MEASUREMENT OF LIMB OCCLUSION PRESSURE AND A SURVEY OF CURRENT KNOWLEDGE AND PRACTICE OF PERI-OPERATIVE TOURNIQUET USE AT KENYATTA NATIONAL HOSPITAL

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF MEDICINE IN ORTHOPAEDIC SURGERY AT THE UNIVERSITY OF NAIROBI

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DECLARATION

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It has not been presented in any other university for an award of degree.

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DEDICATION

I dedicate this dissertation to the Almighty for always providing, nurturing and protecting.

I also dedicate this dissertation to my wife and children for their immeasurable support and love.

In addition, I dedicate this dissertation to my parents and siblings for their immense support and guidance throughout.

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LIST OF ABBREVIATIONS

ERC…….Ethical Research Committee

KNH ……...Kenyatta National Hospital

UON ……...University of Nairobi

LOP…….Limb Occlusion Pressure

AORN…….Association of Peri-Operative Registered Nurses

Pa CO2……Partial pressure of carbon dioxide

kPA …….Kilopascals

CD……...Cluster of Differentiation

CAM……...Cell Adhesion Molecule

NMDA……N-methyl D-aspartate

DVT……Deep Venous Thrombosis

PVD……Peripheral Vascular Disease

ORIF……. Open Reduction Internal Fixation

SD……..Standard Deviation

IQR……Interquartile Range

BP……..Blood Pressure

ABSTRACT

Background:

Surgical tourniquet use is widespread in various limb surgeries. Tourniquets have evolved from primitive non-inflatable/non-pneumatic types to automated personalized inflatable/pneumatic types.

In deciding the tourniquet cuff inflation pressure to be applied when using pneumatic tourniquets, many users traditionally use a fixed "routine" pressure that in majority of cases is much higher than what is recommended and subsequently more detrimental. In order to minimize pressure related tourniquet complications, it is advocated to use the lowest and safest tourniquet pressure which brings about the concept of preoperative Limb Occlusion Pressure (LOP) Measurement. This pressure can be objectively measured and is of great value in guiding the tourniquet user in application of the minimum, safe and adequate tourniquet pressure to achieve a desirable bloodless surgical field and also to reduce risks of complications that may arise from using unnecessarily high pressures.

Personnel involved in use of surgical tourniquets have varied knowledge and practices/ experiences when it comes to key areas pertaining to tourniquet use. Thus in order to promote safe tourniquet practices and subsequently enhance patient safety, it is important to have a survey to assess parameters pertaining to tourniquet use.

Objective: To measure LOP pre-operatively in study participants presenting to KNH, in whom tourniquet use was planned or anticipated for a surgical procedure and to describe the knowledge and practices about current use of tourniquets at KNH.

Study Population: Comprised two parts. The first part consisted of study participants aged 18 - 65 years who presented with unilateral lower limb injury/condition for which use of a surgical tourniquet was planned/anticipated.

The second group consisted of tourniquet users who were identified as anyone directly or indirectly involved during use of a surgical tourniquet.

Study Site: The study was conducted at KNH. For LOP measurement, 107 consenting adult study participants were recruited from the orthopedic wards. Totally, 100 tourniquet users were recruited from departments of orthopedic surgery, plastic surgery, general surgery and anaesthesia.

Methodology and Data collection: Limb Occlusion Pressure was measured pre-operatively using a manually inflatable surgical pneumatic tourniquet and dorsalis pedis arterial colour/spectral Doppler sonography to objectively identify the appearance and disappearance of the dorsalis pedis pulse waveform following gradual inflation of the pneumatic tourniquet in the selected participants.

Semi-structured questionnaires were administered to tourniquet users to collect information on their knowledge and practices about key areas pertaining to tourniquet use.

Results

The mean LOP was 155.1(38.7 SD) mmHg. Other patient parameters evaluated were mid thigh circumference (mean 42.1cm; p-value <0.001) and this had a direct positive correlation with measured LOP. Cuff width: thigh circumference ratio (mean 0.24; P-value <0.001) had a negative correlation with measured LOP while there was negligible correlation between patients age and measured LOP (P-value 0.999).

From the assessment of tourniquet users' knowledge and practices, varied proportions were obtained from responses for different aspects pertaining to tourniquet use which included limb exsanguination, tourniquet pressures, tourniquet time, deflation intervals, indications and possible contraindications of tourniquet use, wound closure practices, tourniquet associated

complications, among others. However of significance, it was noted that 70% of users still used high fixed tourniquet inflation pressures which may be detrimental, and that none of the users based their tourniquet inflation pressures based on LOP.

Conclusion

The study revealed that majority of study participants had low limb occlusion pressures (LOP) compared to the standard fixed routine tourniquet inflation pressures traditionally employed during lower limb surgeries. Even after adding recommended pressure values in addition to measured LOP, the values were still lower as compared to traditionally used inflation pressures.

None of the users were familiar with LOP measurement despite available evidence that LOP measurements enable the use of lower and safer tourniquet inflation pressures.

The survey from the tourniquet users revealed that majority of tourniquet users were familiar with the types of tourniquets available. However, it was noted that 97% of tourniquet users had had no formal training in tourniquet use. Key areas pertaining to tourniquet use were all varied among tourniquet users, and therefore more ongoing formal education is necessary to streamline knowledge and practice of safe tourniquet use.

The findings of this study reflect the need to adopt evaluation of Limb Occlusion Pressure before surgical pneumatic tourniquet use, with an ultimate aim to reduce pressure related tourniquet complications. The findings of the survey should guide tourniquet users to reanalyze their tourniquet use practices and make prudent evidence-based decisions when using tourniquets.

CHAPTER ONE

INTRODUCTION

A surgical tourniquet is a device widely utilized during limb surgeries for occluding blood flow distal to the tourniquet application site (1-3). Use of this device allows minimizing blood loss, improving visualization of the surgical field and as a result also reducing the operating time by expediting the surgery. Various tourniquet designs exist and their use depends on experience and availability (4-7).

However, use of tourniquets is not without complications (8, 9). Two controllable parameters dictate the chances of complications associated with their use. One is the tourniquet pressure and the other is the tourniquet time. Both are directly proportional to the chances of developing complications which may range from tourniquet pain to paralysis and compartment syndrome (1, 4, 5, 27, 52, 58, 65).

These complications are potentially avoidable by advocating for use of lower tourniquet pressures (36, 39). Varied literature exists about limits for tourniquet pressure and time. As regards to tourniquet pressures, traditionally many surgeons have applied high tourniquet pressures which they have been accustomed to and not based on any evidence (57,66,78). However, it has been noted that these pressures are much higher than what is required to produce a satisfactory bloodless operating field. This observation has led to the development of measuring limb occlusion pressure (LOP) as a guide to allow application of the lowest as well as safest tourniquet pressure and thus minimizing complications associated with using unnecessarily high pressures (36, 39). This study aimed to demonstrate the limb occlusion pressures by measuring them preoperatively and comparing them to the traditionally used high tourniquet pressures (300 - 450 mmHg or higher; and in some cases higher than 450 mmHg when using non-inflatable tourniquets such as the Esmarch bandage).

Thus this study aimed to advocate patient safety by measuring limb occlusion pressures pre-operatively in participants and change practice from that of applying deleterious high tourniquet pressures traditionally and routinely used.

Tourniquet time refers to the duration of time a tourniquet has been applied to a limb to occlude blood flow before deflation. Generally most surgeons have the tourniquet deflated after approximately two hours of use and allow a deflation interval before reapplication if need be. Additionally, health care workers involved in use of surgical tourniquets should be familiar with guidelines on safe use of tourniquets and complications associated with improper use. It was important to have a survey on what these health care workers are familiar with as encompassed in their knowledge, attitude and practices as pertaining to tourniquet use. Such information was not available at KNH and thus this study aimed to provide information which is ultimately aimed at guiding in policy making.

1.1 Definition of tourniquet

Tourniquet is a word derived from French which means “turn”(1).

It is an appliance used for occluding movement of blood in part of a limb for a duration until it is released (2).

1.1.1 Historical Background

Tourniquets have been used since ancient times and have proved to be beneficial with correct use, as well as risky when improperly used (3).

In Rome, metallic strips covered in leather were utilized in war situations to minimize loss of blood from injured extremities (1).

Figure 1: Picture of ancient bronze and leather tourniquet.

In the 16th century, Paré, is credited to have developed a constricting strap for minimizing blood loss from injured limbs. Later, Morel innovated the use of a bandage attached to a rod that would allow compression when rotated (1).

In the 18th century, Petit in France developed an appliance which had an encircling strapping that had a screw included on the upper part. On rotation of the screw-like part, pressure would be applied on a metallic piece allowing for compression to the part of the limb.

Figure 2: Picture of Petit's tourniquet

Initially these tourniquets required assistants to hold down the appliance but with Petit's invention this hindrance was overcome (1).

1.1.2 Types of tourniquets in use in medical practice

Tourniquet designs have evolved over time. The initial primitive types have now been replaced by personalized tourniquet systems. There are various types of tourniquet designs available in the market today with different specifications (4,5).

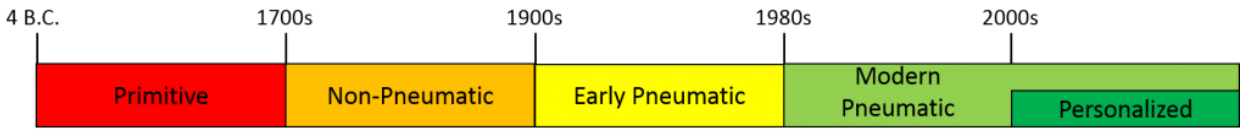

Figure 3: Diagram showing evolution of tourniquets.

The Esmarch bandage was previously used as a tourniquet, but currently its use remains as an exsanguination bandage applied before inflation of pneumatic tourniquets. However, the Esmarch tourniquet despite its unpredictably high pressures, still continues to be used as a tourniquet (6,7).

Broadly, based on functional use, tourniquets can be grouped as emergency tourniquets and surgical tourniquets. Emergency tourniquets are applied to stop catastrophic exsanguination from injured limbs. Their main application is during pre-hospital triage and pre-hospital transfer especially in combat situations. It is however, important to note that application of emergency tourniquets should be as a last resort to control bleeding due to adverse effects of improper and prolonged use. Surgical tourniquets enable surgical interventions to be carried out quickly, precisely and without risk of excessive blood loss.

Based on design, tourniquets can also be grouped as either non-inflatable or inflatable. Devices which cannot be inflated are generally made of stretchable material with elasticity. Esmarch bandage/tourniquet is an example. Inflatable/pneumatic tourniquets use compressed gas to inflate a bladder or cuff which then generates pressure on the applied area.

Modern tourniquets have inbuilt capacity to allow for application of desired pressures (8).

1.2 Indications for tourniquet use

In the medical field, tourniquets have been used in many scenarios. In First Aid or triage situations, they have been used to prevent catastrophic exsanguination from injured limbs. In such emergency situations, correct application knowledge and total duration of application are crucial in determining whether the tourniquet will worsen or improve the situation.

During surgery, tourniquets have been crucial in reducing blood loss as well as establishing bloodless operating fields and thus decreasing surgical time. They have also been used as part of First Aid appliances to stop bleeding in major limb trauma (3, 11).

In addition, tourniquets are used during administration of local or regional anaesthesia to prevent systemic dissemination of local anaesthetic agent, thus maintaining their concentration at the targeted area (8).

In some combat situations, military personnel have been known to apply tourniquets prophylactically (before inflation) to extremities and are inflated in case of injury (1).

1.3 Complications of tourniquet use

Tourniquet though valued amongst users, have also been associated with various complications. These complications may arise at any point during their use and range from mechanical/chemical burns and tourniquet pain, to nerve and muscle injuries. More serious injuries including deep venous thrombosis (DVT), severe ischemic injuries, reperfusion injuries and compartment syndrome have also been shown to occur. Incorrect application, unnecessarily high pressures and long duration of application have resulted in deleterious outcomes, such as post-tourniquet paralysis, digital necrosis and death (1).

It is therefore important that tourniquet users understand possible changes that occur with tourniquet utilization prior to using them (2,5). This helps in providing safe practice to the

patients on whom these important, but equally potentially limb and life threatening appliances (tourniquets) will be used.

1.4 Study Justification

A surgical tourniquet is widely used in limb surgery with its main indication being reduction of intra-operative blood loss and providing a relatively bloodless operating field, thus improving visualization and expediting the surgery (1). The tourniquet inflation pressure is directly proportional to the chances of tourniquet associated complications. Traditionally surgeons using pneumatic surgical tourniquets have used tourniquet pressures ranging from 300 - 450mmHg. These pressures are unnecessarily high and deleterious. It is advisable to use a lower and safer tourniquet pressure which will in turn minimize complications. This brings about the concept of a measurable pre-operative pressure (limb occlusion pressure - LOP) to guide the tourniquet user during a planned surgery (36, 39). Pre-operative measurement and awareness of the LOP can guide the tourniquet user in application of the correct, adequate and safe amount of pressure to the limb being operated, and thus allow for safe use of tourniquets. This allows avoidance of application of unnecessarily high tourniquet pressures which have been associated with complications.

Currently at KNH, measurement of limb occlusion pressure is not being carried out and tourniquet pressures are applied in most cases, as per surgeon preference. This study thus aimed to introduce and demonstrate the concept of measuring LOP pre-operatively, and comparing the findings to what has traditionally been practiced. Gold standard measurement of LOP is done using dorsalis pedis arterial Doppler sonography and is measured as the tourniquet pressure at which the dorsalis pedis pulsation is obliterated as evidenced objectively on Doppler sonography. This study aimed to carry out the pre-operative LOP measurement using the above mentioned technique.

The study findings are aimed to guide in policy making and advocate for pre-operative LOP measurements.

In addition, it was important to have a survey on current knowledge and practice on key areas pertaining to tourniquet use amongst users who are either directly or indirectly involved in their use. Tourniquet users were described as health care workers directly or indirectly involved in peri-operative tourniquet use. These included any personnel involved directly or indirectly in applying the tourniquet, monitoring during use or at removal. It was important to have a survey on the current knowledge and practices amongst health care workers involved in use of surgical tourniquets (66, 78). Information from this survey is aimed at enabling determination of potential loop holes or gaps in knowledge and practice amongst tourniquet users, which may consequently compromise safe patient care.

Thus, these findings may influence overall knowledge on tourniquet use. In addition, these findings will aim to determine how safe practices and interventions can be instituted.

1.5 Research question

What are the limb occlusion pressures (LOP) when measured pre-operatively in participants who will require use of a surgical tourniquet during a surgical procedure?

What is the current knowledge and practice on peri-operative tourniquet use amongst its users?

1.6 Hypothesis

Null hypothesis states - Limb occlusion pressures (LOP) are as high as the conventional pre-set tourniquet pressures routinely and traditionally used for limb surgeries.

Tourniquet users are familiar with the guidelines and recommendations of safe use of tourniquet and associated complications of improper use.

1.7 Broad Objective

- To measure limb occlusion pressures (LOP) pre-operatively in study participants with lower limb injury or condition requiring a surgical intervention, for which a surgical tourniquet use is anticipated/planned.
- To describe the knowledge and practice about surgical tourniquet use amongst health care workers involved in use of tourniquets at KNH.

1.7.1 Specific Objectives

1. To measure the LOP in unaffected lower limbs pre-operatively (using a manually inflatable surgical pneumatic tourniquet and colour/spectral arterial Doppler sonography) in participants on whom use of tourniquet is planned/anticipated for a surgical procedure.
2. To determine the knowledge and practice about tourniquet application, cuff pressure, tourniquet time, LOP, complications and contraindications of use amongst its users.

CHAPTER TWO

LITERATURE REVIEW

2.1 Physiological changes in tourniquet application and deflation.

Tourniquet application and deflation alters normal physiology (8,9). These physiological changes are evident either during application or following release of tourniquet, and have multi-systemic implications. Changes affecting the cardiovascular system have been shown to be present from exsanguination to release (8). Application of the tourniquet as well as carrying out exsanguination results in augmentation of resistance in the vasculature as well as an elevation in the volume of circulating blood (2). It has been shown that application of tourniquets to both lower limbs, may lead to a an elevation of volume by 750 milliliters (2).

When releasing the tourniquet, redness results from short-lived augmentation in blood volume channeled to the previously temporarily ischaemic extremity. Additionally, on tourniquet release, there is reduction of central venous and systolic blood pressure secondary to blood redistribution and the effects of circulating chemicals from the previously occluded extremity. This phenomenon is short-lived but may be alarming (2).

Temperature perturbations following application of tourniquets have been demonstrated. Increase in the body temperature results from decreased transfer of heat to the ischaemic limb as well as reduced loss of heat from the occluded limb. Two hours of tourniquet use can lead to increase in the core temperature by approximately 0.5°Celsius (2).

Also, upon deflation, rechanneling of temperature from the patient's body and the efflux of cold blood (coming through the occluded area), into the rest of the body probably decreases the core temperature. It is important to be aware of these tourniquet-induced thermal changes during the intra-operative period (2,10).

The elapsed duration that tissue maintains its temperature similar to that of the temperature of the body following cessation of its blood supply is known as the ischaemia time (warm). Warm ischemia time exceeding eight hours results in complications arising from reperfusion complications. However, the little data available on this concept of warm ischaemia time indicate the risk is limited (11,12).

The elapsed duration that tissue is cold and occluded from blood flow is known as cool ischaemia time. This duration and resultant complications does not have a clearly described trend (12).

End-tidal carbon dioxide concentration has been shown to increase immediately following tourniquet deflation (2). This increase (measured in kPa) is observed more with release of lower extremity tourniquets than with upper extremity tourniquets (2,13). The elevation of $PaCO_2$ due to removal of inflation pressure leads to a rise in blood flow to the brain which in patients with traumatic brain injury may be hazardous. In some instances velocity of middle cerebral artery flow following tourniquet release has been shown to demonstrate an increase of up to 50% (14).

Increasing ventilation following tourniquet release can minimize elevation of intracranial pressure as a result of blowing out the built up carbon dioxide (2).

Various parameters in the coagulation system have been shown to be affected both by tourniquet inflation and deflation. Tourniquet use induces changes in both coagulability and fibrinolysis.

Inflation of tourniquet increases coagulability of blood due to thrombocyte aggregation (2,15,16). Following tourniquet deflation , fibrinolysis is augmented secondary to production of tissue plasminogen activator (16,17,18).

Serum electrolytes such as potassium and lactate are mildly elevated upon releasing of tourniquets (19–21). After release, reperfusion injury mediated by free radicals may occur (22).

Neutrophil migration is also increased. These particular white blood cells partake in important events in the cascade of injury due to re-established blood flow (23). Leukocyte infiltration and development of neutrophils CD11b, CD18, endothelial cell adhesion molecule-1 (CAM-1) form stages of the cascade of the deleterious effects of reperfusion (24).

2.2 Location of tourniquet application

Tourniquets should be applied carefully and comfortably at the point of the greatest circumferential area so as to afford protection against nerve injury (25, 26, 27). Following initial deflation, the tourniquet should be smoothened out and applied after ensuring proper skin protection has been applied at the application site. Numerous protective material are present in the market with Soffban® and velbands® paddings being popular choices (27). Soffban® skin protection padding remains a popular choice and when used results in fewer deleterious outcomes rather than in cases of non usage of skin protection material (28). Skin preparation solutions may cause chemical burns to unprotected skin below the tourniquet (29) and measures should be taken to avoid seepage of these skin solutions below the tourniquet.

2.3 Cuff size and inflation pressures

Tourniquet users routinely apply fixed inflation pressures and many do not reflect on the blood pressure of the patient. (27,30,66). Different types of tourniquet cuffs are available, and generate different pressures depending on their cuff size and mode of application.

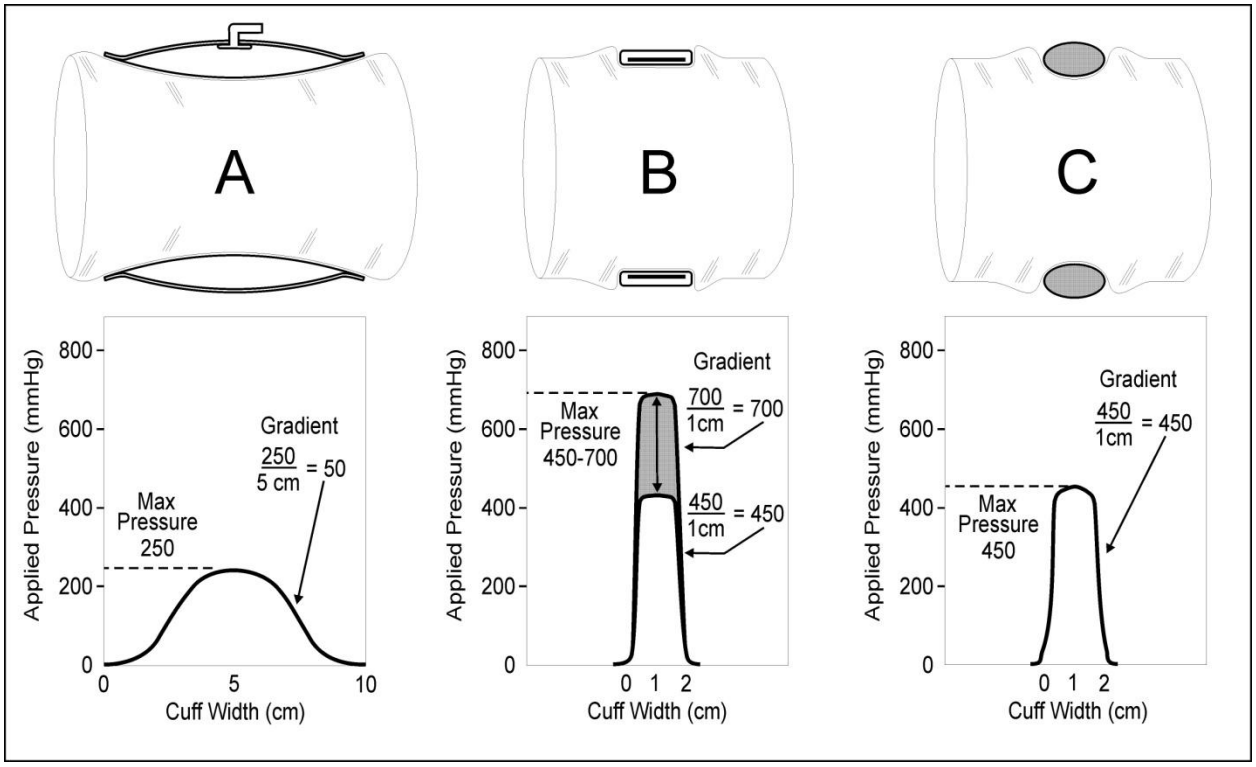

Figure 4: Diagram showing different pressures generated by different tourniquet types and sizes

(A) modern pneumatic surgical tourniquet cuff, (B) non-pneumatic, non-surgical military tourniquet designed for self-application on the battlefield, and (C) a non-pneumatic elastic ring designed in an attempt to combine exsanguination and tourniquet functions.

The Esmarch tourniquet has been vilified mainly for resulting in unpredictable and very high pressures following application (31). When selecting an appropriate cuff, its location, bladder design, shape, length and width are some of the important factors to be considered.

The length and breadth of the tourniquet cuff should ideally be customized keeping in mind the size of the extremity. Overlapping is desired to be at least three inches and not exceeding six inches. Excess overlap has been shown to result in increased tourniquet pressures and wrinkling

of underlying soft tissue. Unexpected intra-operative release has been observed with smaller cuff lengths that do not provide the recommended overlap.

The Association of Peri-Operative Registered Nurses (AORN) recommendation is that the width be more than fifty percent of the diameter of the application site (2).Cuffs which have more breadth reduce deleterious outcomes as a result of allowing distribution of pressure to a bigger area (31, 32). Comparison between narrow and wide cuffs has demonstrated that broader cuffs (14 cm) produce less discomfort than less broader cuffs (7 cm) (33).

Most orthopedic surgeons traditionally apply cuff pressures ranging between 200–300 mmHg for adults (66). Various methods have been attempted to lower effective cuff pressure (34-39). One example is double tourniquet technique in hand surgery to change the point of compression (34). Controlled hypotension to bring down systolic blood pressure can also be used to decrease direct cuff pressure against tissues (35). Doppler technique in conjunction with oximetry to confirm occlusion of pulse helps to identify lower inflation pressures (36,38).This has proved useful to reduce tourniquet pressures individualized to each patient. In addition, cuff pressure synchronization with systolic blood pressure has also been shown to allow for use of lower inflation pressures (37).

2.4 Limb Occlusion Pressure (LOP)

Limb Occlusion Pressure (LOP) can be defined as the least required pressure; at a particular time; in a particular tourniquet cuff; applied to a particular limb; at a particular site, to occlude arterial blood flow. In essence, LOP is the minimum applied tourniquet pressure which stops blood flow which can be objectively assessed using Doppler sonography over an arterial pulse (27). This measurement has been employed by AORN and assists in application of correct cuff inflation pressure (8). LOP measurement allows for reduction of excessive pressure-related complications. (8, 36, 74-77).

Conventionally LOP is evaluated by gradually inflating the cuff and recording the pressure at which arterial pulse is obliterated distal to the cuff. Objectively this is demonstrated and verified by Doppler studies. It is important to note that cuff pressure based on LOP measured pre-operatively is most often than not less than the traditionally employed inflation pressures. It has been shown that application of LOP has been sufficient to maintain a satisfactory bloodless surgical field.

One study demonstrated that the mean calculated tourniquet pressure was 202.3 ± 34.2 mmHg for adequate bloodless surgical field in the upper extremity. This is less than the 250–300 mmHg routinely utilized (39).

In order to minimize tourniquet pressure, blood pressure (systolic) to which an allowance of pressure is added) may be utilized. However, this is suboptimal because of erratic and variable relation between systolic blood pressure and limb occlusion pressure.

Advances in automation have led to development of novel tourniquet systems that are capable of automatically measuring LOP (37). These highly automated tourniquet systems have a comparable accuracy to the gold standard Doppler technique (38).

The AORN recommends the addition of the following margins of safety to the measured LOP for non-paediatric patients.

- + 40 mmHg for LOP < 130 mmHg,
- + 60 mmHg for LOP 131–190 mmHg
- + 80 mmHg for LOP > 190 mmHg
- In paediatric population, addition of safety margin of 50 mmHg is recommended for any measured LOP (40).

2.5 Tourniquet Time

Allowed maximum tourniquet time during limb surgery remains controversial. Duration of release before re-application (deflation interval) also remains controversial as well as timing of release based on pre or post wound closure (42,43).

The usual considerations are surgeon preference, elapsed tourniquet time and blood loss (41,44). Blood loss control is improved if tourniquet is released after closing of incision and helps expedite the surgery (42,44). It is prudent to keep inflation time to a minimum to minimize potential complications. Tourniquet time varies with the patient's age, physical status, and the vascular supply to the extremity. No strict guidelines exist.

Neurological complications occur more frequently with prolonged tourniquet use (45,46). It has been recommended to assess the operative situation at 2 hours and if the anticipated duration of surgery is anticipated to be more than 2.5 hours, then a 10 minute deflation interval is recommended at that point and at subsequent 1 hour intervals (47). In animal studies, 2 hours of tourniquet-induced ischaemia has been shown to significantly increase radionuclide presence below the cuff (47). The time-induced ischaemia has been associated with death of fibres (48).

Deflation interval of ten to fifteen minutes is recommended to allow restoration of muscle adenosine triphosphate (ATP) (49,50). For the pediatric population, inflation time of less than 75 minutes has been recommended for lower extremity surgery in younger children (27).

2.6 Tourniquet Complications

Tourniquet use has complications, some of which may be catastrophic. These complications can range from simple transient pain to digital necrosis to pulmonary embolism and even death. These complications can arise at any point during tourniquet use; and the physiological effects associated with application and deflation can contribute to/or expedite these complications.

Thus, it is important for peri-operative team members to understand how to use tourniquets effectively and safely to provide the best possible care to patients (5,50). All the tissues under a tourniquet are prone to injury and complications. Nerve tissue is generally affected by compression and myofibrils are affected by ischaemia. Tourniquet inflation and release usually leads to multi-systemic effects (5).

The clinical syndrome of tourniquet pain remains intriguing and can manifest intra or post-operatively despite anaesthesia and analgesia (51). This phenomenon is due to various factors and not solely due to pressure below the appliance (52).

During general anesthesia, this pain manifests as an increase in heart rate and mean arterial pressure. This phenomenon is more common under general anesthesia and occurs most often during lower-limb surgeries (52, 54).

Ketamine has been shown to reduce the elevation in arterial blood pressure as a result of tourniquet pain as well as assisting to reduce the pain (2,53). The exact etiology is not known. Neural pathways to the skin may play a role (54).

Tourniquet pain may also be explained by compression-induced release of prostaglandins by the injured cells which are excitatory to pain receptors (55).

Additionally, limb ischemia causes central sensitization via the activation of N-methyl D-aspartate (NMDA) receptor due to repeated nociceptive afferent input from the affected limb (55,56).

Tourniquet pain has important impacts on anesthesia. Various interventions such as application of numbing local anaesthetic creams and infiltration with local anesthetics have been tried to reduce tourniquet pain. Addition of opioids, clonidine, epinephrine and local anesthetics during spinal block have been employed. However, none of these interventions have attained complete success in pain relief.

Ketamine, dexmedetomidine, magnesium sulfate, clonidine and remifentanil infusions have also been studied, but the only intervention that has been shown to effectively work is deflating or removing the tourniquet itself (33,57).

Nerve tissue is one of the commoner, if not the commonest tissue affected by tourniquet complications (58, 59). If not mediating tourniquet pain, prolonged compression and ischaemia to nerves can result in palsies and paralysis. In one review, post-tourniquet paralysis has been noted, with an incidence of paralysis in the upper limb more frequent than in the lower limb when using pneumatic tourniquets (59). In another study, cases of post-tourniquet paralysis following hand operations have been reported (60). Sciatic nerve injury has also been reported after lower limb tourniquet (61).These complications, though rare may have guarded outcomes which may be debilitating.

Burns due to skin prepration chemicals are associated with improper tourniquet application maneuvers. Solutions containing alcohol used for skin preparation are usual culprits for these burns (29).

Graver complications such as vascular injuries following tourniquet use have been reported with sequelae such as amputations (8).

Deep venous thrombosis (DVT) has also been reported following tourniquet use (62,63). One study , however did not show any difference in post-operative DVT between two groups - one in which tourniquet was used and one in which it was not used (64).

Compartment syndrome is also another limb threatening complication following tourniquet use (27,65). It is recommended that during tourniquet use, any intra-operative and post surgical increased muscular swelling or stiffness in the operated area should be noticed and evaluated, despite the recommended time or pressure limits. If compartment syndrome is suspected, prompt fascial release should be undertaken (27,65).

2.7 Techniques to avoid Tourniquet Complications

Knowledge on evidence-based safe tourniquet practices remains wanting (57,66,78).However, generally, tourniquets over time have been noted to be safe instruments/ appliances, with minimal complications if used safely.

Guidelines have been developed to inform tourniquet users about safe tourniquet use practices (27). American First Aid guidelines and European Resuscitatiom Council have supported the use of tourniquets in emergency situations. However, it is paramount to note that despite the support of routine tourniquet use, a simple but crucial recommendation states that training should be ongoing for users (1).

It is important to be aware of potential complications arising with tourniquet use and especially with improper use. As mentioned, these complications can arise at any point during tourniquet use, and thus should be anticipated and necessary interventions taken to avoid or manage these complications.

Considerations about relative contraindications to tourniquet use; type of tourniquet available; underlying skin protection; cuff size; inflation pressure; tourniquet time and deflation procedure are mandatory. Considerations about drug pharmacokinetics are crucial. Tourniquet inflation results in separation of a limb from the remaining body and in addition can change the volume of distribution of some anaesthetic medications.

The elapsed time between administration of antibiotics and inflation of tourniquet is a significant aspect to be considered during peri-operative antibiotic prophylaxis. Generally guidelines suggest that the antibiotic must be completely infused prior to the inflation of the tourniquet. Clinical evidence has suggested that prophylactic antibiotics are required to be administered at least five to ten minutes before tourniquet inflation to allow penetration into tissues (67,68).

AORN board of directors has approved practices for the safe use of tourniquets (27). Patient safety is the key consideration when deciding on purchase of a tourniquet. Potential contraindications and risk factors for tourniquet use should be communicated to the surgical team by peri-operative nurses. Also, the cuff should be applied safely to the appropriate location. LOP measurement is recommended as well as adherence to recommended tourniquet time. Continuous monitoring during use is crucial. Development of intra-operative hypertension and tachycardia may reflect tourniquet pain.

The AORN also emphasizes ongoing education, competency assessment, and validation among tourniquet users regularly. The Association of Surgical Technologists has also recommended that the team members partake in training of appropriate tourniquet use.

2.8 Contraindications to Tourniquet use

Absolute contraindications to tourniquet use remain controversial. In most cases, tourniquets can safely be used but certain conditions should warrant caution. Indivduals with severely infected limbs and individuals with severe cardiac conditions should not have tourniquets used on them (27). Certain conditions such as peripheral neuropathy, deep venous thrombosis (DVT) Reynaud's disease, and peripheral vascular disease (PVD) should ideally be excluded before considering tourniquet use (27). Use of tourniquets in patients with sickle cell disease remains controversial (69,70). Sickling episodes may occur with tourniquet as a result of blood stasis acidotic milieu, and reduced oxygenation. Recommendations to prevent sickling with tourniquet use include hyperoxygenation, hyperventilation, adequate hydration, acidosis prevention, and extremity exanguination. However, these strategies remain unproven. Equally unproven is pre-operative use of hydroxyurea to increase hemoglobin F production, a process that may take up to 8 weeks to occur (69). In patients with sickle cell disease, it remains unproven whether

complications are increased when using tourniquets. In instances, they have been used safely in these patients (71).

Peripheral vascular disease (PVD) and tourniquet utilization remains a controversial area (72). However some studies have shown that tourniquet use in patients with PVD is relatively safe (30,73).

In conclusion from the literature review, it is crucial to comprehend that despite its benefits; a surgical tourniquet is not without risks. Additionally, it is paramount to follow correct and recommended usage of surgical tourniquets with emphasis on limb occlusion pressure measurement and to understand potential deleterious outcomes and contraindications of tourniquet use. Health care workers involved in surgical tourniquet use should be familiar with recommended practices with an overall aim of promoting patient safety.

CHAPTER THREE

METHODOLOGY

3.1 Study Design

A cross sectional analytical study design was adopted to assess the limb occlusion pressure measurement and explore the knowledge and practices in key areas pertaining to tourniquet use amongst tourniquet users.

3.2 Study Site

The study was conducted at Kenyatta National and Referral Hospital. Participants for LOP measurement were recruited consecutively from those admitted as inpatients to the adult orthopedic wards on the sixth floor. The study was carried out at the bed side of each study participant in the ward.

Additionally, surgical tourniquet-users practicing or training at KNH present during the study period were recruited purposively for answering the questionnaire-based survey at their specific departments (orthopedic surgery, general surgery, plastic surgery, anaesthesia) or KNH work stations.

3.3 Study Population

The study population was drawn from two populations:

The first group comprised of participants with unilateral lower limb affection on whom limb occlusion pressure was measured using the unaffected limb.

The second group included tourniquet-users - resident doctors, consultants, clinical officers, orthopedic trauma technicians from orthopedic surgery, plastic surgery, general surgery and anaesthesia departments.

3.3.1 Inclusion Criteria - Participants

- Participants aged between 18 - 65 years, presenting with unilateral lower limb affection/condition in whom tourniquet use was anticipated for a surgical intervention during the study period.
- Participants who had consented to participate in the study.

3.3.2 Exclusion Criteria - Participants

- Participants with previous history of injury to the currently unaffected limb.
- Participants with previous history of surgery in the currently unaffected limb.
- Participants with history of known peripheral vascular disease/sickle cell disease/DVT.

Tourniquet users – Inclusion Criteria

- A consenting resident doctor, consultant, clinical officer, orthopedic trauma technician working in the orthopedic surgery, plastic surgery, general surgery and anaesthesia departments during the study period.

3.4 Sample Size Calculation

The aim of this study was to measure LOP pre-operatively in study participants and to determine the current knowledge and practices of tourniquet users pertaining to key areas of surgical tourniquet use.

The sample size was estimated using the formula for mean estimation (Fisher's et al,)

$$\boldsymbol{n \geq \frac{{Z_{\alpha/2}}^2\, \sigma^2}{d^2}}$$

Where, $\boldsymbol{z_{\alpha/2}}$ was the critical value in the standard normal distribution at α-level of significance for a two sided test **(α=0.05, $\boldsymbol{z_{\alpha/2} = 1.96}$)**

$\boldsymbol{\sigma}$ was the estimated population standard deviation of the characteristic being measured; limb occlusion pressure in this study. (One study demonstrated that the mean calculated tourniquet pressure was 202.3 ± 34.2 mm Hg for adequate control of blood loss in upper extremity) (39). ($\boldsymbol{\sigma = 34.2}$)

$\boldsymbol{d}$ was the desired margin of error ($\boldsymbol{d}$**=7 %**)

Using this formula and defined parameters the study recruited **107** participants.

The medical professionals were recruited purposely to assess the knowledge of tourniquet use and their practices in carrying out the procedure involving its use. It was aimed to recruit 100 tourniquet users for answering the questionnaire-based survey about current knowledge and practices among tourniquet users.

3.5 Sampling Method

Considering the study population, consecutive sampling was used to select the 107 participants for LOP measurements.

A total of 100 medical professionals (tourniquet users) meeting the inclusion criteria were selected for the knowledge and practices questionnaire-based study.

3.6 Study Procedure

3.6.1 Recruitment and data collection from study participants

Participants were recruited consecutively from those admitted in the adult orthopedic wards at KNH. Eligible participants meeting the inclusion criteria were identified and their informed written consent was obtained upon agreement to be part of the study.

The measurement of LOP was carried out in the wards at the participant's bedside using a manually inflatable surgical pneumatic tourniquet (with a circular manometer dial graduated in mmHg - Riester) and a portable ultrasound machine capable of carrying out arterial Doppler

ultrasound (ACUSON P500 Ultrasound System - Siemens® - 2016). Before LOP measurement, the participant's supine Blood Pressure measurement was taken on the upper arm using a digital manometer machine (Omron® M2 intellisense automatic blood pressure monitor).

Prior to the LOP measurement, an experienced sonographer carried out identification of dorsalis pedis arterial pulse waveform on colour/spectral sonography under supervised training by a sonologist on 20 participants in a pilot group.

The LOP measurement entailed applying a surgical tourniquet inflatable adult cuff (10 cm wide) to the unaffected lower limb at mid thigh level (mid point between inguinal fold and superior pole of patella) following skin padding using 2 layers of Soffban® skin protection padding.

Following tourniquet cuff application and before inflation, the dorsalis pedis artery was identified using the portable ultrasound probe on colour/spectral Doppler by the sonographer. Once identified, the tourniquet cuff was gradually inflated until the arterial pulse as visualized on the Doppler scan, disappeared as confirmed on the Doppler scan by the sonographer.

The minimum inflation pressure at which the dorsalis pedis artery pulsation disappeared on the colour/spectral Doppler was recorded as the limb occlusion pressure.

The same procedure was repeated twice more to obtain a total of 3 LOP measurements with an interval of five minutes deflation between each measurement.

Following recording of the third LOP measurement, the tourniquet cuff was removed from the participant's limb and the procedure was complete.

The 3 measured LOPs and a calculated average were recorded in the data collection sheet which also included additional parameters – age, sex, supine blood pressure, mid-thigh circumference and cuff width: thigh circumference ratio.

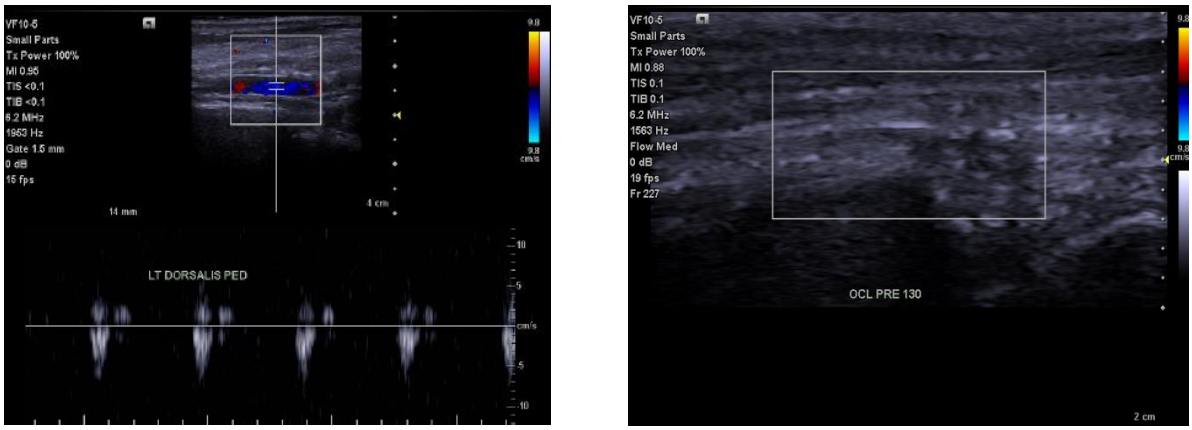

Figure 5 – Picture showing identification of dorsalis pedis on colour/spectral sonography (left) and its occlusion on tourniquet inflation (right)

3.6.2 Recruitment and data collection from tourniquet users

Tourniquet users were informed about the study and a semi-structured questionnaire (appendix 4) was administered to the users who accepted to fill it.

3.7 Data management and analysis

The collected data was entered and stored in Microsoft Excel sheets. Data was exported to STATA version 13, for cleaning and analysis. Data cleaning was done to check and correct for missing observations, incorrect entries and duplicates.

Univariate analysis was done to describe the participant characteristics and the LOP measurements, tourniquet users knowledge and practices. Measures of central tendency (mean/median/mode) and dispersion (SD/IQR) were reported for continuous/discrete variables such as LOP measurements. Categorical variables such as tourniquet users' knowledge and practices were tabulated; frequencies and proportions were reported.

Graphs were used to show the distribution of data; for continuous/discrete variables histograms were plotted and bar/pie charts for categorical variables.

3.8 Ethical Considerations

Ethical approval to conduct the study was sought from the Department of Orthopedic Surgery, University of Nairobi, and from the Kenyatta National Hospital/University of Nairobi - Ethics & Research Committee (KNH / UON – ERC). Consent was obtained from the participants after informing them about the importance of the findings in guiding tourniquet pressures based on limb occlusion pressures, and in addition using the questionnaire findings to add to the knowledge on safe tourniquet use and associated complications of improper use. Refusal to participate in the study was without any consequences.

The overall aim was to disseminate the findings accrued from the study to build on knowledge pertaining to key areas of tourniquet use, and promote LOP measurement to guide tourniquet inflation pressures, thus promoting patient safety.

CHAPTER FOUR

RESULTS

4.1 Characteristics of the Study Participants/Patients

The Limb Occlusion Pressures (LOP) were evaluated/ measured pre-operatively. Male were the majority constituting three quarters (n=81; 75.7%) of the study sample. These participants/patients were aged between 18 and 65 years with a median age of 37 years (IQR=28-45).

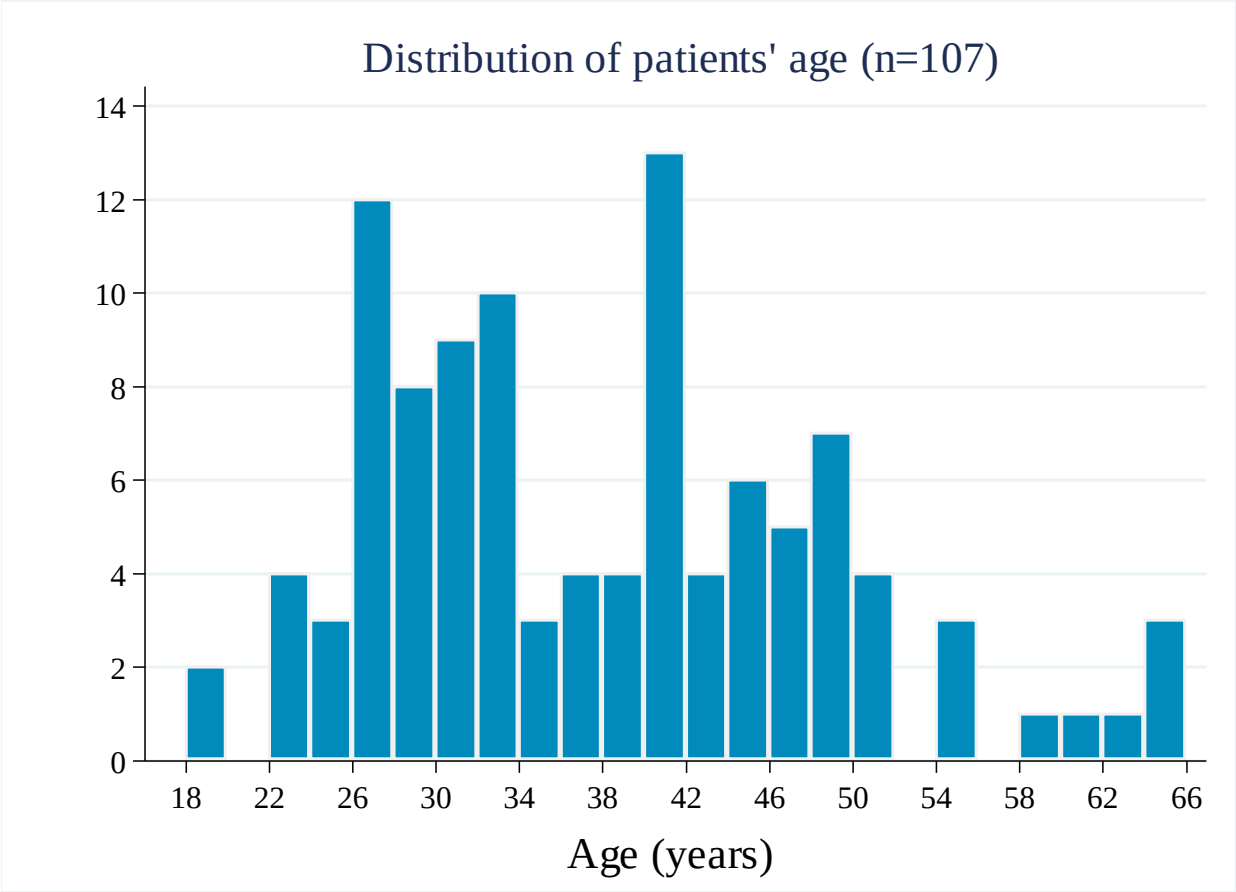

Figure 6: Distribution of patients' age (years)

The distribution of the patients' age was bimodal (two peaks) at 27 years and 41 years.

The supine blood pressure was taken for all the patients; figure 7 shows the distribution of supine systolic and diastolic blood pressure readings. Systolic supine BP ranged from 95mmHg to

170mmHg with a median of 117mmHg (IQR=110mmHg-129mmHg) and Diastolic supine BP ranged from 57mmHg to 99mmHg with a median BP of 77 mmHg (IQR=70.0-82.0mmHg).

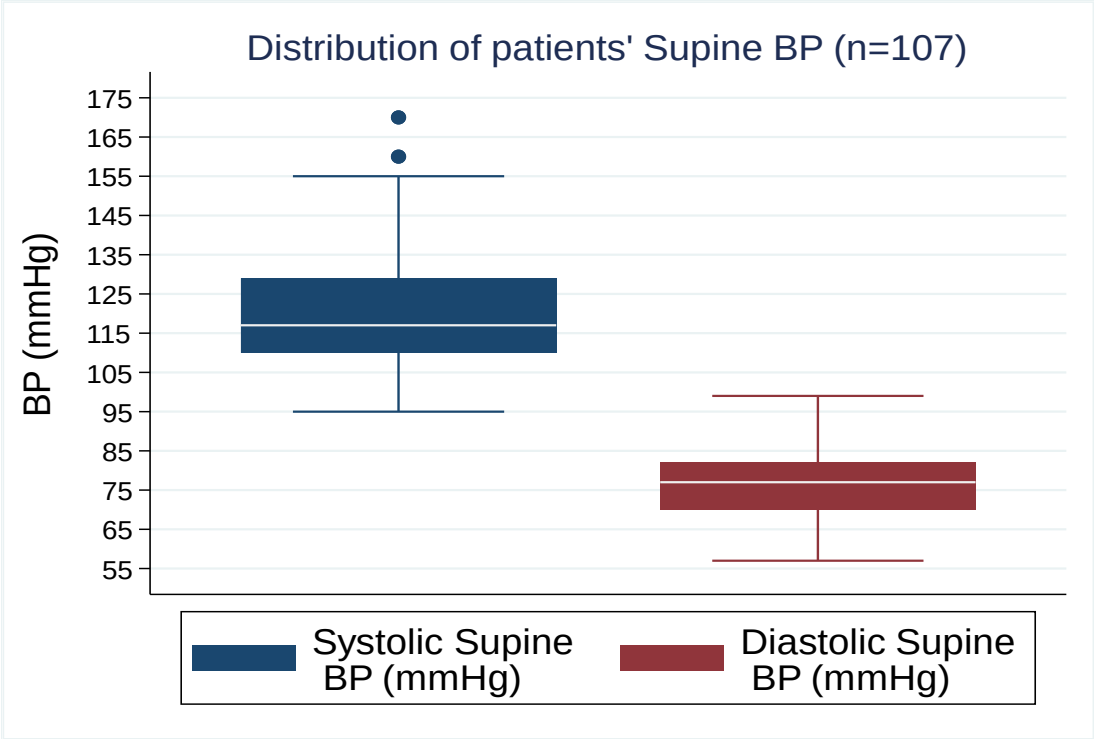

Figure 7: Distribution of Supine Systolic and Diastolic Blood Pressure (mmHg)

Mid thigh circumference ranged between 30cm and 66cm with a mean of 42.0 cm (SD=6.9cm). The inflatable cuff width: thigh circumference ratio ranged from 0.15 to 0.33 with a mean of 0.24 (SD=0.04). The figures 8 and 9 show the distribution of mid thigh circumference measurements and cuff width: thigh circumference ratio, respectively.

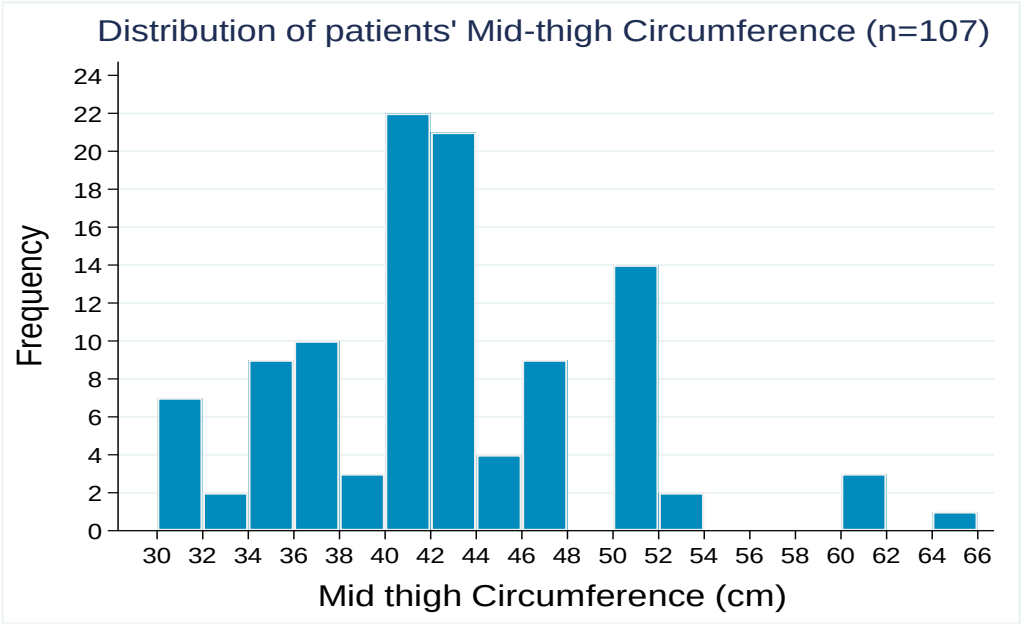

Figure 8: Distribution of Mid thigh Circumference readings (cm)

Three quarters of the patients had a mid thigh circumference less than 48cm.

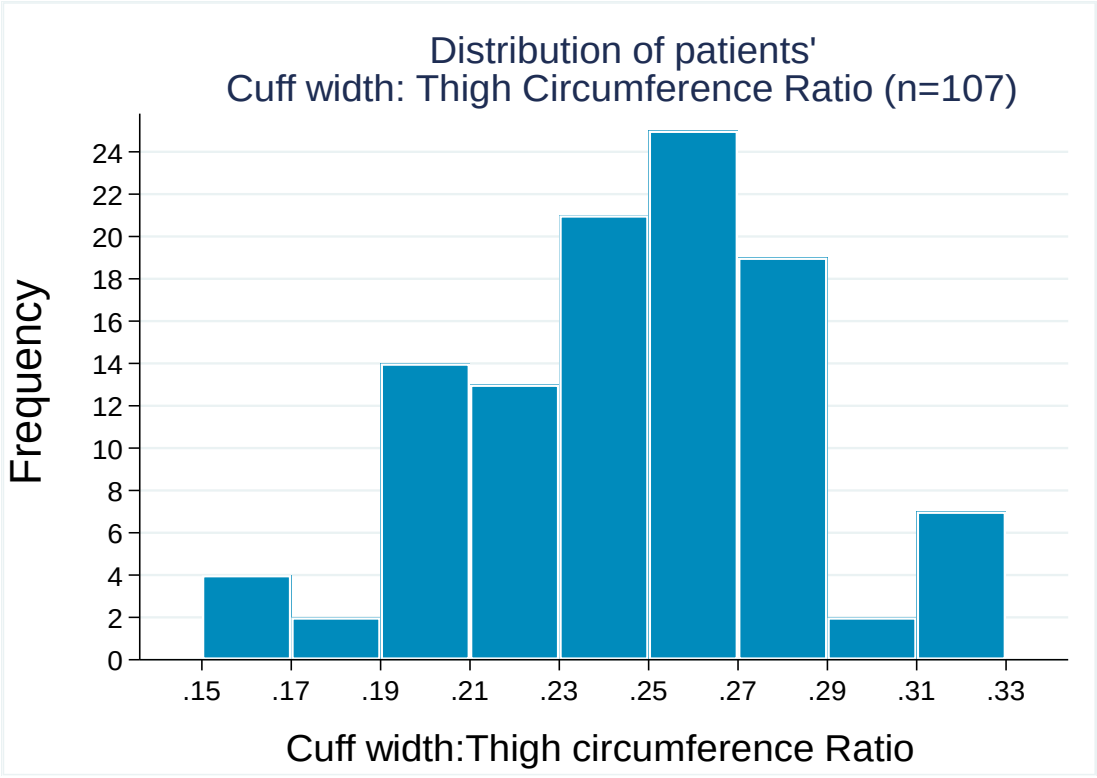

Figure 9: Distribution of Cuff width: Thigh circumference ratio

4.2 Assessment of LOP in unaffected lower limbs

LOP measured ranged from as low as 100mmHg to as high as 300mmHg. The distribution was bimodal with 120mmHg and 180mHg being the most frequent readings. Three quarters of the patients had a recording of less than 180mmHg.

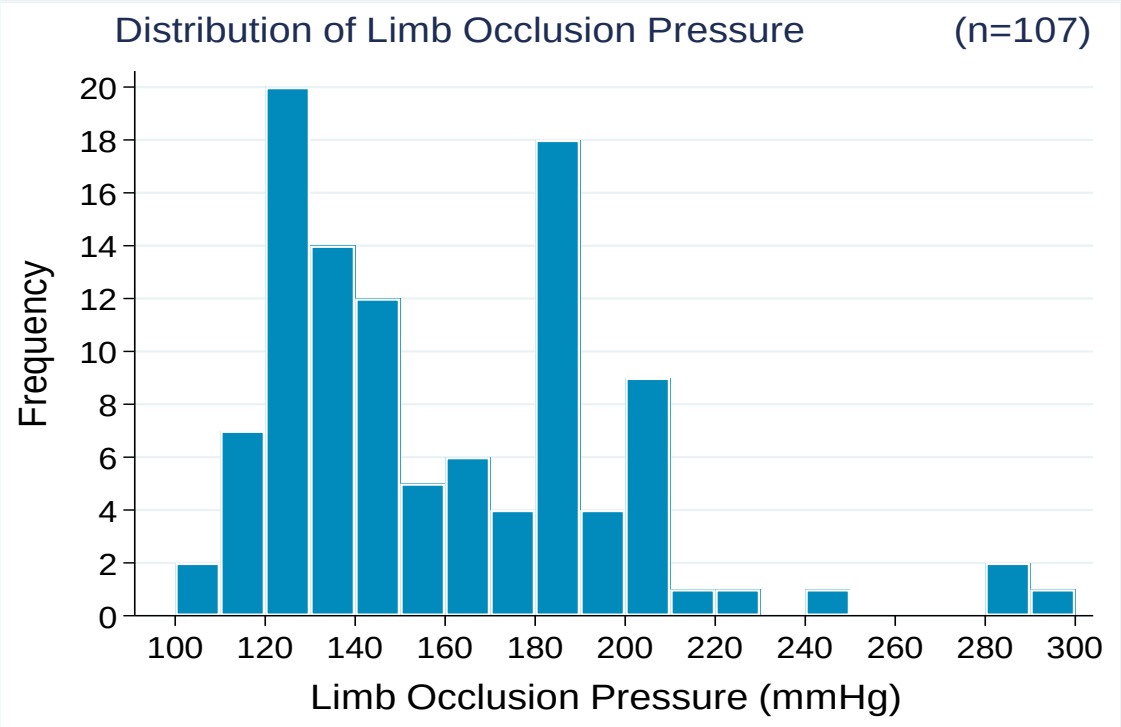

Figure 10: Distribution of LOP measurements (mmHg)

The table 1 shows the summary statistics for the patient characteristics.

Table 1: Summary statistics for the patient characteristics and LOP

Variable	Mean (SD)	Median (IQR)	Min	Max
Age (Years)	37.7(11.0)	37.0(28.0-45.0)	18.0	65.0
Mid thigh circumference (cm)	42.1(6.9)	42.0(37.0-47.0)	30.0	66.0
Cuff width: Thigh circumference (cm)	0.24(0.04)	0.24(0.21-0.27)	0.15	0.33
Supine Systolic BP (mmHg)	119.4(14.8)	140.0(120.0-180.0)	95.0	170.0
Supine Diastolic BP (mmHg)	76.5(9.1)	77.0(70.0-82.0)	57.0	99.0
Limb Occlusion Pressure	155.1(38.7)	140.0(120.0-180.0)	100.0	300.0

4.3 Correlation between patient age, supine BP, mid thigh circumference and LOP

Scatter plots were used to explore the relationship between the participants' age, supine BP, mid thigh circumference, cuff width: thigh circumference and the LOP readings. As shown in figure 11, there appears to be a positive linear relationship between thigh circumference vs. LOP and Supine BP vs. LOP. Cuff width: thigh circumference ratio was inversely related with LOP readings.

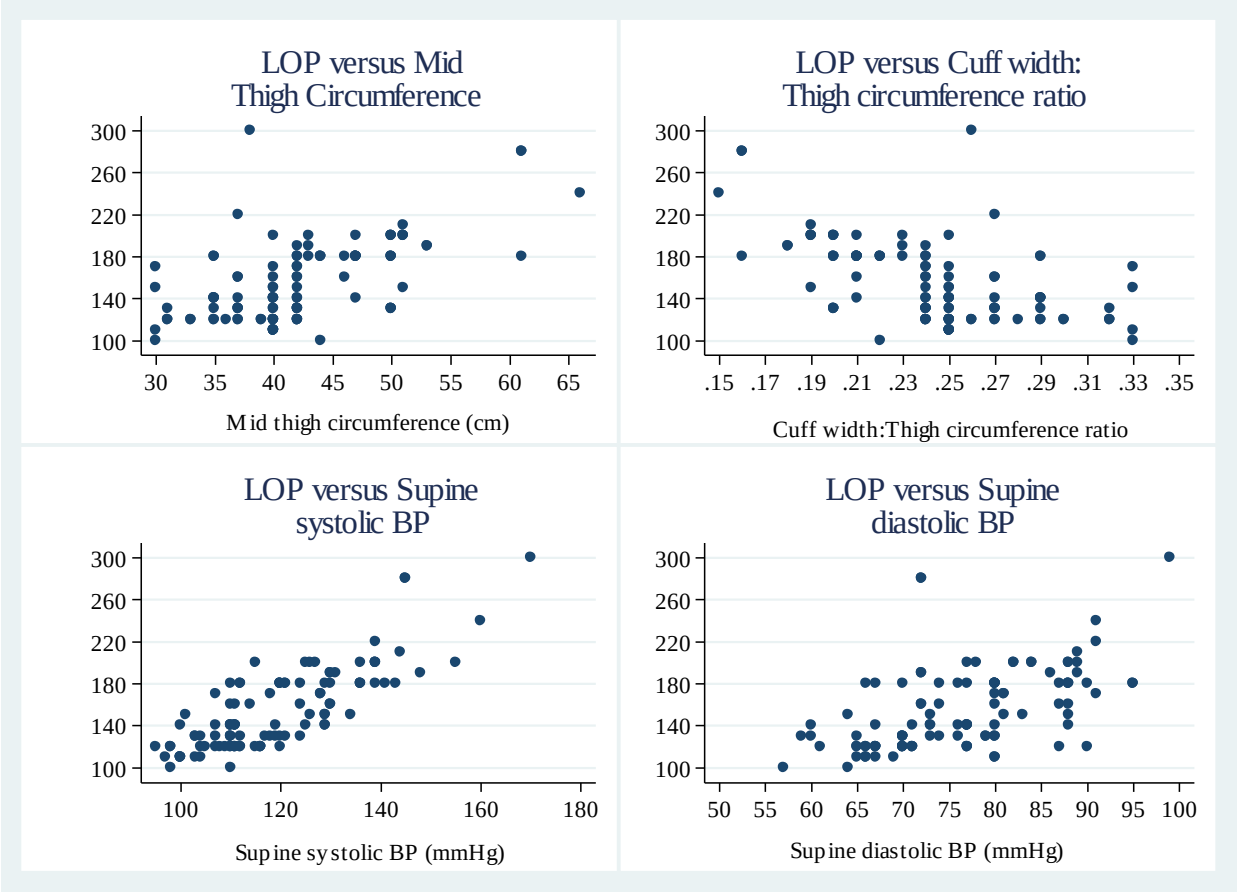

Figure 11: Supine BP, mid thigh circumference, cuff width: thigh circumference ratio versus LOP

There was no linear relationship between participants' age and LOP readings, as shown in Figure 12.

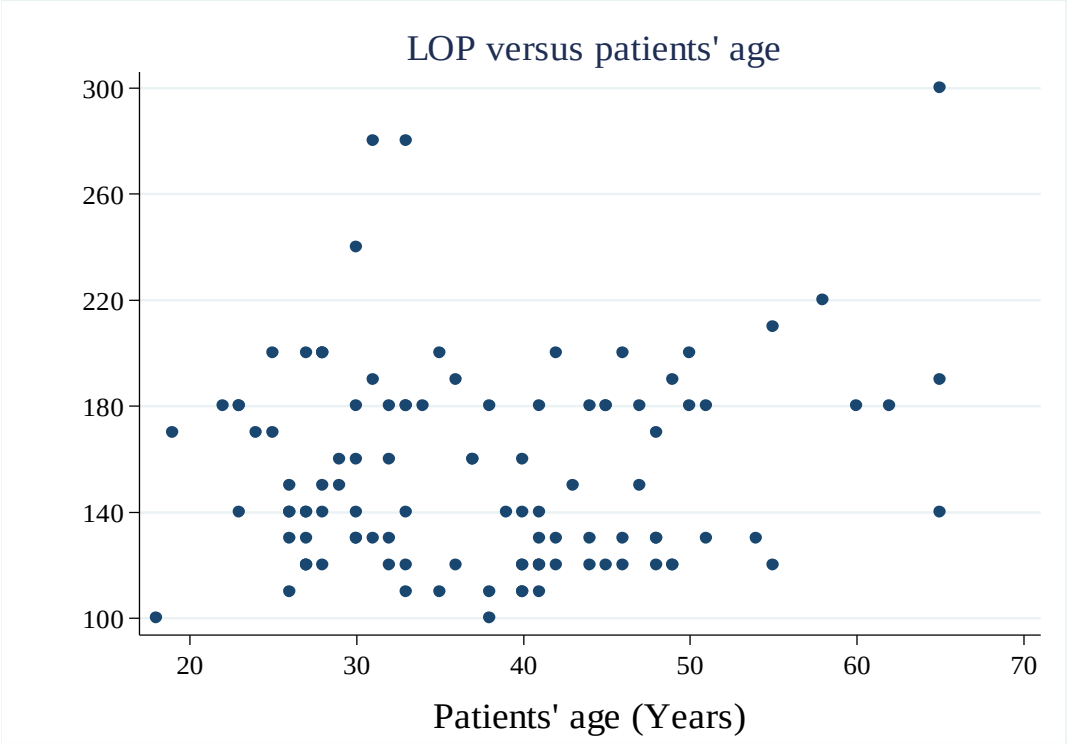

Figure12: Patients' age versus LOP

Spearman rank sum tests of correlation were done to evaluate the linear relationship between the patients' characteristics and the LOP recorded. Under the null hypothesis that there is no significant linear relationship between each of the patient characteristic and LOP recorded, and alpha level of significance 0.05, mid thigh circumference, cuff width: thigh circumference ration, and blood pressure were found to be significantly correlated with LOP readings.

There was a moderately strong positive correlation between mid thigh circumference (Rho=0.561), supine diastolic BP (0.596) and LOP; high strong positive correlation (Rho=0.778) between supine systolic BP and LOP; and a moderately strong negative correlation (Rho=-0.562) between cuff width: thigh circumference ration and LOP.

Table 2: Correlation between patient characteristics and LOP

Patient characteristic	Spearman Rho (Strength of correlation)	P-value	Interpretation
Age (X1)	0.016	0.999	Negligible correlation
Mid thigh circumference (X2)	0.561	<0.001	Moderate strong positive correlation
Cuff width: Thigh circumference (X3)	-0.562	<0.001	Moderate strong negative correlation
Supine Systolic BP (X4)	0.778	<0.001	High positive correlation
Supine Diastolic BP (X5)	0.596	<0.001	Moderate strong positive correlation

AORN recommends that for adults, an additional safety margin (as shown below) be added to the measured LOP.

- + 40 mmHg for LOP < 130 mmHg,
- + 60 mmHg for LOP 131–190 mmHg
- + 80 mmHg for LOP > 190 mmHg

Using the above reference guide for tourniquet pressure application, the expected pressure to employ during tourniquet use was computed by adding this reference quantity for each of the given LOP measurements. Figure 13 shows the distribution of the expected tourniquet pressure.

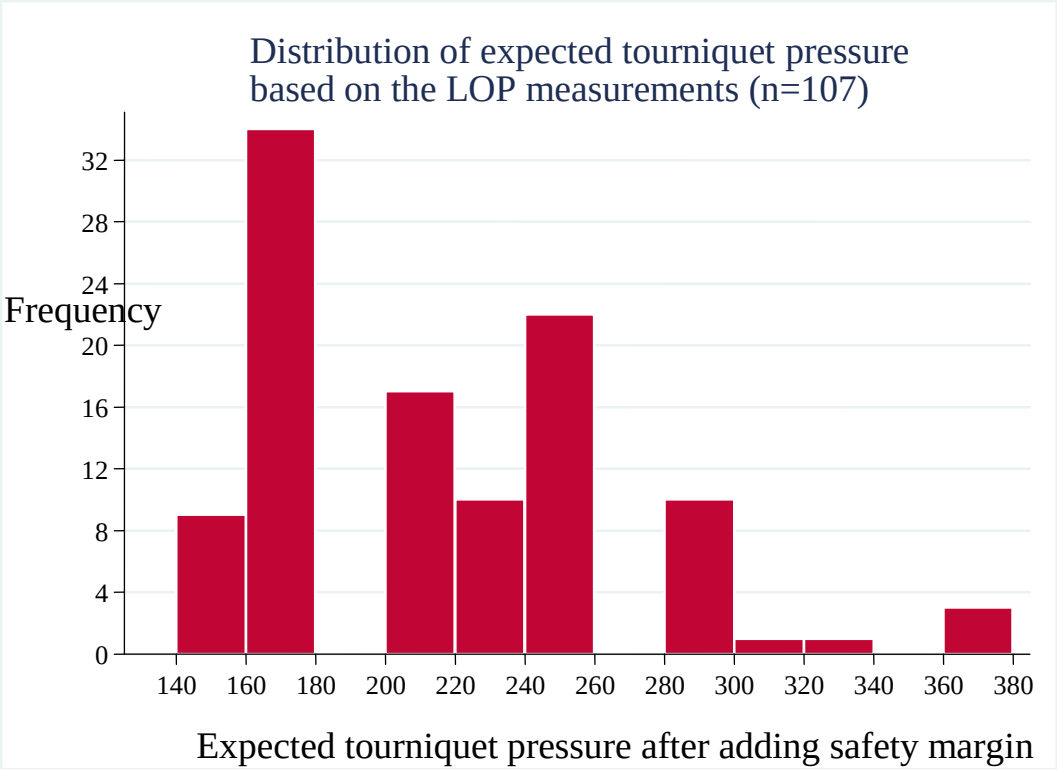

Figure 13: Distribution of the expected tourniquet pressure based on the LOP readings

It was evident that the pressure likely to be applied when using the tourniquet would be less than 300mmHg which has traditionally been used as a fixed standard pressure by many surgeons for lower limb surgeries.

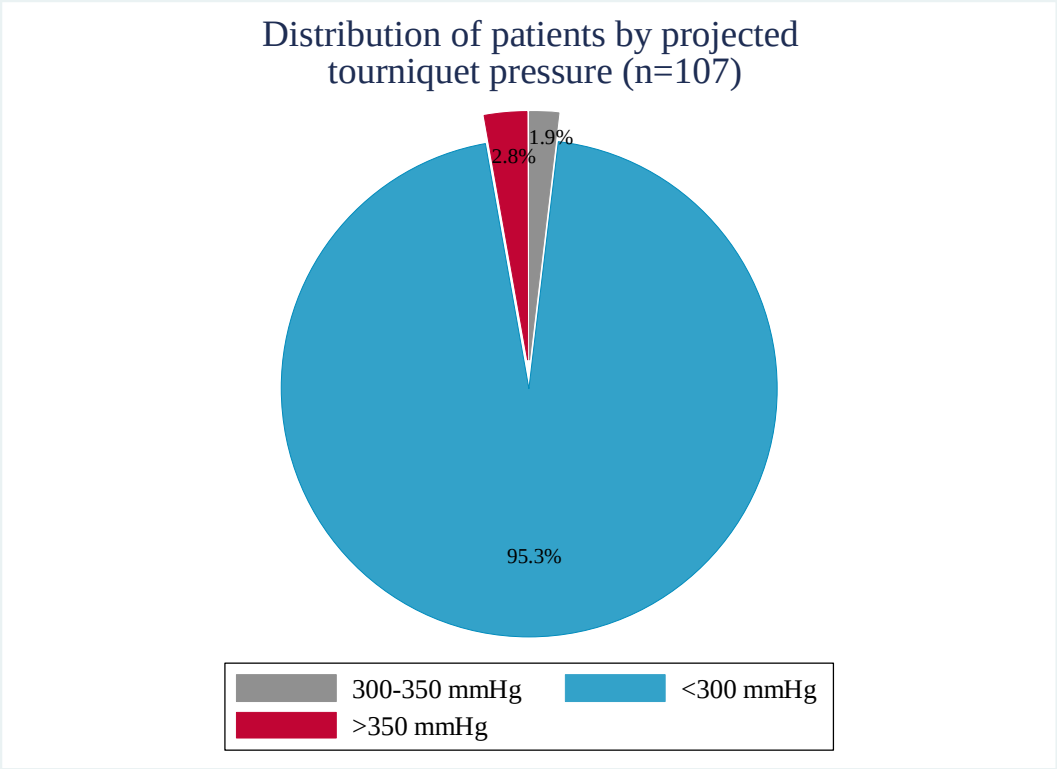

Figure 14: Patient classification by projected tourniquet pressure

For most of the patients (102/107; 95.3%), the tourniquet pressure after addition of the safety margin would still be lower than 300mmHg.

4.4 Knowledge and practice about tourniquet use among users

A semi structured questionnaire was administered to a total of 100 tourniquet users to assess their knowledge and practices pertaining to key areas of surgical tourniquet use. The respondents included orthopaedic trauma technicians, consultant surgeons, and residents rotating in orthopaedic surgery, general surgery, plastic surgery and anaesthesia. Their years of experience in their current practices ranged from as low as 2 years to as far as 40 years. It was important to note that not all questions were answered fully as responders filled the questionnaire based on their capabilities/experience.

4.4.1 Respondents' knowledge of tourniquet application

Most (97/100; 97.0%) of the respondents had never received any formal training on the tourniquet use despite the fact that all of them are directly or indirectly involved in its use in their practice. More than half of the respondents (58/100; 58.0%) were involved in all the stages of the tourniquet use, that is; application, supervision during application, monitoring during use and release/deflation. Approximately, a quarter (22/100; 22.0%) was only involved in the application and release, whereas the rest (6/100; 6.0%) took part in the monitoring during use.

Pneumatic tourniquets were more commonly (67/100; 67.0%) used compared to the Esmarch tourniquets (47/100; 47.0%). Some respondents used both the pneumatic as well as the elastic Esmarch tourniquets in their practice.

Asked whether the limb to be operated was exsanguinated before tourniquet inflation, most agreed (71/76; 93.4%) and the rest (5/76; 6.6%) reported that exsanguination depended on the indication for surgery. In practice, at least half of the respondents (54/93; 58.1%) usually elevate the limb alone for exsanguination while the others (39/93; 41.9%) use an exsanguination bandage in addition to limb elevation for limb exsanguination.

The duration of limb elevation for exsanguination was 5 minutes (59/72; 81.9%), 10 minutes (10/72; 13.9%) or 15 minutes (3/72; 4.2%).

Table 3: Respondents' knowledge of tourniquet use

Variable	Response	Count(percent)
Have any formal training in tourniquet use? (n=100)	No	97 (97.0%)
	Yes	3 (3.0%)
Involvement in tourniquet use (n=100)	All stages	58 (58.0%)
	Application and release	22 (22.0%)
	Monitoring during use	6 (6.0%)
Types of tourniquets used (n=100)	Pneumatic tourniquets	67 (67.0%)
	Esmarch tourniquets	47 (47.0%)
Is the limb to be operated exsanguinated	Limb exsanguinated	71 (93.4%)
before tourniquet inflation? (n=76)	Depends on the indication	5 (6.6%)
How is exsanguination carried out? (n=93)	Elevate limb alone for exsanguination	54 (58.1%)
	Use an exsanguination bandage plus elevation of limb	39 (41.9%)
Duration of limb elevation for	5 minutes	59 (81.9%)
exsanguination (n=72)	10 minutes	10 (13.9%)
	15 minutes	3 (4.2%)

The study also sought to find out respondents' understanding of possible contraindications to limb exsanguination. When asked about the conditions in which limb exsanguination may not be carried out before using a tourniquet, three quarters (40/53; 75.5%) mentioned diabetes mellitus. Other conditions mentioned were malignancy (6/53; 11.3%) and anaemia (7/53; 13.2%). Notably, the response rate to this question was quite low, as close to half (47/100; 47.0%) of the respondents did not answer.

Asked about the timing of prophylactic antibiotic administration prior to tourniquet application/inflation, majority of the respondents (60/70; 85.7%) mentioned a duration of 30 minutes before the application/inflation of the tourniquet; and the rest (10/70; 14.3%) said 10 minutes. Interesting to note, most of the respondents (49/61; 80.3%) do not usually confirm

whether the patient has been given pre-incision prophylactic antibiotics before applying the tourniquet/inflating it.

As for skin protection measures, soft band/soft padding (other names used included Soffban® or orthowool) is the most commonly used (74/100; 74.0%) material by the respondents, followed by crepe bandage (27/100; 27.0%). In other instances gauze (5/100; 5.0%) and surgical drapes (3/100; 3.0%) were mentioned to be used.

To assess the respondents' tourniquet application practices when using the pneumatic tourniquet, they were asked to report the inflation pressure applied for lower limb surgery in adult patients. More than two-thirds (63/90; 70.0%) of the respondents mentioned 250-300mmHg. While some (19/90; 21.1%) mentioned a high inflation pressure of 400mmHg.Others (8/90; 8.9%) mentioned low inflation pressure of 100mmHg.

To determine the tourniquet pressure to be used when using inflatable tourniquets, about half (38/73; 52.1%) use standard preset pressure, a third (24/73; 32.9%) base it on the patient's blood pressure while the rest (11/73; 15.1%) base it on the patient's age, extremity and size. It was noted that none of the respondents use LOP to determine the tourniquet pressure to be used.

Table 4: Knowledge of patient preparation before tourniquet use

Variable	Response	Count(percent)
Prophylactic antibiotic administration	30 minutes before	60 (85.7%)
Timing (n=70)	10 minutes before	10 (14.3%)
Confirm if patient received prophylactic	No	49 (80.3%)
Antibiotics before tourniquet use? (n=61)	Yes	12 (19.7%)
Skin protection method used (n=100)	Soft band/soft padding	74(74.0%)
	Crepe bandage	27 (27.0%)
	Gauze	5 (5.0%)
	Surgical drapes	3 (3.0%)
Inflation pressure used for adult patients	100mmHg	8 (8.9%)
When using a pneumatic tourniquet (n=90)	250-300mmHg	63 (70.0%)
	400mmHg	19 (21.1%)
How do you determine the tourniquet	Standard preset pressure	38 (52.1%)
Pressure to used? (n=73)	Based on BP	24 (32.9%)
	Based on age extremity and size	11 (15.1%)
	Based on LOP	0

Tourniquet use would last either 120 minutes (59/77; 76.6%) or 150 minutes (18/77; 23.4%) before deflation for lower limb surgeries. In cases where deflation interval is required before re-application and proceeding with the surgery, three quarters (58/77; 75.3%) would allow a 5-minute interval before re-application. The rest reported allowing either a 10-minute (10/77; 13.0%) or 30-minute interval (9/77; 11.7%). If closing the wound, some (22/67; 32.8%) respondents request for tourniquet release after closure but before dressing, or (24/67; 35.8%) after wound closure and dressing while the rest (21/67; 31.3%) deflate before closure.

Indications and contraindications for tourniquet use are demonstrated in figures 15 and 16 as reported by users. Figure 17 shows the frequency of tourniquet associated complications known by users.

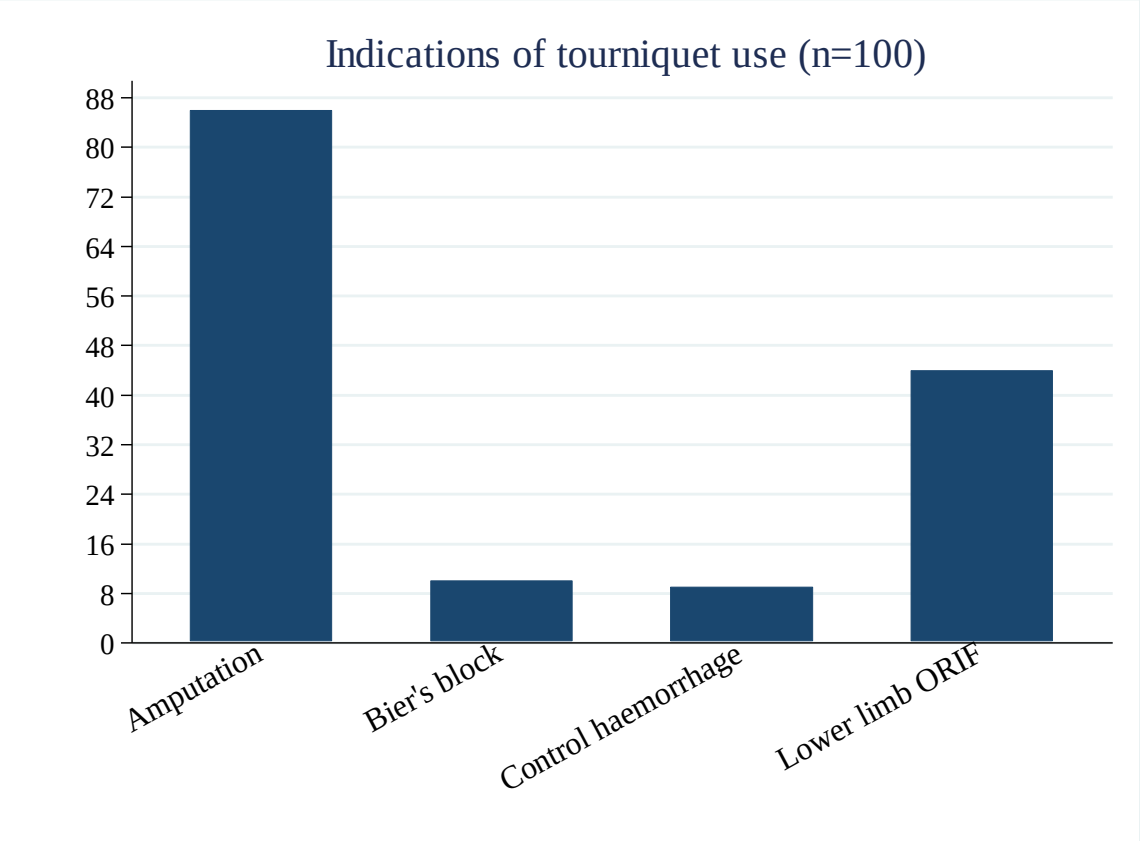

Figure 15: Knowledge of tourniquet use indications

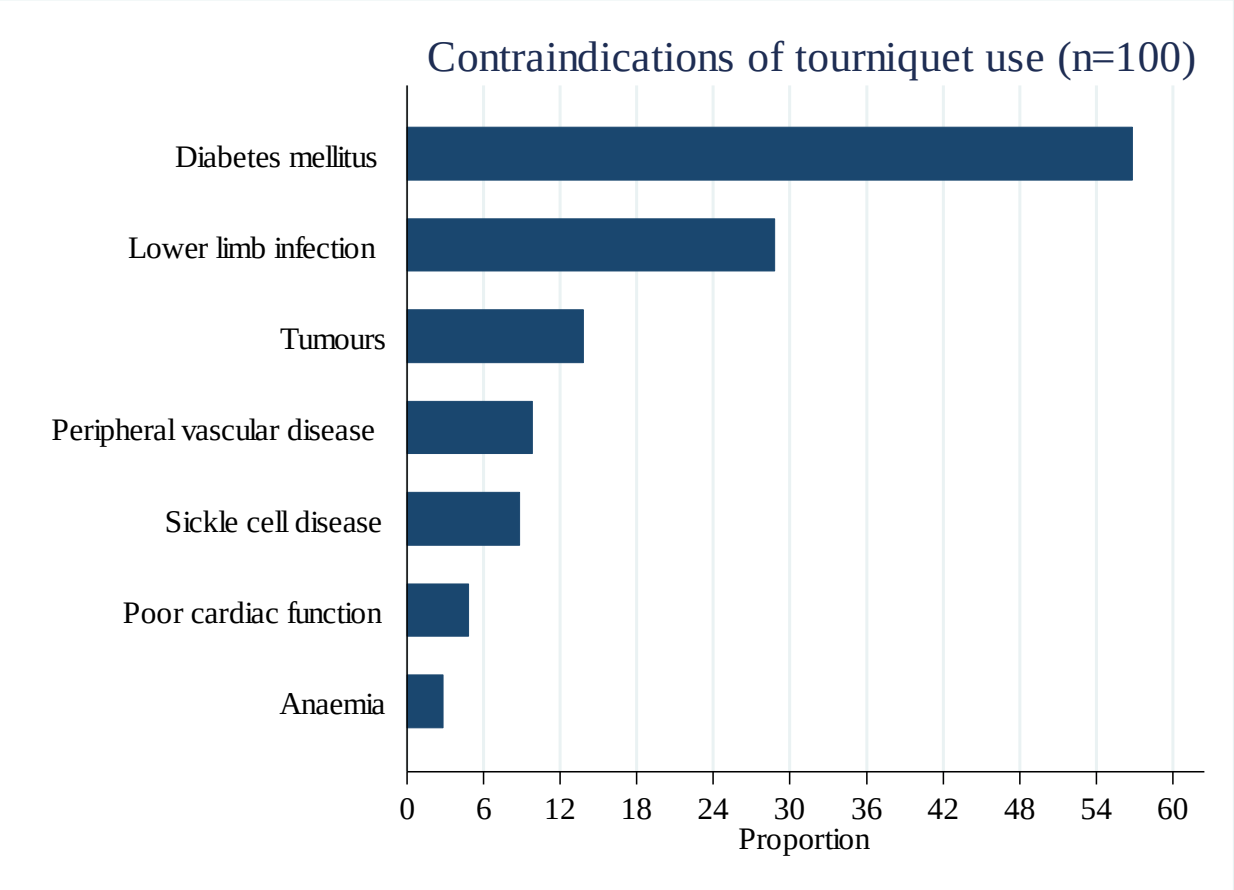

Figure 16: Knowledge of tourniquet use contraindications

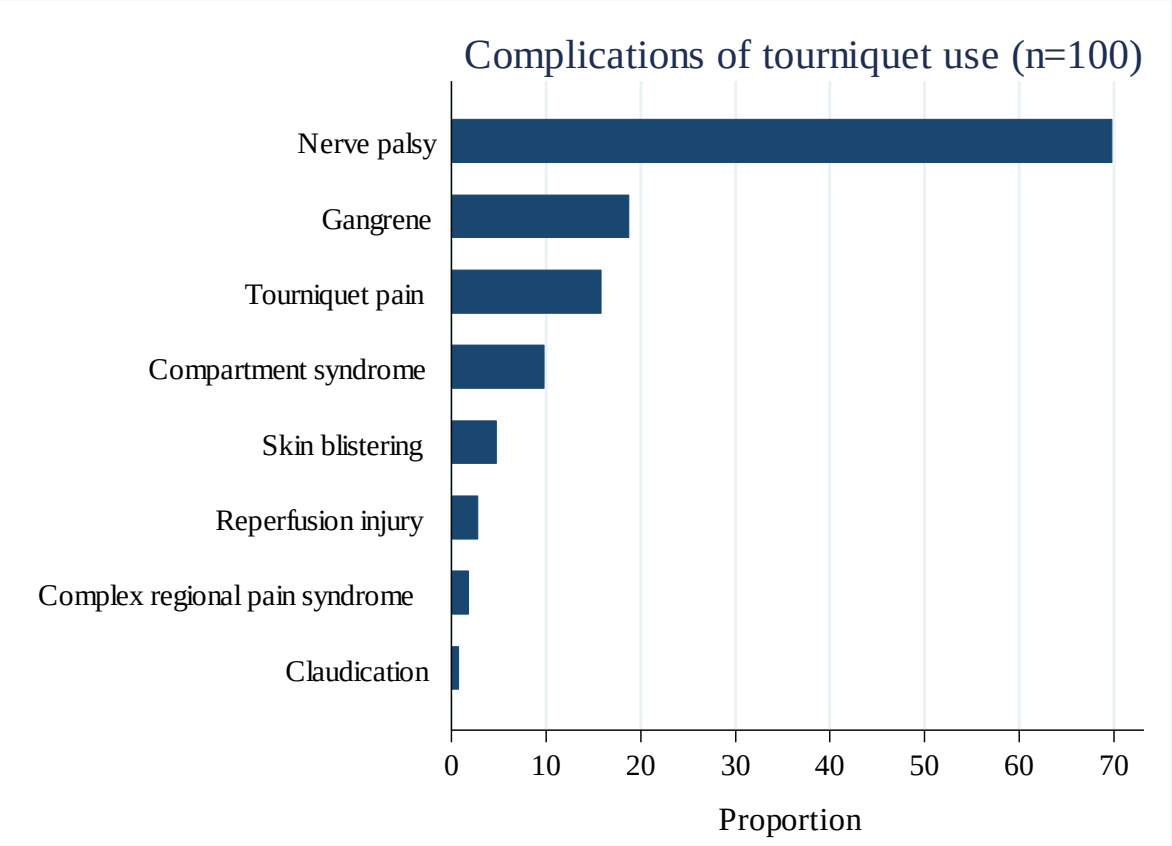

Figure 17: Tourniquet use related complications

Table 5: Tourniquet use practices

Variable	Response	Count(percent)
Ever encountered any complications post-operatively	No	65 (77.4%)
attributed to tourniquet use? (n=84)	Yes	19 (22.6%)
Complications encountered (n=19)	Nerve palsy	19 (100.0%)
	Tourniquet pain	9 (47.4%)
	Skin blistering	5 (26.3%)
Is LOP measured before tourniquet use? (n=100)	No	100(100.0%)
Is consent sought for possible tourniquet use? (n=100)	No	100(100.0%)
Do you think tourniquet use consent should be sought?	No	2 (2.0%)
(n=100)	Yes	98 (98.0%)
Tourniquet release	After closure	24(35.8%)
	Before closure	21(31.3%)

DISCUSSION

Tourniquets have been used since antiquity (1) and have evolved from primitive non-inflatable/non-pneumatic types to currently available sophisticated automated personalized inflatable/pneumatic types.

Use of surgical tourniquets is generally considered a safe practice. However, improper use has led to potentially avoidable complications (1, 5, 51-54, 58-61).

The main indication of a surgical tourniquet is to minimize intra operative blood loss and thus improves visualization and expedites surgical procedures. Other indications include tourniquet use during regional anaesthesia, controlling haemorrhage in emergency situations, and prophylactic tourniquet application during combat situations.

This study was divided into two participant populations. The first part included study participants who had a lower limb injury/condition that may have required use of a surgical tourniquet for a surgical intervention. Pre-operative Limb Occlusion Pressure (LOP) measurement was carried out in these participants. For participants' comfort, LOP measurement was carried out on the unaffected lower limb.

Limb Occlusion Pressure measurement has been shown to allow the use of a lower and safer tourniquet inflation pressure when using pneumatic tourniquets. In this study it was aimed to demonstrate that LOP measurements were significantly lower than the fixed higher inflation pressures which tourniquet users have been traditionally using.

In this study it was found that three quarters of the patients had an LOP recording of less than 180mmHg which is significantly lower than the 250-300mmHg (or sometimes higher) tourniquet inflation pressures routinely and traditionally employed by surgeons.

Even after taking into consideration the addition of a margin of safety to measured LOP, 95.3% of participants had measurements of less than 300mmHg (figure 14). From this observation, it may be inferred that instead of using traditionally fixed inflation pressures based on self experience and not on any evidence, measurement of LOP, and addition of a margin of safety can allow for use of lower inflation pressures. Additionally, one study (39) found that the calculated tourniquet pressure (measured using Doppler studies) was lower and was well below 250-300mmHg traditionally used by surgeons to allow for a satisfactory operating field. Similarly, Olivecrona et al (74) found that using cuff inflation pressures based on LOP were significantly lower compared to a control group in whom LOP was not measured.

Mc Ewen et al (75) found that using LOP plus a margin of safety of 40, 60, or 80mmHg (for LOP < 130, 130 - l90, or 190+ mmHg respectively) with a standard breadth cuff will lead to an average cuff pressure of 223 mmHg which was 11% lower than typical practice and up to 80 mmHg (32%) lower on some patients.

It has been noted that using wider cuffs allow for use of lower cuff inflation pressures compared to standard width cuffs (75-77). In this study, although a standard width cuff was used during LOP measurements, it can be inferred from the referenced studies that use of a wider cuff may allow for lower cuff pressures and thus ultimately help to reduce the incidence of pressure-related tourniquet complications. Reilly et al (76) found similar findings in a paediatric population.

In this study, the measured LOP was directly proportional to the mid thigh circumference in majority of participants. This correlation may be used to predict higher LOP depending on extremity size though the correlation was moderately strong (p-value <0.001). Additionally, the cuff width: mid thigh circumference was inversely proportional to LOP.

The main aim of this study was to demonstrate the measured levels of LOP in patients objectively using Doppler sonography. The gold standard arterial Doppler sonography was used to measure LOP in this study. Other methods (36) have been shown to have no statistical significance over the gold standard technique for LOP measurement despite being more expensive. In this study it was more feasible to carry out LOP using the described conventional method.

As mentioned, it can be inferred from the above studies that post-operative tourniquet related complications would also be significantly less if we adopt using cuff pressures based on LOP measurements. However, this would require future studies to evaluate post-operative complications as well as intra-operative blood loss against control population groups in whom surgeries are done using traditionally used fixed/conventional pressures.

Although Supine systolic blood pressure had a positive correlation with LOP, blood pressure cannot be relied on alone to determine cuff inflation pressure as the relationship is usually variable and therefore this method remains suboptimal. Ishi et al (37, 38) reported using a novel system that could apply tourniquet pressures in relation to intraoperative blood pressure alterations. However, the cost of this automated synchronized tourniquet systems may be a hindrance to their use in the local setting.

Varied evidence exists about limits for tourniquet time, inflation pressures and cuff sizes. Not much data exists on knowledge and practice of the guidelines and recommendations of safe tourniquet use amongst tourniquet users.

The second study population consisted of tourniquet users – defined as any user directly or indirectly involved during any stage of use of a tourniquet.

It was found that for the 107 study participants, only 2 participants had LOP greater than 250 – 300mmHg (which from the questionnaire based study was the commonest pressure range used

during lower limb surgery from the survey of tourniquet user practices in this study - 70% - table 4 results). Some respondents (21%) actually use a much higher inflation pressure of 400mmHg which may be detrimental and lead to pressure related tourniquet complications. It was interesting to note that most (97/100; 97.0%) of the respondents had never received any formal training on the tourniquet use despite the fact that all of them are directly or indirectly involved in its use in their practice.

Pneumatic tourniquets were more commonly used (67%) compared to the Esmarch tourniquets (47%). Some respondents used both the pneumatic as well as the elastic Esmarch tourniquets in their practice. Akinyoola et al (7) proposed that Esmarch tourniquets could safely be used when pneumatic ones were not available. However, the Esmarch tourniquets may be detrimental as evidenced in other studies (6,7,31).

Odinnson in Norway (57) found that 72% of surgeons used pneumatic tourniquets and 14% used the Esmarch bandage as a tourniquet. The use of pneumatic tourniquets was similar to that found by St. Clair Gibson in South Africa (78).

With regards to limb exsanguination, St. Clair Gibson et al (78) found that 68% elevate the limb and 59% use Esmarch bandage for exsanguination. In this study, it was found that 58.1% elevate the limb alone while 41.9% use an additional exsanguination bandage in addition to limb elevation before tourniquet inflation. Yalcinkaya et al (66) found that up to 90% of users exsanguinated the limb using an Esmarch bandage before tourniquet inflation.

It was found that the duration of limb elevation for exsanguination varied between 5 – 15 minutes. Majority (81.9%) elevated for only 5 minutes while a small 4.2% elevated for 15 minutes. Warren et al (49) found the optimal duration of elevation for exsanguination to be 5 minutes at an elevation angle of 90 degrees for lower limbs.

It was interesting to note that diabetes mellitus was mentioned as a possible contraindication to both limb exsanguination and tourniquet use in general. This parameter had not been evaluated by the referenced studies.

This observation may probably imply that users were wary of using tourniquets in diabetics who may probably have pre-existing peripheral vascular disease and peripheral neuropathy as complications of diabetes. Some users (11.3%) mentioned malignancy as a contraindication of tourniquet use.

Majority of the respondents mentioned that antibiotics should be administered 30 minutes prior to inflation of tourniquet. Other users (14.3%) mentioned that antibiotics should be administered prophylacticaly ten minutes prior to inflation. However, 80.3% of users never confirm if prophylactic antibiotics have been administered. By inference, this implies that the peri-operative team should be more vigilant and ensure that the antibiotic has been administered.

For skin protection below the tourniquet, it was found that 74% used soft padding.

In one study (66) more than 94% of users applied soft padding for skin protection below the tourniquet. This was reflected in this study as well, as majority did the same. Din et al (28) found that skin protection was important and that when no skin protection was applied, skin related complications were more prevalent. Yang et al (29) also reported chemical burns complicating tourniquet use.

As regards to inflation pressures when using pneumatic tourniquets, 70% of users apply a pressure between the range of 250-300mmHg for lower limb surgeries. With greater than half mentioning that they used standard preset pressures. None of the users used LOP to determine the tourniquet inflation pressure. It was inferred that as majority of the users had had no formal training in tourniquet use, they probably relied on the value of 250-300mmHg through self experience and what they have been seeing other tourniquet users practice. This was similar to

findings by Yalcinkaya et al (66) who additionally showed that many users employed higher fixed tourniquet pressures for lower limb surgeries (mean 345mmHg).

Odinnson and Yalcinkaya (57, 66) found that the commonest method used by users to determine the tourniquet pressure was based on patients' systolic blood pressure. With users who preferred fixed pressures, 300mmHg was used for lower limbs.

St. Clair Gibson et al found that 64% of users believed that tourniquet pressures of 400mmHg or less were safe while 22% used a formula based on systolic BP to calculate the tourniquet pressure. Similarly, in this study, 32.9% of users based tourniquet pressures based on blood pressure.

Tourniquet time allowed for lower limb surgery of 120 minutes was mentioned by 76 % of users. This was in keeping with practices by the users of the referenced studies (57,66,78).

In this study 75% of users deflated the tourniquet for 5 minutes before re-application. St. Clair Gibson et al (78) noted that 6-10 minutes was the commonest deflation interval reported by users. A deflation interval of 30 minutes, reported by 11% of users in this study seems to be too long and an average of 10 minutes is recommended by the AORN.

When it came to release of tourniquet, there was varied preference whether to do it before wound closure (31.3%); after wound closure but before dressing (32.8%); or after wound closure and dressing (35.8%). It was inferred that this probably depended on the users personal past experience. However, Abbas et al (18) found that intra-operative tourniquet release and trying to achieve haemostasis before wound closure and dressing does not minimize overall loss of blood with no effect in preserving blood after knee arthroplasty. Other studies have reported similar findings (42, 43).

With regards to contraindications of tourniquet use, 56% reported diabetes mellitus as a possible contraindication followed by lower limb infection, tumours and peripheral vascular disease. Abu Daka et al (72) recommend that tourniquets should not be used in patients with PVD and if need be a vascular surgeon should assess the limb preoperatively before tourniquet use. Interestingly Wolthius et al (73) noted that morbidity was less when tourniquets were used in patients with peripheral vascular disease.

Kumar et al (8) advise that there are no absolute contraindications to tourniquet use. However, care should be taken in the patients with severe peripheral vascular disease, sickle cell disease, severe crush injury, diabetic neuropathic patients and patients with history of deep vein thrombosis and pulmonary embolism.

In this study sickle cell disease was mentioned as a potential contraindication to tourniquet use. Higher complication rates of up to 36% have been reported when using tourniquets for orthopaedic operations in sickle cell disease patients (69).However other studies have reported that tourniquets can safely be used in these patients(70,71).Therefore more studies need to be done to evaluate safety of tourniquet use in sickle cell patients. Nevertheless, targeted peri-operative management is warranted when using tourniquets in these patients.

Majority of users (77%) had never encountered complications associated with tourniquet use but almost 70% were aware that nerve palsy can occur as a complication. Skin complications and tourniquet pain were reported as other complications, albeit less. This may imply that probably users may not be aware of other complications and probably keener intra and post-operative observations may help in picking these complications. In contrast Yalcinkaya et al (66) reported intra-operative breakthrough bleeding by 42.2% of respondents which was not mentioned by any of the users in this study. Nerve injury was reported by 28.4% respondents in the same study.

Majority of the users (98%) agree that consent for use of a tourniquet during surgery should be included as part of the surgical consent. This implies that users are aware of potential tourniquet complications that may occur and thus possibly feel that the patient should be made aware of these.

CONCLUSION

The study revealed that majority of study participants had low limb occlusion pressures (LOP) compared to the standard fixed routine tourniquet inflation pressures traditionally employed during lower limb surgeries. Even after adding a recommended pressure value in addition to measured LOP, the values were still lower as compared to traditionally used inflation pressures.

None of the users are familiar with LOP measurement despite available evidence that LOP measurements enable the use of lower and safer tourniquet inflation pressures.

The survey from the tourniquet users revealed that majority of tourniquet users were familiar with the types of tourniquets available. However, it was noted that 97% of tourniquet users had had no formal training in tourniquet use. Key areas pertaining to tourniquet use, which included limb exsanguination, tourniquet pressures, tourniquet time, deflation intervals, indications and possible contraindications of tourniquet use, wound closure practices, tourniquet associated complications among others were all varied among tourniquet users, and therefore more ongoing formal education is necessary to streamline knowledge and practice of safe tourniquet use.

The outcomes of the survey should be important for tourniquet users to re-evaluate their practices and replace traditional practice with guided evidence-based best practices to allow for safe tourniquet use.

RECOMMENDATIONS

The following recommendations drawn from the results of this study may improve overall tourniquet safety and thus promote better patient care:

1. It is important to measure LOP pre-operatively in patients on whom a surgical tourniquet use is planned or anticipated for a surgical procedure. This LOP measurement will allow for use of a lower thus safer individualized tourniquet inflation pressure per patient compared to routinely used higher tourniquet pressures. The ultimate aim of this measurement is to prevent surgical tourniquet-related complications brought about by using unnecessarily high inflation pressures.

2. Also it is important to promote use of pneumatic tourniquets in which the inflation pressure is controllable. It is recommended that non-pneumatic elastic tourniquets (such as the Esmarch bandage) be used as an exsanguination bandage and not as a tourniquet as the pressures generated by such bandages may be high and erratic.

3. Additionally, it is recommended that all tourniquet users (either directly or indirectly involved in use of a surgical tourniquet) undergo some form of formal theoretical and practical training about key areas pertaining to tourniquet use. This will enable awareness amongst users regarding improper use, avoiding use of unnecessarily high tourniquet inflation pressures, and thus ultimately avoiding or minimizing potential tourniquet-related complications.

4. It is also recommended that when taking surgical consent, the patient should be informed about the possible use of a surgical tourniquet (if indicated) and made aware about

possible potential complications that have been known to occur with tourniquet use. If possible a surgical tourniquet use consent should be obtained in addition to the surgical consent.

5. It is recommended that a tourniquet "check list" be proposed and adopted in the operating theatre as an inclusion/additional part of the "time out procedure" to ascertain that the following have been adhered to:

- the indication for tourniquet use,
- the correct type and size of tourniquet,
- the correct skin protection/padding,
- the correct tourniquet application site,
- the need to elevate/exsanguinate the limb or not, before inflation,
- the correct timing of antibiotic administration before inflation of the tourniquet,
- the correct inflation pressure preferably based on pre-operative LOP measurement,
- the recommended cut-off for tourniquet time before deflation,
- the correct deflation interval.

6. It is recommended that any other users involved in use of tourniquets should mention to the other team members about any possible loop holes they may feel need to be addressed before the tourniquet is used. This will ensure that any concerns are addressed in time and thus promote patient safety.

7. It is recommended that future multi-centre studies be carried out based on findings of this study to target more tourniquet users and other peri-operative team members who may be involved with tourniquet use. Additionally, future studies may be carried out to evaluate LOP for upper limb surgical tourniquet use.

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APPENDIX 1- INFORMED CONSENT FORM (ENGLISH) – LOP STUDY

Title: Measurement of Limb Occlusion Pressure and A survey of current knowledge and practice of peri-operative tourniquet use at Kenyatta National Hospital.

Investigator: Dr. Adamji Salim H.I.

Supervisors: Dr. G. Museve, Dr. E. Oburu and Dr. A. Aywak.

Investigator Note:

Thank you for agreeing to read this form. It offers information about this study which will help you decide if you will take part in this study or not. Appropriate translation will be carried out in the language you are most comfortable with.

Introduction:

A tourniquet is a pressure device that is applied during operation on a limb above the region to be operated. Its aim is to reduce loss of blood during operation. Its use is widespread in limb surgery.

Limb occlusion pressure (LOP) is an important measurement that can be carried out before the operation so as to determine the minimal tourniquet pressure that will allow for a desirable blood-less operating field.

The measurement of this pressure can prevent use of unnecessarily high tourniquet pressures during surgery that may result in potential complications.

Data on pre-operative measurement of limb occlusion pressure is not available locally. This study aims at measuring LOP in our set up.

Procedure:

If you agree to be part of this study, I as the principal investigator will recruit you if you have a condition in your lower limb for which a surgical intervention is required; and in which use of a tourniquet is anticipated/planned.

Before the surgery, the limb occlusion pressure in your unaffected lower limb will be measured using a temporarily and gradually inflated pneumatic tourniquet cuff and arterial Doppler ultrasound. This is a short and non-invasive measurement procedure whose cost will be incurred by the principal investigator.

Benefits:

The measured limb occlusion pressures shall guide in using lower and safer tourniquet pressures during surgeries. Findings of this study will be interpreted to you, the University of Nairobi, and Kenyatta National Hospital and thus help in policy making, which will in turn improve care of patients in whom tourniquet use is planned.

Risks:

The measurement of Limb Occlusion pressure using a pneumatic tourniquet and arterial Doppler sonography is a safe and short procedure. There are no foreseen risks. However, if at any point during the measurement you feel any discomfort, the measurement procedure shall be abandoned and this will have no consequences to your management, which shall continue without any compromise.

Confidentiality:

If you agree to be part of this study, the information you give will be held in strict confidence and only used for the purpose of the study by the researcher and/or supervisor. Your name and signature/ thumb print will only appear on the consent form and not on any other material. No names will be published.

Your participation is voluntary and you may drop out of the study at any point without any consequences. Kindly note that participants will not receive any monetary compensation for participating in this study.

Ethical consideration: I have been granted approval from the KNH/ UON Ethics and Research Committee to conduct this study. Enquiries on ethical considerations can be obtained from:

Prof. M.L. Chindia,

Secretary, KNH - UoN Ethics Research Committee
Kenyatta National Hospital,
P.O. Box 20723 -00202 Nairobi
Tel: (020) 2726300-9
Email:uonknh_erc@uonbi.ac.ke

If during the course of this you have any questions concerning this research you should contact:

Dr. Salim H.I. Adamji (principal investigator),

P.O. Box: 44605 - 00100 Nairobi
Mobile: 0720246834
Email: salimadamji@hotmail.com

To indicate that you understand the conditions of this study and consent to participate in it, please sign or put your thumbprint in the space provided below.

I confirm that the study has been fully explained to me and I give full consent to participate in it.

Participant's Name _____

Participant's Signature/ Thumb print _____ Date _____

I confirm that I have explained to the participant details about this study.

Investigator's Signature _____ Date _____

APPENDIX 2 - FOMU YA IDHINI - KISWAHILI

Kichwa: Upimaji wa "Limb Occlusion Pressure" (LOP) na utafiti wa ujuzi wa utumiaji wa matumizi ya torniketi katika Hospitali Kikuu ya Kenyatta.

Mpelezi: Dr. Adamji Salim H.I.

Wasimamizi: Dr. G. Museve, Dr. E. Oburu na Dr. A. Aywak.

Maono ya mpelelezi:

Asante kwa kukubali kusoma fomu hii. Inatoa maelezo kuhusu utafiti huu ambayo itasaidia kuamua ikiwa utashiriki katika utafiti huu au la. Tafsiri sahihi itafanywa kwa lugha ambayo unaelewa.

Utangulizi:

Torniketi ni kifaa ambacho kinatumiwa wakati wa upasuaji kwenye mguu. Hiki kifaa kinafungwa juu ya mahali ambayo itapasuliwa. Lengo lake ni kupunguza upotezaji wa damu wakati wa upasuaji.

"Limb occlusion pressure" (LOP) ni kipimo muhimu ambacho kinaweza kufanyika kabla ya upasuaji ili kujua ile kipimo cha chini ambayo itawezesha upasuaji bila kupoteza damu.

Upimaji wa LOP unaweza kuzuia matumizi ya presha nyingi wakati wa upasuaji, ambao unaweza kusababisha matatizo.

Utafiti juu ya kupima LOP kabla ya upasuaji hazijafanywa katika hospitali kikuu ya Kenyatta. Utafiti huu una lengo la kupima LOP katika wagonjwa ambao wana hudumiwa kwetu.

Utaratibu:

Ikiwa unakubali kushirika katika utafiti huu, mimi kama mpelelezi mkuu nitakuongeza kwa utafiti ikiwa una shida ya mguu ambayo upasuaji umepangwa; na ambayo matumizi ya torniketi inatarajiwa / iliyopangwa.

Kabla ya upasuaji uliopangwa, LOP katika mguu wako usioathiriwa utapimwa kwa kutumia torniketi na doppler ultrasound. Hii kipimo ita chukua muda mfupi na usio na uvamizi.

Gharama ya kipimo itatokana na mpelelezi.

Faida:

Upimaji wa "Limb Occlusion Pressure" (LOP) itasaidia kutumia presha kidogo ya torniketi ambayo pia ni salama, wakati wa upasuaji. Matokeo ya utafiti huu utafafanuliwa kwako, Chuo Kikuu cha Nairobi, na Hospitali ya Taifa ya Kenyatta na hivyo kusaidia katika maamuzi ya sera, ambayo pia itaimarisha huduma ya wagonjwa ambao matumizi ya torniketi hupangwa.

Hatari:

Upimaji wa "Limb Occlusion Pressure" (LOP) kwa kutumia torniketi na "Doppler ultrasound" ni utaratibu salama na mfupi. Hakuna hatari zinazotarjika. Hata hivyo, wakati wowote kati ya upimaji, unahisi usumbufu wowote, utaratibu wa kupima utaachwa na hii haitakuwa na madhara kwa usimamizi wako, ambao utaendelea bila shida yoyote.

Usiri:

Ikiwa unakubali kuwa sehemu ya utafiti huu, taarifa unazopa itafanyika kwa ujasiri thabiti na kutumika tu kwa madhumuni ya utafiti na mtafiti na / au msimamizi. Jina lako na saini / alama ya kidole kitaonekana tu kwenye fomu ya idhini na si kwa nyenzo nyingine yoyote. Hakuna majina yatachapishwa.

Ningependa kusingatia kuwa matibabu yako hautaathirika kutokana na uamuzi wako wa kukataa au kushiriki katika utafiti huu. Umepewa uhuru na nafasi ya kuacha kuhusika katika utafiti huu bila matatizo yoyote wakati wowote utafiti huu unapoendelea. Tafadhali kumbuka kuwa washiriki hawatapokea faida yoyote ya fedha kwa ajili ya kushiriki katika utafiti huu.

Kuzingatia maadili: Nimepewa kibali kutoka kwa Kamiti za Utafiti na Maadili ya KNH/ UON ili kufanya utafiti huu.Maswali kuhusu maadili yanaweza kupatikana kutoka:

Prof. M.L. Chindia,

KNH - UoN Ethics Research Committee
Hospitali kikuu chaKenyatta,
SLP: 20723 - 00202 Nairobi
Simu: (020) 2726300-9
Barua pepe:uonknh_erc@uonbi.ac.ke

Ukiwa na maswali yoyote kuhusu utafiti huu unapaswa kuwasiliana na:

Dr. Salim H.I. Adamji (mpelelezi mkuu),

SLP: 44605 - 00100 Nairobi
Simu: 0720246834
Barua pepel: salimadamji@hotmail.com

Ili kuonyesha kwamba unaelewa masharti ya utafiti huu na kwamba unakubali kushiriki katika hilo, tafadhali weka sahihi au weka kidole chako kwenye nafasi iliyotolewa hapa chini.

Ninathibitisha kwamba utafiti umeelezewa kikamilifu kwangu na mimi nimekubali kikamilifu kushiriki katika hilo.

Jina ya Mshiriki _____

Sahihi/kidole ya Mshirikii _____ Tarehe _____

Ninathibitisha kwamba nimeelezea maelezo ya mshiriki kuhusu utafiti huu.

Sahihi ya Mpelelezi _____ Tarehe _____

APPENDIX 3 - DATA COLLECTION SHEET - LOP MEASUREMENTS

Serial Number: _____

Age in Years: _____

Sex: M □ F □

Diagnosis: _____

Affected lower limb: R □ L □

Unaffected lower limb: R □ L □

Supine Blood Pressure (mmHg): Systolic _____ Diastolic _____

Site of tourniquet cuff application during LOP measurement: _____

Circumference of thigh at site of tourniquet application (centimetres) _____

Ratio of cuff width to thigh circumference _____

Inflation pressure (mmHg) causing obliteration of arterial pulse waveform on sonography.

- Measured value 1 _____ (LOP)
- Measured value 2 _____ (LOP)
- Measured value 3 _____ (LOP)
- Calculated Average _____ (LOP)

APPENDIX 4 - DATA COLLECTION SHEET (QUESTIONNAIRE)

Serial No…… (To be allocated by the principal investigator)

Age (optional) …….

Sex: Male …….. Female…….

Occupation/ Post ……

Year or level of training……..

Number of years in current post or practice……

(Kindly answer the following questions to the best of your capabilities)

1) **Have you had any formal training in tourniquet use?** (circle appropriately)

   Yes No

2) **Are you directly or indirectly involved in use of a tourniquet in your practice?**

   (circle appropriately)

   Yes No

3) **If yes, at what stage may you be involved in its use?** (tick appropriately)

- □ Application
- □ Supervision during application
- □ Monitoring during use
- □ Release/deflation
- □ All stages

4) **What type/s of tourniquets do you use in your practice?**

- …….
- ……..

5) **Is the limb to be operated exsanguinated before tourniquet inflation?** (circle appropriately)

Yes No

6) **If yes, how is exsanguination carried out in your practice?** (tick appropriately)

- Elevation of limb alone
- Use of exsanguination bandage
- Use of exsanguination bandage and elevation

7) **If lower limb is elevated for exsanguination, what is the duration of elevation?**

……..... (duration in minutes).

8) **Are there certain conditions in which limb exsanguination will not be done when using tourniquet?**

- ……..
- ……..

9) **At what duration before application of tourniquet, are prophylactic antibiotics administered to the patient?**

…… (duration in minutes).

10) **Do you as the tourniquet applier/supervisor confirm if pre-incision prophylactic antibiotic/s has/have been administered before tourniquet application or inflation?** (circle appropriately)

Yes No

11) **What kind/s of skin protection or padding is/are used under the tourniquet in your practice?**

- ……..
- ……..

12) **If using a pneumatic tourniquet, what inflation pressure is applied for lower limb surgery?**

…… (mmHg)

13) **How do you determine the tourniquet pressure when using inflatable tourniquets?**(tick appropriately)

- ☐ Standard routine preset pressure
- ☐ Based on age, extremity and size
- ☐ Based on blood pressure
- ☐ Based on pre-measured limb occlusion pressure (LOP)

14) **In your practice, what duration of time do you allow tourniquet use before its release during lower limb surgery?**

..…… (duration in minutes).

15) If a deflation interval is required before re-application and proceeding with the surgery, what minimum duration is allowed as the deflation interval?

. …….. (duration in minutes).

16) If you are the one closing the wound, when do you request for tourniquet release?

(tick appropriately)

- ☐ Before wound closure.
- ☐ After wound closure but before dressing.
- ☐ After wound closure and dressing.

17) List 3 indications of tourniquet use in your practice?

- …….
- …….
- …….

18) List 4 conditions you know of, in which tourniquet use may be contraindicated.

- ……..
- ……..
- ……..
- ……..

19) List 4 complications of tourniquet use?

- ……..
- ……..
- ……..
- ……..

20) Have you ever encountered any complications post-operatively that you may attribute to tourniquet use? (circle appropriately)

Yes No

21) If Yes, list the complication/s below.

- ……
- ……
- ……

22) Is limb occlusion pressure (LOP) measured before tourniquet use in your practice?(circle appropriately)

Yes No

23) In your practice, is consent for possible tourniquet use included in the surgical consent? (circle appropriately)

Yes No

24) If No, do you think tourniquet use consent should be included? (circle appropriately)

Yes No

WORKPLAN

Proposal writing	August 2017 – November 2017
Presentation of proposal	February 2018
Submission for ethical approval	February 2018
Data collection and analysis	June 2018 – August 2018
Dissertation writing	August 2018

STUDY BUDGET (in Kenya shillings)

Research fees (KNH/ERC)	3000/=
Stationery	16,000/=
Statistician	25,000/=
Doppler ultrasonography	107,000/=
Pneumatic tourniquet	45,000/=
Contingencies	10,000/=
Total	206,000/=