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ORIGINAL CONTRIBUTION

Periosteal block versus intravenous regional anesthesia for reduction of distal radius fractures: A randomized controlled trial

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Abstract

Objective: We compare periosteal block and intravenous regional anesthesia (IVRA) as anesthetic techniques for reduction of distal radius fractures when performed by emergency department (ED) clinicians following brief training.

Methods: This was a single-center, nonblinded randomized controlled trial of a convenience sample of patients presenting with distal radius fractures requiring closed reduction. Primary outcome measure was patient reported fracture reduction pain score, rated on a 100-mm visual analog scale. Secondary outcomes included adjunct pain medication use, ED length of stay, remanipulation rates, participant satisfaction, clinician assessed efficacy, and clinician-assessed ease of the procedure.

Results: Eighty-one patients were randomized to receive IVRA ($n = 41$) or periosteal block ($N = 40$). Reduction pain scores were not normally distributed. Median (25th–75th percentile) pain scores in participants assigned to IVRA and periosteal block were 5 (1–27.5) and 26 (8.5–63) mm, respectively, ($p = 0.007$). Use of adjunct medications during reduction was higher for the periosteal block group compared with IVRA (57.5% vs. 22.5%, $p = 0.003$). Remanipulation rates were 17.5% for periosteal block versus 7.5% for IVRA ($p = 0.31$). There was no difference in length of stay, patient satisfaction, or clinician's assessed ease of the anesthetic technique. There was a difference in clinician's assessment of efficacy between groups, with IVRA described as "extremely effective" by 65% and periosteal block described as "extremely effective" by 25% ($p = 0.003$).

Conclusions: When performed by a diverse group of ED clinicians periosteal block provided inferior analgesia to IVRA but may provide an alternative when IVRA cannot be performed.

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INTRODUCTION

Distal radius fractures are a common injury treated in the emergency department (ED). Effective anesthesia is required for reduction of displaced fractures. Several techniques are utilized, including hematoma blocks, intravenous regional anesthesia (IVRA; also known as Bier block), regional nerve blocks, and procedural sedation. A Cochrane review of anesthetic techniques concluded that there are insufficient comparative studies.[1] The few studies that have been conducted suggest that IVRA results in lower pain scores and more adequate reduction in comparison with a hematoma block.[1–4] However, IVRA is more resource-intensive requiring monitoring for local anesthetic systemic toxicity and may require a longer ED length of stay,[1] given that the cuff must remain inflated for 30 min following anesthetic injection.

Tageldin et al.[5] described a novel technique known as a periosteal block (Figure 1) in a series of 42 patients with distal forearm fractures. This technique involves injection of local anesthetic around the periosteum of the distal radius proximal to the fracture. In this study, blocks were performed by two experienced orthopedic doctors. None of the 42 patients required remanipulation and the reduction was described as painless by 83% of patients and minimally painful by 14% of patients. Furthermore, no additional analgesia was required during the reduction. To date no randomized controlled trials have been performed comparing the periosteal block to other commonly used techniques nor has it been studied in the hands of a more diverse group of emergency medicine clinicians.

The periosteal block potentially offers an anesthetic option that requires fewer ED resources and more efficient treatment. It is also a relatively straightforward technique to learn and requires no specialized equipment. This study aims to assess the effectiveness of periosteal block in comparison to IVRA, which was standard of care in our ED at the time of this study.

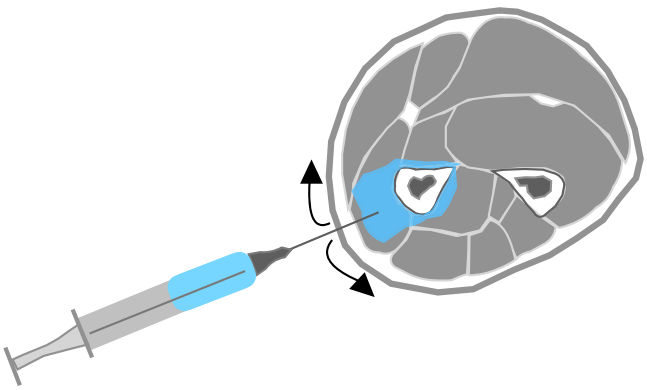

FIGURE 1 Periosteal block technique: 15 ml of 1% lidocaine is inserted 6 cm proximal to the wrist joint. A small wheal is placed under the skin with a 25-gauge needle, and then a 20-gauge needle is used to infiltrate around the radius in close proximity to the bone. By pulling traction on the skin a single injection site can be used to access the radial, dorsal, and volar surfaces of the radius. When an ulnar styloid fracture is present the process is repeated on the ulna using 3 ml of anesthetic.

Our hypothesis was that periosteal block performed by emergency physicians after brief training provides equivalent anesthesia compared to IVRA during distal radius fracture reduction. The primary aim of the study was to compare reduction procedural pain scores using visual analog scale (VAS)[6] in patients randomized to either IVRA or periosteal block. The secondary aims were to compare adjunct pain medication use during the reduction, remanipulation rates, clinician assessed ease of the anesthetic technique, clinician-assessed efficacy of the anesthetic technique, patient satisfaction, ED length of stay, and adequacy of reduction as assessed by blinded orthopedic review.

METHODS

Study design

We performed a single-center nonblinded, randomized, controlled trial comparing the efficacy of periosteal block to IVRA in a convenience sample of patients presenting with displaced distal radius fractures requiring closed reduction. The trial was registered with the Australia New Zealand Clinical Trials registry (ACTRN12618000226202) and approved by the New Zealand Health and Disability Ethics Committee (Ref 18/NTB/11). The trial protocol was reviewed by the Ngāi Tahu Research Consultation Committee. The study was designed and reported in keeping with CONSORT guidelines[7] for reporting of randomized controlled trials. Adverse events were monitored by the primary investigator (SB). All participants provided written informed consent.

Study setting and population

Dunedin Hospital ED is a metropolitan, regional referral center with an annual census of approximately 45,000 patient visits. Trained ED registrars and consultants who were the treating clinicians performed patients' screening, enrollment, study procedures, and data collection. Subjects were enrolled when a study investigator was available.

We included adult patients ≥16 years of age who presented with a displaced distal radius fracture requiring closed reduction. A convenience sample of participants was recruited when a trained clinician was present in the ED during the period between May 2018 and November 2020. Patients were excluded if they were unable to provide informed consent; had an open fracture, evidence of compartment syndrome, a known allergy to local anesthetic, a history of sickle cell disease or Raynaud's, a severe distracting injury, severe peripheral vascular disease, a systolic blood pressure >200 mm Hg, or severe hepatic failure; or needed bilateral manipulation.

Study protocol

All consultants and trainees in the ED were offered training on how to perform the periosteal block and enroll patients in the study.

Participating physicians received a 60-min training session on the periosteal block and IVRA protocols, which concluded with a practical session using a gelatin forearm model and an assessment of competency.

Participants were randomized to receive either IVRA or periosteal block. Group allocations were performed in blocks of 20 through random computer-generated numbers with 1:1 allocation to each group. Assignments were placed in sealed envelopes and opened by the clinician after consent was obtained to participate in the study.

Guides with instructions for how to perform each procedure (Appendix S1) were placed in these sealed envelopes. IVRA was performed using a double-cuff pneumatic tourniquet and 3 mg/kg 0.5% prilocaine injected intravenously through a peripheral cannula in the hand of the injured extremity. Periosteal blocks were performed using the protocol described by Tageldin et al.[5] using 15 ml or 1% lidocaine inserted 6 cm proximal to the wrist joint. A small wheal was placed under the skin with a 25-gauge needle at the lateral aspect of the radius. This was exchanged for a 20-gauge needle that was used to infiltrate around the lateral aspect of the radius in close proximity to the bone (Figure 1). By pulling traction on the skin, the same injection site was used to direct the needle along the dorsal and volar aspects of the radius without removing the needle. If an ulnar styloid fracture was present the process was repeated, and a second injection was performed around the ulna using 3 ml of lidocaine. Both arms of the study included a 10-min wait time between administration of anesthetic and reduction of the fracture to allow time for the block to take effect. During the reduction, clinicians were able to provide additional pain medications to patients as clinically indicated if pain was not controlled by the block alone.

Outcome measures

The primary outcome was the difference in reduction procedural pain scores in the two arms of the study measured on a 100-mm VAS immediately following the reduction. Participants were asked to rate their baseline pain prior to the start of either anesthetic technique. Then anesthetic technique and the fracture reduction were performed, and patients were asked to rate the pain of the reduction immediately afterward. Participants were awake during the procedures and could not be blinded to the anesthetic technique they received. The clinicians who performed the procedure were not blinded. Clinicians recorded whether remanipulation was required for each participant, details of the procedure, including medications administered prior to randomization, and any adjunct medications required during the reduction procedure. For each participant, clinicians ranked the ease of performing the anesthetic technique as extremely easy, very easy, somewhat easy, difficult, or extremely difficult. For each participant, clinicians ranked the efficacy of the anesthetic technique as extremely effective, very effective, somewhat effective, or not at all effective. Length of stay was calculated from timestamps in the hospital electronic medical record system. A blinded review of X-rays was performed by an orthopedic surgeon to determine whether the reduction was adequate given the fracture pattern present or whether they would have repeated an attempt at closed reduction in ED, in which case the reduction was classified as inadequate.

Data analysis

A clinically significant difference in pain scores is context-dependent,[8] and this has not previously been defined for pain during distal radius fracture reduction. Prior ED-based studies of patients with acute traumatic pain have defined scores between 9 and 13 mm as the minimally clinically significant difference.[9–11] Based on this we estimated 10 mm to be the minimum clinically significant difference in pain score to show equivalence of periosteal blocks for pain control during manipulation.[12] Based on the prior study by Tageldin et al.,[5] the expected standard deviation in VAS in this population was 15 mm. Using 80% power and type 1 error rate of 0.05, we estimated that we would need a total sample size of 78 participants.

The a priori primary outcome was comparison of mean fracture reduction pain scores. However, summary statistics for the primary outcome variable did not show a normal distribution and thus we compared and report medians and (25th–75th percentile). An intention-to-treat design was used and differences between the randomized groups were assessed using the Wilcoxon rank sum test due to nonnormality of the data. The main outcome was also analyzed in a per-protocol analysis. Summary statistics for secondary outcome variables are presented as mean ± SD or *n* (%). Secondary outcomes were compared using chi-square tests or Fisher's exact tests where appropriate for categorical data and Student's *t*-test for numeric data. All data were analyzed in R (version 3.6.1) using R studio (version 1.2.5019). A two-sided *p* value of <0.05 was considered statistically significant. A post hoc analysis was performed in per-protocol fashion to compare mean change in pain scores from baseline given baseline pain scores were slightly higher in the periosteal arm compared to IVRA.

RESULTS

Out of 125 people screened, we enrolled 81 participants and randomized them to either IVRA or periosteal block (Figure 2). One participant randomized to the IVRA group was excluded because data forms were not completed; therefore, 40 participants from each group were included for intention-to-treat analyses. Of the participants randomized into the IVRA group three were switched to receive periosteal block: two because the discomfort from the cuff was too severe to proceed with injection of prilocaine and in one participant because the cuff did not fit their arm. One participant randomized to the periosteal block group received IVRA because the pain was too severe after the block to start the reduction. Therefore, 38 participants in the IVRA and 42 participants in the periosteal block arm were included for per-protocol analyses.

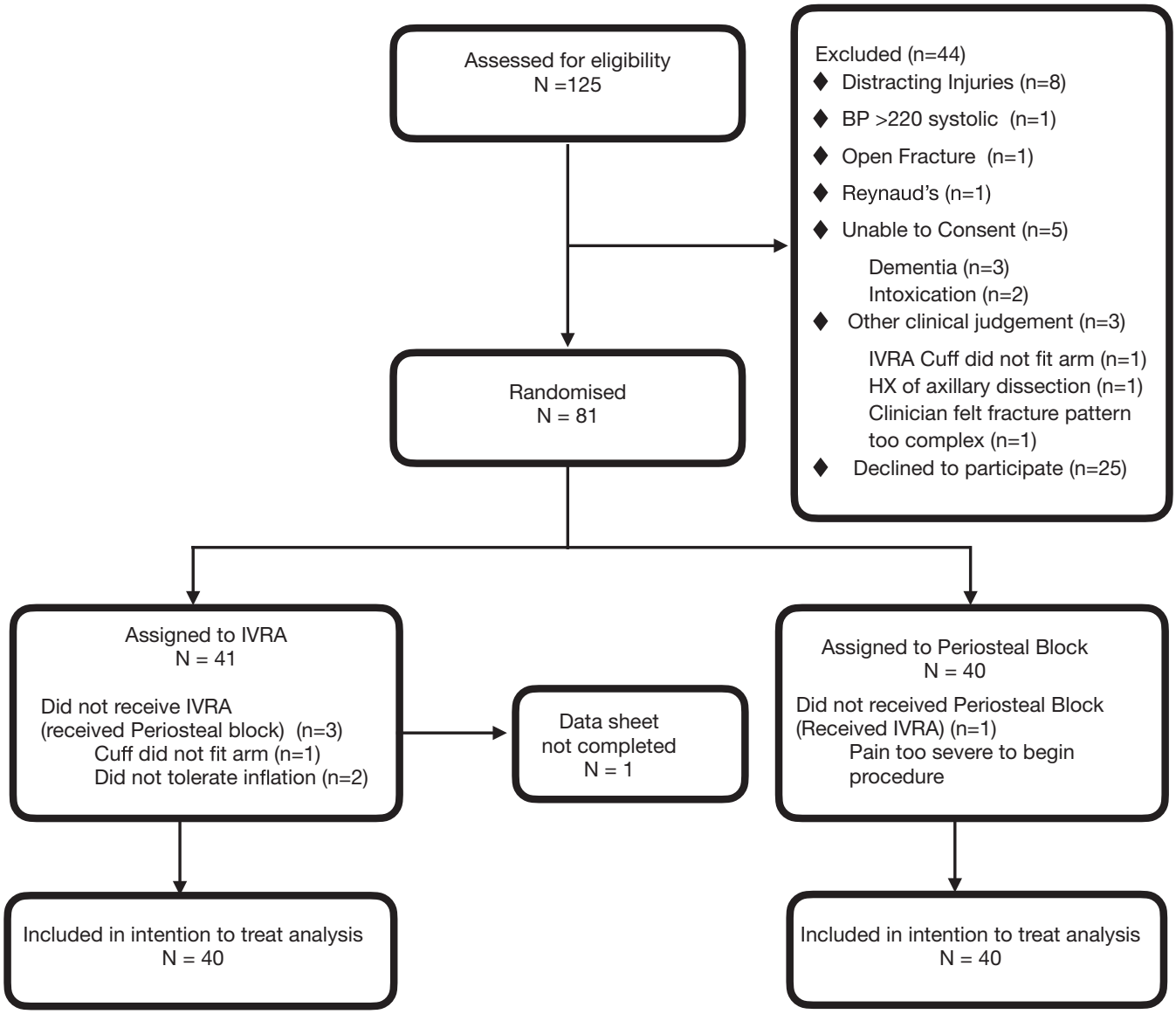

FIGURE 2 Participant flow diagram. HX, history; IVRA, intravenous regional anesthesia.

Baseline characteristics of the participants according to their randomized groups are presented in Table 1. Pain scores prior to reduction were normally distributed, with a mean ± SD of 49.4 ± 26.5 mm and ranged from 0 to 100 mm. Both groups had a high rate of premedication use. The most commonly administered premeditations were paracetamol and fentanyl in both groups. There were 27 different clinicians involved in the trial, the median number of participants enrolled by each clinician in the trial was two and ranged from one to 13. The median (range) number of prior anesthetic procedures performed by the clinicians was 15 (0–300) in the IVRA group and 3.5 (0–20) in the periosteal block group.

For the primary outcome procedural VAS, Figure 3 depicts the prereduction (Figure 3A) and postreduction (Figure 3B) pain scores in both groups. Pain score data are evenly distributed across the measure at prereduction. There is notable skewing of the data for the pain scores in the IVRA group following the reduction, with most of the data centered around low pain scores, indicating a nonnormal distribution. Comparison of median pain scores showed that there was a statistically significant difference in the median pain scores reported between participants assigned to receive IVRA compared with participants assigned to receive the periosteal block (median [25th–75th percentile] 5 [1–27.5] mm and 26 [8.5–63] mm, respectively, $p = 0.007$). Per-protocol analysis revealed similar findings between participants who received IVRA compared with participants who received the periosteal block (median [25th–75th percentile] 3 [1–23.8] mm and 27.5 [10–63] mm, respectively, $p = 0.001$).

Table 2 presents the findings of the secondary outcomes of the study. There were no statistically significant differences between groups for the rate of remanipulation ($p = 0.31$), length of stay ($p = 0.96$), participant satisfaction ($p = 0.11$), or the clinician's assessment of the ease of the anesthetic technique ($p = 0.07$). The clinician's assessment of the efficacy of the anesthetic technique differed between groups ($p = 0.003$). Using IVRA, the efficacy of the anesthetic was described as "extremely effective" 65% of time,

TABLE 1 Demographic and baseline characteristics by randomization group

	IVRA ($n = 40$)	Periosteal block ($n = 40$)
Age (years)	55.8 ± 19.6	59.2 ± 18.6
Gender		
Female	30 (75)	33 (82.5)
Male	10 (25.0)	7 (17.5)
Ethnicity		
European	34 (85.0)	37 (92.7)
Māori	5 (12.5)	1 (2.5)
Other	1 (2.5)	2 (5.0)
Use of premedication	36 (90.0)	31 (77.5)
Paracetamol	18 (45.0)	14 (35.0)
Ibuprofen	8 (20.0)	7 (17.5)
Codeine	9 (22.5)	5 (12.5)
Morphine	9 (22.5)	7 (17.5)
Fentanyl	12 (30.0)	11 (27.5)
Midazolam	1 (2.5)	0 (0.0)
Patient-administered inhaled nitrous oxide/oxygen	5 (12.5)	5 (12.5)
Pain before the procedure	45.3 ± 27.1	53.6 ± 25.7

Note: Data are reported as mean ± SD or *n* (%).

Abbreviation: IVRA, intravenous regional anesthesia.

while the periosteal block was described as "extremely effective" only 25% of the time. Use of adjunct medications during the reduction was significantly higher for the periosteal block group compared with IVRA group (57.5% vs. 22.5%, respectively, $p = 0.003$). On blinded orthopedic review four participants (10%) in the periosteal block group had inadequate reduction compared to zero in the IVRA group. Given that a zero creates numeric inaccuracy in statistical analysis, Fisher exact test was not performed.

Post hoc analysis of change in pain score from baseline showed a mean reduction of 25.3 mm for IVRA compared to 15.3 mm in the periosteal block arm ($p = 0.23$). One participant in the periosteal block arm experienced vasovagal syncope following injection and recovered without intervention. There were no other adverse events.

DISCUSSION

This randomized controlled trial demonstrated lower median pain scores for IVRA compared to periosteal block when performed by a diverse group of ED clinicians following brief training. Together with the secondary outcomes this study suggests that periosteal block did not provide equivalent procedural pain control given the higher median pain scores, the lower clinician-assessed efficacy, and the increased use of adjunct medications in the periosteal block group compared with IVRA group. When performed by ED clinicians with brief training, the periosteal block resulted in less favorable pain control compared to IVRA.

Tageldin et al.[5] found that 83% of patients receiving a periosteal block reported no pain during fracture reduction and 14% reported minimal pain, defined as pain scored between 1 and 3 on a 10-point VAS, in a case series of 42 patients. Wan Ali et al.[13] also reported on using the periosteal block, in a case series of 19 patients where four patients reported no pain, 12 reported minimal pain, and three reported a pain score of 4/10, which was slightly above the criteria for minimal pain. Their study was also performed by a small group of orthopedic specialists. These findings are in contrast with our own, where the median pain score was 26 mm and just under half of patients in the periosteal group reported a pain score above 30 mm, compared with less than a quarter in the IVRA group. Tageldin et al. also reported that no patients required remanipulation within their study, whereas seven of 40 participants in the periosteal arm of our study required remanipulation.

There are several possibilities for the apparent discrepancies between our study and that of Tageldin et al. The use of a different VAS may lead to differing answers by patients in reporting pain scores. It is possible that discrepant findings are the result of inadequate training and experience performing the periosteal block by clinicians in our study. Pain control achieved through periosteal block may improve with experience. Although clinicians at our center were more experienced with IVRA, the median number of prior procedures was still only 15. Being able to identify and cannulate a peripheral vein and apply a pneumatic cuff tourniquet are the main technical skills required for success of IVRA. As these are common skills among ED physicians, the success of IVRA is likely a less operator- and experience-dependent technique. In contrast the periosteal block requires performing a ring block adjacent to the periosteum of the radius, which was novel to clinicians. Anatomic differences such as the depth of subcutaneous tissues at the wrist and other patient variation may have impacted the success of the block in those with less experience. We did not have enough participants in our study to stratify pain scores based on clinician experience with the technique.

Effective analgesia is needed to achieve adequate reduction during manipulation. In this study, four of 40 (10%) of participants in the periosteal block group were defined as having inadequate reduction on orthopedic review, while no participants had inadequate reduction in the IVRA group. There was no statistically significant difference in remanipulation rates between the two groups, albeit a higher proportion of participants in the periosteal block arm underwent remanipulation. The rate of inadequate reduction and remanipulation rates were secondary outcomes of the study and sample size calculations were based on the primary outcome of VAS pain scores. It is possible that a larger trial may have shown significant differences between groups in remanipulation rates given the relationship between effective analgesia and adequate reduction. As part of the study protocol, participants received adjunct medications to manage pain during the reduction. We found that a considerably higher proportion of participants required adjunct medications in the periosteal block group during the manipulation.

Emergency clinicians tailor selection of anesthetic techniques for reduction of distal radius fractures considering several factors

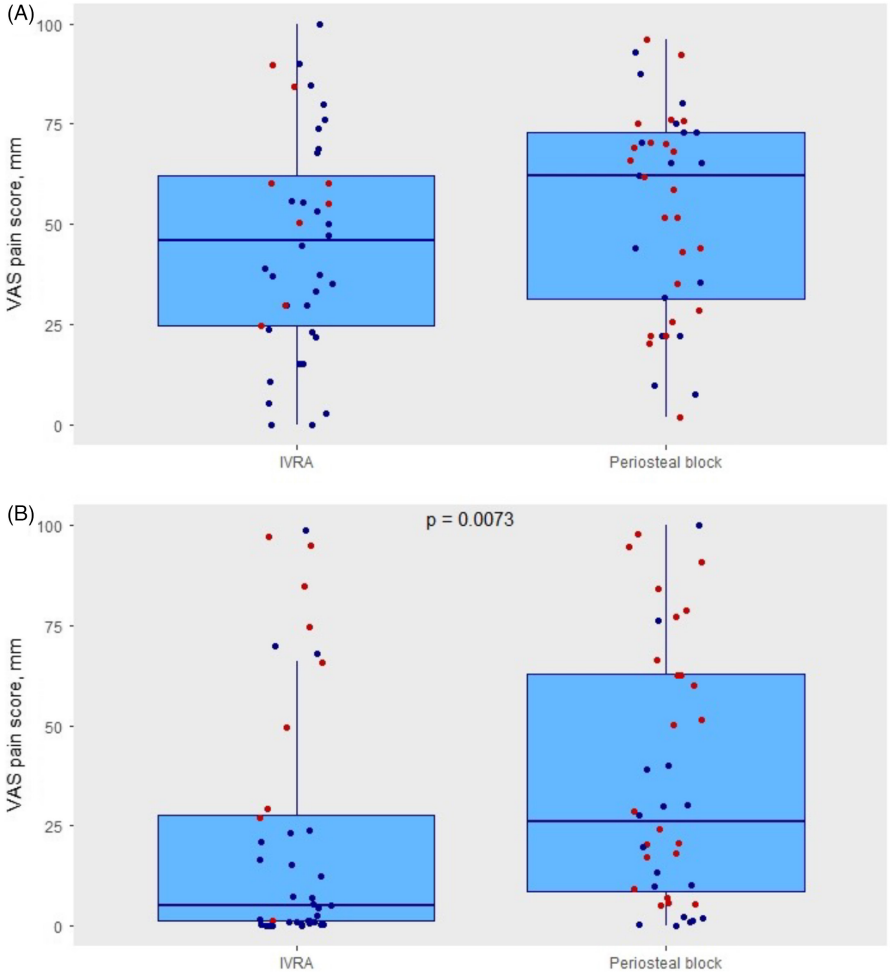

FIGURE 3 Box-and-whisker plots showing the distribution of VAS pain scores at baseline (A) and reduction (B) in the randomized groups. Individual data points are shown on the plots in blue where adjunct medications were not used and in red where adjunct medications were used. *p*-values were calculated for postreduction pain scores between groups using the Wilcoxon rank sum test. IVRA, intravenous regional anesthesia; VAS, visual analog scale.

including patient preferences and characteristics, department staffing and resources, and their own skill and experience. We were surprised that there was no difference in length of stay, which we felt would be a potential benefit of periosteal block. It is likely that factors unrelated to the reduction (i.e., time in waiting room, waits for discharge planning, waiting with nursing staff with casting skills) were more important determinants of length of stay.

In this study the periosteal block with use of adjunct medications was performed safely and facilitated successful reduction in the majority of participants. Given that there are several contraindications to IVRA, the periosteal block may provide an alternative in these situations. Further research comparing periosteal block to hematoma block would help to better define the role for this technique. Similar to our results, prior studies of hematoma block have shown it to have higher pain scores and increased rates of remanipulation when compared to IVRA,[2] but the relative efficacy of these local infiltration-based techniques is unknown.

LIMITATIONS

This was a single-center study in which participants were enrolled as a convenience sample when a trained clinician was available. Overall clinician familiarity and experience were higher on average with IVRA compared to the periosteal block. In our study a diverse group of clinicians underwent brief training to perform the periosteal block, and it is possible that the periosteal block may have performed better following increased experience with the technique. Baseline pain scores were slightly higher in the periosteal block group (53.6 mm) versus (45.3 mm) in the IVRA group; this must be considered when interpreting the study results.

Adjunct pain medication was not administered via standardized protocol and different doses and types of medications will have had variable impact on reported pain scores. Pain medications used were at the discretion of the treating clinician who could not be blinded to the anesthetic technique they had performed; this may have further biased pain medication administration. Although this may limit direct comparison of the two techniques, it models real-world ED practice where we tailor medication administration to the needs of the individual patient. Pain scores were not measured at multiple time points during the procedure, which may have further helped to show the impact of adjunct medications. Lastly, our study was not powered to detect a difference in rates of remanipulation. As reduction success is related to adequacy of analgesia, a study and analysis plan specifically designed to assess this may have detected a difference in the adequacy of reduction.

TABLE 2 Secondary outcomes

	IVRA $n = 40$	Periosteal block $n = 40$	p value
Remanipulation	3 (7.5)	7 (17.5)	0.311
Adjunct medications	9 (22.5)	23 (57.5)	0.003
Morphine	1 (11.1)	4 (17.4)	—
Fentanyl	6 (66.7)	6 (26.1)	—
Ketamine	1 (11.1)	0 (0.0)	—
Midazolam	1 (11.1)	0 (0.0)	—
Patient-administered inhaled nitrous oxide/oxygen	3 (33.3)	14 (60.9)	—
Length of stay (min)	296 ± 146	295 ± 118	0.961
Inadequate reduction	0 (0.0)	4 (10.0)	—
Patient satisfaction			0.114
Not at all satisfied	1 (2.5)	0 (0.0)	
Partially satisfied	2 (5.0)	3 (7.5)	
Satisfied	7 (17.5)	8 (20.0)	
More than satisfied	5 (12.5)	13 (32.5)	
Extremely satisfied	25 (62.5)	16 (40.0)	
Clinician assessed ease of anesthetic technique			0.066
Extremely easy	12 (30.0)	8 (20.0)	
Very easy	24 (60.0)	20 (50.0)	
Somewhat easy	3 (7.5)	10 (25.0)	
Difficult	0 (0.0)	2 (5.0)	
Extremely difficult	1 (2.5)	0 (0.0)	
Clinician assessed efficacy of the anesthetic technique			0.003
Extremely effective	26 (65.0)	10 (25.0)	
Very effective	6 (15.0)	15 (37.5)	
Somewhat effective	7 (17.5)	12 (30.0)	
Not at all effective	1 (2.5)	3 (7.5)	

Note: Data are reported as *n* (%) or mean ± SD. *p*-values were calculated using Student's *t*-test for numeric variables and chi-square tests or Fisher's exact tests where appropriate for categoric variables.

Abbreviation: IVRA, intravenous regional anesthesia.

CONCLUSIONS

When performed by a diverse group of ED clinicians, periosteal block provided inferior analgesia to intravenous regional anesthesia but may provide an alternative when intravenous regional anesthesia cannot be performed.

AUTHOR CONTRIBUTIONS

Sierra Beck conceived the study. Sierra Beck, Aileen Conboy, and Alana Brunner-Parker designed the trial. Sierra Beck and Alana Brunner-Parker supervised the conduct of the trial and data collection. Sierra Beck and Alana Brunner-Parker managed the data, including quality control. Rosemary Stamm analyzed the data. Sierra Beck and Rosemary Stamm drafted the manuscript, and all authors contributed substantially to its revision. Sierra Beck takes responsibility for the paper as a whole.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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