inflation alone activated a systemic formation of the thrombosis.\textsuperscript{34}

In another study, researchers confirmed that cellular interactions that augment blood coagulability were increased in the perioperative period for patients who underwent total knee arthroplasty. They also concluded that these responses were more prominent during tourniquet-assisted total knee procedures.\textsuperscript{35}

II.c. The perioperative nurse should collaborate with the surgeon and anesthesia professional to address considerations related to the plan for anesthesia or ischemic preconditioning.\textsuperscript{36} [2: Moderate Evidence]

The purpose of ischemic preconditioning is to increase the tolerance of tissue to a longer period of ischemia by initiating brief periods of ischemia or influencing skeletal muscle tolerance with anesthetic regimens.\textsuperscript{37} Several studies have investigated the correlation between various anesthesia or preconditioning techniques and oxidative stress related to ischemia and reperfusion that occurs after the release of a tourniquet.\textsuperscript{38-44,56-54}

To reduce oxidative stress related to tourniquet inflation, preconditioning techniques may be planned to initiate short intervals of temporary ischemia (eg, three cycles of five minutes, followed by five minutes of reperfusion just before tourniquet inflation).\textsuperscript{44,45,59,61} Perioperative nurses may participate in activities related to preconditioning (eg, retrieving medications, setting up equipment, coordinating the timing of skin preparation, documenting intervals of inflation). By collaborating with the surgeon and anesthesia professional, the nurse will be better prepared to assist in preconditioning-related activities.\textsuperscript{53}

II.d. Before the patient enters the OR, a pneumatic tourniquet cuff should be selected using the following considerations.

- The width of the tourniquet cuff should be as wide as possible without inhibiting surgical site exposure.\textsuperscript{50,55}
- Contoured tourniquet cuffs should be used for patient extremities in which there is a tapering of the extremity between the upper and lower edge of the cuff.\textsuperscript{43,39,65}
- The length of the tourniquet cuff should be sufficient to provide bladder overlap on the limb and full engagement of the hook-and-loop fasteners. [2: Moderate Evidence]

Confirming that a tourniquet with the appropriate cuff size and shape is available before the patient enters the OR decreases the risk of using the wrong cuff size or shape or causing a delay to search for the appropriately sized cuff while the patient is under anesthesia.

Improper tourniquet cuff application may lead to skin injuries (eg, pressure necrosis, friction burns).\textsuperscript{4} The risk of injury to tissue and nerves increases when more pressure is required for vessel occlusion. The ratio of the cuff width to the limb circumference has an inverse relationship with limb occlusion pressure (eg, wider cuffs require lower tourniquet pressures, narrower cuffs require higher tourniquet pressures).\textsuperscript{20} Choosing the wrong cuff size or shape could lead to unnecessarily higher pressures and increase the risk for injury.

Wider cuffs minimize the risk for injury to underlying tissue by dispersing pressure over a greater surface area. In clinical trials, using a wider cuff has been found consistently to occlude blood flow at a lower pressure in adult patients.\textsuperscript{30,65-67} Similar results were found using wider cuffs in children.\textsuperscript{10} Contoured tourniquet cuffs have been found in clinical trials to occlude arterial flow at lower pressures than straight tourniquet cuffs of equal width. Contoured tourniquet cuffs minimize the risk of excessive pressure on one edge of the cuff, migration of the cuff, and a shearing injury to underlying tissue.\textsuperscript{1,2,6,10,65}

A sterile cuff should be used when the cuff will be very close to the sterile field. A single-use cuff should be used when adequate protection of the cuff from contamination cannot be assured. [3: Limited Evidence]

Researchers conducted a study at two hospitals to assess microbial colonization on reusable tourniquet cuffs versus sterile single-use disposable tourniquets. They found that 23 of the 34 reusable tourniquet cuffs were contaminated before surgical application. Although they did not follow the patients to find out the incidence of surgical site infection in the 23 patients who had contaminated cuffs applied, the researchers concluded that sterile single-use tourniquet cuffs are preferred to decrease the bacterial load when the cuff is placed in close proximity to the surgical site.\textsuperscript{56}

Potential risks for patient injuries and complications associated with dual-bladder cuffs used for intravenous regional anesthesia should be identified and safe practices should be established. [3: Limited Evidence]

Reports indicate that complications associated with intravenous regional anesthesia include local anesthetic toxicity, seizures, cardiac arrests, compartment syndrome, thrombophlebitis, discoloration, or widespread petechiae.\textsuperscript{52} When using intravenous regional anesthesia, there is a risk for local anesthetic toxicity caused by accidental tourniquet failure or leakage around the tourniquet due to high venous pressure.\textsuperscript{49,60} Complications can also occur that are related to tubings and misconnections (eg, attaching to distal versus proximal cuffs) when using dual cuffs for intravenous regional anesthesia.\textsuperscript{50,21}
PNEUMATIC TOURNIQUET

Because nerve damage may result from excessive tourniquet pressure and rhabdomyolysis has been reported with the tourniquet pressure set at an extreme pressure (ie, 520 mm Hg) even though the application time was relatively short (ie, 45 minutes), alarms are necessary to warn about conditions that may cause patient harm.\textsuperscript{104,109}

Recommendation V

Tourniquet inflation time and patient condition should be monitored while the tourniquet cuff is inflated.

Tourniquet inflation time has a direct correlation to tourniquet-related complications (ie, increased inflation time increases the risk for injury). The patient’s systemic response to ischemia is dependent on both tissue type and tourniquet time.\textsuperscript{20} While cardiac muscle has a higher demand for oxygen, skeletal muscle is considered highly susceptible to ischemia.\textsuperscript{100-101} This is because of the higher volumes of skeletal muscle mass releasing toxic substances into the circulatory system when reperfusion occurs, which can then lead to a severe inflammatory response.\textsuperscript{102,105} Excessive tourniquet inflation time (ie, two to three hours) may result in metabolic changes; muscle damage; impaired pulmonary, hepatic, or renal function; neurological complications; or pain.\textsuperscript{108,113}

To determine the efficacy and safety of distally placed pneumatic tourniquets, researchers initiated a retrospective study to review 3,027 procedures during which the surgeons used ankle tourniquets. Following a chart review, the researchers determined that the duration of ankle ischemia was as short as four minutes to as long as 139 minutes. Tourniquet failure was reported in 50 cases. Clinically, five complications were determined (ie, three post-tourniquet syndrome, one sickle cell-related problem, one DVT) and all eventually resolved. Based on the study, the authors concluded that an upper limit of two hours resulted in fewer complications.\textsuperscript{42}

In a prospective study of awake patients, researchers investigated tolerance of intraoperative tourniquet pain. The study was designed to include 1,000 patients undergoing elective foot surgery with a local block, but 12 patients were excluded because the surgeon chose not to use a tourniquet. This left a sample size of 988 patients. The researchers found that 31 patients (3.1%) expressed pain during the procedure and eight of those experienced symptoms (eg, breakthrough bleeding from reduced tourniquet pressure, oversedation, excessive restlessness) that required the surgeon to interrupt the procedure. Of those eight patients, the anesthesia professional converted four patients to general anesthesia. The maximum tourniquet inflation time was 90 minutes (ie, range two to 90 minutes, median 18 minutes). The researchers concluded that for foot procedures with local blocks and ankle tourniquets, a tourniquet time of up to 30 minutes is tolerated by patients younger than 70 years of age, but 1% of the patients will report pain for each 11 minutes beyond 30 minutes. They recommended caution when administering local anesthesia to patients older than 70 years, especially if the tourniquet inflation time is expected to be longer than 30 minutes.\textsuperscript{54}

In a retrospective review of more than 1,000 patients who had total knee arthroplasties (ie, primary and revision knee replacements), researchers set out to identify risk factors that contribute to neurological complications. All patients had tourniquet times greater than 120 minutes. The researchers reported that 90 patients (7.7%) experienced 129 peroneal and/or tibial nerve palsies. They concluded that extended tourniquet times, the patient’s age (ie, postoperative neurological dysfunction was associated with younger age), and the presence of preoperative flexion contractures were contributing factors to neurological complications. The authors also reported that total tourniquet time and a reperfusion interval only modestly decreased the risk of nerve injuries.\textsuperscript{111}

Twenty-six patients undergoing arthroscopic anterior cruciate ligament repairs participated in a prospective open randomized study that compared metabolic effects of using wide, curved tourniquet cuffs at a pressure of 250 mm Hg in one group and narrow, straight cuffs at a pressure of 350 mm Hg in the other. The researchers reported a significant correlation between femoral vein lactate levels and tourniquet time. They found the test parameters for measuring muscle injuries and anaerobic metabolism were the same between the two groups for the first hour of tourniquet inflation, but the metabolic changes increased as the tourniquet time increased.\textsuperscript{110}

V.a. Pneumatic tourniquet inflation time should be kept to a minimum. [2: Moderate Evidence]

Even with relatively short tourniquet inflation times (ie, 26 minutes ± eight minutes), researchers have found significant markers of systemic inflammatory response when they were measured 15 minutes after tourniquet deflation.\textsuperscript{115} Inflation times of 60 minutes for an upper extremity and 90 minutes for a lower extremity have been identified as a general guideline for inflation duration.\textsuperscript{112} However, some sources indicate that two hours is a safe time limit for tourniquet inflation.\textsuperscript{20} In pediatric patients, inflation times of less than 75 minutes for lower extremities has been recommended.\textsuperscript{114}

Irreversible skeletal muscle damage is thought to begin after three hours of ischemia and is extensive at six hours.\textsuperscript{115} Allowing intermittent reperfusion restores oxygenation and releases toxins.\textsuperscript{32} Deflating the tourniquet every two hours with at least a 10-minute reperfusion time has been identified as a strategy to consider to decrease the risk for tissue damage.\textsuperscript{20} Another approach is to release the tourniquet after 90 minutes for at least 10 to 15 minutes for the first reperfusion period, then 15 to 20 minutes for each subsequent reperfusion period.\textsuperscript{116} However, it has also been reported that implementing reperfusion periods after