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RESEARCH PAPER

Financial impact of ultrasound-guided lumbar plexus and sciatic nerve blocks with electrostimulation for tibial plateau leveling osteotomy surgery in dogs

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Abstract

Objective To determine the anesthesia cost from ultrasound-guided lumbar plexus and sciatic nerve blocks confirmed with electrostimulation for unilateral tibial plateau leveling osteotomy (TPLO) surgery in dogs.

Study design Prospective, randomized, blinded clinical trial.

Animals A group of 20 dogs weighing 33.9 ± 6.0 kg (mean ± standard deviation).

Methods All dogs were administered hydromorphone and atropine, propofol for induction of anesthesia and isoflurane for maintenance. Hydromorphone and carprofen were administered for recovery. The dogs were randomly assigned to one of two groups, lumbar plexus and sciatic nerve blocks with ropivacaine [regional anesthesia (RA)] or sham blocks with saline [control (CON)]. Fentanyl was administered for rescue analgesia intraoperatively and postoperatively. The cost to manage anesthesia was divided into fixed and variable costs using the micro-costing method. The variable costs were compared using Student's *t* test or Mann–Whitney *U* test.

Results The fixed anesthesia costs were equal between groups at US$354.00 per case. The variable anesthesia cost range was US$27.90–100.10 for RA and US$21.00–180.50 for CON. Overall, cost per dog in CON was from –US$6.9 to US$80.4 compared with RA. For 160 TPLO cases per year, hospital cost when RA is performed decreased the cost by $12,864 per year up to increased cost by $1104 per year, depending on the requirements for systemic drugs and incidence/severity of anesthesia complications. The estimated fee charge per case for service necessary to reimburse the cost of a new ultrasound (US$25,000.00) and nerve locator (US$925.00) over their life span of 6 and 10 years, respectively, is US$26.62.

Conclusions and clinical relevance Ultrasound-guided lumbar plexus and sciatic nerve blocks with electrostimulation confirmation can increase the anesthesia cost through use of specific equipment. However, in most cases, the anesthesia cost decreased as a result of decreased costs for pain management and treatment of complications.

Keywords cost analysis, lumbar plexus, regional anesthesia, sciatic nerve.

Introduction

Cranial cruciate ligament disease or rupture (CCLD) in dogs is a common injury presented for surgical repair. An estimate in 2003 showed that a single veterinarian may operate on 29–186 dogs with CCLD per year (Wilke et al. 2005). At that time, the client mean cost for CCLD surgical repair varied between US$898 and US$1840 (Wilke at al. 2005). A more recent study from Canada stated that the client mean cost range was Can$3480–3544 for tibial plateau leveling osteotomy (TPLO) surgical correction of CCLD in dogs (Nicoll et al. 2014). Thus, the financial impact of CCLD repair in veterinary practice is significant.

Although different anesthesia regimens have been described for CCLD surgical repair, the isolated cost of anesthesia for this procedure has not been published. Systemic administration of opioids, epidural anesthesia and nerve blocks are some of the modalities recommended for analgesia in dogs during surgical correction of CCLD (Campoy et al. 2012; Vettorato et al. 2012; Bartel et al. 2016; Boscan & Wennogle 2016; Romano et al. 2016).

In the present study, an anesthesia cost analysis was performed comparing ultrasound (US)-guided nerve blocks (lumbar plexus and sciatic nerve) confirmed with electrostimulation *versus* the anesthesia cost with systemic administered analgesia. The study hypothesis was that US-guided nerve blocks will increase the anesthesia cost for the veterinarian. Additional supplies and time to perform the blocks will incur an increased anesthesia cost for TPLO surgeries.

Materials and methods

The study was designed as a randomized prospective, single-blinded clinical trial to be conducted simultaneously with another study (Warrit et al. 2019). The clinical trial was approved by the Colorado State University Institutional Animal Care and Use Committee (no. 09-1299A) and Clinical Board Review Committee. Owner consent was obtained for all dogs included in the trial.

A power calculation using studies that tabulated drug requirements for TPLO surgery estimated that a minimum of 10 dogs per group were necessary to detect rescue analgesia differences with 80% power and an alpha error of 5%. The inclusion criteria to participate in the trial included unilateral CCLD requiring TPLO surgery, complete blood cell count and diagnostic profile within normal limits, body condition score 5−6/9 and American Society of Anesthesiologists status of 2. Dogs administered behavior-modifying drugs were excluded.

TPLO surgery was performed in all dogs by the same surgeon using the same technique, materials and equipment (Kowaleski et al. 2012; Warrit et al. 2019). Anesthesia, pain assessments and management were performed by a single anesthetist unaware of the dog group allocation following a standard predetermined protocol.

A group of 20 dogs were randomly assigned to one of two groups by pulling the assigned group from a sealed envelope. Group regional anesthesia (RA) was administered US-guided lumbar plexus and sciatic nerve blocks with ropivacaine (1.5 mg kg^{-1}; Fresenius Kabi LLC, IL, USA) divided equally between the lumbar plexus and sciatic nerve. Plexus and nerve location and blockade success were evaluated using electrostimulation. The group control (CON) was administered US-guided injections at the same sites using equivalent volumes of sterile saline. Plexus and nerve location and absence of blockade were evaluated using electrostimulation.

The general anesthesia protocol administered to all dogs was hydromorphone (0.2 mg kg^{-1}; Hydromorphone Injection USP; West-Ward Pharmaceutical Corp., NJ, USA) and atropine sulfate (0.02 mg kg^{-1}; Med-Pharmex Inc., CA, USA) administered subcutaneously 30 minutes before induction of anesthesia. Propofol (PropoFlo; Abbott Laboratories Inc., IL, USA) was administered intravenously (IV) until endotracheal intubation was achieved. Anesthesia was subsequently maintained with isoflurane (Isoflurane USP; Akorn Inc., IL, USA) in oxygen delivered with a circle rebreathing system. An IV bolus of lactate Ringer's solution (10 mL kg^{-1}; LRS; Hospira Inc., IL, USA) was administered before anesthesia induction and continued during anesthesia at 5 mL kg^{-1} hour^{-1} IV. The isoflurane vaporizer was 2% with oxygen 1 L minute^{-1} at the beginning of anesthesia while monitoring equipment was attached, presurgery radiographs were obtained to plan the TPLO surgery and the US-guided blocks were performed. After blocks were performed, the vaporizer was decreased to 1.25%.

Heart rate (HR), respiratory rate (f_R) and invasive arterial blood pressure were monitored to determine when the dogs responded to surgical stimulation or when bradycardia, apnea or hypotension occurred. Baseline values (average of three to five readings) for HR, mean arterial pressure (MAP) and f_R were obtained approximately 10 minutes after reducing the isoflurane vaporizer to 1.25%, without any stimulation. After the start of surgery, response to stimulation was recorded when the dog moved or when HR or MAP or f_R increased $\geq$20% above baseline. If a response occurred, rescue analgesia consisting of fentanyl (2 μg kg^{-1}; Fentanyl Citrate USP; Hospira Inc.) was administered IV until HR, f_R and MAP returned to within 20% of baseline values. If three doses of fentanyl were insufficient to abolish the response to surgical stimulation, the vaporizer setting was increased by 0.25% and O_2 flow increased to 2 L minute^{-1} for 10 minutes and the rebreathing bag emptied. Alternatively, if hypotension (defined as MAP < 60 mmHg) developed, the vaporizer setting was decreased by 0.25% and O_2 flow increased to 2 L minute^{-1} for 10 minutes and the rebreathing bag emptied. If the MAP did not increase, LRS (10 mL kg^{-1}) was administered IV as a bolus over 5 minutes. Then if the MAP was not improved, hetastarch (5 mL kg^{-1}; Novaplus; Hospira Inc.) was administered IV over 5 minutes. If hypotension continued, a continuous rate infusion of dopamine (DOPamine HCL injection USP; Hospira Inc.) was initiated at 5 μg kg^{-1} minute^{-1} and adjusted as needed until MAP > 60 mmHg.

If HR decreased below 20% from baseline, atropine (0.02 mg kg^{-1}) was administered intramuscularly in the triceps muscle. If the end-tidal carbon dioxide ($P_{E'}CO_2$) exceeded 55 mmHg (7.33 kPa), intermittent manual ventilation was initiated until $P_{E'}CO_2$ was <55 mmHg (7.33 kPa). Administration of rescue analgesia, fluid administration and vasoactive drugs were recorded.

At the end of surgery, carprofen (2.2 mg kg^{-1}; Rimadyl; Zoetis Inc., MI, USA) and hydromorphone (0.1 mg kg^{-1}) were administered subcutaneously for postoperative analgesia. At the end of anesthesia (extubation), a published recovery score was utilized to determine the recovery quality (Becker et al. 2013). If the recovery score was >2, dexmedetomidine (1 μg kg^{-1} IV; Dexdomitor; Zoetis Inc.) was administered until the dog was calm and relaxed and the recovery score was <2.

Postoperatively, pain was assessed using a Modified University of Melbourne Pain Scale (UMPS), Colorado State University Acute Canine Pain Scale (CSUPS) and visual analog pain scale (VAS). A dog was considered painful when UMPS $\geq$

2, CSUPS ≥ 1 or VAS > 2. If a dog was considered painful, the anesthetist, unaware of the study group, started a continuous IV infusion of fentanyl (2 μg kg^{-1} hour^{-1}). If the pain scores continued to be above any scale threshold, additional fentanyl boluses (2 μg kg^{-1}) were administered IV. If a dog showed adverse side effects from fentanyl (e.g. dysphoria), methadone (0.2 mg kg^{-1}) IV or dexmedetomidine (1 μg kg^{-1}) IV was an additional option to decrease the pain score below all pain scale thresholds.

If a dog was restless (e.g. barking, pawing at the kennel door), the investigator unaware of the study group could choose to administer either dexmedetomidine (1 μg kg^{-1}) IV or acepromazine (0.01 mg kg^{-1}; Promace; Boehringer Ingelheim Vetmedica Inc., MO, USA) IV. The time from discontinuing isoflurane to the time of administration of rescue analgesia postoperatively was recorded.

The urinary bladder was manually emptied in all dogs before extubation, and the dogs were taken outside about 2 hours after extubation and then every 2–4 hours. When the dogs returned to their kennel after their first walk, 30 minutes of physical therapy was performed (cold compression, range of motion, transcutaneous electrical nerve stimulation and laser therapy).

Cost calculations

Data to calculate the anesthesia cost were divided into fixed and variable costs using the micro-costing approach (Frick 2009; Xu et al. 2014). The micro-costing method collects detailed data from all resources utilized for a medical procedure (every input consumed per patient). The method allows comparisons of within-procedure cost and the procedure cost-effectiveness or cost benefit. The micro-costing method is a method used in the medical field to identify the influence of individual techniques for procedures that involve multiple variables. Accordingly, in the present study, the anesthesia cost was divided into fixed and variable costs (Table 1). The fixed anesthesia cost included expenditures that were identical for all dogs in both groups (e.g., anesthesia premedication drugs, catheter placement, fluid administration sets, endotracheal tube, anesthesia machine usage, oxygen supply, monitoring equipment, heating devices, anesthetist and basic postoperative nursing care). The variable costs included, for example fees assigned according to duration of anesthesia, adjunct drugs, fluids administered and complication management.

The variable anesthesia costs were calculated by tabulating the amount of drugs used, care and complication management during the perioperative period up to 12 hours after extubation from anesthesia. The isoflurane volume used was calculated using the formula in Appendix A with vaporizer settings and oxygen flow rates recorded every 5 minutes during anesthesia.

Table 1 Colorado State University fixed and variable anesthesia costs. Drug cost per unit is the institution retail price*

Fixed cost	Cost (US$)
Anesthesia	129
Postoperative care	225
Variable cost (vial or unit)	**Cost per unit (US$)**
Propofol (1%, 20 mL)	13.71
Isoflurane (250 mL)	26.52
Fentanyl (20 mL)	13.37
Lactated Ringer's solution (1 L)	12.01
Hetastarch (500 mL)	29.17
Dopamine (40 mg mL^{-1}, 5 mL)	7.49
Dexmedetomidine (0.5 mg mL^{-1}, 10 mL)	141.30
Methadone (10 mg mL^{-1}, 2 mL)	70.14
Hydromorphone (2 mg mL^{-1}, 2 mL)	3.12
Ropivacaine (0.5%, 30 mL)	11.43
Echogenic needle	12.00
Additional nursing care (per day)	25.00

*Anesthesia fixed cost includes anesthesia premedication drugs, catheter placement, fluid administration sets, endotracheal tube, anesthesia machine usage, O_2 supply, monitoring equipment, heating devices and anesthetist professional fee. Postoperative care fixed cost includes basic postoperative care for 24 hours, professional fee and overhead.

The numbers used to calculate the variable anesthesia cost were based on our hospital cost to clients (Table 1).

The service fee for US and nerve locator use was calculated using the following formula:

Fee charged for service = Total purchase price/(Estimated unit lifetime × Estimated number of TPLO surgeries per year)

The number of TPLO surgeries per year was estimated at 160 at our veterinary hospital. The purchase price for a new US unit with one probe and a nerve locator for veterinary use varies significantly (US$15,000–29,500). For the study calculations, the cost of a new US unit with an estimated life of 6 years was US$25,000 (Fujifilm Sonosite Inc., WA, USA) and US$925 for a new nerve locator (Stimpod 450; Mila International Inc., KY, USA) with an estimated life of 10 years.

Statistical analysis

Data were analyzed using Shapiro–Wilk test to assess data distribution (GraphPad Prism 6.07; GraphPad Software Inc., CA, USA). Student's *t* test or Mann–Whitney *U* test was used to determine differences between groups. Differences between groups were considered significant when $p < 0.05$. As the majority of the data were not normally distributed, data are presented as median (range). A Pearson's correlation test was used to determine any association between variable cost and anesthesia duration. All dollar values are shown in US$ at the time of writing.

Results

Data were collected between January 2015 and July 2016. All the information necessary to calculate cost was collected from 20 client-owned dogs, aged 1–8 years. Dogs were a variety of breeds and both sexes. The 20 dogs weighed 33.9 ± 6.0 kg (mean ± standard deviation), and weight was not different between groups.

The TPLO surgery cost to clients included professional fees, use of the surgery room, instruments, materials and supplies. The cost varied slightly among dogs, depending on the surgical implant. Cost for RA was $2040 (1866–2191) and for CON was $2141 (1891–2190) ($p = 0.63$).

The radiology cost to clients for pre- and postoperative radiographs was $269 per dog and equal between groups. Similarly, physical therapy that was performed postoperatively on the surgical limb was $203 per dog and was the same for all dogs. The veterinary hospital administration overhead fee was the same for all dogs at $24.50 per dog.

The fixed anesthesia cost, including anesthesia premedication, catheter placement, fluid administration sets, endotracheal tube, anesthesia machine use, oxygen supply, monitoring equipment, heating devices, anesthetist professional fee and basic postoperative nursing care, was $354 per dog (Table 1). Propofol was used to induce anesthesia, and no differences in dosage (volume) or cost were observed between groups ($p = 0.74$; Tables 2 & 3). The cost of isoflurane to maintain anesthesia was similar between groups ($p = 0.27$; Tables 2 & 3). Performing the lumbar plexus and sciatic nerve blocks required an insulated needle and ropivacaine (0.5%; 1.5 mg kg^{-1}; 0.3 mL kg^{-1}), which are included in RA as variable costs (Tables 2 & 3). These costs were not included in CON for analysis to imitate the cost of cases with no RA. Dogs in CON required more intraoperative fentanyl rescue analgesia that resulted in higher cost in CON ($p = 0.02$; Tables 2 & 3).

In RA, four out of 10 dogs (40%) were hypotensive at some point during anesthesia (MAP < 60 mmHg), and MAP improved in three of these dogs following decreases in the isoflurane vaporizer setting by 0.25% and administration of a crystalloid fluid bolus (10 mL kg^{-1}). The fourth dog required additional administration of hetastarch (5 mL kg^{-1}). In CON, eight of 10 dogs (80%) were hypotensive during anesthesia and six of these dogs required a decrease in the isoflurane vaporizer setting (0.25%), administration of LRS bolus (10 mL kg^{-1}), hetastarch (5 mL kg^{-1}) and a continuous infusion of dopamine to improve MAP to >60 mmHg (Table 2). The remaining two hypotensive dogs responded to decreasing the isoflurane vaporizer setting (0.25%) and administration of a LRS bolus. Owing to the greater number of interventions necessary, the cost to manage hypotension under anesthesia in CON was higher ($p = 0.002$; Tables 2 & 3).

During recovery from anesthesia, at extubation, more dogs in CON were agitated and required rescue analgesia and/or sedation (Tables 2 & 3). During the first 12 postoperative hours, based on the scoring systems, more dogs in CON were administered opioids and sedatives that increased the variable

Table 2 Number of dogs that were administered a drug and total drug volumes [median (range)] administered per group for tibial plateau leveling osteotomy anesthesia. RA, dogs administered ropivacaine for lumbar plexus and sciatic nerve blocks and CON, dogs administered sham blocks with saline. Body weight [median (range)], 35.3 (25–41) for RA and 32.0 (24–47) kg for CON. LRS, lactated Ringer's solution; *n*, number of dogs

Time point	Drug	Group RA ($n = 10$)		Group CON ($n = 10$)	
		n	Volume (mL)	*n*	Volume (mL)
Anesthesia	Propofol	10	15 (6–20)	10	19 (7–21)
	Fentanyl	10	11 (1–21)	10	16 (6–43)
	Isoflurane	10	14 (9–17)	10	14 (10–19)
	LRS CRI*	10	776 (498–1100)	10	710 (360–1350)
	LRS bolus†	4	0 (0–360)	8	295 (0–740)
	Hetastarch	1	0 (0–125)	6	123 (0–185)
	Atropine	7	1.2 (0–2.9)	9	1.5 (0–2.6)
	Ropivacaine	10	10.7 (7.5–12.5)	0	0
	Dopamine‡	0	0	6	6 (0–23)
Recovery (extubation)	Dexmedetomidine	1	0 (0–0.08)	5	0.03 (0–0.15)
Postoperative	Fentanyl	5	3 (0–20)	9	12 (0–23)
	Methadone	0	0	1	0 (0–0.5)
	Dexmedetomidine	3	0 (0–0.14)	6	0.06 (0–0.6)
	Acepromazine	4	0 (0–0.2)	4	0 (0–0.14)

*LRS bolus administered before induction (10 mL^{-1} kg^{-1}) and continuous rate infusion (5 mL kg^{-1} $hour^{-1}$) during anesthesia.
†LRS boluses administered for treatment of hypotension.
‡Dopamine calculated in mL after dilution with sterile 0.9% saline to 800 μg mL^{-1}.

Table 3 Anesthesia variable cost calculation for dogs anesthetized for tibial plateau leveling osteotomy. Dogs were assigned to be administered ropivacaine for lumbar plexus and sciatic nerve blocks (group RA, $n = 10$) or sham blocks with saline (group CON, $n = 10$). Data are median (range) using volumes from Table 2 and costs from Table 1. Final variable cost calculation was prorated for an average 33.9 kg dog. Dopamine CRI, continuous rate infusion includes the cost of a dopamine vial, sterile 0.9% saline for dilution, syringe pump use, syringe and extension tubing; LRS, total volume of lactated Ringers' solution administered; RA needle, insulated echogenic needle designed for regional anesthesia

Time point	Drugs	Group RA		Group CON		*p*-value
		(mL per dog)	(US$ per kg)	(mL per dog)	(US$ per kg)	
Anesthesia	Propofol	15 (6–20)	0.3 (0.1–0.4)	19 (7–21)	0.3 (0.2–0.5)	0.74
	Fentanyl	11 (1–21)	0.2 (0.03–0.5)	16 (6–43)	0.4 (0.09–0.8)	0.02
	Isoflurane	14 (9–17)	0.04 (0.03–0.06)	14 (10–19)	0.05 (0.03–0.06)	0.27
	LRS	910 (730–1400)	0.3 (0.2–0.5)	1080 (920–1350)	0.4 (0.3–0.5)	0.04
	Hetastarch	0 (0–125)	0 (0–0.3)	123 (0–185)	0.28 (0–0.3)	0.05
	Atropine	1.2 (0–2.9)	0.02 (0–0.04)	1.5 (0–2.6)	0.02 (0–0.05)	0.06
	Ropivacaine	10.7 (7.5–12.5)	0.11	–	0	
	RA needle	–	12	–	0	
	Dopamine CRI	–	0	6 (0–23)	± 39.49	
Recovery (extubation)	Dexmedetomidine	0 (0–0.08)	0 (0–0.1)	0.03 (0–0.15)	0.05 (0–0.2)	0.09
Postoperative	Fentanyl	3 (0–20)	0.06 (0–0.4)	12 (0–23)	0.3 (0–0.4)	0.31
	Methadone	0	0	0 (0–0.5)	0 (0–0.51)	0.47
	Dexmedetomidine	0 (0–0.14)	0 (0–0.19)	0.06 (0–0.6)	0.09 (0–0.84)	0.22
	Acepromazine	0 (0–0.2)	0 (0–0.002)	0 (0–0.14)	0 (0–0.001)	0.98
Variable cost for average 33.9 kg dog			46.9 (27.9–100.1)		103.6 (21.0–180.5)	

cost (Tables 2 & 3). The number of personnel assisting the dogs to walk outside was similar between groups. In CON, one dog became extremely restless requiring additional incision site care with bandage replacement and an additional IV catheter placement after the first one became dislodged. The postoperative data from this dog was not used for analysis and was considered an outlier.

No association or correlation between the anesthesia variable cost and anesthesia duration were observed ($r^2 = 0.001$; $p = 0.86$). The anesthesia durations were not different between groups (178.5 ± 10 and 167 ± 6.4 minutes for RA and CON, respectively, $p = 0.4$).

When variable anesthesia costs were tabulated and indexed by body weight, the estimated cost, median (range) per kg, was $1.03 (0.47–2.60) for RA and $1.89 (0.62–4.16) for CON ($p = 0.017$). Using the mean body weight of 33.9 kg from all dogs in the study, the estimated median (range) variable anesthesia cost per dog was $46.9 (27.90–100.10) for RA and $103.6 (21.00–180.50) for CON (Table 3). Therefore, depending on the amount of intraoperative rescue analgesia, hypotension management, recovery drugs used and postoperative drug requirements, the anesthesia variable cost per dog in CON differed from RA by –$6.90 to +$80.40.

Our veterinary hospital manages an average of 160 TPLO surgeries per year. Thus, using the nerve blocks described in this study, the annual anesthesia variable cost could be either increased by $1104.00 or decreased by up to $12,864.00, depending on the amount of systemic drugs and interventions required per case.

A service charge for use of the US and nerve locator equipment was calculated based on the initial cost and number of surgeries in the expected lifetimes:

Service charge for US = $25,000/(6 years × 160 cases) = $26.04.

Service charge for nerve locator = $925/(10 years × 160 cases) = $0.58.

Discussion

The study hypothesis that inclusion of US-guided nerve blocks will increase anesthesia cost was partially proven. However, the overall cost appeared to be decreased in most cases. The RA group required less intraoperative analgesia, postoperative analgesia and complication management such as hypotension during anesthesia and agitation during recovery. A similar increased cost of care has been previously described in dogs developing anesthesia complications such as hypotension that requires colloid and dopamine treatment (Smith et al. 2017). The difference in variable anesthesia cost is small when tabulated for the individual dog but when calculated for the number of TPLO surgeries performed at the authors' veterinary hospital per year, it becomes a significant sum of money.

A break-even cost recovery of a US and nerve locator was calculated as $26.62 for each surgery. This number will vary according to hospital caseload, and does not include time or cost of training personnel to perform nerve blocks. Nonetheless, once used routinely the cost savings may be substantial.

Calculation of anesthesia costs is difficult. Choice of drugs is influenced by veterinarian preferences, availability and manufacturer cost of specific drugs, and institutional policies governing purchase and retail prices of drugs. In some practices, drugs may be dispensed as cost per milliliter of drug indexed to body weight, whereas in others, drugs may be dispensed by vial and not by the specific dose, with the client liable for the cost of the entire vial. The duration of anesthesia and surgery may play a role in cost (Smith et al. 2017). Although in the present study there was no difference in anesthesia duration, cost will increase if obtaining nerve blocks prolongs anesthesia.

Previous studies addressing regional anesthesia for stifle surgery procedures in dogs show similar results in terms of drug requirements. Portela et al. (2013) showed that regional anesthesia reduced the postoperative rescue analgesia required for at least 2 hours after performing an orthopedic procedure. Romano et al. (2016) showed that regional anesthesia lowered the isoflurane and postoperative rescue analgesia requirements. Boscan & Wennogle (2016) showed that regional anesthesia decreased the intraoperative parenteral analgesia requirements including rescue analgesia. In the present study, 88% of the dogs from CON compared with 50% of the dogs from RA required at least one intervention to maintain low pain scores during the postoperative period.

The study has several limitations to consider. The small sample size prevented us from drawing firm conclusions regarding the financial disadvantages and advantages when performing regional anesthesia for TPLO surgery. Different drugs and doses may alter the anesthesia variable cost. For example some dogs in RA may have not needed postoperative hydromorphone to maintain adequate analgesia. A third limitation is that the anesthetist unaware of the randomization could have noticed signs of motor dysfunction in some dogs during the recovery period. In the present study, we estimated the price for a new US unit and nerve locator from commercially available companies in the veterinary field (Fujifilm Sonosite Inc. and Mila International Inc., respectively). The price and life span of a new US unit and nerve locator vary significantly and the equipment choice is personal. The authors do not recommend the purchase of a new US unit to only perform RA. However, access to a US unit in a clinic will allow its use for US-guided regional anesthesia, improving patient care, and the cost for these procedures will contribute to recovering cost of the unit. Another study limitation is that although the lumbar plexus and sciatic blocks were performed by an anesthesiologist with experience in US-guided regional anesthesia, the success of nerve blocks was not confirmed. Nonetheless, significant differences between the groups were documented suggesting that the nerve blocks supplied analgesia whereas the saline injections did not. Electrostimulation confirmed that the local anesthetic had the desired effect on the plexus and nerve motor function.

Similar to the results obtained in the study, Liu & John (2010) showed that using ultrasonography to guide regional anesthesia techniques for surgery in humans can generate additional profit. This is made possible, in part, by decreasing pain management cost and increasing success rate.

Conclusion

The use of ultrasonography to guide regional anesthesia confirmed with electrostimulation increases the anesthesia cost. However, as observed in most cases, regional anesthesia decreased the anesthesia cost by improving pain management and decreasing the incidence and severity of anesthesia complications.

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Authors' contributions

KW and PB: study design, data collection, data analysis and interpretation, preparation of the manuscript. GG: study design, data collection and interpretation, preparation of the manuscript. CG: surgical procedures, data collection, preparation of the manuscript. All authors approved the final version of the manuscript for publication.

Conflict of interest statement

Authors declare no conflict of interest.

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Appendix A. Isoflurane volume calculation

$$\frac{\text{Fresh gas flow}\left(\text{mL minute}^{-1}\right)\times \text{VA}(\text{vol\%})\times \text{Duration}(\text{minutes})}{\text{Saturated gas volume}\left(\text{mL mL}^{-1}\right)\times 100(\text{vol\%})}$$

where VA is volatile anesthetic concentration.

The saturated gas volume for isoflurane is 194 mL from 1 mL of isoflurane liquid.

