FOOT & ANKLE INTERNATIONAL

Survey of Tourniquet Use in Orthopaedic Foot and Ankle Surgery

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ABSTRACT

***Background*: Tourniquet technique varies among foot and ankle surgeons, and to establish a standard practice guideline the current standard of care should be examined. *Methods:* One hundred and forty responses were received after 253 surveys were mailed to American Orthopaedic Foot and Ankle Society (AOFAS) members, concerning type of tourniquets, location, and pressures used. *Results:* Cuff pressures most commonly used were 301 to 350 mmHg for thigh cuffs (49% of thigh cuff users) and 201 to 250 mmHG for calf and ankle cuffs (52% of calf cuff users, 66% of ankle cuff users). A substantial number of foot and ankle surgeons who use calf and ankle cuffs frequently use pressures above 250 mmHg (41% of calf cuff users, 19% of ankle cuff users). Only 9% use limb occlusion pressure when determining cuff pressure. *Conclusion:* Based on the existing evidence-based literature these pressures may be higher than necessary for many patients, and increased adoption of optimal pressure setting techniques as reported in the literature may help reduce tourniquet pressures used and risk of tourniquet injury. Respondents reported experiencing or hearing reports of breakthrough bleeding, nerve injury, and skin injuries under the cuff.**

Key Words: Guidelines; Standards; Survey; Tourniquet

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INTRODUCTION

There are risks associated with tourniquet use and complications, ranging from mild skin irritation and friction burns (with or without fluids under the cuff) to nerve damage and paralysis.[2,6,24,25,32,35] A review by Kam et al.[14] summarizes the physiology, hazards, and clinical implications of tourniquet use. Guidelines have not been clearly defined,[14] except for one that is regularly updated and published in the nursing literature.[3] Tourniquet technique is ultimately the responsibility of the surgeon in charge.

Tourniquet pressures may be optimized by using wider and contoured tourniquet cuffs and limb occlusion pressure measurement to determine cuff pressure.[9,10,15,17–18,26,28,30] Some studies suggest that certain limb protection materials and techniques may help prevent skin injuries under the cuff.[19,32,39]

This survey was conducted to find out which aspects of tourniquet technique have consensus among surgeons, which aspects vary among surgeons, how the reported techniques correspond with the existing evidence-based literature, and what risks, contraindications, and complications surgeons are familiar with and concerned about.

MATERIALS AND METHODS

We mailed a two-page survey with an addressed return envelope to 253 American Orthopaedic Foot and Ankle Society (AOFAS) members, 250 located in the United States and three in Ontario, Canada. Addresses were selected and supplied by AOFAS. Surveys were sent to an average of five members from each of 49 different states (range one to 12). The survey questions are shown in Figure 1. The questions were derived from a similar survey of tourniquet use in pediatric patients.[39] Percentage results were based on the total number of completed surveys unless otherwise

1. How many foot and ankle surgical procedures do you perform in a typical year? (0–50, 50–100, 100–150, over 150)
2. Where do you perform surgery (if more than one applies, please rank in order of use)? (Teaching hospital, Community Hospital, Office, Daycare center, Other)
3. What anesthetic do you use *(if more than one applies, please rank in order of use)*? (General, Local, Regional)
4. Which are the types of foot and ankle procedures you perform *(rank in order of frequency)*? (Forefoot, Midfoot, Hindfoot, Ankle, Arthroscopy, Trauma/Infection)
5. Who applies the cuff to your patients? (Surgeon, Nurse, Anesthetist, Other)
6. Is an underlying sleeve or padding material normally used under the cuff? (No, Yes: Stockinette, Yes: Cotton cast padding)
7. What location do you use for the cuff *(if more than one applies, please rank in order of use)*? (Thigh, Calf, Ankle)
8. If you apply the cuff at the calf or ankle, how often do you require a sterile cuff? (Don't use calf or ankle cuffs, Never, Less than ½ cases, More than ½, Always)
9. Do you experience problems with the fit of the cuff due to limb taper or sliding of the cuff distally on the limb during the procedure? (For each location: 'Don't use, Never/rarely, Sometimes, Often')
10. How do you most commonly exsanguinate the foot prior to tourniquet inflation? (Don't exsanguinate, Esmarch (rubber) bandage, Tensor bandage, Elevation, Other)
11. With local or regional anaesthetic, do you experience problems with patient tolerate of the cuff? (For each location: 'Don't use, Never/rarely, Sometimes, Often')
12. What type of tourniquet machine do you most commonly use? (Electronic – Zimmer ATS, Other Electronic, Non-Electronic, Don't know)
13. What factors do you consider in determining the cuff pressure? (Limb size, Limb occlusion pressure, Blood pressure, Other)
14. What pressure setting do you most commonly use for your patients? (For each location: Don't use, 200 or less, 201–250, 251–300, 301–350, Over 350)
15. What contraindications do you consider for tourniquet use? (Vascular disease or bypass, DVT, Infection, Tumor, Other)
16. What types of tourniquet-related injuries and complications have you experienced or have you heard reported from your colleagues for these 3 locations? (For each location: Strikethrough bleeding/unable to occlude at normal pressures, Nerve related injuries, Skin injuries (blister, rash, edema, contusion, abrasion), no fluid under cuff, Skin injuries involving fluid leakage under cuff)
17. What types of tourniquet-related hazards, if any, are you concerned about for each location?

Fig. 1: Survey questions.

noted. For many of the questions, the respondents may have selected several choices; therefore the total percentages may add up to more than 100. When results were characterized as "exclusively", the respondents chose one answer only. When results were characterized as "included," it stipulated the percentage of those selecting the response either alone or with other choices.

RESULTS

Detailed results are shown in Figures 2 through 5 and Tables 1 through 3. We received 140 completed surveys (55% response rate). One hundred and thirty-nine of the 140 foot and ankle surgeons indicated that they regularly use a tourniquet. No surveys were returned unopened, not completed, or marked undeliverable.

The typical respondent performs more than 100 surgical procedures per year at a teaching or community hospital, performs a wide variety of procedures throughout the foot and ankle including arthroscopy and trauma and infection treatment, uses general anesthesia most often followed by regional anesthesia, applies the cuff himself, and uses cast padding under the cuff.

Cuff fit, location and pressure selection

Ninety-four percent of surgeons use thigh cuffs (32% exclusively) and the most frequently used thigh cuff pressures reported cover a wide range from 200 mmHg or less to 351 mmHg or more (Figure 2). Most surgeons who use thigh cuffs (61%) experience problems fitting

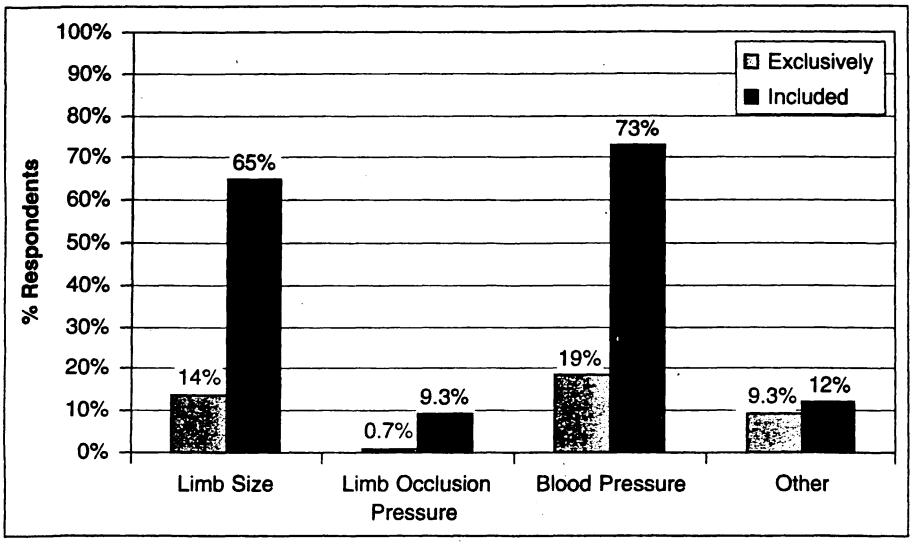

Fig. 2: Responses to "What factors do you consider in determining cuff pressure?"

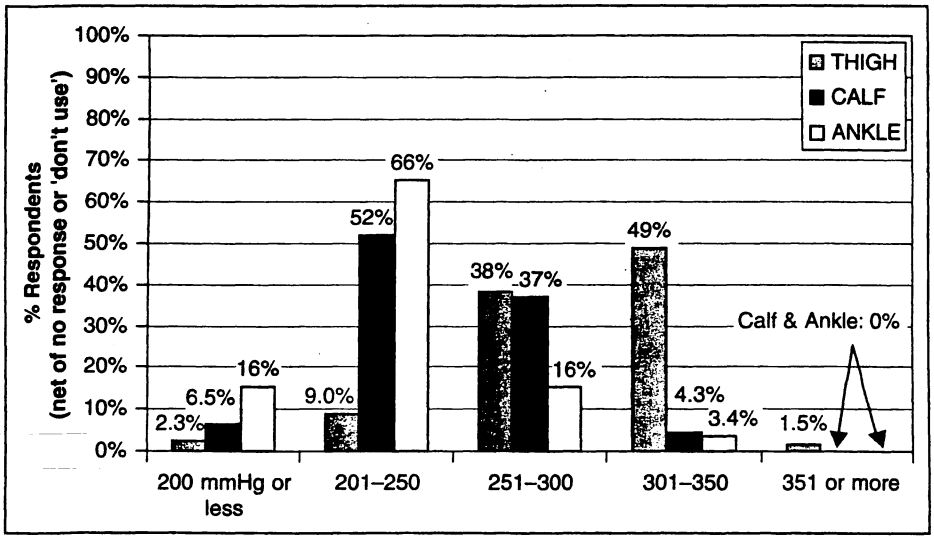

Fig. 3: Responses to "What pressure setting do you most commonly use for your patients?"

the cuff to the thigh "sometimes" or "often." One surgeon listed poor fit or application at the thigh as a concern and one listed morbid obesity as a contraindication to thigh cuff use because of inadequate cuff fit. Cuff fit is less of a problem at the calf and ankle than at the thigh, with 67% and 80% never or rarely experiencing problems when using a calf or ankle tourniquet, respectively.

Thirty percent of the respondents use a calf cuff (none exclusively) and 56% use an ankle cuff (6% exclusively), with pressures ranging from less than 200 mmHg to 350 mmHg. Pressures are slightly higher for the calf cuff (58.5% most frequently use 250 mmHg or less) compared to the ankle cuff (82% use 250 mmHg or less), a trend consistent with the generally higher cuff pressures required at larger limb circumferences (Figure 3).

Most surgeons consider blood pressure (73%) or limb size (65%) in determining cuff pressure, and 43% consider these two factors together (see Figure 2). Only 9% consider limb occlusion pressure (the minimum cuff pressure required to stop arterial flow past the cuff), usually in combination with other factors.

Sterile cuffs are never required by 58% of calf or ankle cuff users and always required by 24%. One surgeon pointed out that sterile cuff use is sometimes dictated by hospital supply rather than surgical requirements.

Elastic bandage ankle tourniquets

Twenty percent of respondents indicated that they use an elastic bandage as a tourniquet at the ankle or calf. Two survey respondents using elastic bandage tourniquets specified their techniques (three wraps over stockinette). Comments from surgeons

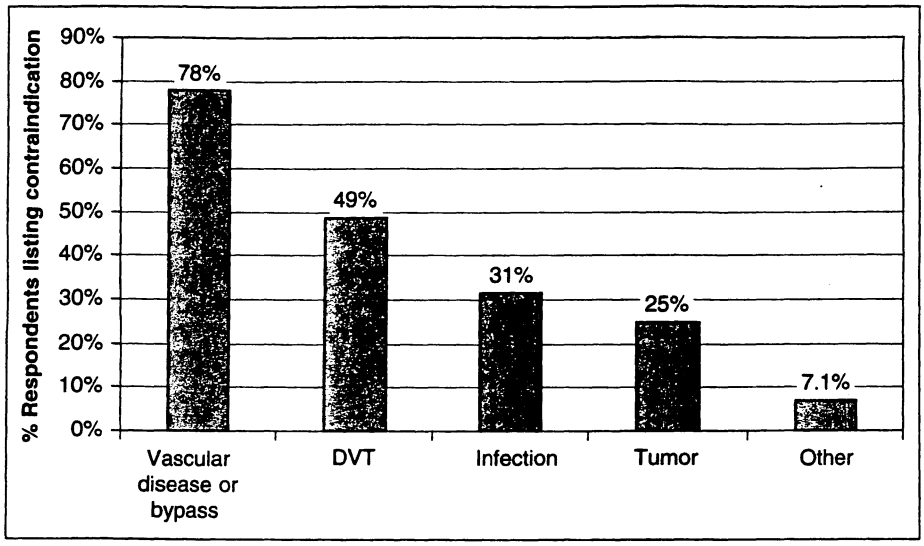

Fig. 4: Responses to "What contraindications do you consider for tourniquet use?"

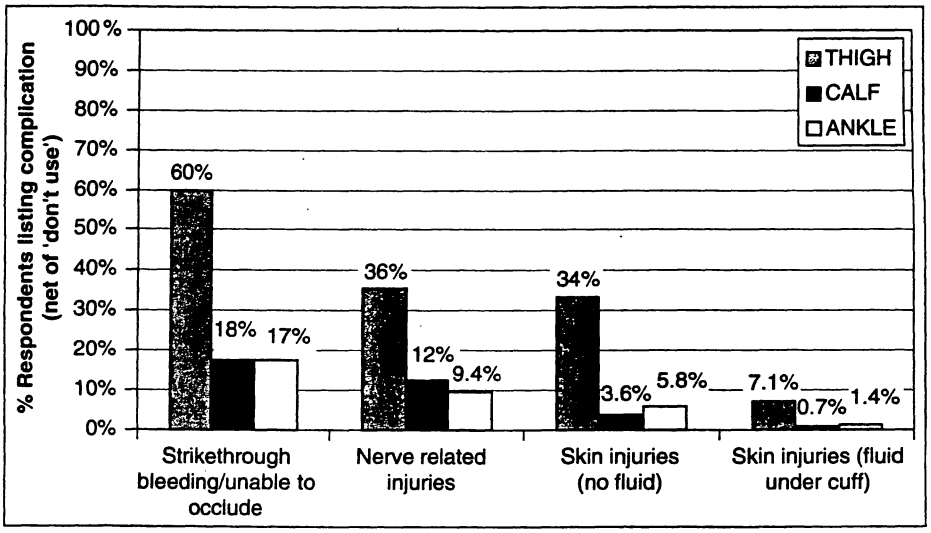

Fig. 5: Responses to "What types of tourniquet-related injuries and complications have you experienced or have you heard reported from your colleagues for these three locations (thigh, calf, ankle)?"

who use elastic bandages included: no complications so far with 4-inch wide bandage wrapped four times concern with unregulated pressure but no complications in 4000+ cases, maximal time of 1 hour with an elastic bandage versus 2 hours for a pneumatic cuff, No complications in 18 years of exclusive use with three-times wrapped bandage over a stockinette. One surgeon who uses a pneumatic cuff commented that the elastic bandage has a higher potential for damage.

Exsanguination

Seventy-three percent of surgeons use an elastic bandage (62% exclusively) and 8.9% use a tensor bandage ("Ace" wrap) for exsanguination. Fifteen percent elevate the limb only, and 11% use an elastic bandage or tensor bandage with limb elevation. No respondents noted complications related to exsanguination technique. Only 2.9% of the respondents do not exsanguinate.

Tourniquet instrument

Six percent gave no response and 21% did not know what type of tourniquet instrument they most commonly use. These seemingly high proportions may be due to surgeons working at a variety of sites and using the wide variety of equipment supplied at these sites. Eighty-three percent of the remaining surgeons use an electronic tourniquet instrument most often, 10% use a nonelectronic instrument exclusively, and 7% use both.

Table 1: Respondent demographics

Survey response summary:

	Number	Percent	
Sent (none returned undeliverable):	253		
Responded (all complete):	140	55%	percent of delivered
Don't or rarely use a cuff:	1	1%	percent of responded
Use Esmarch as ankle tourniquet:	28	20%	percent of responded

NOTE: 5/140 respondents (3.6%) use Esmarch ankle tourniquet exclusively.

How many foot and ankle surgical procedures do you perform in a typical year?

No response	1.4%
0-50	19%
50-100	24%
100-150	9.3%
over 150 (mode)	47%

Where do you perform surgery? (if more than one applies, please rank in order of use)

	Any rank	1st	2nd	3rd	4th
Teaching hospital	43%	34%	1.4%	0.7%	0.0%
Community hospital	59%	38%	6.4%	0.7%	0.0%
Office	5.0%	1.4%	2.1%	0.7%	0.0%
Daycare center	24%	7.9%	4.3%	0.0%	0.0%
Other:	1 military, 1 government, and 1 orthopaedic specialty hospital				

What anesthetic do you use? (if more than one applies, please rank in order of use)

	Any rank	1st	2nd	3rd
General (mode rank 1)	94%	44%	32%	11%
Local (mode rank 3)	74%	7.9%	26%	38%
Regional (mode rank 2)	88%	31%	41%	10%

Which are the types of foot and ankle procedures you perform? (rank in order of frequency)

	Any rank	1st	2nd	3rd	4th	5th	6th
Forefoot (mode rank 1)	98%	41%	12%	17%	9.3%	4.3%	2.9%
Midfoot (mode rank 4)	92%	0.0%	5.7%	19%	22%	20%	14%
Hindfoot (mode rank 3)	94%	11%	16%	21%	16%	11%	5.7%
Ankle (mode rank 2)	96%	16%	34%	24%	6.4%	2.1%	0.0%
Arthroscopy (mode rank 6)	78%	0.7%	4.3%	8.6%	14%	19%	22%
Trauma/infection (mode rank 3)	88%	10%	9.3%	18%	9.3%	14%	16%

Contraindications

Vascular disease or vascular bypass was the most commonly listed contraindication (78%), followed by deep vein thrombosis (49%), infection (31%) and tumor (25%) (Figure 4). Twenty-five percent listed vascular disease or bypass as the only contraindication. One surgeon applies a cuff but does not use it unless necessary in patients with vascular disease or bypass or infection. Four surgeons specified that they would use a cuff in the presence of infection but would not exsanguinate (one of four), would exsanguinate above the infection only (one of four), or by elevation only (two of four).

Complications

For thigh, calf, and ankle locations, the most common complication respondents have experienced or have heard colleagues report is breakthrough bleeding, followed by nerve injuries, skin injuries without fluid collecting under the cuff, and skin injuries involving fluid under the cuff (Figure 5). No responses were given for thigh, calf, and ankle locations in 19%, 73%, and 71% of respondents, respectively. Note that these results refer to the number of respondents listing familiarity with the complications either from personal experience or hearsay and therefore reflect the level of awareness.

Table 2: Current Practice

Who applies the cuff to your patients?				
No response	1%			
	Exclusively	Included		
Surgeon (mode)	54%	74%		
Nurse	18%	34%		
Anesthetist	0.7%	1.4%		
Other	5.7%	14%		
Is an underlying sleeve or padding material normally used under the cuff?				
No response	0.7%			
No	10%			
Stockinette	16%			
Cotton cast padding (mode)	66%			
Stockinette and/or cast pad:	5.0%			
NOTE: 2/140 respondents (1.4%) use padding at the ankle but not at the thigh.				
What location do you use for the cuff? (if more than one applies, please rank in order of use)				
	Any rank	1st	2nd	3rd
Thigh (mode rank 1)	94%	56%	21%	7.1%
Calf (mode rank 2)	30%	6.4%	16%	6.4%
Ankle (mode rank 1)	56%	26%	18%	3.6%
NOTE: Use thigh exclusively: 45/140 respondents (32%)				
Use calf exclusively: 0/140 respondents				
Use ankle exclusively: 8/140 respondents (5.7%)				
5/8 using ankle location exclusively use Esmarch as cuff				
One respondent uses Esmarch at calf.				
If you apply the cuff at the calf or ankle, how often do you require a sterile cuff?				
No response	7.1%			
Don't use calf/ankle	33%			
Never (mode)	58%			
Less than 1/2 cases	15%			
More than 1/2	2.4%			
Always	24%			
NOTE: Net of no response or 'don't use calf/ankle'				
How do you most commonly exsanguinate the foot prior to tourniquet inflation?				
No response	0.7%			
Don't exsanguinate	2.9%			
	Exclusively	Included		
Esmarch bandage (mode)	62%	73%		
Tensor bandage	8.9%	12%		
Elevation	15%	26%		
Other	0.0%	0.0%		
NOTE: 11% use Esmarch or Tensor with elevation				
Percentages are net of no response and 'don't exsanguinate'.				
What type of tourniquet machine do you most commonly use?				
No response	5.7%			
Don't know	21%			
	Exclusively	Included		
Electronic Zimmer ATS (mode)	66%	75%		
Other Electronic	15%	18%		
Non-Electronic	10%	17%		

NOTE: 83% use electronic only (Zimmer ATS, non-Zimmer, or both)
6.8% use both electronic (any brand) and non-electronic
Percentages are net of no response and 'don't know'.

Table 3: Perioperative difficulties

Do you experience problems with the fit of the cuff due to limb taper or sliding of the cuff distally on the limb during the procedure?

	THIGH:	CALF:	ANKLE:
No response	2.9%	7.9%	10%
Don't use	1.4%	55%	41%
Never/rarely	40%	67%	80%
Sometimes	54%	27%	16%
Often	6.7%	5.8%	4.3%

NOTE: Net of no response or 'don't use' for each location

With local or regional anesthetic, do you experience problems with patient tolerance of the cuff?

	THIGH:	CALF:	ANKLE:
No response	7.9%	16%	15%
Don't use	33%	50%	32%
Never/rarely	57%	62%	82%
Sometimes	22%	34%	12%
Often	22%	4.3%	5.4%

NOTE: Net of no response or 'don't use' for each location

Actual complication rates cannot be determined or estimated from these results.

Tourniquet-related hazards of concern and general comments

Sixty-five of 140 surgeons (46%) commented on the tourniquet-related hazards they are concerned about. Nerve injury was the most common concern, with 25 nonspecific comments, four specific to thigh cuffs, and five specific to peroneal nerve injury with calf cuffs (associated in one comment to the cuff being placed too far proximally). Only one comment was specific to nerve injury with ankle cuffs. In this survey the scope of nerve injury was not specified in detail and could include both minor, transient numbness or paraesthesia and more severe problems such as longer-term paralysis.

Concern over deep vein thrombosis was mentioned nonspecifically by two surgeons, specific to thigh cuffs by five, and specific to calf cuffs by five. Five surgeons mentioned concern with tourniquet time and four specified that tourniquet time should not exceed 2 hours. Only one noted a lower maximum (1 hour, specifically for an elastic bandage tourniquet).

Other concerns were skin injuries (eight), contusion, crushing, or muscle damage (five), compartment syndrome (five), and chemical burns under the cuff (three). Unique concerns included difficulty judging tendon tightness with ankle cuffs, difficulty in dorsiflexing the foot with calf and ankle cuffs, ischemic pain from thigh cuffs, vessel injury, poor wound healing, venous engorgement from inadequate tourniquet placement, inability to occlude, breakthrough bleeding from foot manipulation, and compromised surgical and radiographic access from calf and ankle cuffs. Eleven of 65 surgeons (17%) commented that they had no concerns or that complications were rare.

DISCUSSION

The main findings of the survey were that the most frequently used tourniquet pressures vary widely among surgeons. Few use limb occlusion pressure measurement to optimize cuff pressure, and based on the existing literature, commonly used cuff pressures may be higher than necessary for many patients. Most surgeons exsanguinate the limb, use a limb protection material under the cuff, and use an electronic pneumatic tourniquet instrument. Many surgeons have experienced or heard of complications, such as breakthrough bleeding, nerve injury, and skin injury under the cuff. Nerve injury, skin injury, and deep vein thrombosis, are the most frequently cited concerns.

In a similar survey, podiatrists who regularly perform foot and ankle surgeries indicated similar variable cuff pressures, less frequent use of limb occlusion pressure measurement, more frequent use of ankle and calf tourniquet locations, and less frequent use of an elastic bandage as an ankle tourniquet compared to the orthopaedic surgeons in the current survey.[13]

The high (55%) response rate to the survey indicates a strong interest in tourniquet technique and issues among foot and ankle orthopaedic surgeons. A similar overall response of 50% was reported in a recent combined mail (13 of 40) and e-mail (33 of 52) survey

of pediatric tourniquet techniques.[39] In comparison, an e-mail survey of tourniquet technique among podiatrists who regularly perform foot and ankle surgeries had a 19% response rate.[13] It cannot be determined if there are biases in tourniquet technique between respondents and nonrespondents; however, it is likely that surgeons who use a tourniquet regularly are more likely to complete the survey than surgeons who do not use a tourniquet. Therefore, the true percentage of surgeons who do not use a tourniquet is likely higher than the one of 140 (0.7%) indicated in our results.

When selecting cuff pressure, only 9% consider limb occlusion pressure, usually in combination with other factors (see Figure 2). Limb occlusion pressure is defined as the minimal cuff pressure required to occlude arterial flow in the involved limb (using the tourniquet cuff as applied for the surgical case and measured prior to cuff inflation), and therefore accounts for all factors affecting occlusion including blood pressure, limb size, tissue properties, cuff fit, and cuff design.[9,15,17,18,21,28,30,41] Limb occlusion pressure is measured by gradually increasing cuff pressure and noting the pressure at which distal arterial flow stops. Distal arterial flow can be monitored by Doppler stethoscope (which is somewhat awkward and time consuming). Automated equipment for determining limb occlusion pressure has been used successfully in clinical trials but is not yet commercially available.[17,18,41]

Only 11% of surgeons reported that they most frequently used pressures of less than 250 mmHg at the thigh, a range that would correspond with optimal cuff pressure (limb occlusion pressure plus a 40 to 80 mmHg safety margin) for most patients studied.[18,28,30,41] Similarly, setting the cuff pressure at systolic blood pressure plus 100 mmHg, while not providing an optimal cuff pressure, would typically result in pressures less than 250 mmHg, which were found to be adequate for most patients in a clinical series and reduced postoperative thigh pain.[40] One and a half percent reported using 351 mmHg or more, which may be higher than necessary for most patients based on clinical studies in which thigh cuff pressures substantially lower than 351 mmHG were found to be adequate for most patients.[18,26,28,30,40,41]

Forty-one percent of surgeons who use calf cuffs and 19% who use ankle cuffs use pressures of 251 mmHg or more. Some published studies suggest that if wide, contoured cuffs are used[17,26] and limb occlusion measurement is used to set cuff pressure,[9,17] pressures of more than 250 mm Hg may seldom be required at the calf or ankle.[9,22] Lower tourniquet pressures also should improve tourniquet tolerance[10] and reduce the risk of complications.[23,27]

Twenty percent of the responding surgeons reported using elastic bandages as ankle tourniquets, a high proportion compared to the eight of 317 (2.5%) of podiatrists responding to a similar survey.[13] Some of the literature suggests that elastic bandage ankle tourniquets do not cause a higher incidence of complications,[4,38] while its use as a tourniquet has been criticized because of the unrecorded and potentially high pressures that can be applied.[20,31] Laboratory studies have shown that pressures of 1000 to 1400 mmHg can be generated beneath an elastic bandage using typical techniques (stretching and wrapping three to five times).[1,20] In multiuser testing of various elastic bandage widths and number of wraps, Biehl found standard deviations of 35 to 53 mmHg and a maximum of 321 to 413 mmHg.[4]

No respondents noted complications related to exsanguination technique. The elastic bandage has been criticized as being too aggressive for exsanguinations, with the tensor bandage preferred because of its lighter compression.[8] Several case reports of pulmonary embolism upon exsanguination using an elastic bandage have been published, and it has been suggested that the sudden increase of venous flow caused by the pressure of the elastic bandage dislodged pre-existing thrombi.[5,12,29,36]

Deep vein thrombosis was specified as a concern by 12 surgeons; one prospective randomized trial suggested that thigh cuff use does not increase the risk of deep vein thrombosis for forefoot surgery patients.[37]

Only one comment was specific to nerve injury with ankle cuffs, suggesting that past concerns with injury to the unprotected nerves at the ankle[3,33] are no longer widely held, and some surgeons have argued that this concern is unfounded based on retrospective reviews.[8,16]

Generally, it is accepted that both tourniquet pressure and time should be minimized to decrease the risk of injury, and accordingly several survey respondents noted tourniquet time limits. Although it is impossible to define a maximal safe tourniquet time for all patients, the maximal suggested periods of continuous tourniquet ischemia are considered to be 1 hour,[7] 90 minutes,[11] or 2 hours.[14] The 90-minute limit is supported by an animal study in which a significant increase in myofibrillar degeneration index was observed when the initial period of continuous tourniquet ischemia was increased from 90 minutes to 2 hours. The authors concluded that three 60-minute or two 90-minute periods separated by 5-minute reperfusion intervals produced minor injury to the muscle cells compared to a 2 plus 1-hour pattern or a 3-hour uninterrupted period.[34]

Tourniquet complications presently are hard to define. Before the modern generation of electronic tourniquet instruments became widely used, tourniquet complications were often clearly attributed to accidental applications of excessive pressure or long tourniquet times,

sometimes resulting in complete paralysis. Improvements in equipment and techniques generally have lead to lower tourniquet pressures being used and increased awareness of minimizing tourniquet time, and as a result a tourniquet nerve injury in current practice may be incomplete and its cause never determined. The incidence of tourniquet paralysis is therefore likely under-reported.[14] In some patients a tourniquet-related neurologic deficit may be attributed to reflex sympathetic dystrophy or direct trauma to the nerve by surgery.

A survey of this nature can only report the respondents' estimates, opinions, recalled experience, and hearsay; therefore, it cannot be used to establish recommended practice guidelines. There also are limitations on the specificity of the questions and responses in a general survey of this type, particularly regarding contraindications and complications. The intention of the survey was to show the general trends and the areas of concern among respondents. Evidence-based literature in each specific area would need to be consulted to estimate actual complication rates and to determine the best ways to minimize them.

The results can, however, show which aspects of reported practice agree with the existing evidence-based literature. Lack of consensus among respondents in certain aspects of practice may suggest that existing clinical evidence should be reexamined and possibly researched further.

Based on survey responses from 140 of 253 foot and ankle orthopaedic surgeons in the United States and Canada, tourniquet practice is varied. Few respondents use optimal cuff pressure setting techniques such as limb occlusion pressure measurement. Thigh cuffs are most commonly used, followed by ankle and calf, and almost all use some form of limb protection material under the cuff. Use of an elastic bandage for exsanguination and as an ankle tourniquet is common and few respondents expressed concern over the associated risks that have been discussed in the literature. Most surgeons usually use an electronic tourniquet instrument. Nerve injury is the most common concern, followed by deep vein thrombosis and skin injuries with and without fluids collecting under the cuff. Based on the most frequently used pressures and infrequent use of limb occlusion pressure measurements reported in this survey, we think that guidelines should include explicit recommendations for using limb occlusion pressure measurements to determine the optimal cuff pressure for each patient and for using tourniquet cuffs that occlude at lower pressures as described in the existing evidence-based literature. Wider adoption of these techniques may help minimize the risk of tourniquet complications.

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