Procedures under Tourniquet

Ivan N Ramos-Galvez
Alastair McCrirrick

Applying a pressurized pneumatic cuff to a limb can be used to prevent the central spread of local anaesthetic during intravenous regional anaesthesia. It may also be used to reduce bleeding and improve the surgical field when operating on an exsanguinated limb. Using a tourniquet can induce significant physiological changes depending on the duration of inflation and the general status of the patient.

**Tourniquet application**

**Maintaining a bloodless field during limb surgery**

The cuff should be wider than half the limb diameter and should be applied over smooth padding. The edges of the cuff must overlap to ensure it exerts even pressure all round the limb. Ideally, the overlap should be on the opposite side of the limb to the main neurovascular bundle. The limb is then exsanguinated either by elevation for 1 minute or by the application of Esmarch bandaging or a Rhys-Davies exsanguinator. (In the presence of infection or tumour, exsanguination by methods other than elevation is usually contraindicated.) When applied to the leg, the tourniquet is usually inflated to a pressure 100 mm Hg above systolic arterial blood pressure; on the arm it is inflated to 50 mm Hg above systolic arterial blood pressure. The pressure required depends on the size of the muscle mass to be compressed. During preparation of the surgical field, skin cleaning solutions should not come into contact with the tourniquet padding. If alcohol or iodine-based cleaning solutions soak into the padding they can cause skin irritation. Diathermy burns have also resulted from pooling of liquid around the tourniquet.

---

Ivan N Ramos-Galvez

Alastair McCrirrick is Consultant in Anaesthesia and Intensive Care at Gloucestershire Royal Hospital, UK. He qualified from Southampton University and joined the Royal Air Force. He completed his anaesthetic training in Bristol and the South West Region. He now specializes in intensive care and anaesthesia for major bowel and vascular surgery. His particular interests include anaesthesia for carotid endarterectomy.
Physiological changes

**During inflation**
- Rising vollaemia and systemic vascular resistance lead to increased blood pressure, central venous pressure and heart rate
- Temperature reduction in non-perfused limb
- Anaerobic metabolites being produced

**After deflation**
- Reperfusion of limb
  - Reduction in vollaemia and systemic vascular resistance lead to decreased blood pressure, central venous pressure and heart rate
  - Core temperature falls
  - Mixed acidosis, decrease in pO₂ and pH while pCO₂, K⁺ and free radicals increase
- Reactive hyper-reperfusion

---

Intravenous regional anaesthesia

A machine equipped with two tourniquets is optimal for intravenous regional anaesthesia. Intravenous access is obtained in the limb before application of the tourniquet. Great care must be exercised during exsanguination to avoid dislodging the intravenous cannula. After exsanguination, the proximal tourniquet cuff is inflated and local anaesthetic is introduced into the limb. (If the cuff were to fail at this stage the local anaesthetic would spread centrally resulting in a potentially toxic plasma concentration of local anaesthetic agent.) After a few minutes, the distal cuff is inflated and then the proximal cuff can be let down. The result is a tourniquet compressing a section of limb that has itself been rendered insensitive by intravenous regional anaesthesia. This is an attempt to reduce tourniquet-related pain (see below). The tourniquet must remain inflated for a minimum of 20 minutes to allow the local anaesthetic to bind to tissues. Deflation before 20 minutes may precipitate systemic local anaesthetic toxicity.

**Physiological changes**

Figure 1 summarizes the physiological changes that occur during inflation and deflation of a tourniquet.

**Cardiovascular**

Increases in systemic blood pressure, central venous pressure and heart rate have been reported immediately after tourniquet inflation. These changes are related to the sudden increase in blood volume (up to 15%) combined with a reduction in the capacitance of the vascular bed. Reciprocal haemodynamic changes may be expected following tourniquet deflation due to a decrease in systemic vascular resistance and venous return while the limb is reperfusing. The magnitude of the haemodynamic changes can be reduced by the use of regional anaesthesia. Preoperative ketamine, 0.25 mg/kg, moderates the rise in blood pressure after tourniquet inflation. In some patients, who have been otherwise cardiovascularly stable, a sudden marked rise in arterial pressure may occur about 1 hour after tourniquet inflation. In these patients, the arterial pressure may continue to rise, despite increasing the depth of anaesthesia, and only resolves when the tourniquet is deflated. Severe hypertension and/or concerns about possible ischaemic limb damage are the two factors that most commonly limit the duration of tourniquet inflation. The exact physiological mechanisms involved in this late arterial pressure rise are unclear.

Generalized muscle perfusion remains above normal for up to 15 minutes after tourniquet deflation. This is caused by the release of anaerobic metabolites triggering reactive vasodilatation in capillary beds within the muscle fibres.

**Temperature**

While the tourniquet remains inflated, the temperature of the non-perfused limb falls. This has some protective effect against ischaemic damage. However, during reperfusion, blood is exposed to cold tissues and on deflation there can be a reduction in core temperature of up to 0.6°C for each hour the tourniquet was used.

**Metabolic changes**

Leaving the tourniquet on for more than 30 minutes produces anaerobic metabolism, resulting in a mixed acidosis with hypoxaemia, hypercapnia, hyperkalaemia and formation of free radicals. These changes are normally well tolerated by healthy individuals but may be detrimental to patients with poor cardio-pulmonary reserve. The acidosis can be partly corrected by a short period of hyperventilation immediately after tourniquet deflation. Maintaining anaesthesia with a propofol infusion rather than a volatile agent may significantly reduce the formation of free radicals. Nevertheless, caution is advised when bilateral tourniquets are required and, whenever possible, simultaneous inflation should be avoided.

**Complications**

The incidence of complications is related to the inflation pressure and the duration of inflation.

**Limb ischaemia** is the most serious complication. Current recommendations regarding the upper limit for the duration of inflation vary between 30 minutes and 4 hours (30 minutes is the time taken for the onset of anaerobic metabolism). Nevertheless, after 1 hour of ischaemia, electron microscopy can detect depletion of glycogen granules in the sarcoplasm of muscle fibres. After 2 hours, lesions associated with acidosis (e.g. mitochondrial swelling), myelin degeneration and Z-line lysis can be identified. These changes are reversible with reperfusion and it may be that intermittent reperfusion–exsanguination during surgery prolongs the safe limit of tourniquet application by preventing excessive anaerobic metabolism. This may, however, be at the expense of supplying more substrate for the formation of free radicals.

**Local anaesthetic toxicity:** if the cuff is being used for intravenous regional anaesthesia it must remain inflated for at least...
Pressure-related nerve damage can be caused by a tourniquet with possible rupture of the Schwann cell membrane. This may lead to neuralgia paraesthetica, which usually resolves within a few weeks or months.

Excessive pressure can also damage underlying vessels, increasing the incidence of microemboli formation in the exsanguinated limb. This increases the risk of pulmonary microvascular injury (small pulmonary emboli). Prolonged tourniquet times have been related to respiratory failure requiring postoperative ventilation, especially in trauma. In a properly exsanguinated healthy limb, alterations in blood clotting physiology are usually minimal and theoretically should have no clinical impact. The incidence of deep vein thrombosis (DVT) may be higher when a tourniquet is used, but this has not been substantiated in arthroscopic knee surgery. Thromboprophylaxis must be considered in all patients aged over 40 years who have surgery performed under tourniquet with general anaesthesia, especially if there are other risk factors for DVT formation.

Tourniquet pain can occur 45–60 minutes after tourniquet inflation. Patients undergoing surgery under regional anaesthesia initially experience a dull ache in the exsanguinated limb after about 30 minutes of tourniquet application. This may occur even when a second cuff is inflated on an anaesthetized section of limb. As the pain worsens, patients may become restless and eventually the pain may become unbearable despite the presence of an otherwise satisfactory block. The pain may be transmitted through C fibres (slow, persistent, poorly localized pain), which are more resistant to local anaesthetic than Aδ fibres (sharp, fast pricking pain). At the onset of neural blockade, when the concentration of local anaesthetic is high, both are inhibited. As the local anaesthetic is metabolized, the concentration becomes insufficient to block C fibres despite continuing to anaesthetize Aδ fibres. This theory is supported by the observations that longer-acting local anaesthetic agents reduce the incidence of tourniquet pain and that its onset is delayed if a larger dose of local anaesthetic is used. There is also a reduction in the incidence of pain if clonidine is added to the local anaesthetic solution. Once tourniquet pain has developed it is difficult to treat, other than by releasing the tourniquet. General anaesthesia may need to be used if the surgery is continuing. Opiates alone are disappointing and tend to cause side-effects from excessive dose once the tourniquet is released and the afferent stimulus ceases.

Hypertension: patients undergoing general anaesthesia with a tourniquet in situ can develop signs of hypertension and tachycardia that mimic those seen during painful surgical stimulation. The reasons for the development of hypertension under these circumstances are unclear and it has been traditionally ascribed to the development of limb ischaemia, nerve compression or the development of tissue acidosis. Hypertension developing in these circumstances is often resistant to opiates and is relieved only when the tourniquet is deflated.

Treatment: Figure 2 lists treatments for complications.

---

**Further Reading**

---

**Treatment of complications**

**Easing the metabolic hurdle**
- Whenever possible use a regional technique, even combined with general anaesthesia
- Preoperative ketamine, 0.25 mg/kg, prevents hypertensive response to tourniquet
- Total intravenous anaesthesia with propofol helps to scavenge the free radicals produced
- Hyperventilate after tourniquet deflation to reduce acidosis
- Caution with simultaneous tourniquets

**Easing the tourniquet pain**
- Reduce tourniquet time as much as possible
- Whenever possible use a regional technique, even combined with general anaesthesia
- Use longer-acting local anaesthetics to reduce incidence
- Use clonidine mixed with local anaesthetic
- Intrathecal opiates reduce incidence of pain
- If unbearable and patient awake, convert to general anaesthesia
- Caution with adjuvant systemic opiates in awake patient, they may lead to delayed respiratory depression