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A clinical study of the safe use of pneumatic tourniquet in orthopaedic surgery

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Abstract

Specific objective: A study was undertaken to evaluate the superiority of Lowest occlusion pressure method of using the pneumatic tourniquet versus the other routine ways of usage of Pneumatic Tourniquets in Orthopaedics surgery which include the Fixed and Systolic Blood Pressure variants.

Materials and methods: This study included 120 patients of both upper and lower limbs trauma. These patients were randomly included any of the three categories of study after fulfilling the inclusion and exclusion criteria. Three modalities of application of tourniquet were included in this study. They were Fixed, Systolic Blood pressure (SBP) and Lowest Occlusion Pressure methods (LOP). Each category included 40 patients and the results were analysed according to final outcome using Ishii et al. grading, VAS Score criteria.

Results: In our study 120 cases managed by LOP had better results compared to fixed variant and Systolic BP variant in terms of less pressure needed to keep tourniquet, good operative field, pain score (VAS) at tourniquet application region and skin injury (reddening). But no complications like compartment syndrome, deep vein disorder, paresis, nerve injury has occurred before and after surgery

Conclusion: LOP method of using the pneumatic tourniquet is superior to the other methods of using Tourniquet in terms of less pressure needed for elevating tourniquet, Good operative (blood less) field, no skin abrasions.

Keywords: Pneumatic tourniquet, lowest occlusion pressure, systolic blood pressure, orthopaedic surgery

Introduction

The use of pneumatic tourniquet in orthopaedic surgery has been widely debated over the years. A pneumatic tourniquet is a device that allows the surgeon to have a bloodless field for the duration of the surgery [1, 2]. This allows the surgeon to reduce the surgical time since all the anatomic structures are clearly visualised. The reason for debate is due to the post-operative problems experienced by the patient. Tourniquet site pain, tourniquet palsy, chemical burns at the site of tourniquet are common patient related problems consequent to using a tourniquet [3-5]. Great efforts have been made to identify the minimum pressure to which the tourniquet should be inflated so as to avoid the above mentioned problems. [6] In this study, we aim to use the pneumatic tourniquet by inflating it to the lowest occlusion pressure (LOP) and study its effects in terms of quality of bloodless field and post-operative complications. The results were compared with the standard techniques of using a tourniquet described already in the literature.

Methodology

The study was conducted in JSS Hospital, Mysore. All patients admitted in the orthopaedic ward who were planned for upper and lower limb surgeries were included in the study. The study was conducted from September 2013 to October 2015. The design of this study was a comparative study. The patients were randomly categorized into 3 groups while applying pneumatic tourniquet to the limb. As a prerequisite the inclusion and exclusion criteria were accordingly applied to all the three groups.

The first group was named the fixed tourniquet pressure group (FT). In this group the tourniquet pressure was standardized to 250 mm of Hg for upper limb and 350 mm of Hg for

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lower limb. All the patients in this group were operated with the fixed tourniquet pressure irrespective of the systolic blood pressure of the patient.

The second group was the systolic group (SG). In this group the systolic blood pressure of each patient was recorded before surgery. Tourniquet pressure was fixed to 100 mm of Hg above the systolic blood pressure of the patient if the patient was proposed for an upper limb surgery. If the patient was undergoing a lower limb surgery, the tourniquet pressure was fixed to 150 mm of Hg above the systolic blood pressure of the patient.

The third group was the lowest occlusion pressure group (LOP). In this group, the blood pressure of all the patients was recorded. The cuff pressure at which no pulse was recorded was identified as the lowest occlusion pressure (LOP). The pulselessness of the limb was identified by palpation first and then confirmed by hand Doppler. The tourniquet pressure was then set to LOP with safety margin. The safety margin was defined as below:

- a. 40mm of hg if BP is <130mm of hg,
- b. 60mm of Hg if BP 130-190mm of hg,
- c. 80mm of Hg if BP> 190mm of hg.
- d. 50mm of Hg if age of children <10yrs

The blood pressure was recorded in all the patients before inducing general anaesthesia. The outcomes of each of the three groups were studied in terms of quality of bloodless field and the incidence of post-operative complications. The same surgical team operated on all 120 cases to avoid inter-observer differences. The tourniquet cuff used was 60 cm long and 10.5 cm wide for upper limb surgeries and 90 x 15cm for lower limb surgeries. (Figure.1, 2) The same tourniquet cuff was used in all three groups. A single layer of padding was applied between the skin and cuff. (Figure. 3) The limb was prepared and exsanguinated by elevation and an Esmarch bandage. (Figure. 4) The tourniquet was then inflated before surgery begun.

The surgeon rated the quality of the bloodless field as poor, fair, good, or excellent, and noted any changes in the quality of the bloodless field throughout the procedure. A poor field was one in which blood obscured the view; a fair field had blood present but not significantly interfering with surgery; a good field had some blood with no interference with the procedure; and an excellent field had no blood present. The surgeon also noted post-operative complications like tourniquet site pain, tourniquet palsy, chemical burns.

In this study, 120 patients were recruited. Forty patients were randomly categorised into each of the three groups. All the patients were subjected to general anaesthesia. All the patients were operated by one senior author. Informed consent was taken from all the patients in this study. Patients with open injuries or vascular injuries, pre-existing vascular diseases, compartment syndrome, malignancies, infection, and poor skin condition at the site of tourniquet were excluded from this study.

Results

In our study 120 patients were recruited for the study. The patients were randomly selected into each of the three groups. Each group included 40 patients that were subjected to LOP, systemic BP and fixed tourniquet systems (FT) before surgery. All patients were operated under general anaesthesia. The study group contained 86(71.66%) male patients and 34 (28.33%) female patients. In the LOP group, the number of male patients was 28 (70%) and females was 12 (30%). In the

fixed group, the number of male patients was 32(80%) males versus 8(20%) females. Lastly in the SBP group, 26(65%) male and 14 (35%) female patients were included.

The age of the patients varied from 7 years to 73 years old. The mean age of the recruited patients was 37.41 years. The mean age of the patients included in the LOP group was 34.1 years. In comparison, the mean age of patients in the SG group was 40.43 years old and FT group was 37.75 years.

The number of patients recruited for upper limb surgeries and lower limb surgeries was 60 each. The average tourniquet pressure for upper limb surgeries in the fixed group was 250 mm of Hg whereas in the SG group it was 237 mm of Hg and LOP group it was 175.4mm of Hg. The average tourniquet pressure for lower limb surgeries was 350mm of Hg in the fixed group, whereas in the SBP and LOP group it was 286 and 185.35 mm of Hg respectively.

The quality of bloodless field was described as excellent in a total of 33 patients in all the three groups put together. Among the 33 patients, 14 (35%) belonged to the LOP group, 9(22.5%) to the SBP group and 10 (25%) to the fixed group.

The pain at tourniquet site was evaluated within one hour after surgery. The patients who belonged to the LOP group had an average pain score of 5.8 as measured on the Visual Analogue Scale (VAS). An average VAS score of 7.02 was found in the patients of the SBP group. An average score of 7.6 on the VAS scale was observed in the fixed group.

The skin at the tourniquet site was inspected for abrasions, burns, flaring in all the three groups and results were tabulated. Among the 120 patients, 11 (27.5%) of them who had skin abrasions belonged to the LOP group, 35 (87.5%) belonged to the SG group and 40(100%) of them belonged to the fixed group. (Figure.) None of the patients had chemical burns or tourniquet palsy.

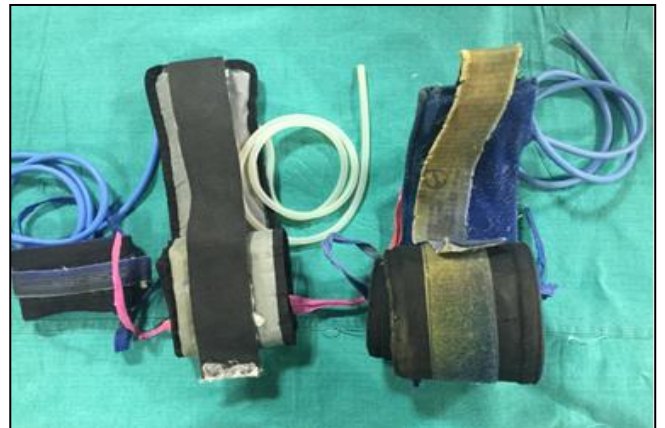


Fig 1: Tourniquet cuff (Paediatric, Upper Limb, Lower Limb)



Fig 2: Modern pneumatic Tourniquet system

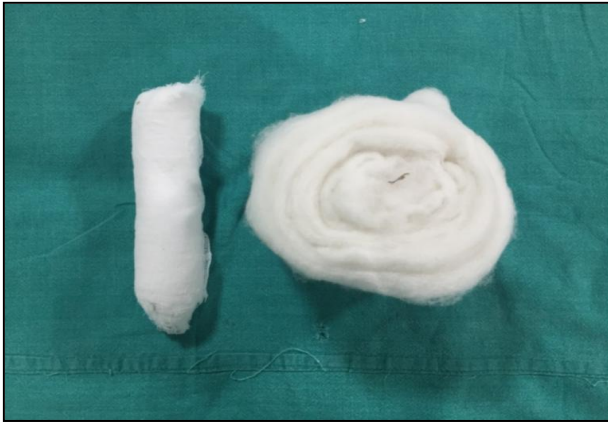


Fig 3: Orthopaedic cotton roll and roller gauze



Fig 4: Esmarch bandage

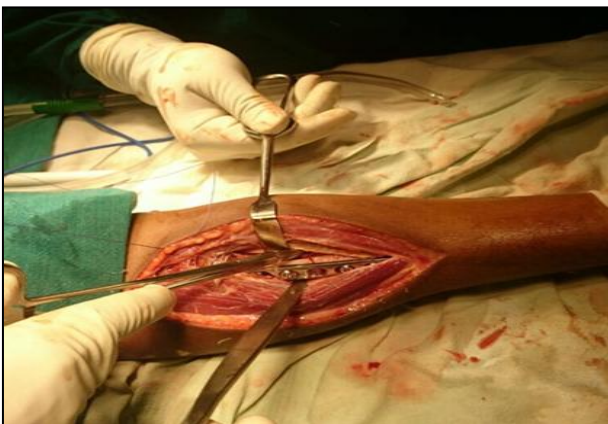
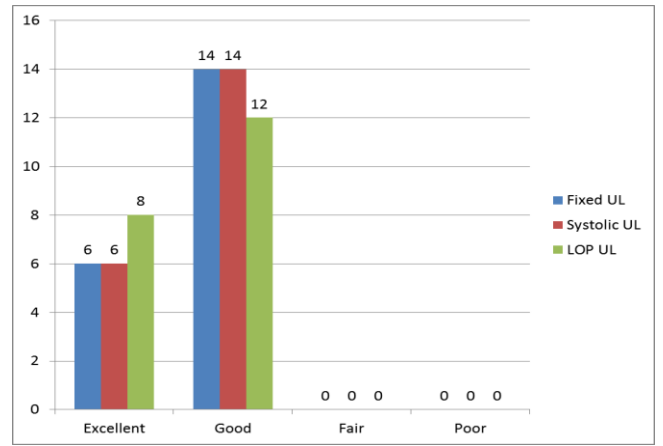


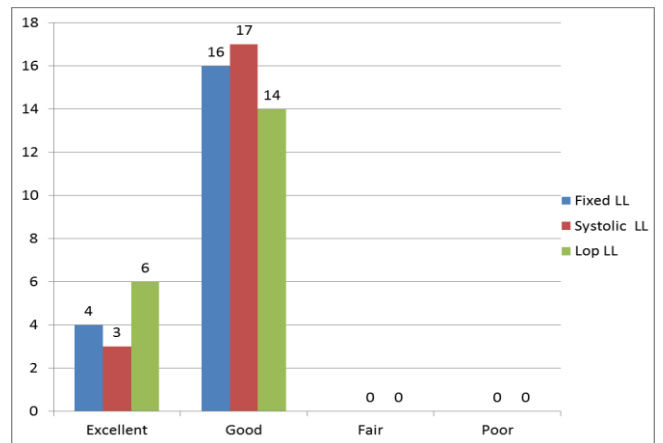
Fig 5: Proximal 1/3rd both bones fracture (Rt side) operated with plate and screws under LOP



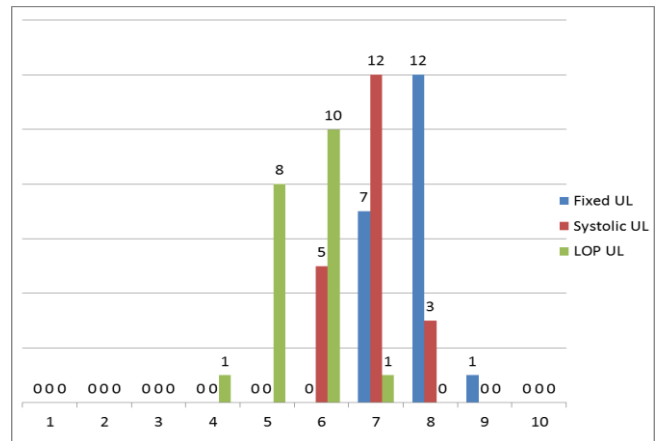
Fig 6: Skin abrasion after tourniquet use



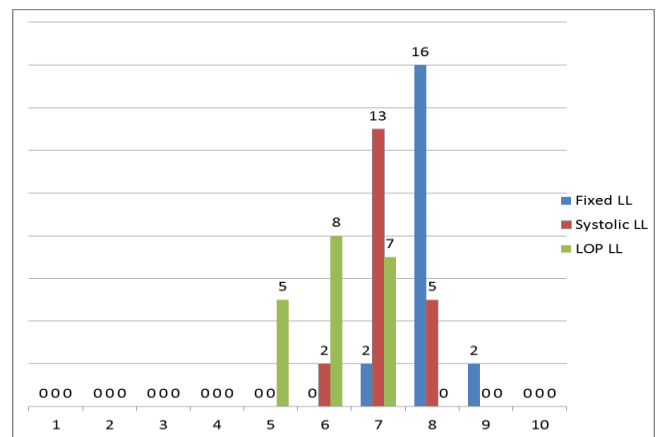
Graph 1: Quality of bloodless field in upper limb surgeries



Graph 2: Quality of bloodless field in lower limb surgeries



Graph 3: VAS score after upper limbs surgeries



Graph 4: Vas Score after lower limb surgeries

Discussion

Pneumatic tourniquet is commonly used in orthopaedic surgery to provide a clean, dry operative field, which improves visualisation of anatomical structures and reduce the operating time.

It would be ideal if the tourniquet is inflated to the lowest pressure for the shortest duration of time. In this study we attempted to compare three different methods of using the pneumatic tourniquet. The outcomes were studied in terms of quality of bloodless field and incidence of post-operative complications like tourniquet pain, chemical burns or tourniquet palsy.

During the study, any form of bias was ruled out by randomly allotting patients to any of the three groups. Each group had an equal number of patients. Possible differences in outcome based on the upper or lower limb surgeries were ruled out in allotting equal number of patients for upper and lower limb surgeries in each group. It was made sure the same surgical team operated on all the patients. All the results were recorded based on the observation of the senior author. The functional outcome was evaluated based on the quality of bloodless field and post operative complications.

All surgeries were done under General Anaesthesia^[7], as the use of brachial block or Bier block for upper limb surgery and spinal anaesthesia for lower limb surgery would hamper the assessment of post-operative tourniquet palsy.

Limb occlusion pressure usually was determined by gradually increasing tourniquet pressure until the distal blood flow was interrupted⁸. Previous studies^[9, 10] showed that cuff inflation pressure based on LOP measured for each patient before inflation of cuff were generally lower than predetermined generic inflation pressure but were sufficient to maintain a satisfactory operative field. After limb occlusion pressure is measured, tourniquet pressure is typically set by adding to the LOP an additional safety margin that is selected to be greater than the magnitude of any increase in LOP normally expected during the operation.

In 2009 Association of Peri-Operative Registered Nurses (AORN) U.S. recommended that tourniquet pressure for normal adults be set at the LOP measured plus safety margin was defined as 40mm of hg if BP is <130mm of hg, 60mm of hg for BP 130-190mm of hg, 80mm of hg for BP> 190mm of hg. AORN recommended safety margin of 50mm of hg above the measured LOP of children younger than 10yrs of age. As per the recommendations, the LOP was calculated with the safety margin and the tourniquet pressure was set in all patients of the LOP group.

The surgeon rated the quality of the bloodless field using the evaluation method applied by Ishii *et al.* as poor, fair, good, or excellent, and noted any changes in the quality of the bloodless field throughout the procedure⁶. A poor field was one in which blood obscured the view; a fair field had blood present but not significantly interfering with surgery; a good field had some blood and no interference with the procedure; and an excellent field had no blood present.

The quality of bloodless field was described as excellent in a total of 33 patients in all the three groups put together. (Figure. 4) Among the 33 patients, 14 (35%) belonged to the LOP group, 9 (22.5%) to the SBP group and 10 (25%) to the fixed group. This clearly indicates that LOP group provided a better quality of bloodless field in majority of the patients compared to the SG and FT groups. (Graph.1, 2)

Tourniquet related complications increase as tourniquet time increases^[3, 4, 5]. Experimental data suggests that severity of tourniquet ischemia is dependent not only on tourniquet time

but also on tissue type. Serum creatine phosphokinase concentration is elevated in response to muscle damage at and distal to the tourniquet cuff. Further interruption of blood supply results in cellular hypoxia, tissue acidosis, and potassium release^[11] which on reperfusion are eventually corrected in the systemic circulation.

In our study, the average duration of tourniquet use in the LOP group was 64.2 minutes. In comparison, the average time of tourniquet use in the SG and FT group was 69.9 minutes and 70.06 minutes respectively.

Tourniquet induced pain is due to one of 3 reasons like nerve fibre related with pain transmitted along slow conducting unmyelinated C-fibres, during compression there is spontaneous firing activity in dorsal horn neurons around tourniquet application site and limb reperfusion pain when blood flow is restored and toxic metabolites removed. The average pain score was 5.8 as measured on the Visual Analogue Scale (VAS) in the LOP group. An average VAS score of 7.02 and 7.06 was found in the patients of the SG and the FT group respectively. This proves that LOP was clearly effective in reducing post-operative pain. (Graph.3, 4)

Ochoa *et al.*, Lundborg study suggests that localizes compression of nerve segment is a principal factor in the pathogenesis of tourniquet paralysis. The cause of blistering of skin is seepage of antiseptic solution into the padding beneath the cuff during skin preparation, resulting in a chemical burns. This is prevented by wrapping a plastic drape around the distal edge of cuff. In our study, none of the patients suffered from tourniquet palsy or chemical burns.

Since the new way of tourniquet synchronised to lowest occlusion pressure of that particular limb, it needed less pressure than fixed (conventional) method and systolic blood pressure method. This can maintain good to excellent bloodless operative field while minimising potential complications. Thus LOP method of tourniquet application appears to be reasonable and safe for use in orthopaedic surgery.

Conclusion

This new tourniquet system synchronized with LOP is a reasonable device to maintain a bloodless surgical field in orthopaedic limb surgery. It seemed to contribute to safety by lowering tissue pressure, preventing mid- and post-surgical complications. Although the incidence of complications in tourniquet usage is fortunately very rare, a more practical method of using the tourniquet during surgery is recommended by the authors.

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