Challenging the Dogma of Tourniquet Pressure Requirements for Upper Extremity Surgery

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Abstract

Background Traditional teaching supports upper extremity tourniquet pressure to be set at 250 mm Hg. Complications have been associated with increased pressure and duration of tourniquet use. We hypothesized that there will be no significant difference in intraoperative variables between tourniquet pressures of 125, 150, 175, or 200 mm Hg as compared with the current practice of 250 mm Hg during mini-open carpal tunnel release.

Case Description A retrospective review was conducted of patients undergoing open carpal tunnel release from June 2009 to June 2012. Those undergoing surgery with a tourniquet pressure of 250 mm Hg were compared with those with lower tourniquet pressures regarding their demographics, operative and anesthesia time, and whether the tourniquet pressure needed to be increased to 250 mm Hg during surgery.

Literature Review A total of 432 patients underwent carpal tunnel release over the 3-year period. There were no differences with respect to patient demographics. There was no significant difference between operative or anesthesia time between different tourniquet pressure groups. There were no reported problems with breakthrough bleeding or difficulty with visualization of structures in any of the pressure groups. None of the patients with lower tourniquet pressures needed the tourniquet pressure to be adjusted during surgery.

Clinical Relevance This study demonstrated that using lower tourniquet pressures had no effect on the operation for open carpal tunnel release including effect on operative or anesthesia time, breakthrough bleeding, or complications directly related to tourniquet pressures. Orthopedic surgeons may consider reducing tourniquet pressures during carpal tunnel release.

Keywords

- pneumatic tourniquets
- tourniquet pressure
- upper extremity surgery
- carpal tunnel release

Pneumatic tourniquets are commonly used in upper extremity orthopedic surgery.¹ They help to maintain a clear and relatively bloodless surgical field, minimize blood loss during procedures, and decrease length of surgery with better visualization of anatomic structures.¹ Complications from tissue damage due to tourniquet use can occur, and delay in muscle strength recovery, compression neurapraxia, wound hematomas, ischemic neuropathy, and ischemic tissue necrosis have been reported.^{2,3} Most importantly, patients find the tourniquet uncomfortable at best and pain-

ful at worse, especially when it is common practice to insufflate it to pressures of 250 mm Hg for most hand surgery procedures.⁴ Although these complications have been associated with pressure and duration of tourniquet use,⁴ precise effect of the range of these parameters is unclear, and as a result, guidelines for duration and minimum pressure of tourniquets remain controversial and have yet to be assessed in a clinical setting.⁴ Traditional teaching supports the routine pressure for upper extremity tourniquet be at 250 mm Hg.^{1,4–6} Recommendations for tourniquet pressures

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in patients originate from animal studies performed in the early 1990s that first demonstrated physiologic and morphologic nerve conduction abnormalities following tourniquet use greater than 350 mm Hg,⁵ with subsequent studies showing histological tissue damage and muscle injury following tourniquet uses between 200 and 350 mm Hg.⁶ Our study's primary question was whether there is a need to insufflate the tourniquet pressure to 250 mm Hg during the most common hand surgery procedure performed, namely, carpal tunnel release. Specifically, we sought to assess the intraoperative effects of setting tourniquet pressures less than the accepted 250 mm Hg. We hypothesize that setting tourniquet pressures lower than 250 mm Hg will have no effect on the intraoperative variables such as operative time, anesthesia time, or extent of breakthrough bleeding during carpal tunnel surgery.

Materials and Methods

After obtaining institutional review board approval, a retrospective study was conducted analyzing the outcomes of patients who underwent surgical treatment for carpal tunnel syndrome over a 3-year period between 2009 and 2012. Patients undergoing the surgery in conjunction with other upper extremity procedures were excluded. All surgeries were performed by two fellowship-trained surgeons with the same surgical technique. The only variable was the tourniquet pressures used. All patients had intravenous sedation per anesthesia. For surgical technique, an 18-inch tourniquet was insufflated after ensuring adequate local anesthesia with 1% lidocaine without epinephrine and 0.25% plain Marcaine and exsanguination. An incision was made between Kaplan cardinal line and distal wrist crease following the ulnar border of the ring finger, and sharp dissection was carried down to palmar fascia. The transverse carpal ligament was divided until the contents of the flexor canal were identified ensuring no masses were found, and this was performed distally and proximally. The tourniquet was deflated, hemostasis obtained, and skin edges were reapproximated with 4-0 nonabsorbable monofilament suture. One surgeon served as the control group, and performed surgeries with a tourniquet pressure of 250 mm Hg. The other surgeon assigned patients to tourniquet pressures of 125, 150, 175, 200, or 250 mm Hg based on their intraoperative systolic blood pressure prior to tourniquet insufflation, and were assigned to a group that was the next highest up from their systolic blood pressure reading. The primary outcome that was assessed was whether using a lower tourniquet pressure than 250 mm Hg negatively impacted the ability to perform a carpal tunnel release. Specifically, intraoperative and perioperative blood pressures were recorded by the anesthesia team as part of their routine monitoring using automated blood pressure cuffs. In addition, intraoperative tourniquet pressure and time, operative time (measured as the time between incision and tourniquet deflation), total anesthesia time (measured as anesthesia "start" and "end" times recorded), and any intra- or perioperative complications including any changes

made to tourniquet pressure intraoperatively or note of breakthrough bleeding were recorded.

Statistical Analysis

Results were summarized as counts and percentages for categorical data, and means with corresponding standard deviations for continuous data. Between-group mean differences were compared using one-way analysis of variance for continuous variables, and Mantel-Haenszel chi-square tests for categorical data.

Results

There were 432 patients who underwent mini-open carpal tunnel release. A summary of patient characteristics is included in ►Table 1. In terms of demographic information, age, gender, body mass index, and workers compensation were assessed. Both groups were similar in terms of these measures.

There were 10 patients in the 125 mm Hg group, 58 patients in the 150 mm Hg group, 64 patients in the 175 mm Hg group, 96 patients in the 200 mm Hg group, and 204 patients in the 250 mm Hg group. ►Table 2 summarizes average systolic and diastolic blood pressures in the preoperative, intraoperative, and postoperative period for each group of tourniquet pressures. ►Fig. 1 reflects these values and compares preoperative and intraoperative systolic blood pressures for each of the tourniquet pressure groups, showing that, overall, intraoperative systolic pressures dropped from the preoperative readings. The average duration of tourniquet use was 8 minutes, with no significant difference between tourniquet pressure groups ($p < 0.05$). The average incision to closure time was 18 minutes (range of 8–33 minutes), and average anesthesia time was 45 minutes (range of 25–88 minutes). There were no differences in operative or anesthesia time between tourniquet pressure groups ($p < 0.05$). None of the patients required changing of tourniquet pressure intraoperatively in the lower tourniquet pressure cohort, nor did any patient develop breakthrough bleeding. There were few postoperative complications overall with 13 out of 432 patients developing superficial wound dehiscence that healed by secondary intention. These were most likely unrelated to the pressure of the tourniquet. Six of these patients are in the 250 mm Hg group (3%) and seven in

Table 1 Patient characteristics

	<i>n</i> = 432
Average age (SD)	59 (15)
Range	19–93
Sex	
Female	242 (56%)
Male	190 (44%)
Workers compensation (%)	118 (27%)
Average body mass index (SD)	32 (7)
Range	15–59

Table 2 Blood pressure readings by tourniquet pressure

	125 mm Hg	150 mm Hg	175 mm Hg	200 mm Hg	250 mm Hg
Preoperative systolic (range)	116 ± 15	128 ± 16	136 ± 21	133 ± 22	130 ± 22
Preoperative diastolic (range)	65 ± 8	76 ± 11	77 ± 11	76 ± 16	75 ± 12
Intraoperative systolic (range)	95 ± 6	106 ± 12	121 ± 16	116 ± 20	124 ± 21
Intraoperative diastolic (range)	55 ± 12	59 ± 11	64 ± 11	62 ± 13	65 ± 15
Postoperative systolic (range)	112 ± 9	121 ± 19	133 ± 22	129 ± 21	126 ± 22
Preoperative diastolic (range)	65 ± 9	71 ± 11	73 ± 11	74 ± 12	72 ± 13

the group < 250 mm Hg (3%). There were no deep space infections and none of the patients required a secondary procedure.

Discussion

Pneumatic tourniquets are widely used in upper limb surgery. The purpose of the tourniquet is to create a relatively bloodless field and reduce blood loss during surgery.³ Despite its wide use, recommendations related to duration and especially pressure remain controversial, and are based on upper limits of pressure (250 mm Hg in the upper extremity) and time (1–3 hours) above which complications are more likely to occur.⁴ As a result, orthopedic surgeons typically practice fixed pressure inflation, setting the pressure to 250 mm Hg for every patient within the upper extremity for every procedure. Complications associated with tourniquet use include postoperative pain or discomfort, delay of recovery of muscle strength, compression neuropraxia, tissue necrosis, and local and systemic effects of deflation-based reperfusion injury.^{1–3}

Evidence-based recommendations to decrease pressure-related injuries and postoperative complaints due to tourniquet use relate to establishing the minimum pressure needed to occlude arterial flow to the upper limb. Studies have consistently demonstrated that, by measuring this arterial occlusion pressure (AOP) and selecting cuff inflation pressure accordingly, providers can decrease tourniquet-related com-

plications.^{6–8} Tourniquet pressure based on occlusion of flow is generally lower than the accepted 250 mm Hg, and satisfactorily creates a bloodless field intraoperatively.⁹ The average calculated AOP was 202.3 ± 34.2 mm Hg to achieve hemostasis in the upper limb.¹⁰ AOPs are determined manually by inflating tourniquets until distal arterial pulses cease, and is verified with Doppler ultrasonography. A new method estimating AOP, and thereby the most appropriate tourniquet pressure, has been proposed by Tuncali et al, who reported a formula to apply in the operative setting related to systolic blood pressure of the patient divided by a predetermined coefficient.¹¹ Although this recommendation established a way to determine appropriate tourniquet pressure based on the individual patient's arterial occlusion, and has demonstrated a safety benefit, it has not been practical for clinical practice as it is time intensive, requires operator skill,^{2,11} or requires an investment in new materials, with added expense, as with newer tourniquets that automatically measure arterial pressure beneath the tourniquet.²

Given the issues with tourniquet use, some have advocated tourniquet-free hand surgery using a tumescent solution comprising an epinephrine concentration of 1:1,000,000 added to a certain amount of lidocaine per 50 mL solution. This has been used in a variety of procedures including burn contractures and congenital hand and upper extremity surgeries, and has shown to be effective in creating a bloodless operative field.^{12,13}

Despite research related to establishing different methods for determining occlusion pressure, there is a lack of evidence assessing the practical effects of intraoperatively reducing tourniquet pressures. The primary aim of this study was to determine if reduced tourniquet pressures negatively affected operative variables in patients undergoing mini-open carpal tunnel release. The significance of these results will help us refine indications of standard tourniquet pressure for soft tissue procedures of the hand that may be associated with better patient outcomes and satisfaction. This may be of increasing clinical importance with a move to do many of these procedures in a procedure room without the involvement of an anesthesiologist and as such the patient not experiencing pain and discomfort with the tourniquet pressure settings of 250 mm Hg. The study found no difference in outcomes, including total operative time, anesthesia time, surgeon report of breakthrough bleeding or having to adjust the tourniquet pressure intraoperatively, or development of complications at the time of follow-up between patients

Fig. 1 Comparison of preoperative and intraoperative systolic blood pressures by tourniquet pressure groups.

assigned to tourniquet pressures of 125, 150, 175, 200, or 250 mm Hg. Factoring in the tourniquet time did not change this effect either. Additionally, the relationship between systolic and diastolic blood pressures was assessed in the pre-, intra-, and postoperative periods. Patients were assigned to 125, 150, 175, 200, or 250 mm Hg based on their immediate intraoperative systolic blood pressure. We noted that intraoperative systolic blood pressures were lower than what was measured preoperatively and as such can be used to guide tourniquet pressure setting.

Our study has several limitations. First, patients were not truly randomized to different tourniquet pressure groups, and were assigned to a tourniquet pressure based on their immediate intraoperative systolic blood pressure. Therefore, there were different numbers of patients within different groups. This patient cohort may not have the power required to completely detect the true incidence of tourniquet complications. An improved randomization process may have assisted in creating a more equal distribution of patients to the respective pressure groups. Nonetheless, this may be practically difficult as the tourniquet pressure was set based on the systolic blood pressure within the operating room immediately before the surgical procedure. Second, although both surgeons had similar operative approaches to the procedures, one surgeon performed all his surgeries at 250 mm Hg, while the other surgeon randomized to different tourniquet groups. This division in randomization of patients may introduce a confounding variable based on surgeon. However, there was no difference between patient demographics, tourniquet time, operative time, anesthesia time, or intraoperative complications when comparing the different surgeons at the same tourniquet pressure and as such the surgeon who performed all surgeries at a tourniquet pressure at 250 mm Hg served as a control. Duration may be less of a concern in carpal tunnel release as it is a relatively short procedure that requires tourniquet use times well under the recommended maximum time of 2 hours. Nevertheless, it provided evidence that soft tissue procedures within the hand and forearm can be safely performed under lower tourniquet pressures, and has led us to use lower tourniquet pressures.

These limitations notwithstanding, given the results of this study, we recommend a lower tourniquet pressure than 250 mm Hg that can be based on immediate intraoperative systolic blood pressure. From the results of this study, intraoperative blood pressures were on average lower than blood pressures taken prior to surgery, and using a lower tourniquet pressure was as effective as using a tourniquet set at 250 mm Hg. The use of lower tourniquet pressures based on the intraoperative systolic blood pressure for cases performed with local anesthesia should be considered for patient benefits of lower intraoperative blood pressure.

Ethical Statement

Procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Declaration of Helsinki of 1975, as revised in 2000 and 2008. Informed consent for research purposes was obtained per institutional protocol.

Note

This study was approved by institutional review board (number: 13-000840).

Conflict of Interest

None.

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