Tourniquet uses and precautions

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Abstract

Tourniquets have been used for centuries to control bleeding on the battlefield. Their use in the operating theatre helps provide a bloodless field in order to make surgery safer and more accurate. However, their duration of use should be minimized and care should be taken in order to reduce complication risk. Relative contraindications for tourniquet use include: extreme hypertension; reamed intramedullary nailing; peripheral vascular disease and open wounds that require debridement.

Keywords Complications; limb surgery; tourniquet

Introduction

Tourniquets act as constricting devices to control bleeding. As with many innovations in surgery they were initially used as life-saving measures during warfare. Now commonly used in limb surgery, they have been in use for centuries, with specimens available in collections dating back to Roman battlefield relics from the 2nd century.

Historically, tourniquets were used to reduce blood loss and prevent exsanguination. Modern trauma practice now encourages compression rather than tourniquet application in order to control haemorrhage. In the modern operating theatre tourniquets are commonly used to help provide a bloodless field for surgery.

Indications for tourniquet use

Always consider whether a tourniquet is necessary. Often the choice to use a tourniquet is by received wisdom. The use of a tourniquet does not substitute for careful soft tissue dissection and judicious use of cautery. However, in for example hand surgery, the excellent blood supply combined with the need to clearly visualize intricate structures should mean that tourniquet use is a pre-requisite to minimize the risk of iatrogenic injury.

Consider a tourniquet when contemplating:

- elective lower limb surgery of the knee and lower leg
- elective upper limb surgery of the elbow, forearm and hand
- emergency or urgent surgery of closed injuries to the same
- open injuries of the hand.

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Tourniquets are typically placed on the upper arm or thigh. When undertaking surgery to digits, the tourniquet can be placed around the proximal aspect of the digit. In these cases, some surgeons use the cut finger of a sterile glove with the tip removed and rolled up the digit. This works well; however, there are reported cases where this improvized device has been incompletely removed. This has led to case reports of digit ischaemia, tissue necrosis and consequent amputation. A better method is to use an elastic material (the same glove finger), clamped in a single loop around the proximal phalanx. After surgery the surgeon can be confident that this has been removed in its entirety.

Contraindications for the use of a tourniquet

These include:

- open injuries of the limb
- wounds that require debridement and irrigation
- reamed intramedullary nailing
- peripheral vascular disease
- diabetic foot disease.

In the surgical treatment of open limb injuries, it is necessary to make an assessment of the devascularized zone of injury. This cannot be achieved under tourniquet conditions and may lead to an underestimation of the injury zone size. This can predispose to inadequate wound management (debridement) and suboptimal results (increased infection risk).

Intramedullary reaming prior to nail insertion can generate heat within the medullary canal and surrounding bone. Fat emboli are also produced and enter the venous system. The mechanical and chemical effects of these emboli within the pulmonary and systemic circulation are well documented, with potential clinical sequelae that include hypoxaemia, a petechial rash and clinically detectable cognitive effects. Tourniquet use can increase the incidence of bone thermal necrosis and predispose to an 'embolic hit' with pulmonary and systemic effects after deflation of the device.

Patients with peripheral vascular disease are predisposed to thromboembolic events after tourniquet use. These patients have arterial walls that are less compliant with peripheral tissue perfusion that is already reduced. Tourniquet use will likely be of less benefit and will also predispose to further ischaemic damage to tissue that is already compromised. By definition, patients with diabetic foot disease have small vessel vascular disease. Blood flow is limited even without a tourniquet and a constant aim of operative intervention should be adequate to remove all non-viable tissues.

Tourniquet efficacy

All tourniquets work by compressing both the arterial and venous blood supply. A poorly applied tourniquet, with inadequate pressure can rapidly cause tissue congestion by restricting venous drainage, but allowing arterial flow. This can predispose to increased intraoperative haemorrhage.

The following factors adversely affect tourniquet efficacy:

- hypertension
- low arterial wall compliance (e.g. arteriosclerosis)
- venous congestion and reduced vessel compliance (e.g. varicose veins)
- obesity or conical thighs.

Hypertension requires a higher tourniquet pressure to overcome blood flow. In extreme cases this can predispose to local complications such as nerve and muscle injury. Steps should be taken to control hypertension prior to elective surgery. Consideration should always be given to whether the use of a tourniquet is warranted and justified.

Arteriosclerosis increases the risk of arterial wall injury with the subsequent risk of thromboembolic disorders. Varicose veins reduce the ability to efficiently exsanguinate the limb prior to application leading to backflow during the procedure. Difficulty in positioning the tourniquet and keeping it in place make limit their use in obese patients due to a large diametric difference in the proximal and distal diameter of the area of the limb where the tourniquet is applied. The pressure differential between the tourniquet pressure and the pressure within the tissues is further worsened by obesity with a lower tissue pressure achieved for the same tourniquet pressures.

In some cases where surgery is of particularly long duration, tourniquets may be applied and inflated and deflated as necessary. However this is not without difficulty, and dealing with the reactive hyperaemia that can follow deflation may be problematic, especially in the bleeding that this causes. A rough rule of thumb is to release the tourniquet after 2 hours of ischaemic time.

Choosing a tourniquet

Tourniquet design has changed little over the past few decades, barring some automation and digitalization of settings and alarms. Modern surgical tourniquets are composed of pneumatic bladder covered with a reinforced material to prevent puncture. There is a fastening device, which is often composed of an adjustable plastic click-lock. Tourniquet ends often have Velcro to prevent slippage against each other. Flexible tubing can then be connected to the inflation and control unit, where the desired pressure can be set and monitored. Newer units have built-in timed alarms to alert the operating room personnel regarding tourniquet time, usually at 30-minute intervals. Compressed air is used to inflate the tourniquet and the control unit maintains the set pressure automatically. The inflation often makes a clicking noise, to alert the surgeon about function, and repeated clicking can be a sign of a leak in the system. The reductions in manufacture costs and increased costs of sterilization, combined with the risks associated with cross contamination have resulted in the use of disposable tourniquets.

A double-unit system can be used to provide tourniquets where proximal and distal tourniquets are required sequentially (e.g. for Bier's blocks). The Bier's block is a classic example of initially inflating the most proximal part of the tourniquet. Local anaesthetic is then injected intravenously anaesthetizing the arm. Inflating the distal part of the tourniquet and then releasing the proximal aspect can prolong tourniquet tolerance time. The tourniquet is therefore applied over an anaesthetized aspect of the involved limb for the majority of the procedure.

Local tourniquets can be applied around the proximal phalanx of digits and toes. These can be made of any suitable elastic material. Care should be taken to ensure that the tourniquet is of appropriate width in order to reduce the risks of local injury by preventing areas of very high pressure. It is imperative that the tourniquet is removed in its entirety at the end of the procedure. Incomplete removal of a tourniquet can lead to ischaemia and loss of the digit.

Using a tourniquet

The choice of whether or not a tourniquet is required should be part of the preoperative plan or strategy. Taking into account the pre-anaesthetic blood pressure, body shape of the patient, girth of the limb and the distal neurovascular status are essential in selecting appropriate patients for tourniquet.

The site that the tourniquet is to be applied should be inspected and ascertained to be outside the zone of operation and injury. Enough space should be present for the patients' limb to be adequately prepared for surgery and the appropriate drapes applied. For this reason, it is impractical to use tourniquets for most surgery proximal to the knee or elbow. When choosing a site, efforts should be made to apply the tourniquet as proximal as possible. Do not apply a tourniquet to a site where a nerve crosses a bone as this increases the likelihood of nerve damage. Using a tourniquet in muscular areas such as over the quadriceps or biceps muscles is ideal, as these can cushion the neurovascular structures and protect them from injury.

Appropriate wool padding should be applied prior to the application of an inflatable tourniquet. The function of this is to ensure that there are no areas of high pressure due to creases in the reinforced tourniquet material. The tourniquet can then be applied. Prior to tightening, ensure that the connector tubing is accessible and will stay out of the operative field once secured. Tighten down and secure the tourniquet using its provided fastenings; however do not tighten it so much that it acts as a venous tourniquet when deflated, reducing outflow of blood from the limb. This acts as a hindrance when elevating the limb to exsanguinate it, and if a long procedure is planned, occlusion of the venous outflow will worsen the intraoperative view upon deflation.

A tourniquet should be inflated at the last possible moment to ensure that the minimum tourniquet time is required. In elective surgery, some surgeons may choose to use a roll-on inflatable exsanguinator; others simply elevate the limb during preparation. The tourniquet can be inflated once preparation is complete prior to placing the limb on the operating table. It is advisable to avoid the use of an exsanguinator where deep venous thrombosis is suspected, such as cases of prolonged preoperative immobilization. In the upper limb, a sterile elastic rubber bandage can be used to exsanguinate the forearm after prepping and just prior to making the skin incision.

A properly functioning tourniquet applies a compression tissue pressure higher than the patient's systolic arterial pressure. A commonly used tourniquet application pressure is 100 mmHg above systolic blood pressure. Another useful method is to use twice the pre-anaesthetic resting systolic blood pressure in a normal patient. If the patient is obese, this will usually need to be higher (up to 50 mmHg can be added). In practice, one should be wary of using pressures higher than 350 mmHg unless absolutely necessary. High pressures can predispose to increased postoperative pain, soft tissue damage and neurovascular injury. Minimize tourniquet time in cases where higher pressures are required.

Complications of tourniquets

Tourniquets have the potential to induce serious consequences. Direct complications include: skin damage; muscle necrosis and neurovascular compromise (often a nerve neurapraxia). These can be limited with appropriate padding; the use of correct tourniquet width (for the patient's size); minimizing the application time and applying the lowest effective pressure for an individual patient. Indirect complications include: thromboembolic events and distal tissue ischaemia.

At the end of each case, ensure that all tourniquet material has been removed and that no residual constriction has been left at the tourniquet site. Check distal pulses and the capillary refill time in limb extremities after deflation. This can be delayed briefly immediately after tourniquet deflation and is usually then followed by a period of reactive hyperaemia. This reaction should be considered when tourniquets are deflated prior to wound closure.

Summary

Tourniquets are useful devices to provide a bloodless surgical field and reduce the chance of iatrogenic damage. Patient factors and the anticipated surgical time should be carefully considered. The optimal pressure should be applied for the minimum duration. Apply and remove the tourniquet with care and ensure that the distal circulation and neurological status have not been compromised after each procedure. ◆

FURTHER READING

Shaw JA, Murray DG. The relationship between tourniquet pressure and underlying soft-tissue pressure in the thigh. *J Bone Joint Surg Am* 1982; **64:** 1148–52.

