Procedures under tourniquet

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Abstract

Limb tourniquets are commonly used to help facilitate surgery by producing less blood in the surgical field. This may also shorten operative time and reduce intraoperative blood loss. These advantages need to be weighed against potential complications such as post-tourniquet syndrome, skin damage, deep vein thrombosis, rhabdomyolysis and ischaemic pain. Physiological changes in the cardiovascular, respiratory, metabolic, haematological and neurological systems also occur.

keywords Deep vein thrombosis; pathophysiology; post-tourniquet syndrome; tourniquet; tourniquet pain

Royal College of Anaesthetists CPD Matrix: 3A08

Learning objectives

After reading this article, you should be able to:

- correctly apply the tourniquet
- list the physiological effects associated with the use of tourniquet
- name the complications associated with the use of tourniquet

Applying the tourniquet

Tourniquets are applied to the upper and lower extremities to improve visualization of the operative field and to reduce intraoperative blood loss. Although simple and easy to apply, their use is associated with a number of potential problems.

The diameter of the cuff should be wider than half the diameter of the limb. It is usually applied to the proximal areas of the limb to be operated on, where there is the most fat and muscle and where it is reasonably distant from the surgical field (Figure 1). The edges of the cuff must overlap in order to create an even pressure all around the cuff.

While padding beneath the tourniquet is recommended, it should not exceed two layers in order to avoid a reduction in the transmitted pressure beneath it. Excessive padding decreases the efficacy of the tourniquet and increases the arm circumference. The padding should also be smooth and without creases because this can cause bullous skin lesions. Ensure that the padding is not soaked in the iodine or alcohol used to prepare the skin prior to surgery to avoid chemical burns. Tourniquet systems should undergo regular checks (Box 1).

Tourniquet inflation

Limb exsanguination

Before tourniquet inflation, the limb should be exsanguinated. Limbs can be exsanguinated by

- passive method: this is done by raising the upper limb by 90° or the lower limb by 45°
- active method: winding an elasticated Esmarch bandage from distal to proximal or by hand-over-hand manual exsanguination.

Active exsanguination is more effective than elevation alone, but it is contraindicated in patients with infection, painful fractures being managed with intravenous regional anaesthesia (IVRA) or malignancy.

Tourniquet pressure

In the past, the recommended pressures were 75–100 mmHg above systolic blood pressure for upper limb and 100–150 mmHg above systolic pressure for lower limb surgeries. Others used a standard pressure of 200–250 mmHg for the upper and 250–300 mmHg for the lower limb. The Association of Perioperative Registered Nurses (AORN) have recently recommended using the limb occlusion pressure (measured by gradually increasing tourniquet pressure until distal blood flow is interrupted) with a safety margin of 40 mmHg for limb occlusion pressures of <130 mmHg, 60 mmHg for those of 131–190 mmHg and 80 mmHg for those of >190 mmHg.[1]

Tourniquet pressures should be lower in children, although at the moment there are no guidelines as to what pressures should be used. AORN have suggested adding 50 mmHg to limb occlusion pressure for children.

With intravenous regional anaesthesia (IVRA e.g. Bier's block), it is necessary to use double tourniquet cuffs to improve safety and patient comfort. As the diameter of the cuff is narrower, it may be necessary to use higher pressures.

Tourniquet inflation duration

There are many different recommendations as to how long a tourniquet can be inflated, but the most widely accepted figure is 2 hours, with 3 hours being the upper safety limit.

Tourniquet deflation

Some advocate early release of the tourniquet to achieve haemostasis before wound closure. Studies mainly looking at knee arthroplasty have shown that this practice increases perioperative blood loss.[1]

With delayed tourniquet release, a closed wound with a firmly applied dressing can produce a haemostatic effect during the initial reactive hyperaemia that occurs just after deflation.

However, with delayed tourniquet release, there is an increased risk of other complications. These include delayed detection of major arterial injury such as direct trauma or thrombosis and inadequate control of subcutaneous bleeding leading to haematoma formation. This may increase the risks of wound dehiscence, infection and patellar tracking in the case of knee arthroplasty.

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Figure 1 Correct application of a tourniquet on the upper thigh with padding.

Routine checking and maintenance of the tourniquet system

- Set up a schedule for regular checks: e.g. every month
- Visual inspection for damage to the cuff, tubing and machine
- Turn on the unit. Most tourniquet systems now have self checks and automatic calibration.
- After inflating the cuff, check for leaks
- Do not ignore alarms! Newer systems have audiovisual alarms for air leaks and kinked tubing resulting in deviation from desired pressure.

Box 1

Concerning the optimal timing of tourniquet release, two recent meta-analyses agreed that early tourniquet release before wound closure would decrease the risk of complications.[2,3] The meta-analysis in 2014 found no significant difference in blood loss between early and delayed tourniquet release.[2] On the contrary, the meta-analysis in 2017 looking at 16 trials found an increase in total blood loss and operation time for early tourniquet release. Therefore, it suggested that if the patient has preexisting anaemia, there may be some benefit in delayed tourniquet release.[3]

Another study looked into staggered release of tourniquets, in which the tourniquet was fully deflated for 30 seconds and then reinflated, and this was repeated twice at 3 minute intervals before complete removal. Promising results were shown with less bradycardia and hypotension at 15 minutes. There was also less rise in serum lactate and end-tidal CO_2 when compared to the standard release group. However serum ionized calcium was noted to be higher.[4]

Contraindications to use of a tourniquet are shown in Box 2.

Physiological effects of tourniquet

Metabolic

Within 8 minutes of inflating the tourniquet, anaerobic metabolism begins, resulting in cellular acidosis. Cellular hypoxia and hypercapnia leads to release of myoglobin, intracellular enzymes, adenosine and potassium.

Contraindication to using a tourniquet

Absolute contraindications

- A limb with an arteriovenous fistula or previous vascular surgery
- Malignancy in the operating limb
- Peripheral vascular disease
- Sickle cell disease

Relative contraindications

- History of deep vein thrombosis or pulmonary embolism
- Obesity
- Rheumatoid arthritis
- Severe hypertension
- Skin grafts

Box 2

On release of the tourniquet, there will be a rise in serum potassium and lactate levels and an increase in $PaCO_2$ with subsequent acidosis, with the rise in serum potassium levels peaking 3 minutes after deflation.

Cardiovascular

On inflation: there is approximately a 15% increase in blood volume and up to 20% increase in systemic vascular resistance after tourniquet inflation. This leads to a rise in blood and central venous pressures which usually dissipate within 5 minutes.

After around 30 minutes of tourniquet inflation, blood pressure and heart rate will start to rise again due to tourniquet pain.

After deflation: immediately there will be a transient drop in blood pressure due to the decrease in systemic vascular resistance, release of vasoactive mediators (e.g. adenosine) and myocardial depressant factors from the ischaemic limb. This may be accompanied by an increase in cardiac index and vasospasm can occur.

No more than one tourniquet should be inflated at a time as this will cause a significant increase in central venous pressure and may lead to acute cardiac failure and even cardiac arrest.

Remote ischaemic preconditioning – remote ischaemic preconditioning (RIPC) is a novel method where ischaemia followed by reperfusion of one organ is believed to protect remote organs either due to the release of biochemical messengers in the circulation or activation of nerve pathways, resulting in release of messengers that have a protective effect. In human skeletal muscle, preconditioning has been used for myocardial protection with the beneficial effect being attributed to regulation of endothelial protection, although its possible benefit during surgery is not clear.

Temperature

Inflation: the limb with the inflated tourniquet will gradually decrease in temperature and may reach room temperature.

After deflation: during reperfusion of the ischaemic tissues, the core body temperature may drop by up to 0.6°C for each hour that the tourniquet was inflated.

Haematological

Tourniquet inflation and pain results in systemic hypercoagulation. Significantly higher levels of prothrombin fragment

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