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Ultrasound Mapping of Nerve Stimulator Response during Sciatic Nerve Blockade and Relation to Postoperative Pain Scores

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1. Abstract

1.1 Background and Purpose: Ultrasound guided sciatic nerve blockade has rapid onset but at 24 hours pain is greater than nerve stimulator techniques. Injection of the nerve branches or trunk and sub-sheath blockade increase success and reduce onset times but risk injury. This study mapped needle coordinates for sciatic nerve blockade with nerve stimulation and its relation to postoperative pain scores.

1.2 Method: Angle and distance of the needle tip and infusion catheter from the popliteal sciatic nerve at which stimulated plantar flexion occurred were measured. Pain scores at post-anesthesia unit discharge and 24 hours were recorded.

1.3 Results: 81% of opioid naïve patients reported immediate analgesia and 20.8% at 24 hours. In opioid tolerant patients 56.8% reported immediate analgesia and 9.1% at 24 hours. Plantar flexion was observed with the needle in the posterior medial quadrant near the sciatic nerve. Opioid tolerant patients reported adequate analgesia when the needle was located more medially and proximally to the sciatic nerve.

1.4 Conclusion: Stimulated plantar flexion is isolated to a narrow angular range in the posterior medial quadrant adjacent to the sciatic nerve. Opioid tolerant patients report adequate analgesia if the needle and catheter are more medial and proximal to the nerve surface.

2. Introduction

Sciatic nerve blockade by ultrasound guidance for lower extremity surgery achieves adequate analgesia for 94% of patients and is dependent on circumferential distribution of local anesthetic around the nerve during the procedure [1,2]. Nerve stimulator guided sciatic nerve blockade eliciting toe plantar flexion at minimal currents below 0.6 and above 0.3 mA provides adequate analgesia in 80% of patients [1]. Ultrasound guided nerve blockade is performed in shorter time intervals with less procedure related patient discomfort but the pain reported at 24 hours is greater than for nerve stimulator based techniques [3]. Combined nerve stimulator and ultrasound sciatic nerve blockade techniques require a longer time interval to perform but the visual analog pain scores at 24 hours after surgery are lower with nerve stimulator based techniques [4,5]. Injection of the common peroneal and posterior tibial branches or a single injection of the sciatic nerve trunk proximal to this division resulting in improved analgesia is controversial [6,7]. Sub-sheath sciatic nerve blockade techniques require identification of the para-neural and sub-epineural spaces but the high success rate and rapid onset time using this approach are offset by concern for neurologic injury by inexperienced practitioners [8,9]. Ultrasound based studies of popliteal sciatic nerve blockade report on the quality of spread of local anesthetic around the nerve being the endpoint for good levels of analgesia. Prolonged analgesia with a continuous infusion of local anesthetic at the sciatic popliteal region demonstrated by ultrasound that the catheter tip should be placed within 1 cm of the nerve surface [10]. Although qualitative and semi-quantitative ultrasound based descriptions of needle and local anesthetic placement near the sciatic nerve have been described, detailed mapping of the geometric coordinates using nerve stimulation to localize the optimal point of needle placement and catheter fixation and the relation with immediate and delayed pain scores is lacking [6,9,10]. The purpose of this study was to map by ultrasound the optimal needle position and infusion catheter sites for popliteal sciatic nerve blockade by nerve stimulator elicited toe plantar flexion and to determine if a relation existed between these coordinates and post-anesthesia care unit discharge and 24 hour postopera-

tive analgesia measured by the pain scores in patients having lower extremity surgery.

3. Method

After receiving IRB approval from the University of Washington Human Subjects Division, patients provided written informed consent prior to undergoing foot and ankle surgery and were enrolled for participation in a popliteal sciatic nerve block study. The preoperative data collected were age, gender, ASA physical status, height, weight, calculated BMI, and use of chronic opioid analgesia. Exclusion criteria were pre-existing neuropathy, neurologic disease, recent trauma or other comorbidity affecting sensation in the lower extremities.

General inhalational endotracheal anesthesia with sevoflurane and intraoperative analgesia with intravenous fentanyl, morphine and/or hydromorphone was administered to all patients for their surgery. Inadequate pain relief following nerve blockade was treated with supplemental analgesia with intravenous fentanyl, morphine and/or hydromorphone and oral oxycodone in bolus doses in the immediate postoperative period and as patient controlled analgesia in the 24 hour period following surgery. As a result of the variety of analgesic narcotic medications administered peri-operatively due to both patient and prescribing practitoner preferences, all opioid dosages were converted to equipotent values in mg of intravenous morphine sulphate using a standardized opioid conversion calculator in order to permit comparison of opioid dosages between patients.

During the nerve block procedure ultrasound guided short axis view measurements of the angle of the nerve stimulator needle tip and its radial distance from the center of the sciatic nerve at a point proximal to its bifurcation in the popliteal region were recorded when toe plantar flexion at a current less than 0.6 mA and above 0.3 mA was attained after which 25 ml 0.5% ropivacaine were injected. The point of reference for distance was the center of the sciatic nerve trunk for measurement of the length of the radian in mm. The point of reference for angular measurement was the posterior sagittal surface of the sciatic nerve that was deemed 0 degrees and angles were measured in a clockwise direction. A Life-Tech ProLong II 100 mm 30 degree bevel needle was used and the infusion catheter was threaded to a distance 3 to 4 cm past the needle tip and an infusion of 0.25% bupivacaine at 10 ml/hour was commenced. The angle and distance of the catheter tip from the center of the short axis of the sciatic nerve visualized on ultrasound were also measured. Ultrasound imaging was performed using a Sonosite M Turbo machine with a 10 MHz 38 mm linear array probe. Nerve stimulation was performed with the Life-Tech Tracer III generator. Imaging, measurements and nerve stimulator interpretation were performed at the time of nerve blockade by concordance between two supervising regional anesthesia faculty experienced in both ultrasound and nerve stimulator guided regional anesthesia. The pain score at the time of Post-Anesthesia Care Unit (PACU) discharge and at 24 hours after injection were recorded. PACU discharge and 24 hour postoperative analgesia were considered adequate if patients reported pain scores of 2 or less and inadequate if pain scores ranked 3 or greater. Needle and catheter tip ultrasound measurements for each patient were converted into cartesian coordinates and categorized by their respective PACU discharge and 24 hour pain scores as outlined previously and plotted on scatter-grams. Linear regression analysis determined the mean coordinates for needle and catheter locations for adequate or inadequate analgesia at time of PACU discharge and 24 hours after nerve blockade.

4. Results

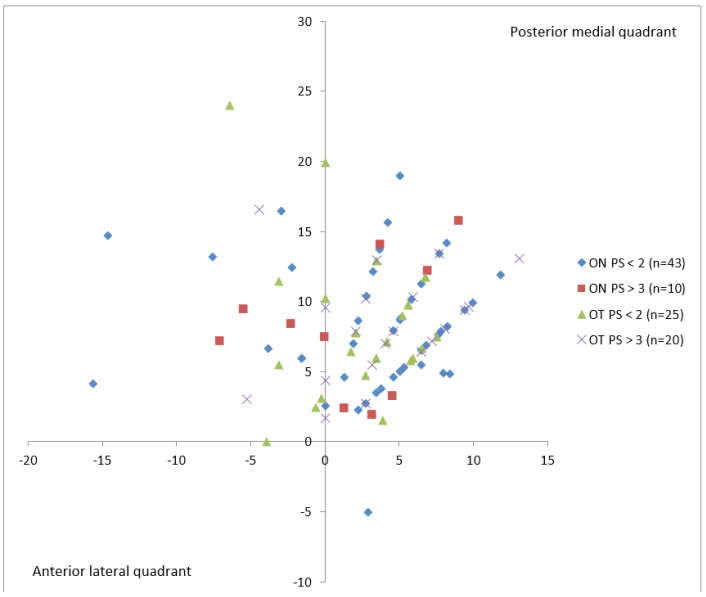
Measurements were recorded for 97 patients and their preoperative demographics are outlined in Table 1.

Table 1: Patient demographics.

N = 97	Female (N = 44)	Male (N=53)
	Opioid Naive	
N = 53	26	27
Age (yrs)	57.31(15.12)	55.96(15.07)
BMI (kg/m2)	28.37(5.47)	29.18(4.83)
ASA	2(1)	2(1)
Preop Pain Score	5(3)	5(3)
Daiiy Opioid Dose	0	0
PACU Pain Score < 2 (N=43, 81.1%)	24 (92.3%)	19 (70.4%)
24 Hour Pain Score < 2 (N=11, 20.8%)	5 (19.2%)	6 (22.2%)
	Opioid Tolerant	
N = 44	18	26
Age (yrs)	47.72(13.68)*	48.12(15.34)
BMI (kg/m2)	28.06(6.23)	28.74(6.35)
ASA	2(1)	2(1)
Preop Pain Score	7(4)	6(3)
Daily Opioid Dose	21.21(24.64)	46.59(72.98)
PACU Pain Score < 2 (N=25, 56.8%)	7 (38.9%)	18 (69.2%)
24 Hour Pain Score < 2 (N=4, 9.1%)	2 (11.1%)	2 (7.7%)

Data expressed as mean (SD). Opioid dose converted to mg intravenous Morphine. * $p < 0.05$.

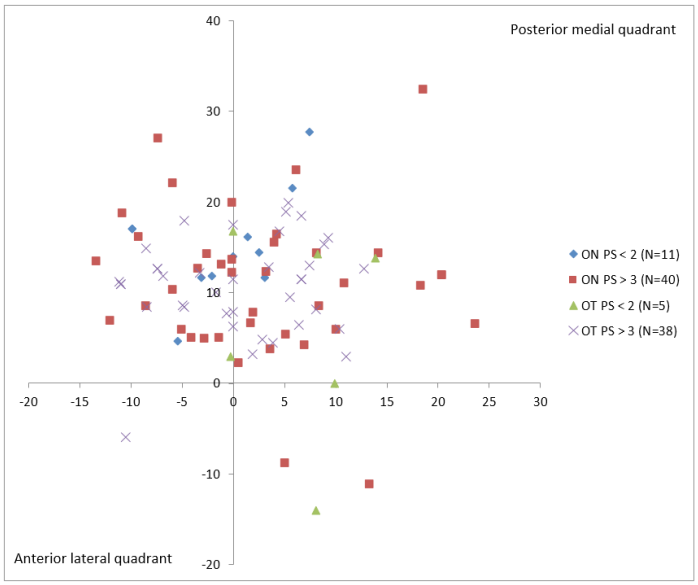
Figure 1 is the plot of the coordinates of the nerve block needle tip for each patient grouped by their post-operative care unit discharge pain scores and opioid naivete or tolerance. The (+x, +y) quadrant corresponds to the posterior medial region of the sciatic nerve and points cluster in this area where adequate plantar flexion response to nerve stimulation was most frequently observed during nerve blockade.



ON – Opioid naïve, OT – opioid tolerant, PS – pain score.

Figure 1: Plot of ultrasound guided needle localization of toe plantar flexion in response to nerve stimulation of the sciatic nerve and Post-anesthesia Care Unit discharge pain scores in 98 patients categorized by opioid naïvete and tolerance.

Figure 2 is the plot of the coordinates of the infusion catheter tip for each patient grouped by 24 hour postoperative pain scores and by opioid naivete and tolerance. The (+x, +y) and (-x, +y) quadrants correspond to the respective posterior medial and posterior lateral regions of the sciatic nerve and most catheter tips were observed in these regions.



ON – Opioid Naïve, OT – Opioid Tolerant, PS – Pain Score.

Figure 2: Plot of ultrasound localized nerve block catheter tip in relation to the sciatic nerve and 24 hour post-operative pain scores in 96 patients categorized by opioid tolerance or naivete.

Figure 3 is the plot of the coordinates of the needle tip and corresponding infusion catheter in relation to the sciatic nerve using the measurements previously reviewed for opioid naïve and tolerant patients that reported pain scores of 0 for both the PACU discharge and the 24 hour postoperative time intervals.

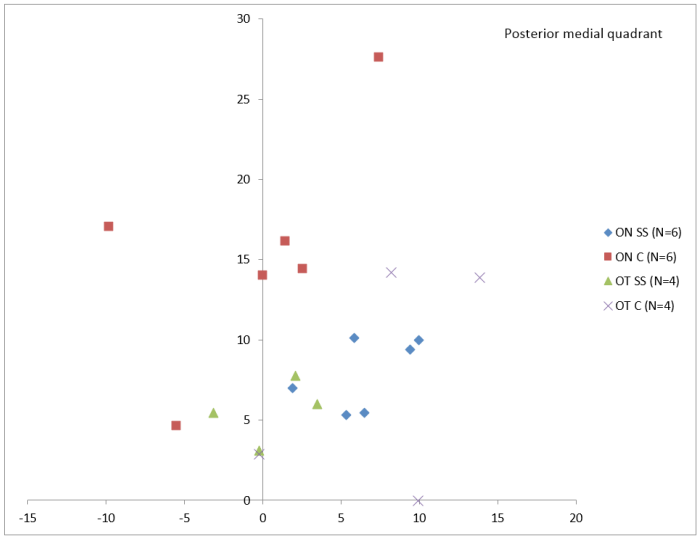


Figure 3: Sciatic nerve plot of ultrasound guided needle localization of plantar flexion twitch response (SS) and corresponding nerve block catheter tip (C) in opioid naïve (ON) and tolerant (OT) patients with pain score 0 in both the immediate and 24 hour postoperative periods.

5. Discussion

The only statistical difference between the demographic groups was the age distribution between opioid naïve and tolerant females ($p < 0.05$, paired t-test). Adequate analgesia at time of PACU discharge was greatest for the opioid naïve female group (92.3%) and least for the opioid tolerant female group (38.9%) and was similar both for opioid tolerant and naïve males (70.4% and 69.2%). A lower frequency of adequate analgesia at 24 hours was measured in all groups and was the least in opioid tolerant males (7.7%). Higher perioperative pain scores and increased opioid requirements during the recovery period in opioid tolerant patients have been previously described and guidelines have been recommended for their care [11]. The gender and group differences in adequacy of analgesia at time of PACU discharge and 24 hours following sciatic nerve blockade relates to operator variability of procedural personnel in this study since all blocks were performed by residents, nurse anesthetists and faculty at different levels of training and a specific set of experienced operators had not been assigned for all patients.

Table 2 is the linear regression summary for the mean coordinates for needle and catheter localization for opioid naïve and tolerant patients categorized by adequacy of analgesia at the time of PACU discharge and 24 hours later. Figure 4 is the polar coordinate plot of these same points. Plantar toe flexion by nerve stimulation was observed most frequently with the needle in the region of the posterior medial quadrant of the sciatic nerve. This would be expected because the posterior tibial nerve furnishes motor innervation to the muscles of the foot and it is the medially located branch distal to the bifurcation of the sciatic nerve trunk.

Table 2: Mean linear regression coordinate values for patient groups categorized by opioid tolerance and Post-anesthesia Care Unit and 24 hour postoperative pain scores.

	Sample Size (n)	Y-coordinate (sin theta)	Angle (Degrees)	X-Coordinate (mm)
	Opioid Naive			
PACU PS < 2	43	3.22	23	8.21
PACU PS > 2	10	1.43	10	8.14
24 Hour PS < 2	11	0.93	357	15.22
24 Hour PS > 2	40	2.95	16	10.78
PACU/24 PS = 0	6	2.91	14	11.75
	Opioid Tolerant			
PACU PS < 2	25	2.52	18	8.25
PACU PS > 2	20	4.03	29	8.35
24 Hour PS < 2	6	6.63	58	5.64
24 Hour PS > 2	38	0.63	4	10.74
PACU/24 PS = 0	4	4.23	39	6.65

PACU – Post-anesthesia care unit, PS – Pain score, PACU/24 – Combined pain scores at both time intervals = 0.

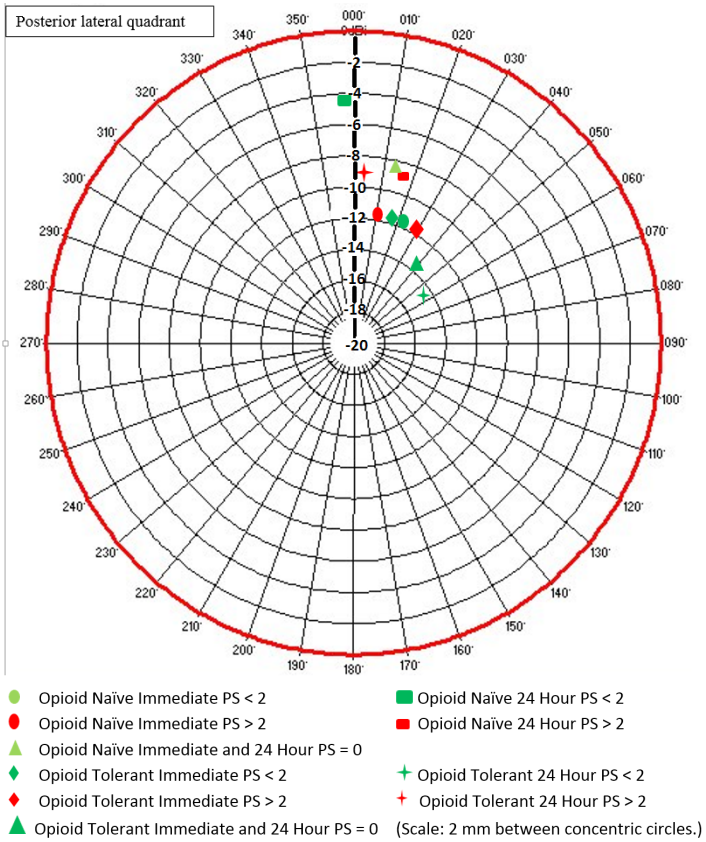


Figure 4: Polar plot of mean regression coordinates as related to pain scores and opioid tolerance.

The optimal angle and depth of needle placement for single injection sciatic nerve blockade that had greater analgesic success rates in opioid naïve and tolerant patients was in the area between 18 and 23 degrees medial from the posterior midline and 8.2 to 8.3 mm from the center of the nerve. In opioid naïve patients the catheter location that provided adequate analgesia at 24 hours was located closer to the sagittal plane in the 357 to 14 degree range and depth could vary from 11.75 to 15.2 mm from the nerve center. In opioid tolerant patients with adequate analgesia at 24 hours it was demonstrated that both the needle and catheter were localized more medially and proximal to the nerve surface in the range of 39 to 58 degrees medial from the nerve posterior sagittal midline and 5.6 to 6.7 mm from the nerve center. These results corroborate the report that the infusion catheter should be fixed at a position one cm from the nerve surface but in opioid tolerant patients this distance appears to be reduced by one half to two thirds [10]. Patients with pre-existing neuropathy and other neurologic comorbidities that could influence outcomes were excluded and greater proximity of the needle and catheter to the nerve in opioid tolerant patients in order to achieve adequate analgesia could not readily be explained. Catheter dislodgement and migration readily explains the loss of analgesic effect at 24 hours and newer catheters with reduced mobility have been developed to address this phenomenon.

One limitation that this study encountered was the use of the discrete pain score instead of the more accurate visual analog scale and the former was selected for ease of use by patients and perioperative nursing staff. Another drawback was the lack of duly assigned regional anesthesia expert staff or trainees performing all the procedures which introduces operator variability and this led to the lower frequency of adequate analgesia in most patient groups in this study.

6. Conclusion

Ultrasound mapping of the toe plantar flexion twitch response to sciatic nerve stimulation during nerve blockade in the popliteal area demonstrated that adequate analgesia was achieved when the needle was in a narrow field in the posterior medial quadrant region near the nerve. Adequate analgesia at the post-anesthesia care unit discharge and 24 hour postoperative periods in opioid tolerant patients required needle and catheter positioning more medially and closer to the surface of the nerve compared to opioid naïve patients. Future studies enrolling more opioid tolerant patients and evaluation of sub-paraneural catheter placement are needed to determine the hypothesized mechanism of local anesthetic resistance and improve analgesic outcomes in this group.

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