matters

Effectiveness of an "axillary ring block" in reducing tourniquet pain in volunteers: Double-blind, randomized crossover clinical trial

Correspondence
jschoenh@aims.unc.edu

Disciplines
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Jay W Schoenherr, Andrey Bortsov, Cody Rowan, Avery Calhoun, Alex Fletcher, Richard H Gracely, Randall Coombs
Anesthesiology, University of North Carolina; Center for Neurosensory Disorders, University of North Carolina

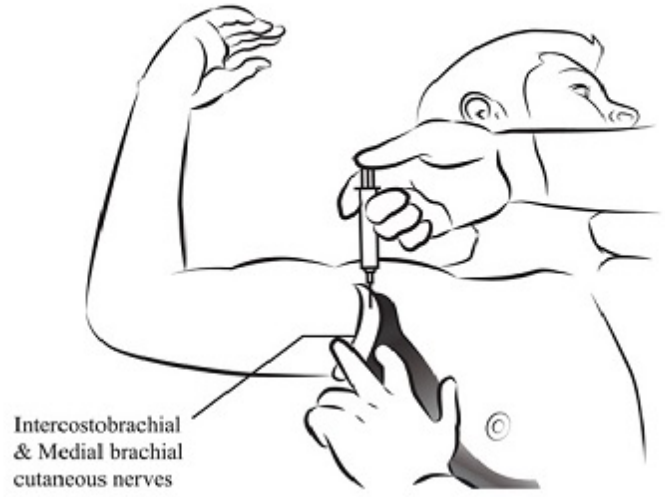
Abstract
Background and Objectives: Orthopedic surgeons commonly use an upper arm tourniquet to avoid excessive surgical bleeding. An "axillary ring block" has been used to help patients better tolerate the discomfort from the tourniquet. The primary objective of this study was to determine if an "axillary ring block" with 0.25% bupivacaine with epinephrine 1:200,000 was effective in decreasing tourniquet pain.
Methods: This was a prospective, controlled, blinded, crossover trial involving 24 adult volunteers. 12 men and 12 women underwent subcutaneous axillary ring injection with 0.25% bupivacaine with epinephrine 1:200,000 or normal saline prior to inflation of an upper arm tourniquet. Approximately 1 month later, all subjects returned to have the opposite solution injected. The primary endpoint was the total time that the tourniquet was inflated.
Results: The volunteers who were injected with bupivacaine/epinephrine tolerated the upper arm tourniquet for a longer period than those who received saline (mean of 30.5 min) vs. 22.4 min (p= 0.014). The bupivacaine/epinephrine axillary ring injection also decreased pain at the tourniquet site by 1.0 pain scale unit (p= 0.025) and pain below tourniquet by 1.1 units (p= 0.001).
Conclusions: We demonstrated that bupivacaine axillary ring injection may decrease the level of discomfort under an upper arm tourniquet.

Introduction
Discomfort secondary to the use of a pneumatic tourniquet for limb surgery is a common obstacle in anesthetic management. Prior studies have shown that awake volunteers experience a vague, dull pain after tourniquet inflation that is tolerated for an average duration of 31 min, extended to 45 min with sedation [2] [3]. Prolonged tourniquet inflation (>30–60 min) produces a gradual increase in heart rate and blood pressure, the incidence of which is related to the type of anesthesia [2]. A cutaneous mechanism is thought to be responsible, as demonstrated by the attenuation of tourniquet discomfort by topical eutectic mixture of local anesthetic agents (EMLA) [4] [5]. A sympathetically mediated pathway has essentially been disproven by the lack of effectiveness of stellate ganglion block for upper arm tourniquet discomfort, although the study was small [6]. The leading hypothesis for the mechanism of tourniquet pain is the loss of inhibition of unmyelinated, slow-conducting C fibers. These fibers are usually inhibited by fast, myelinated A-delta fibers which are blocked after approximately 30 min of tourniquet inflation and mechanical compression [2]. After brachial plexus anesthesia, the anatomy and innervation of the upper arm has led to an additional subcutaneous infiltration of local anesthetic of the medial aspect of the upper arm [7]. This is called the "axillary ring block," and it targets the intercostobrachial nerve and the medial cutaneous nerve of the arm. The intercostobrachial nerve is the lateral cutaneous branch of the ventral primary ramus of T2. It provides innervation to the skin of the axilla and the medial aspect of the proximal arm. The intercostobrachial nerve communicates with the medial cutaneous nerve of the arm, which is a branch of the medial cord of the brachial plexus. Both of these nerves are routinely missed with supraclavicular or infraclavicular brachial plexus anesthesia, and this study was designed to determine the effectiveness of the axillary ring block in decreasing tourniquet pain. It was hypothesized that the axillary ring block will decrease tourniquet pain and increase tourniquet tolerance period.

Objective

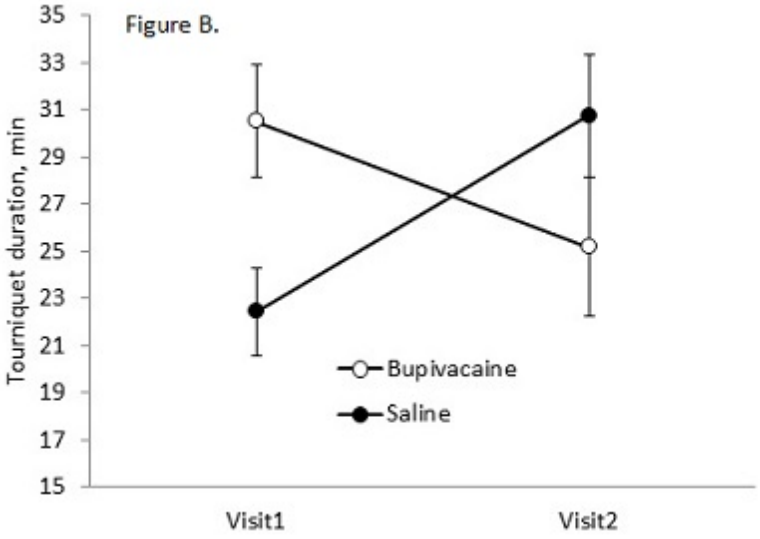
This study was designed to determine the effectiveness of the axillary ring block in decreasing tourniquet pain in healthy volunteers.

Figure A. Axillary Ring Block

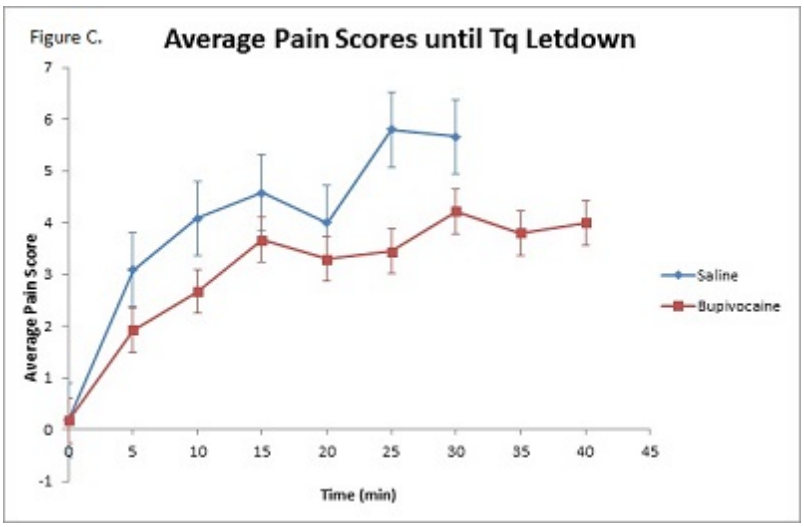


a

Figure B.



b



c

Figure D. Characteristics of Study Participants

		Sequence allocation group		
		Bupivacaine-Saline	Saline-Bupivacaine	Total
n		12	12	24
Age	Mean(SD)	32(10)	32(11)	32(10)
Sex	Female	6	6	12
	Male	6	6	12
Dominance	Dominant	6	6	12
	Non-dominant	6	6	12
Laterality	Left	6	7	13
	Right	6	5	11
Race	Caucasian	11	8	19
	Asian	1	2	3
	Black	0	1	1
	Hispanic	0	1	1

d

Figure E. Experiment results by treatment group during the first study visit

	Treatment	Mean	Lower 95% CL	Upper 95% CL	p-value
Time Tourniquet On	Bupivacaine	30.5	26.1	35.0	
	Saline	22.4	18.0	26.9	
	difference	-8.1	-14.0	-2.1	0.014
Pre-deflation pain at tourniquet, 0-10 NRS	Bupivacaine	3.6	2.6	4.6	
	Saline	4.6	3.6	5.6	
	difference	1.0	0.1	1.8	0.025
Pre-deflation pain below tourniquet, 0-10 NRS	Bupivacaine	5.0	4.0	5.9	
	Saline	6.1	5.2	7.1	
	difference	1.1	0.4	1.8	0.001

e

Figure Legend

Figure 1.

(A) Illustrated representation of the axillary ring block [1].

(B) Significant carryover effect was observed (first arm received bupivacaine during the first visit and saline during the second visit; second arm received saline at the first visit and bupivacaine at the second visit).

(C) Average pain scores at the tourniquet site and time of inflation for volunteers who received a bupivacaine axillary ring injection during their first session.

(D) Characteristics of study participants.

(E) Experimental results by treatment during the first study visit.

After receiving IRB approval, written informed consent was obtained from 24 volunteers for this prospective, controlled, blinded, crossover trial. Exclusion criteria included age younger than 18 or older than 70, pre-existing paresthesia or neuropathy of any kind, history of excessive alcohol consumption (>3 drinks per night), regular use of analgesics, history of any drug abuse, baseline systolic blood pressure ≥150 mm Hg, baseline diastolic blood pressure ≥85 mm Hg, BMI ≥35, pregnancy, and history of allergic reaction to local anesthetics. Participants were given the option to withdraw from the study at any time.

Randomization tables were generated by the study statistician and forwarded to the Investigational Drug Service (IDS). The IDS staff prepared the 20 mL syringes with either saline or 0.5% bupivacaine with epinephrine 1:200,000. The participants were randomized into 2 sequence allocation groups which determined whether the participant would receive bupivacaine or saline first. Randomization was also stratified by gender (6 males and 6 females in each group). Within each of these groups, half of the participants received axillary ring blocks on their dominant arm and the other half on their non-dominant arm (dominance determined based on their 'handedness'). Thus, 3 males and 3 females received saline blocks on their dominant arm, 3 males and 3 females received saline blocks on their non-dominant arm, 3 males and 3 females received bupivacaine blocks on their dominant arm, and 3 males and 3 females received bupivacaine blocks on their non-dominant arm. Participants and investigators were blinded to the substance administered for analgesia (bupivacaine vs. saline). When the participants returned one month later for a second session, they all received the opposite solution from the one they received during the first session, but the same arm (dominant or non-dominant) that was used for the first session was also used for the second session.

The axillary ring blocks were performed in the sitting position with standard ASA monitors. A 1.5 inch, 25 gauge needle was used to inject the solution at the level of the prox-

imal axillary fossa, and the entire width of the medial aspect of the arm was infiltrated with 0.25% bupivacaine with Epinephrine 1:200,000 or saline to raise a subcutaneous wheal. 1 mL of solution for every inch of arm circumference up to a maximum of 15 mL was injected. For each subject, the tourniquet was inflated 10 min after completion of the axillary ring block. Prior to application of the tourniquet, the extremity was wrapped at the tourniquet site with soft gauze to prevent post-tourniquet discomfort and skin bruising. The arm was then elevated to allow passive exsanguination and a 5 inch (12.7 cm) Esmarch wrap was applied systematically from the distal part of the extremity to the tourniquet. This exsanguination of the extremity is routinely combined with a tourniquet to create an almost bloodless surgical field. Once the Esmarch was applied, the tourniquet was inflated to a pressure 100 mm Hg higher than the participant's baseline systolic blood pressure and the Esmarch was unwrapped. From this point forward, a dedicated observer assessed and recorded heart rate, blood pressure on the opposite arm, 0–10 numeric pain rating scores under the tourniquet and anywhere below the tourniquet, sensation to fine touch and pin prick on the dorsum of the hand, and grip strength every 5 min. The subject's response to "pin prick" was described as sharp, touch but not sharp, or no sensation. The subject's response to "fine touch" as measured with a fine piece of cotton was described as normal, decreased, or absent. Grip strength was recorded as full strength, decreased strength, or no motor function. Subjects were asked to tolerate some degree of discomfort, but not severe pain. The primary outcome measure for this study was the amount of time that the subject was able to tolerate the tourniquet, up to a maximum time of 1 h. The tourniquet was deflated prior to the 1 h maximum at the subject's request, or if the subject's heart rate or blood pressure exceeded the maximum parameters set by the American Heart Association:
Up to age 30 190 beats per min.
Age 31 to 35 185 beats per min.
Age 36 to 40 180 beats per min.
Age 41 to 45 175 beats per min.
Age 46 to 50 170 beats per min.
Age 51 to 55 165 beats per min.
Age 56 to 60 160 beats per min.
Age 61 to 65 155 beats per min.
Age 66 to 70 150 beats per min.
Maximum systolic blood pressure; 160 mm Hg.
Maximum diastolic blood pressure; 100 mm Hg.
At the time of the second session, subjects were asked to request release of the tourniquet at the same degree of discomfort that they experienced at the time of deflation during the first session. Important secondary outcomes included pain scores under the tourniquet and pain scores anywhere distal to the tourniquet.

Statistical analyses

The effect of the anesthetic on the primary outcome in this two-period two-treatment crossover study was evaluated in two stages. First, it was necessary to assess carryover effect, as such effects, if substantial, may invalidate the use of the crossover design [8] [9]. Carryover effect is defined as the effect of the treatment from the first period on the treatment effect at the second period, and is tested using the model by Grizzle [10]. If the carryover effect is significant ($p < 0.05$), only the data from the first period should be analyzed using the ordinary parallel group analysis. Secondary outcomes in this study included numeric rating scale pain scores under the tourniquet and below tourniquet, as well as motor and sensory function. Pain trajectories between the two treatment groups were compared using the mixed effects model with random intercepts and random slopes, taking into account the correlated measurement errors within each subject. All analyses were performed using SAS 9.3 (SAS Institute Inc., Cary, NC). P-values of less than 0.05 were considered statistically significant.

Power and sample size

Sample size for this study was determined using the PROC POWER procedure for paired means as implemented in SAS 9.3. Assuming the standard deviation of tourniquet duration is 10 min, Type I error rate 0.05, correlation between repeated assessments within

each subject 0.3, a total of 20 subjects (allocated to 2 equal groups with treatment sequences) will yield the power of 0.98 to detect the difference of tourniquet time of 10 min. The planned sample size was increased by 20% (to a total n= 24) to take into account the likely drop out of study participants.

Results & Discussion

24 healthy ASA physical status I or II men and women were recruited (Fig. 1A). All study participants received the assigned intervention in compliance with the study protocol. Significant carryover effect was observed on the duration of tourniquet placement across the two visits (p= 0.049, Fig. 1B). Therefore, the data only from the first visit was analyzed and presented.

The volunteers who were injected with bupivacaine tolerated the upper arm tourniquet for longer period than those who received saline (mean of 30.5 min (95% confidence interval 25.3 to 35.4 min) vs. 22.4 min (95% CI 18.3 to 26.5), p-value 0.014, Fig. 1E Table 2). Bupivacaine axillary ring injection also decreased pain at the tourniquet site by 1.0 pain scale unit (95% CI 0.1 to 1.8, p= 0.025) and pain below tourniquet by 1.1 units (95% CI 0.4 to 1.8, p= 0.001) (Fig. 1B, Fig. 1E Table 2).

Sensory and motor changes of the hand were found to be quite consistent between study participants. The various times required for the tourniquet to produce decreased sensation and grip strength were similar despite bupivacaine or saline injections. All volunteers demonstrated complete resolution of tourniquet-related sensory and motor changes within 15 min of tourniquet deflation. Patients who received bupivacaine were more likely to have sensory changes (touch and pinprick) immediately before the tourniquet deflation (Fisher exact test, p =0.042 and 0.041, respectively), but not changes in muscle strength (Fig. 1E Table 3). There were no cases of prolonged sensory changes over the medial upper arm after the axillary ring injections.

In this prospective crossover study, we have demonstrated that bupivacaine axillary ring injection decreases reported pain scores in awake subjects after upper extremity tourniquet inflation. However, the separation of the axillary ring block from overall brachial plexus anesthesia may have limited clinical applicability. All patients at our institution who undergo upper extremity surgery with a tourniquet in the absence of general anesthesia have brachial plexus anesthesia. In this study, volunteers received only an axillary ring injection, leaving the majority of the upper arm with intact sensation. It is difficult to determine the exact contribution of the medial upper arm to the overall pain scores from the tourniquet site. The decreased pain score of one point on a 10–point scale may or may not be clinically significant.

The tourniquet's effect on the lower arm also presented a source of distracting discomfort, potentially altering both pain scores and the overall tourniquet time tolerated. Patients with a brachial plexus block would likely not experience this distal discomfort. It is also very likely that this study demonstrates carryover bias. The volunteers' first experience with the axillary ring injection and tourniquet inflation may have affected their second experience. For example, the volunteers who were injected with bupivacaine during their first experience may have reported a certain amount of discomfort and allowed the tourniquet to remain inflated for a certain period of time. During their second visit, injected with saline, their reported pain scores and length of tourniquet time may have been affected by their prior experience. Perhaps that explains why a significant decrease in pain at the tourniquet site was only seen in volunteers who were injected with bupivacaine during their first study session. However, the difference seen between the groups during their first visit would not be subject to the carryover effect, making those results perfectly valid.

Additional Information

Methods

After receiving IRB approval, written informed consent was obtained from 24 volunteers for this prospective, controlled, blinded, crossover trial. Exclusion criteria included age younger than 18 or older than 70, pre-existing paresthesia or neuropathy of any kind, history of excessive alcohol consumption (>3 drinks per night), regular use of anal-

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Supplementary Material

Please see https://sciencematters.io/articles/201605000003.

Funding Statement

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Ethics Statement

This study was done in compliance with the UNC IRB.

Citations

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