minimum tourniquet pressure we used was 140mmHg. Average tourniquet time was 54.055 min (Table 1).

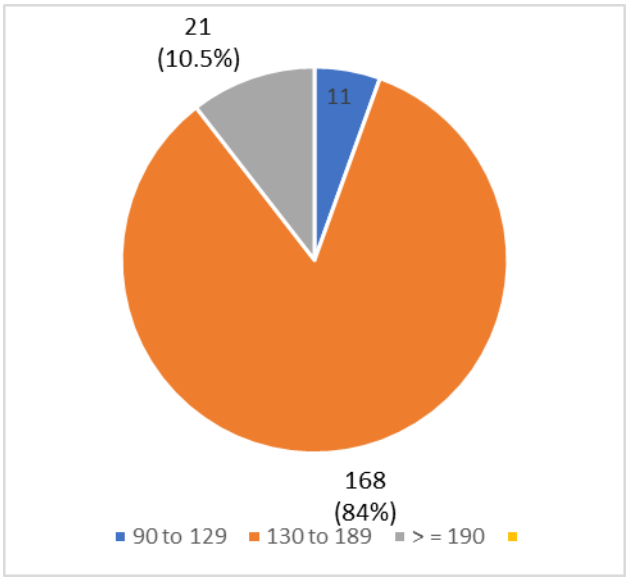

Figure 4: LOP

Table 1: Tourniquet pressure, frequency and percentage

Tourniquet pressure	Frequency	Percentage
140-189mmHg	15	7.5%
190-219mmHg	48	24%
220-250mmHg	137	68.5%

The quality of bloodless field was described as excellent in a total of 176 patients (88 %) (Figure 5).

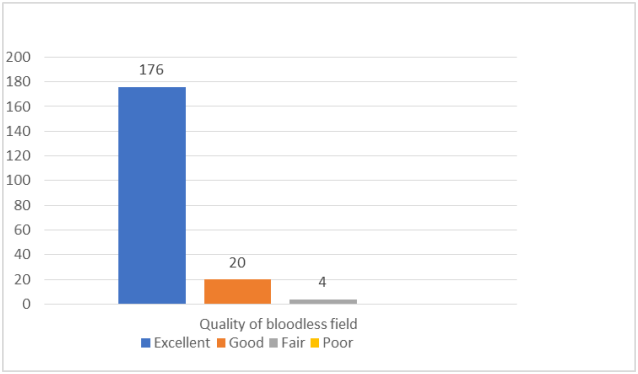

Figure 5: Quality of bloodless field

The skin at the tourniquet site was inspected for injury to skin, redness and blisters. 6 patients (3%) had redness at the skin and 5 patient had tourniquet site pain. None of the patients had chemical burns, injury to skin, blisters or tourniquet palsy.

4. Discussion

Complications related to tourniquet use increase with higher tourniquet pressures.[11,12] Experimental data indicates that

the severity of tourniquet-induced ischemia depends on both the duration of tourniquet application and tourniquet pressure. Elevated serum creatine phosphokinase levels are indicative of muscle damage at and below the tourniquet cuff. Further interruption of blood supply leads to cellular hypoxia, tissue acidosis, and potassium release, which are eventually corrected upon reperfusion.[13]

Tourniquet-induced pain arises from three main factors: pain transmitted along slow-conducting unmyelinated C-fibers, spontaneous firing activity in dorsal horn neurons at the tourniquet site during compression, and limb reperfusion pain when blood flow is restored and toxic metabolites are removed.[14] Studies by Ochoa et al. and Lundborg suggest that localized nerve compression is a key factor in the development of tourniquet paralysis.[15]

Using the new method of synchronizing the tourniquet to the lowest occlusion pressure (LOP) specific to the limb required less pressure compared to the fixed (conventional) method and the systolic blood pressure method. This approach maintained a good to excellent bloodless operative field while minimizing potential complications. Thus, the LOP method of tourniquet application appears to be a reasonable and safe option for use in orthopedic surgery.

5. Conclusion

This new tourniquet technique based on Limb occlusion pressure (LOP), is an effective device for maintaining a bloodless surgical field in orthopedic limb surgery. By reducing tourniquet pressure, this method lowers the frequency and severity of pressure-related complications. The LOP estimation method is simple, quick, and effective, making it feasible for broader clinical use. It ensures safer personalized cuff pressures for tourniquet applications in limb surgery.

6. Conflict of Interest

None.

7. Source of Funding

None.

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