CURRENT STANDARDS AND RECOMMENDATIONS FOR LOWER EXTREMITY TOURNIQUET USE

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INTRODUCTION

Precise visualization of anatomy is essential in performing any operative procedure. A variety of methods of hemostasis are available to the podiatric surgeon to facilitate dissection. Vasoconstrictive agents, such as epinephrine, in conjunction with local anesthesia, offer some degree of hemostasis, however, a pneumatic tourniquet is more effective in rendering a "bloodless field." The pneumatic tourniquet has been described as a "humble, yet potentially dangerous instrument," that when used correctly, facilitates anatomic dissection and dramatically reduces surgical time.

HISTORICAL REVIEW

Devices to achieve hemostasis during surgery have been used since the time of the Romans (around 100 A.D.), but it was Jean Louis Petit, in 1718, who first named his invention "tourniquet", which is derived from the French word *tourner* (to turn). In 1873, Johann Frefrich von Esmarch introduced an elastic bandage that was used to express venous blood, in combination with a tourniquet. The original "Esmarch bandage," however, was a tube the thickness of a finger which was wound tightly around the limb after the blood had been expressed from it. The flat rubber Esmarch bandage used today was designed by von Langenbach. The Martin bandage is a similar device made of cream colored latex. In 1904, Harvey Cushing, was the first to use an inflatable cuff, the forerunner of the contemporary pneumatic tourniquet. Today, Cushing's pneumatic tourniquet, and Esmarch's rubber bandage continue to be the mainstays of modern bloodless-field extremity surgery.

PREOPERATIVE EVALUATION

Before employing a tourniquet, the surgeon should rule out certain disease states which contraindicate the use of these devices including peripheral vascular disease, thrombophlebitis, and sickle cell disease. The use of a tourniquet in patients with sickle cell traits is controversial. One school of thought is that tourniquets can be safely used in this patient population, as long as the limb is carefully exsanguinated before tourniquet inflation. Another opinion is that tourniquet use should be avoided in this patient population.

Other disease states considered to be relative contraindications to tourniquet use include patients with a vasospastic disease such as Reynaud's or Berger's, diabetes mellitus, rheumatoid arthritis, or any other condition associated with a vasculitis or blood vessel disorder.

In patients with a history of venous disease, the preoperative use of heparin in conjunction with a tourniquet, and avoiding placement of the tourniquet over areas of known varicosities, will reduce the incidence of postoperative thrombophlebitis.

APPLICATION OF A TOURNIQUET

Thigh tourniquets are usually preferred over ankle tourniquets. The larger mass of soft tissue in the thigh provides added protection of neurovascular structures. However, a thigh tourniquet is painful and necessitates the use of general or spinal anesthesia.

Several layers of soft, smooth, cotton padding are applied to the skin in a wrinkle-free fashion. Wrinkles or folds in the padding may cause necrosis, blistering, and tourniquet discomfort during surgery. The padding should extend slightly above and below the tourniquet to ensure even pressure distribution. Care must be taken to prevent preparation solutions from contacting the cotton padding, as burns secondary to iodine have been observed. An appropriately sized pneumatic cuff should be applied snugly over the cotton padding.

Due to the conical shape of the upper thigh, the tourniquet tends to shift distally, compromising compression during inflation. In order to prevent this, an assistant should firmly draw the skin and subcutaneous tissue distally, prior to positioning of the cotton padding and tourniquet. Excessive tourniquet tightening prior to fixing the Velcro fasteners should be avoided for several reasons: it is unnecessary if the flesh is pulled distally in the previously described manner; it interferes with exsanguination of the extremity prior to tourniquet inflation; and it creates a venous tourniquet effect, which increases bleeding when the tourniquet is deflated intraoperatively.

The limb may be exsanguinated through the application of an Esmarch or Martin's bandage. Another method of exsanguination is elevation. The limb should be elevated for two minutes at 60 degrees, or three minutes at 45 degrees prior to tourniquet inflation. This is necessary to exsanguinate venous blood and to allow for compensatory arteriolar constriction. Elevation alone should be used in the event of infection, malignancy, prolonged immobilization, or the presence of a ganglion or soft tissue mass that may rupture with the application of an Esmarch bandage.

Assistance is necessary to elevate the extremity when exsanguinating a limb with an Esmarch bandage. Starting distally, the bandage is fully stretched and applied circumferentially, overlapping the previous turn by 2 cm, thus gradually working up the limb until the distal edge of the cuff is reached. Once the cuff is rapidly inflated, the Esmarch bandage is removed.

The maximum "safe" pressure to which a cuff is inflated has traditionally been 500 mmHg for the adult thigh, with various adjustments for age, blood pressure, weight, and extremity size and shape. Systolic blood pressure may rise as much as 70-100 mmHg during surgery. Therefore, most surgeons inflate a thigh tourniquet to a pressure which is approximately 100 mmHg greater than the preoperative systolic blood pressure. One source has determined an average "minimum" tourniquet pressure of 231 ± 26.5 mmHg to provide adequate hemostasis.

A tourniquet should not be inflated for more than 2 hours, without a "breathing period". This is the time needed to reverse blood acidosis. Five to fifteen minutes (per hour of tourniquet inflation) should elapse before tourniquet reinflation. No accepted safe duration of tourniquet reinflation, after the breathing period, has been established at this time.

Recent literature supports the use of a pneumatic ankle tourniquet, in conjunction with a regional ankle block, as a useful method of obtaining hemostasis during foot surgery. Distal tourniquet use in an extremity was thought to be unsafe due to lack of soft tissue, which would allow for direct compression of the neurovascular structures. However, appropriate padding of this area has been shown to adequately protect these vital structures. In addition, the use of an ankle tourniquet yields hemostasis in the foot without exposing the entire lower limb and thigh to unnecessary ischemia, thus reducing the risk of ischemic complications.

An appropriately-sized tourniquet can be applied over the well-padded supramalleolar area. Following limb exsanguination, the tourniquet is rapidly inflated to a recommended pressure of 100 mmHg greater than the systolic pressure (approximately 250 mmHg). Rearfoot procedures can be performed using a sterile ankle tourniquet to maximize the sterile surgical field.

RELEASE OF A TOURNIQUET

Tourniquet deflation, like inflation, should be rapid. When a tourniquet is released, there is an immediate increase in blood volume to the limb,

with resultant edema. The formation of edema is more apparent following prolonged tourniquet inflation, especially when the duration of the ischemia exceeds 2 hours.

There is a pronounced increase in fibrinolytic activity in the blood following the release of a tourniquet. The vaso vasorum is probably the richest source of plasminogen activation in the vasculature, responding maximally to complete ischemia. Despite this fibrinolytic activity, the incidence of deep vein thrombosis in patients undergoing surgical procedures with a tourniquet is no more than in other orthopedic procedures.

Controversy exists as to whether a tourniquet should be deflated before or after wound closure. If the tourniquet is released before closure, the wound can be inspected for bleeding vessels, which can be appropriately ligated, reducing the risk of postoperative hematoma. However, if meticulous surgical dissection is carried out with appropriate ligation of vessels, wound closure may be performed and a compressive dressing applied prior to tourniquet release. This is thought to reduce postoperative edema and pain associated with tourniquet use. Increased capillary permeability and vascular hyperemia occurs following tourniquet deflation, therefore the use of a surgical drain may be considered.

COMPLICATIONS

The most frequent complication resulting from the use of a tourniquet is nerve paralysis. Divergent opinions exist concerning the cause of the post-tourniquet paralysis syndrome. Some feel that this is due to the direct mechanical crushing of the peripheral nerve under the tourniquet, while others believe that compression causes local ischemia of the nerve producing a physiologic nerve block. The typical tourniquet paralysis syndrome consists of a loss of sensation to light touch, pressure, vibration, and position sense, as well as loss of muscle function. Pain sensation, however, is not lost, and hyperalgesia may result.

Tourniquet pressure paralysis has been found to be transient, with return of motor function followed by an orderly reversal of sensory alteration. In severe cases, complete restoration may not occur. However, this complication is rare if pneumatic tourniquets are used within the constraints of the critical time period and recommended pressures.

Tourniquet-induced hypertension, defined as a 30% increase in diastolic or systolic pressure, has been reported to occur, especially if nitrous oxide or narcotic analgesia is being used. This is more commonly observed in elderly patients and patients with cardiomegaly. Tourniquet-induced pain, which is unresponsive to narcotic administration, results in a release of endogenous catecholamines with subsequent hypertension.

When the use of vasoconstrictive agents is contraindicated, a pneumatic tourniquet is an excellent instrument to maintain a bloodless field, thus facilitating anatomic dissection and reducing surgical time.

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