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Fentanyl sparing effect of ultrasound-guided proximal radial, ulnar, median, and musculocutaneous nerve (RUMM) block for radial and ulnar fracture repair in dogs: a retrospective case-control study

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ABSTRACT. This study retrospectively evaluated the fentanyl-sparing effect of ultrasound-guided proximal radial, ulnar, median, and musculocutaneous nerve (RUMM) block for radial and ulnar fracture repair in dogs. Fentanyl was prepared for intraoperative analgesia in dogs, although proximal RUMM block was performed using 0.5% or 0.25% bupivacaine before surgery in the block group. Dogs without a nerve block were assigned to the control group. The fentanyl dose in the block group [0.8 (0–1.9) µg/kg/hr] [median (interquartile range)] was significantly lower than in the control group [8.4 (7.2–10) µg/kg/hr]. Surgery was performed without fentanyl in >50% of the dogs (5/7), using 0.5% bupivacaine. Ultrasound-guided proximal RUMM block can be useful as an intraoperative analgesic for radial and ulnar fracture repair in dogs.

KEYWORDS: bupivacaine, dog, fentanyl, radial ulnar median and musculocutaneous nerve block, ultrasound

In recent years, nerve blocks for the thoracic limb have been increasingly investigated in dogs and have become widespread in clinical practice [12]. The radial, ulnar, median, and musculocutaneous nerve (RUMM) block was first reported as a landmark method [17] that desensitizes the radial, ulnar, median, and musculocutaneous nerves, and is effective for surgeries distal to the elbow in dogs. An ultrasound-guided technique has been reported to increase the efficacy and safety of the nerve block in humans [1], and an ultrasound-guided RUMM block has been previously used for thoracic limb surgery in a dog [11]. However, the RUMM block has some disadvantages, such as repositioning of dogs and multiple needling [11, 17]. In the RUMM block, the radial nerve is blocked using the lateral approach, while the other nerves are blocked using the medial approach. In recent years, this technique has been improved to proximal RUMM block by changing the puncture site to be more proximal [16].

The proximal RUMM block was developed in an anatomical study using cadavers, in which the puncture site was determined for desensitization of all four target nerves at once [16]. This approach has been effective for thoracic limb surgeries, including radial and ulnar osteosynthesis; however, a control group was not designed in the previous study [16]. Other possible advantages of the proximal RUMM block include fewer complications, which have been reported in brachial plexus blocks such as the unilateral phrenic nerve block, pneumothorax, and Horner's syndrome [3, 8, 18]. Single needling may reduce the possibility of inadvertent intravascular injection and nerve damage. Furthermore, injecting local anesthetics inside the axillary sheath using the proximal RUMM block may minimize the development of a patchy block, which may cause an insufficient block.

Radial and ulnar (RU) fractures are relatively common orthopedic diseases in dogs, and have been well-recognized in miniature- and toy-breed dogs in Japan [2]. As RU fractures occur distal to the forelimbs, the RUMM block might be beneficial for this type of fracture. The theoretical advantage of the proximal RUMM block is that it requires only one needle. Since needling itself is difficult in extremely small-sized dogs, single needling is thought to be advantageous in these dogs.

This study aimed to evaluate the efficacy of ultrasound-guided proximal RUMM block for RU fracture repair in dogs by conducting

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a retrospective case-control analysis of anesthetic records. We hypothesized that the ultrasound-guided proximal RUMM block could reduce the fentanyl requirement during anesthesia.

This study was conducted retrospectively using anesthetic records. Before the surgery, written informed consent was obtained from all the dog owners. We investigated all the anesthetic records from January 2020 to December 2021 for dogs that underwent RU fracture repair at the Japan Animal Referral Medical Center, Nagoya Hospital. All the dogs were confirmed to have their complete blood count, serum biochemical analysis, and chest X-ray imaging within the respective reference range, and had no history of anaphylactic reaction to any drug. The physical status of all the dogs was classified as 1 or 2 according to the American Society of Anesthesiologists Classification. Exclusion criteria were fractures in multiple limbs, use of nerve blocks other than the proximal RUMM block, use of drugs other than bupivacaine for the nerve block, use of anesthetic drugs other than propofol and isoflurane, use of analgesic drugs other than fentanyl during surgery, and insufficient description of the anesthetic record. Dogs that underwent proximal RUMM block were assigned to the block group, and those that underwent surgery without any nerve block were assigned to the control group.

We applied a standardized protocol of general anesthesia for limb fractures as used in our hospital. Premedication was not administered. Fluid therapy was initiated before induction of anesthesia. Anesthesia was induced using 1% propofol for animal (Mylan Seiyaku, Tokyo, Japan) and maintained using isoflurane for animal (Mylan Seiyaku). After induction of anesthesia, the trachea was intubated, and the dog was connected to a semi-closed rebreathing circuit. Spontaneous respiration or ventilator use was maintained at the discretion of the anesthesiologist. For analgesia, fentanyl (Terumo, Tokyo, Japan) was infused during surgery, and non-steroidal anti-inflammatory drugs were administered after surgery. The fentanyl infusion rate was adjusted at the discretion of the anesthesiologist. If the dog showed no response to surgical stimuli, cessation of the fentanyl administration was allowed. In the block group, ultrasound-guided proximal RUMM block was performed with 0.5% or 0.25% bupivacaine (Marcain; Aspen Japan, Tokyo, Japan) using an ultrasound device (ARIETTA 70; Fujifilm, Tokyo, Japan). No nerve block was performed for dogs in the control group.

The dogs were positioned in dorsal recumbency, and the axillary space to be punctured was clipped and sterilized (Fig. 1A). The affected forelimb was abducted, and a high-frequency ultrasound linear probe (L64-VET 18–5 MHz; Fujifilm) was set along the long axis of the axilla. After confirming the brachial plexus, axillary artery, and vein, the probe was slightly rotated clockwise for the left forelimb or counterclockwise for the right forelimb while sliding the probe distally. When the radial, ulnar, median, and musculocutaneous nerves around the axillary artery were confirmed (Fig. 1B), a disposable echogenic veterinary needle (23G, 70 mm; Unisis Corp., Tokyo, Japan) was inserted from the cranial direction toward the nerves, and bupivacaine was injected. During the injection, the location of the needle tip was closely monitored using ultrasound images to avoid inadvertent intravascular or intraneural injections. The volume of bupivacaine injected was determined by ensuring that it was sufficiently diffused around each nerve, which was confirmed using ultrasound imaging (Fig. 1C).

The following data were retrospectively retrieved from the anesthetic records: breed, age, sex, body weight, anesthesiologist, details of local anesthetics used for nerve block, time from induction of anesthesia to the end of surgery (anesthesia time), time from skin incision to the end of surgery (surgical time), and time from induction of anesthesia to skin incision (skin incision time). For the parameters during anesthesia time, the following data were selected: fentanyl dose during anesthesia, number of fentanyl bolus, number of attempts to increase and decrease fentanyl dose, end-tidal isoflurane concentration (Et Iso), heart rate (HR), non-invasive mean arterial pressure (MAP), respiratory rate (RR), end-tidal carbon dioxide partial pressure ($EtCO_2$), breathing pattern (i.e., spontaneous respiration or positive pressure ventilation), body temperature (BT), and use of cardiovascular drugs (i.e., atropine and ephedrine). The average value for each continuous variable during anesthesia was calculated for each dog.

The normal distribution of the data was evaluated using the Shapiro−Wilk test. Continuous variables are described as mean ±

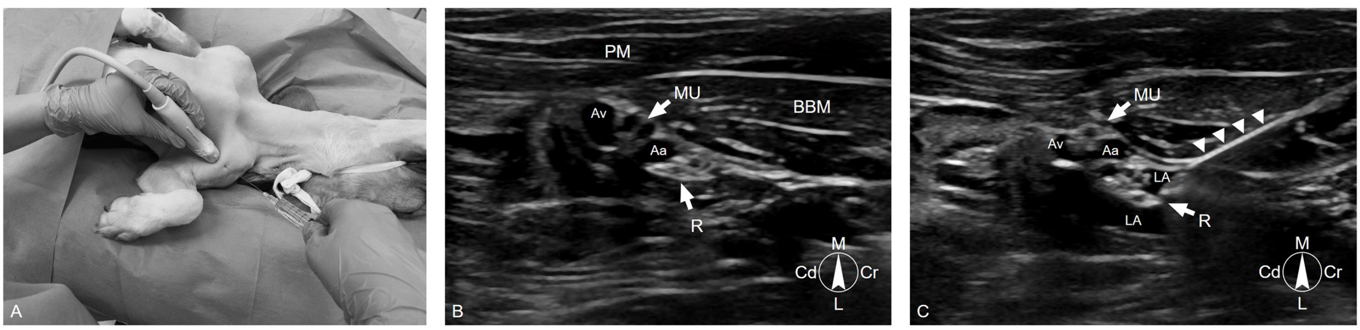

Fig. 1. Ultrasound images of the proximal radial, ulnar, median, and musculocutaneous nerve block. R, radial nerve; MU, median and ulnar nerves; Aa, axillary artery; Av, axillary vein; PM, pectoral muscle; BBM, biceps brachii muscle; LA, local anesthetics; Cr, cranial; Cd, caudal; M, medial; L, lateral. **A**) Positioning of the proximal RUMM block. The dogs were positioned in dorsal recumbency, and the forelimb was abducted. A high-frequency ultrasound linear probe was placed along the long axis of the axilla, and slightly rotated while sliding the probe distally. **B**) Pre-scan image before the procedure. The target nerves are located around the axillary artery. The musculocutaneous nerve is not identifiable in this image. **C**) After pre-scan, an echogenic needle (arrowheads) was inserted from the cranial side. Once the tip of the needle was advanced close to the nerve, the prepared bupivacaine was administered. Echo-free space was observed around the nerve if bupivacaine was injected properly. In this image, local anesthetics can be observed as echo-free space surrounding the radial nerve.

standard deviation for normally distributed data, and median (interquartile range) for non-normally distributed data. The primary endpoint was the fentanyl dose during anesthesia. The secondary endpoints were Et Iso, HR, and MAP during anesthesia. We also investigated the effect of bupivacaine concentrations (0.5% and 0.25%). In this subgroup analysis, bupivacaine dose or volume, fentanyl dose, and the number of dogs without fentanyl use during anesthesia were compared. The relationships between bupivacaine dose or volume and fentanyl dose were also investigated. Welch's *t*-test and Mann−Whitney *U* test was used for parametric and non-parametric data, respectively, to compare the numerical data between the two groups. Fisher's exact test was used to analyze the categorical data. To explore the factors associated with fentanyl dose during anesthesia, a generalized linear model was used. To create a full model, age, sex, body weight, duration of anesthesia, Et Iso, HR, MAP, $EtCO_2$, BT, cardiovascular drug use, and anesthesiologist were used as independent variables. After developing the full model, variables were selected using a stepwise method with Akaike's information criterion. Spearman's correlation test was used to investigate the relationship between bupivacaine dose or volume and fentanyl dose. Statistical analysis was performed using R software version 4.1.2 (https://www.r-project.org). Statistical significance was set at $P<0.05$.

This study included 45 dogs, of whom 10 were excluded: one due to the use of axillary brachial plexus block, and nine due to the use of prohibited intraoperative analgesia or insufficient description of the anesthetic record. Finally, 35 dogs were included, who were divided into the block (15 dogs) and control (20 dogs) groups. Data from all dogs were used for statistical analysis. Nine veterinarians participated as anesthesiologists. The percentage of anesthesiologists who performed anesthesia differed significantly between the two groups ($P<0.001$). When performing the nerve block, no complications such as inadvertent vascular puncture or intraneural injection occurred. Furthermore, no complications were recorded with regard to the cutaneous condition at the puncture site or neurological alterations at the time of re-examination for suture removal approximately two weeks later.

The breed composition and number of dogs of each breed were as follows: Toy poodle (n=14), mix (n=6), Italian grey hound (n=5), Pomeranian (n=4), Shiba-inu (n=2), Yorkshire terrier (n=2), Beagle (n=1), and Whippet (n=1). The characteristics and variables during anesthesia are summarized in Table 1. No significant differences were observed between the two groups with regard to dog characteristics. Anesthesia, surgical, and skin incision times were similar between both groups.

The fentanyl dose was significantly lower in the block group than in the control group [0.8 (0−1.9) µg/kg/hr for block group; 8.4 (7.2−10) µg/kg/hr for control group; $P<0.001$] (Fig. 2). Although the number of fentanyl bolus was similar between the two groups, the number of attempts to increase and decrease fentanyl dose in the block group were significantly smaller than those in the control group ($P=0.002$ and $P=0.011$, respectively). Et Iso, HR, and MAP were similar between both groups. A significant number of dogs maintained spontaneous respiration during anesthesia in the block group (13 of 15 for block group; 1 of 20 for control group; $P<0.001$), although no significant differences were observed in RR and $EtCO_2$ between the two groups. Only two dogs in the block group were administered cardiovascular drugs simultaneously during the surgery, which included atropine and ephedrine. No other cardiovascular drug was administered.

Table 1. Characteristics and variables during anesthesia in the block and control groups

	Block group (n=15)	Control group (n=20)	*P* value
Age (year)	0.6 (0.5−3)	0.8 (0.4−2.5)	0.811
Body weight (kg)	3.2 (2.3−4.3)	2.9 (2.4−3.9)	0.863
Sex (male/female)	9/6	10/10	0.734
Anesthesia time (min)	130 ± 34	121 ± 43	0.509
Surgical time (min)	78 (67−88)	76 (47−98)	0.811
Skin incision time (min)	44 ± 11	41 ± 9	0.303
Fentanyl dose (µg/kg/hr)	0.8 (0−1.9)	8.4 (7.2−10)	<0.001*
Fe bolus	0 (0−0)	0 (0−0.3)	0.698
Fe increase	0 (0−0)	1 (0−1)	0.002*
Fe decrease	0 (0−1)	1 (1−2)	0.011*
Et Iso (%)	1.5 ± 0.3	1.6 ± 0.2	0.236
HR (bpm)	106 ± 18	109 ± 17	0.596
MAP (mmHg)	70 ± 11	77 ± 16	0.155
RR (*f*)	12 (8.5−14)	10 (10−11)	0.426
Et CO_2 (mmHg)	38 ± 6	39 ± 4	0.535
Breath (SPONT/PPV)	2/13	1/19	<0.001*
BT (°C)	35.5 ± 1.4	35.2 ± 0.8	0.434
Drug use (yes/no)	2/13	0/20	0.177

Anesthesia time, time from induction of anesthesia to the end of surgery; Surgical time, time from skin incision to the end of surgery; Skin incision time, time from intubation to skin incision; Fe bolus, number of fentanyl bolus; Fe increase, number of attempts to increase fentanyl; Fe decrease, number of attempts to decrease fentanyl; Et Iso, end-tidal isoflurane concentration; HR, heart rate; MAP, non-invasive mean arterial pressure; RR, respiratory rate; $ETCO_2$, end-tidal carbon dioxide partial pressure; SPONT, spontaneous respiration; PPV, positive pressure ventilation; BT, body temperature; Drug use, use of cardiovascular drug during anesthesia. Continuous variables are described as mean ± SD for normally distributed data, and median (interquartile range) for non-normally distributed data. *$P<0.05$ considered significant.

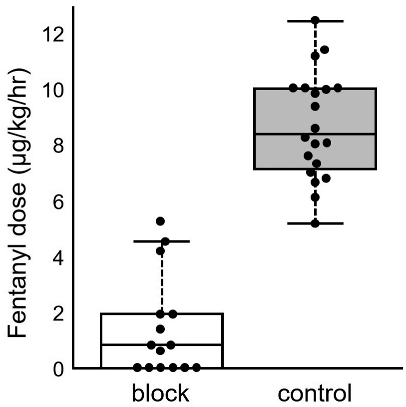

Fig. 2. Box plot of fentanyl dose during anesthesia. Each dot represents an individual value. The fentanyl dose in the block group is significantly lower than that in the control group. In the block group, some dogs were operated upon without any fentanyl.

In the multivariate analysis using the generalized linear model, proximal RUMM block, age, body weight, female sex, and MAP were selected for the final model, and only proximal RUMM block was significantly associated with the fentanyl dose during anesthesia (Table 2). This final model suggested that the proximal RUMM block reduced fentanyl dose by approximately 7 µg/kg/hr (95% confidence interval, −8.52 to −6.09; P<0.001).

Regarding the concentration of local anesthetics, seven dogs were administered 0.5% bupivacaine, and eight dogs were given 0.25% bupivacaine (Table 3). No significant differences were observed in the characteristics of the dogs treated with 0.5% and 0.25% bupivacaine. The volume of bupivacaine was significantly lower in the dogs treated with 0.5% bupivacaine than in those treated with 0.25% bupivacaine (0.3 ± 0.1 mL/kg for 0.5% bupivacaine; 0.6 ± 0.2 mL/kg for 0.25% bupivacaine; P<0.03), while the bupivacaine dose was similar between the dogs treated with 0.5% and 0.25% bupivacaine. The dogs treated with 0.5% bupivacaine tended to be given less fentanyl dose, although the difference was not significant [0 (0−0.7) µg/kg/hr for 0.5% bupivacaine; 1.4 (0.8−2.5) µg/kg/hr for 0.25% bupivacaine; P=0.113]. In contrast, the number of dogs without fentanyl use during anesthesia was significantly larger in the 0.5% bupivacaine group (5 of 7 dogs, 0.5% bupivacaine; 1 of 8 dogs, 0.25% bupivacaine; P=0.041). No significant relationship was observed between the fentanyl dose and bupivacaine dose (correlation coefficient, 0.25; P=0.336) or volume (correlation coefficient, 0.41; P=0.129).

This study revealed the efficacy of an ultrasound-guided proximal RUMM block for RU fracture repair in dogs. This technique was able to significantly reduce the fentanyl dose without any adverse effects, and the surgery was possible completely without the use of intraoperative fentanyl in some dogs. In addition to the fentanyl dose, the number of changes in infusion rate was also reduced, suggesting that the proximal RUMM block made anesthesia more stable. Analysis using the generalized linear model revealed that the proximal RUMM block could reduce the intraoperative fentanyl dose by approximately 7 µg/kg/hr. Although not significant, age, body weight, sex, and MAP were selected as independent factors for the final model since the fentanyl dose has been suggested to be influenced by age, body mass index, and sex in humans [6, 14, 15]. However, it was difficult to explore the details of the relationships between these factors and fentanyl due to the retrospective design of this study. The relationship between fentanyl dosing rate and intraoperative hypotension has been reported in dogs [5]. The potent analgesic effect of the nerve block may have contributed to the

Table 2. Coefficients of a generalized linear model showing factors associated with fentanyl dose during anesthesia

	Estimate	SE	95%CI	*P* value
intercept	11.12	1.85	7.5 to 14.75	<0.001*
Block performed	−7.33	0.63	−8.57 to −6.09	<0.001*
Age (year)	0.22	0.13	−0.04 to 0.48	0.109
Body weight (kg)	−0.32	0.2	−0.71 to 0.06	0.111
Female	1.18	0.63	−0.06 to 2.42	0.072
MAP (mmHg)	−0.03	0.02	−0.08 to 0.01	0.19

95%CI, 95% confidence interval; Block performed, performed ultrasound-guided proximal radial, ulnar, median, and musculocutaneous nerve (RUMM) block; MAP, non-invasive mean arterial pressure. Ultrasound-guided proximal RUMM block is significantly associated with decrease in fentanyl dose during anesthesia. **P*<0.05 considered significant.

Table 3. Characteristics of dogs and variables during anesthesia in dogs administered 0.5% bupivacaine and 0.25% bupivacaine

	0.5% bupivacaine (n=7)	0.25% bupivacaine (n=8)	*P* value
Age (year)	1.8 (0.5−4.4)	0.6 (0.5−0.8)	0.585
Body weight (kg)	4 (2.8−4.7)	2.7 (2.3−3.7)	0.281
Sex (male/female)	6/1	3/5	0.119
Anesthesia time (min)	133 ± 46	127 ± 19	0.634
Surgical time (min)	70 (67−88)	79 (69−88)	0.89
Skin incision time (min)	39 ± 12	49 ± 5	0.088
Bupi dose (mg/kg)	1.6 ± 0.4	1.4 ± 0.5	0.252
Bupi volume (mL/kg)	0.3 ± 0.1	0.6 ± 0.2	0.03*
Fentanyl dose (µg/kg/hr)	0 (0−0.7)	1.4 (0.8−2.5)	0.113
Without fentanyl (yes/no)	5/2	1/7	0.041*

Anesthesia time, time from induction of anesthesia to the end of surgery; Surgical time, time from skin incision to the end of surgery; Skin incision time, time from intubation to skin incision; Bupi dose, dose of bupivacaine; Bupi volume, volume of bupivacaine. Continuous variables are described as mean ± SD for normally distributed data, and median (interquartile range) for non-normally distributed data. **P*<0.05 considered significant.

reduced dose of fentanyl and stabilization of anesthesia [16]. Based on the results of this study, ultrasound-guided proximal RUMM blocks are useful for RU fracture repair in dogs. Other procedures for forelimb surgery may also be suitable, although further studies are warranted [16].

Theoretically, the effect of local anesthesia is more potent at higher concentrations and doses. However, there is a trade-off between the concentration and dose of local anesthetics due to the dosage limits to avoid local anesthetic toxicity [4]. Although the number of dogs without the use of intraoperative fentanyl was significantly higher when 0.5% bupivacaine was administered, no significant difference in the fentanyl dose was observed between the two bupivacaine concentrations. These results suggest that the concentration of local anesthetics may have affected the effectiveness of the proximal RUMM block. In humans, 10 mL of 2% lidocaine showed a more intense effect than 20 mL of 1% lidocaine during epidural anesthesia [13]. In our study, the volume of bupivacaine was relatively higher compared to that in a previous report, in which 0.15 mL/kg of 0.5% ropivacaine was used [16]. As the body weight of the dogs in our study was small (1.6−5.4 kg), a relatively large volume of bupivacaine per body weight may have been required. In contrast, the body weight was 20 ± 8 kg in a previous report [16]. In large-sized dogs, it would be easy to administer local anesthetics around the nerves, even if the dose per body weight is relatively low, because the absolute volume is large. Further studies are needed to identify the appropriate dose of bupivacaine for small-sized dogs.

In both the groups, Et Iso was higher than that reported in a previous study [16], which may have been associated with premedication. No dogs were administered premedication in this study; however, a previous study has reported the use of acepromazine and methadone before induction of anesthesia [16]. The combination of acepromazine and methadone is known to reduce the minimum alveolar concentration of isoflurane in dogs [10]. As an intravenous indwelling catheter was inserted and fluid therapy was initiated before induction of anesthesia in most cases at our institution, premedication was not used.

The higher number of dogs in the block group that maintained spontaneous respiration may have been associated with a lower fentanyl dose. Although respiratory management was left at the discretion of the anesthesiologist, it has been considered that a decrease in the fentanyl dose could reduce the respiratory depression effect of this drug [7], and make it easier to maintain spontaneous respiration. Fentanyl also has adverse effects other than respiratory depression, such as decreased gastrointestinal motility [7]. In humans, opioid reduction protocols are known to improve clinical outcomes [9]. The proximal RUMM block is a promising intraoperative analgesia for the opioid reduction protocol in dogs.

The skin incision time was similar between the block and control groups, suggesting that the ultrasound-guided proximal RUMM block could be performed in a short time, although the time required for the nerve block was not investigated because of the retrospective data collection. The proximal RUMM block was considered to be performed within a few minutes, based on the difference in skin incision time between the two groups. The proximal RUMM block requires neither posture change nor multiple needling, with the potential to reduce implementation time.

Our study has some limitations. First, anesthesia was induced by several anesthesiologists; therefore, the influence of different anesthesiologists on anesthesia induction and administration methods of fentanyl could not be excluded. However, including the anesthesiologist as a factor in the generalized linear model did not affect the results; thus, the anesthesiologist was excluded from the final model by the stepwise method. Second, the retrospective design of this study and the small number of cases made it difficult to adjust for background factors of the dogs between the two groups, which could affect the requirement of fentanyl.

In conclusion, the ultrasound-guided proximal RUMM block was useful in reducing the fentanyl requirement in RU fracture repair in dogs. Further prospective studies are required to evaluate the efficacy and safety of ultrasound-guided proximal RUMM block in dogs.

CONFLICT OF INTEREST. The authors declare no conflicts of interest associated with this article.

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