Tourniquet use in orthopaedic surgery

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Abstract

The application of a tourniquet is a routine adjunct to current orthopaedic surgical practice. It is commonplace for both elective and trauma surgery. This review article seeks to explore the issues surrounding tourniquet and current best practice. The technological evolution in the application of a tourniquet to produce a bloodless field has remained relatively unchanged compared to other more complex advances in modern surgical practice. Despite a tourniquet's relative simplicity, considerable controversy surrounds its exact application; the surgeon constantly seeks a balance between the inevitable morbidity associated with its use versus the advantages conferred by such a device. To trace the history of the tourniquet is of interest and provides a backdrop to understanding the current controversies associated with its use as well as predicting where the next possible evolutions might take place. The tourniquet is often taken for granted, but there is a considerable body of work surrounding its use and safe application. Correct application, training of staff and appropriate use on an individual basis are essential to maximize safety and benefit.

Keywords bloodless field; exsanguination; limb ischaemia; limbs; orthopaedic surgery; tourniquet

Introduction

A tourniquet device is commonly used to provide a bloodless field for operating surgeons on the limbs of patients. Whilst the basic concept of compressing the limb sufficiently to prevent arterial flow to the desired area has likely been around for millennia, modern adaptations to the device have allowed maximum application and benefit, whilst minimizing the considerable risk also associated with its use. This review article seeks to explore the issues surrounding tourniquet use in modern orthopaedic surgery and current best practice.

History of the use of the tourniquet in surgery

The use of the tourniquet has its origins inextricably linked to amputation surgery. The earliest reported tourniquet use in Europe was in Roman times, by the respected medical writer Celsus, who described a simple narrow cloth tied above and below the amputation line to control haemorrhage.[1] The word tourniquet is derived from the French *tourner*, to turn; its origins relate to the French surgeon Jean-Louis Petit, who in 1718 described his screw-type device to compress a limb which did not require an assistant and was easy to remove.[2]

Lister in 1864 is generally credited with using a tourniquet for a procedure other than amputation and was an advocate of limb elevation to exsanguinate it prior to application.

In 1873 Esmarch described the use of a flat rubber bandage to exsanguinate a limb, although he cautioned doing so in the presence of soft-tissue infection.[3]

The American neurosurgeon Harvey Cushing in 1904 described the pneumatic tourniquet, with the advantage that it was quick to inflate, reduced the incidence of nerve palsy and could be adapted with a manometer to monitor pressures. Variants of this type of pneumatic device are still in use today and are commonplace in modern operating theatres.

Emergency tourniquet use is now commonplace in the military, where its use in catastrophic limb injury and haemorrhage has been shown to save lives. This is translating into civilian use for major trauma and haemorrhage in the pre-hospital setting.[4] Modern trauma services now apply tourniquets as a matter of routine with severely injured limbs at risk of significant blood loss. The increasing use of anticoagulants in the general population also means that severe limb injuries are more likely to produce catastrophic blood loss, especially in an elderly population with poor physiological reserves. Tourniquet use is becoming a key device in the management of such cases, before the medical reversal of anticoagulation can take place in the hospital setting.

Correct application and usage of a tourniquet

Choosing the correct site of application

Traditionally the tourniquet is applied to the most proximal part of the operated limb, where the muscle bulk is greatest, protecting peripherally exposed nerves (i.e the above-elbow or above-knee sites).

There is however a general trend in orthopaedic hand and foot surgery towards the use of wrist and ankle tourniquets.[5,6] The cuff should not lie directly over exposed bony surfaces such as the proximal fibula or the malleoli, reducing the risk of direct nerve compression and preventing pressure sores from developing. For an ankle tourniquet the recommended cuff position is a minimum of 2 cm proximal to the malleoli. In foot surgery, evidence suggests an advantage is conferred with ankle tourniquets over leg tourniquets in terms of pain and recovery,[6] with

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no increased incidence of nerve injury.[7] There is similar evidence of reduced pain and improved postoperative recovery in hand surgery using a wrist tourniquet.[5]

Choosing the correct tourniquet size

The length of the tourniquet should be appropriate to the size and circumference of the operated limb, overlapping ideally between 7 and 15 cm.[8] The widest possible tourniquet should be used without entering the surgical field. The radial and longitudinal distribution of tissue fluid pressures using wider cuffs of 12–18 cm have been shown to be maximal at the mid-point of the cuff inflation on the limb, with no difference both at superficial and deep tissue levels, irrespective of limb circumference.[9] Wider cuffs transmit a higher percentage of their tourniquet pressure to the deep tissues, and therefore a lower overall cuff pressure is required. Conversely the use of a narrow cuff in wider circumference limbs, for example the thigh, is relatively contraindicated due to the higher cuff pressure required to occlude the limb.[9] A wider tourniquet of 15 cm has been shown to be less painful and tolerated for longer compared to a cuff width of 7 cm,[10] as lower inflation pressures are required to maintain the same level of blood vessel occlusion. A curved tourniquet is ideal for a conical extremity such as a proximal thigh, especially in patients of large habitus, and affords lower pressures compared to a straight cuff to achieve the same degree of vessel occlusion.[11] The combination of a pneumatic cuff as wide and as contoured as possible, reduces the pressure gradient across the cuff, thus reducing tourniquet pressure levels and helping to minimize the risk of soft-tissue damage and neurovascular injury.[12]

Use of padding with tourniquets

The use of orthopaedic skin padding under the tourniquet should be encouraged. There are a variety of padding materials available which have been shown to significantly reduce the risk of harm from skin abrasions and blister formation after the tourniquet is removed, rather than direct application of the tourniquet to the skin. A study comparing layered fibre padding with doubled layered elastic stockinet showed no difference in skin protection with the type of padding used.[13] It is also noted that the effectiveness of a tourniquet diminishes according to the number of padded layers applied to protect the skin. It is suggested that using more than two layers of skin padding causes a significant drop in transmitted pressure to the limb, thereby reducing the efficacy of the tourniquet.[14] Once in place the tourniquet and padding should be slightly rotated to ensure that no skin is caught in the cuff mechanism.

Risk of skin sterilization preparations and tourniquets

Care should be taken during limb preparation to avoid residual sterilization fluid entering under the tourniquet and the padding. Fluid can be absorbed by the padding and there is a risk of dermal reactions, significant blistering and skin loss.[15] This risk is increased with alcoholic or spirit based preparations,[16] and care should be taken particularly in children and the elderly who are at higher risk of skin damage. Applying a sterile U-drape to stop fluid from entering below the tourniquet, and allowing the skin preparation fluid to dry can negate these risks.

Precautions with exsanguination prior to inflation of a tourniquet

The operated limb should be drained of blood before any procedure begins. In the upper limb, where many procedures are performed under local or regional anaesthetic, evidence suggests that formal exsanguination is superior to elevation with gravity in terms of intraoperative and postoperative pain and recovery time.[17] The surgeon should be aware that formal exsanguination is contraindicated in certain cases, for example infection, where forced limb exsanguination can also force pus, for example in a flexor sheath infection, more proximally, potentially worsening the condition. Care should be taken not to apply the padding or stockinet together with the tourniquet, at too tight a level pre-inflation. The level of pre-inflation compression should be less than the limb venous pressure, usually below 20 mmHg, to prevent venous congestion and pain.[18] This should also mitigate the risks of venous congestion and a converse increase in bleeding if a tourniquet is deflated mid procedure. Delayed tourniquet inflation, particularly in arthroplasty, of around 5 minutes is recommended after intravenous antibiotic administration to allow circulation and appropriate antibiotic prophylaxis.[19] Training of staff in the minutia of the correct application of the tourniquet will have a significant impact on reducing potential complications associated with tourniquet use, thus improving outcome and patient satisfaction.

Duration of tourniquet times and pressures

It is generally accepted that a tourniquet should be inflated for as short a time as possible, at as low a pressure as possible, and deflated after 1.5 hours in the upper limb and 2 hours in the lower limb.[20] Optimum tourniquet duration and pressures remain controversial, are multifactorial and patient specific. In theatres staff should be encouraged and trained to inform the surgeon of the tourniquet time, this should be part of a wider culture of participation and communication between members of theatre staff.

Orthopaedic surgeons usually use set tourniquet pressures in their practice; 250 mmHg in the upper limb and 300 mmHg in the lower limb. However this is somewhat arbitrary and does not account for the fluctuations in intraoperative systolic blood pressure (SBP). One study suggests that during total knee arthroplasty (TKA) in younger patients, patients with a fixed flexion contracture greater than 20 degrees, and prolonged surgical times of 2 hours or more experience a higher incidence of neurological injury.[21] It is postulated that younger patients who may have lower blood pressures compared to the average population are therefore exposed to unnecessarily high tourniquet pressures. Of note, evidence shows that every 30 minutes of extra tourniquet time increases the risk of neurological compromise roughly threefold, and if neurological injury does occur due to the tourniquet it commonly resolves.[21] In TKA intraoperative haemostatic control is better with an associated reduction in operative time when deflation occurs after wound closure.[22] This has also been demonstrated in carpal tunnel surgery.[23]

It is generally accepted that in TKA a tourniquet is associated with increased pain and postoperative swelling, with no real evidence of a reduction in overall blood loss.

When a tourniquet is used in TKA, there appears to be no difference in pain or bruising when releasing the tourniquet

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