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REVIEW

The penile tourniquet

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Tourniquets are commonly used in penile surgery to achieve a bloodless operating field or produce artificial erections intraoperatively. Several techniques have been described, but there is a paucity of data and a lack of guidelines to direct their safe use. In penile surgery, it is the local rather than systemic effects of tourniquet use that are the main concern. Tourniquet time should be kept to a minimum, as the limited data available suggests that reperfusion injury can occur even after short periods of ischaemia. High risk groups such as diabetics and arteriopaths are at particular risk. Further studies are needed to determine safe tourniquet times and pressures.
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INTRODUCTION

Careful haemostasis is an important requisite for any form of surgery as it reduces blood loss and ensures good operating conditions. The use of tourniquets for this purpose dates back to Roman times when constricting straps were used to control haemorrhage during amputation. The term tourniquet is derived from the French verb 'tourner' meaning 'to turn' and was coined by the French surgeon Jean Louis Petit in 1718.[1] However, it is Joseph Lister in 1864 who is credited for being the first person to use a tourniquet device to create a bloodless field for surgeries other than amputation.[1]

A tourniquet can be defined as a constricting or compressing device used to control the blood flow distal to it. They can be lymphatic, venous or arterial depending on the degree of vascular occlusion they produce.[2] Arterial tourniquets are widely used in upper and lower extremity surgery, for intravenous regional anaesthesia, for intravenous regional sympathectomy in the management of complex regional pain syndromes and for isolated limb perfusion with cytotoxic drugs in the treatment of localized malignancy.[3]

Tourniquets are also commonly employed in penile surgery and their use is often detailed in the description of the operative technique of published studies. Despite this, there is a paucity of data and a lack of guidelines to direct the safe use of penile tourniquets. This article reviews the available data regarding tourniquet use in penile surgery.

EVIDENCE ACQUISITION

A literature search was performed using the National Library of Medicine Database. The search protocol included a free-text query using the terms tourniquet, penile surgery and penile tourniquet. No limitation was applied to the year of publication, but only articles published in English were considered. The reference lists of the articles identified by the search were reviewed to identify further pertinent studies. The yield of the search was low and consequently the aim of this review is not to produce a meta-analysis of the published literature, but rather provide a critical analysis and an overview of current knowledge regarding penile tourniquet use.

USE OF THE TOURNIQUET IN PENILE SURGERY

Tourniquets are frequently used in penile surgery to provide the surgeon with a bloodless field in which to operate. Redman popularized the use of a rubber band tourniquet in hypospadia surgery in the 1980s,[4] but tourniquets have been used for penile amputations, repair of penile fractures and for minor surgery including circumcisions, meatomies and meatoplasties. During surgery, tourniquets are also used to produce artificial erections both to assess the integrity of repairs and to evaluate intraoperatively the outcome of corrective procedures on the penis. Artificial erections allow the surgeon to assess the correction achieved during the surgical treatment of Peyronie's disease. Tourniquets also have the added benefit of preventing the washout of local anaesthetics by impeding venous return and in this way have been used to deliver intracavernous chemotherapy.[5]

Several different techniques can be used to create penile tourniquets and these have often been modelled on the digital tourniquets employed in orthopaedic surgery. A commonly employed approach is to use a length of soft latex catheter or a Penrose drain clipped around the base of the penis using artery forceps.[6,7] Other techniques described in the literature include the use of a rubber band[4] and the rolled rubber glove technique of Barnett[8] in which a cylinder is cut from the finger of a surgical glove and rolled proximally over the penis towards the penoscrotal junction. Other surgeons have adapted the latter technique by using the rolled margin of a latex glove which is secured at the base of the penis using a clip.[9]

PATHOPHYSIOLOGICAL EFFECTS OF TOURNIQUET USE

The use of any arterial tourniquet can be associated with complications, but most of the research and published literature on the effects of tourniquets relates to their use on the upper and lower limbs. The pathophysiological consequences of tourniquet use can be broadly

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Table 1 Physiological effects associated with the use of arterial tourniquets. The magnitude of the effects described is dependent on the length of tourniquet application and change in circulating volume

Systemic effects	*Tourniquet application*	*Tourniquet removal*
Cardiovascular effects	• ↑ in circulating blood volume • ↑ systemic vascular resistance • ↑ heart rate and blood pressure after 30–60 min due to 'tourniquet pain'	• Restoration of circulating blood volume • Transient ↓ in blood pressure and central venous pressure • Post-ischaemic reactive hyperaemia
Respiratory effects		• Transient hypercapnoea
Cerebral circulatory changes		• ↑ cerebral blood flow secondary to transient hypercapnoea
Haematological effects	• Possible systemic hypercoagulability	• Short-lived (30 min) ↑ thrombolytic activity in peripheral blood
Temperature change	• ↑ core body temperature	• ↓ core body temperature
Metabolic changes		• ↑ serum potassium and lactate concentrations • Transient ↓ in arterial pH • ↑ oxygen consumption and carbon dioxide production

divided into systemic and local effects. Systemic effects are those related to the application and removal of the tourniquet, whereas local effects and complications are either due to the direct mechanical pressure applied to the tissues beneath the tourniquet or are related to the ischaemia of the tissues distal to it.[3] Ischaemia is the condition that arises when tissues are deprived of blood flow. This leads to inadequate provision of oxygen and nutrients as well as the accumulation of the end products of metabolism.

The systemic effects associated with arterial tourniquet use in extremity surgery are related to the large changes in circulating blood volume that occurs when the applied pneumatic tourniquet is inflated and deflated (**Table 1**). Changes in the volume of distribution impacts on the kinetics of administered drugs and reperfusion of the ischaemic limb on cuff deflation lead to respiratory effects and metabolic changes which are proportional to the duration of the ischaemic insult.[3] The systemic effects of penile tourniquet use have not been formally studied, but they are unlikely to be of any major significance because of the relatively minor changes in blood volume that would occur following penile tourniquet application. The respiratory, haematological and metabolic consequences are also likely to be minimal because of the amount of tissue that is rendered ischaemic.

It is therefore the local effects of tourniquet application that are more relevant to their use as a haemostatic approach in penile surgery (**Box 1**). Compression of the tissue directly beneath the tourniquet may lead to pressure related injuries to the underlying skin, nerves, muscle and blood vessels and the likelihood and degree of injury is dependent on both the duration of application and the pressure the tourniquet exerts.

After tourniquet removal, a reperfusion injury may develop as blood flow is restored to the ischaemic area. This leads to the generation of oxygen free radicals, which can trigger a cascade of events with potentially deleterious consequences.[10,11] Ischaemia–reperfusion injury has been studied in many different tissues and organs and this has revealed a variable susceptibility to the effects of reperfusion.[12] The arteries supplying the penis are end-arteries and this may make the penis more susceptible to early injury.[12]

Box 1 Potential local effects and complications associated with the use of arterial tourniquets

Local effects	
Mechanical compression	• Nerve injury ranging from transient paraesthesia to complete paralysis • Muscle injury • Vascular injury – uncommon • Skin injury - Blistering, pressure necrosis or friction burns due to poorly applied tourniquets
Ischaemia	• Ischaemia-reperfusion injury – Most likely initiated by the release of oxygen free radicals

TOURNIQUET TIME AND PRESSURE

It is generally agreed that the application time for any arterial tourniquet should be kept to a minimum. There is no consensus about the safe tourniquet time that can be used in penile surgery and there is very little research evidence to guide surgical practice. Redman performed a consecutive series of 146 hypospadia repairs in the 1980s using a rubber band tourniquet and reported that ischaemia under 50 min was well tolerated.[4] However, other published studies have suggested that times of up to 90 min in difficult salvage hypospadia repairs can be accepted with no reported problems.[6]

A research paper published in 2002 used white New Zealand rabbits to try and determine the safe tourniquet application time.[12] The researchers divided the animals into several groups and applied a standard circular rubber band to the base of the rabbit penis for a variable length of time which ranged from 10 to 60 min. They then measured the malondialdehyde (an end product of lipid peroxidation) levels in tissue biopsies after the varying durations of ischaemia as a marker of the ensuing reperfusion injury. The researchers also carried out histological assessment of harvested Mathieu-like penile skin flaps. The malondialdehyde levels were statistically higher in all groups when compared to control and this shows that changes suggestive of reperfusion injury can occur even after 10 min of ischaemia. Reassuringly, the epithelial morphology was normal in all groups.

The rabbit is a good animal model to study the physiology of erection as the innervation of the rabbit corpus cavernosum smooth muscle resembles that of human corporal tissue.[13] Nitric oxide derived from both autonomic nerves and the endothelium is recognized as one of the most important factors in the process of erection, as it mediates the relaxation of penile corporeal smooth muscle.[14] A study published in 2008 attempted to look at the potential functional consequences of prolonged penile tourniquet use.[15] The authors looked at how the nitrergic responses of the rabbit corpus cavernosum altered with varying tourniquet application times.[15] The study revealed that endothelium mediated relaxation responses induced by carbachol were not altered in the 20-min tourniquet group, but were significantly reduced in the 40- and 60-min tourniquet groups.

Box 2 Patients at higher risk of complications following penile tourniquet use

High risk patient groups
• Arteriopaths
• Diabetics
• Hypertensive patients
• Sickle cell disease/sickle cell trait
• Obese patients
• Elderly

A further study published in 2007 was carried out to assess the effects that different haemostatic techniques had on urethral wall integrity in a rabbit model of hypospadia repair.[16] Light microscopy studies revealed no significant differences in the histopathological parameters between tourniquet and control groups. Electron microscopy studies did however show that urothelial ultrastructural damage was evident after 30 min of either continuous or intermittent tourniquet time, although none of the changes seen were deemed irreversible. The group also looked at the myocyte apoptosis index and this was shown to be elevated in the tourniquet groups when compared to controls.

Most recently, a Turkish research group demonstrated higher grades of acute inflammation in Wistar rat penile tissue samples taken 24 h after a period of tourniquet application.[17] The group used a rubber band and the changes noted were seen after as little as 10 min of ischaemia. The inflammatory response correlated with decreased levels of vascular endothelial growth factor and increased levels of transforming growth factor receptor-beta and this led the authors to surmise that this may be relevant to the angiogenesis phase of wound healing following penile surgery.

From an ischaemia–reperfusion injury standpoint, the studies described above provide evidence that even short periods of tourniquet induced ischaemia can have deleterious effects, though some of these may be reversible. The potential clinical impact of these reported changes have yet to be studied. It must also be borne in mind that the age of a patient is likely to have a bearing on the safe tourniquet time. The limited number of studies looking at penile tourniquet use have been performed on younger animals, so the findings cannot be easily extrapolated to tourniquet use in older animals.[15]

The optimal tourniquet time will also be dependent on the mechanical compression that the tourniquet exerts. The closer the actual pressure generated is to the minimum effective pressure needed to obstruct arterial flow, the lower the risk of injury and the longer that a tourniquet can be safely left on. Unfortunately, no study has measured the pressures generated by the different penile tourniquet techniques currently used. It is very unlikely that the pressures exerted will be consistent especially as the compression forces generated will be influenced by the clinical expertise of the person applying the tourniquet.

The variability in pressures exerted by different tourniquets was highlighted by a study carried out by Hixson and colleagues[18] in which they measured the pressures under the three most commonly used digital tourniquets: the Penrose drain, the rolled rubber glove and the rubber band. The mean pressures generated ranged from 355 mmHg for the rolled glove and 675 mmHg for the Penrose drain technique to 1080 mmHg for the rubber band. The high compression pressures that can be generated are of concern as studies have shown that tourniquets can cause nerve and muscle injury in animal models when pressures exceed 500–600 mmHg.[19,20]

It is generally agreed that lower pressures are desirable, but there are no human or animal studies to provide guidance on the safe pressure limits for penile tourniquets. The absence of underlying bone, against which vulnerable structures can be compressed, may be protective against potentially damaging effects of the high pressures exerted on the tissues directly beneath the tourniquet.

HIGH-RISK GROUPS

The risks associated with tourniquet use may also be influenced by the age of the patient, their body mass index and associated co-morbidities (**Box 2**). Arteriopaths, diabetic and hypertensive patients may require higher tourniquet pressures to interrupt arterial flow, which consequently renders them more susceptible to pressure-related injuries.

Tourniquet use is contraindicated in patients with sickle cell disease and should be used with caution in individuals with sickle cell trait. The circulatory stasis, hypoxia and acidosis that develop beneath and distal to the tourniquet have the potential to precipitate sickling crisis, thereby increasing the risk of thrombosis, infarction and haemolysis.[3] There are several published case reports that have suggested that with the appropriate precautions tourniquets can be safely used in sickle cell disease sufferers. However, as with any of the high-risk groups, the potential hazards of tourniquet use need to be balanced against the benefits of operating in a bloodless field.

ANTIBIOTIC PROPHYLAXIS

Tourniquets can reduce antibiotic penetration into the tissues distal to the site of compression. It is therefore important to allow sufficient time between administration of prophylactic antibiotics and tourniquet application. Several studies have addressed this issue and have recommended that at least 5 min should be allowed after intravenous administration of an antibiotic before the tourniquet is applied.[21–23]

CONCLUSIONS

Although tourniquets are commonly employed in different types of penile surgery, there is a paucity of data to guide their use. The Association of periOperative Registered Nurses have published guidelines for recommended practice of pneumatic tourniquet use in the United States,[24] but unfortunately, no equivalent publication exists for penile tourniquets.

In penile surgery, it is the local effects resulting from tourniquet use rather than the systemic ones that are the main reason for concern. It is generally agreed that tourniquet time should be kept to a minimum, but the limited data available suggest that reperfusion injury can occur even after short periods of ischaemia. Surgeons should therefore aim to keep tourniquet time to less than 30–40 min with further caution being exercised in high-risk groups.

This review has highlighted the need for further studies in this area. The pressures generated by the different penile tourniquets currently in use need to be measured, so that recommendations can be made about which is likely to be the safest. Ideally, a randomized control trial with long term follow-up is needed comparing patients undergoing penile surgery with and without tourniquet use for haemostasis.

COMPETING FINANCIAL INTERESTS

The authors declare no competing financial interests.

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