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Article

Ultrasound-Guided Sciatic and Saphenous Nerve Blocks Enhance Perioperative Analgesia in Sheep Undergoing Experimental Orthopaedic Hindlimb Surgery

Oliver Rodriguez ¹, Pedro Figueirinhas ^{1*}, Daniela Vazquez ¹, Sara Del-Rosario ¹, Yeray Brito-Casillas ², Sergio Martin ¹, Andrea Paolini ³, Anabel Mateo-Cebrián ⁴ and Raquel Rodríguez-Trujillo ⁵

¹ Departamento de Patología Animal, Universidad de Las Palmas de Gran Canaria, Trasmontaña S/N, 35416 Arucas, Spain

² Instituto Universitario de Investigaciones Biomédicas y Sanitarias, Universidad de Las Palmas de Gran Canaria, 35016 Las Palmas de Gran Canaria, Spain

³ Small Animal Surgery and Anesthesia Service, Department of Veterinary Medicine, University of Teramo, 64100 Teramo, Italy

⁴ Independent Researcher, Las Palmas de Gran Canaria, Spain

⁵ Unit of Reproduction, University Institute of Biomedical Research and Health, University of Las Palmas de Gran Canaria, Trasmontaña s/n, 35413 Arucas, Las Palmas, Spain

* Correspondence: pedro.figueirinhas@ulpgc.es

Simple Summary

Sheep are widely used in experimental orthopaedic research, and ensuring effective pain management during and after surgery is essential for animal welfare and for the reliability of scientific results. General anaesthesia alone may not always provide adequate analgesia during invasive procedures. This study evaluated whether combining general anaesthesia with ultrasound-guided nerve blocks of the sciatic and saphenous nerves could improve pain control in sheep undergoing hindlimb orthopaedic surgery. Two local anaesthetics, lidocaine and bupivacaine, were compared. Sheep receiving nerve blocks showed greater physiological stability during surgery and lower pain scores after surgery than animals receiving general anaesthesia alone. Among the two local anaesthetics, bupivacaine provided more consistent and longer-lasting pain relief than lidocaine. These results suggest that ultrasound-guided peripheral nerve blocks, particularly when performed with long-acting local anaesthetics, are an effective and practical approach to improve perioperative analgesia and animal welfare in sheep used for experimental orthopaedic procedures.

Abstract

The demand for refined anaesthetic protocols in ovine experimental surgery has increased due to ethical considerations and the need to improve perioperative stability. This study evaluated the analgesic efficacy of ultrasound-guided combined sciatic and saphenous nerve blocks using two different local anaesthetics in Hair Canarian Sheep undergoing invasive orthopaedic hindlimb surgery. Fifteen clinically healthy sheep were randomly assigned to one of three groups: lidocaine (2%), bupivacaine (0.5%), or control (general anaesthesia alone). Intraoperative physiological parameters, including heart rate, respiratory rate, and arterial blood pressure, were recorded, and postoperative pain was assessed using a modified Melbourne Pain Scale. Sheep receiving locoregional anaesthesia showed improved intraoperative physiological stability and significantly lower postoperative pain scores compared with control animals. The bupivacaine group exhibited the lowest and most stable heart and respiratory rates during surgery, as well as consistently lower pain scores during the early postoperative period. Lidocaine provided adequate intraoperative

analgesia but showed a reduction in postoperative efficacy over time. Respiratory rate correlated more strongly with pain scores than other physiological parameters. In conclusion, ultrasound-guided sciatic and saphenous nerve blocks significantly enhance perioperative analgesia in sheep undergoing orthopaedic surgery. The use of bupivacaine resulted in superior and longer-lasting analgesia compared to lidocaine, supporting its inclusion in multimodal anaesthetic protocols to improve animal welfare and refinement in ovine experimental models.

Keywords: sheep; ultrasound-guided peripheral nerve block; multimodal anaesthesia; bupivacaine; animal welfare

1. Introduction

The demand for refined anaesthetic protocols in veterinary practice and biomedical research has driven the advancement of multimodal strategies to improve perioperative care, particularly in species with unique physiological challenges such as ruminants. Small ruminants, especially sheep (*Ovis aries*), are widely used in translational research due to their manageable size, docile temperament, and anatomical similarities to humans in orthopaedic and implant studies [1–3]. Among these, the Hair Canarian Sheep breed has gained interest in experimental surgery due to its adaptability and availability in the Canary Islands.

Anaesthetic management in ruminants presents species-specific considerations that differ significantly from those in monogastric animals. Their high salivary output, susceptibility to regurgitation, ruminal tympany, and ventilation–perfusion mismatch during recumbency make them particularly vulnerable during general anaesthesia [4]. Moreover, the anatomical features of their airway complicate the process of endotracheal intubation, requiring careful technique and appropriate positioning to ensure airway protection and avoid aspiration pneumonia [5,6]. The physiological stress induced by these procedures can be minimized through the use of balanced anaesthetic protocols that combine general and regional techniques for improved patient stability [7,8].

In line with current trends in veterinary anaesthesia, the integration of loco-regional anaesthetic techniques into multimodal protocols has shown considerable promise. Regional anaesthesia, particularly in orthopaedic procedures, enhances analgesia, reduces the requirement for inhalational agents, improves cardiovascular stability, and contributes to smoother recoveries [9,10]. Peripheral nerve blocks (PNBs), especially those targeting the sciatic and saphenous nerves, have emerged as effective techniques for hindlimb anaesthesia in companion animals and are increasingly being explored in ruminants [11]. These nerves innervate the majority of the pelvic limb distal to the mid-femur, making them suitable targets for blocking nociceptive input during orthopaedic interventions involving the tibia and stifle.

Ultrasound guidance has become the gold standard for the administration of PNBs, allowing for direct visualization of the needle and perineural structures, thereby increasing the precision and safety of the block [12,13]. Despite its advantages, the application of ultrasound-guided nerve blocks in sheep remains limited in the literature, with most available data extrapolated from studies in dogs, goats, and cattle [9,14,15]. Furthermore, comparative information regarding the efficacy and duration of different local anaesthetic agents in sheep undergoing PNBs is scarce, especially under clinical surgical conditions.

The choice of local anaesthetic plays a critical role in the success of peripheral nerve blocks. Lidocaine, with its rapid onset and intermediate duration of action, is often preferred for short procedures, while bupivacaine offers a longer duration of analgesia but with a slower onset [16]. Understanding the clinical performance of these agents in ovine models is essential for both veterinary and translational applications. However, controlled comparative studies evaluating their intraoperative and postoperative analgesic efficacy in small ruminants are lacking.

In addition to providing adequate analgesia, objective and reliable pain assessment is fundamental for evaluating the efficacy of anaesthetic techniques. As prey species, sheep are known to exhibit stoic behaviour, often masking signs of discomfort or pain, particularly in the presence of humans [17]. Therefore, behavioural scoring systems, such as the adapted University of Melbourne Pain Scale, are essential tools for assessing pain in this species [18,19]. These multidimensional scales combine physiological, behavioural, and biological parameters to provide a more comprehensive evaluation of the animal's pain status.

In this context, the present study aimed to evaluate the clinical efficacy of combined ultrasound-guided sciatic and saphenous nerve blocks in Hair Canarian Sheep undergoing invasive orthopaedic hindlimb surgery. Specifically, the study compared the intraoperative and early postoperative analgesic effects of two local anaesthetic agents—lidocaine and bupivacaine—based on cardiovascular parameters and multidimensional pain scoring. The findings aim to contribute to the refinement of perioperative analgesia in sheep used in experimental orthopaedic models.

2. Materials and Methods

2.1. Animals

The study was conducted at the Veterinary Hospital of the University of Las Palmas de Gran Canaria (Spain), between March and November 2025. A total of fifteen clinically healthy Hair Canarian Sheep, comprising 5 males and 10 females, aged between 1 and 3 years and weighing between 40 and 50 kg, were included in the study. The animals were acquired from a local farm and acclimatized for at least one week prior to study onset. All sheep underwent a complete physical examination prior to enrolment and received routine antiparasitic treatment consisting of ivermectin (0.5 mL/25 kg SC; Vectimax®, 10 mg/mL), fenbendazole (5 mg/kg PO; Panacur®, 100 mg/mL), and deltamethrin (10 mL topical; Butox® Pour-On, 7.5 mg/mL). Food was withheld for 12–24 hours prior to anaesthesia to reduce the risk of regurgitation and aspiration, while water was available until 2 hours before premedication. All procedures were performed in accordance with Directive 2010/63/EU and Spanish Royal Decree 53/2013 on the protection of animals used for scientific purposes. The study protocol was reviewed and approved by the Ethics Committee for Animal Experimentation of the Universidad de Las Palmas de Gran Canaria (CEEA-ULPGC) and authorized by the competent authority (approval code: OEBA_ULPGC 16/2024).

2.2. Experimental Design

This prospective, randomized, controlled, and blinded experimental study evaluated the analgesic efficacy of ultrasound-guided peripheral nerve blocks performed with two different local anesthetics in sheep undergoing orthopedic hindlimb surgery. Fifteen animals were randomly allocated to three groups (n = 5 each). Sheep in the lidocaine group received ultrasound-guided sciatic and saphenous nerve blocks with 2% lidocaine at a total dose of 1 mg/kg, while animals in the bupivacaine group received the same blocks using 0.5% bupivacaine at an equivalent dose. The control group received systemic analgesia without locoregional techniques.

All animals underwent a standardized unilateral tibial ostectomy with placement of a titanium scaffold. The same surgical team and anesthetic protocol were used for all procedures, and nerve blocks were performed by the same experienced anesthetist. The surgical side was alternated between animals to minimize positional bias. Intraoperative physiological variables, including heart rate, respiratory rate, mean arterial pressure, oxygen saturation, and body temperature, were recorded. Postoperative pain was assessed at 2 and 4 hours after extubation using a species-adapted version of the University of Melbourne Pain Scale. The requirement for rescue analgesia was recorded as a secondary outcome. All evaluations were performed by a single blinded observer.

2.2.1. Premedication and Induction of Anaesthesia

All sheep were premedicated intravenously with xylazine (0.05 mg/kg) and ketamine (0.4 mg/kg) and left undisturbed for 15 minutes. Premedication with alpha-2 agonists such as xylazine has been shown to improve sedation quality and contribute to balanced anesthesia in large ruminants, supporting its use in protocols designed to minimize perioperative stress and nociception [20]. After adequate sedation, a 20 G intravenous catheter was aseptically placed in either the cephalic or saphenous vein. Anaesthesia was induced with intravenous propofol (1 mg/kg), titrated to effect, and endotracheal intubation was performed using a cuffed tube under direct laryngoscopic visualization. An orogastric tube was placed following intubation to reduce the risk of ruminal tympany and regurgitation. Baseline physiological parameters were recorded during the sedation period.

2.2.2. Locoregional Anaesthesia

Ultrasound-guided peripheral nerve blocks of the sciatic and saphenous nerves were performed to provide locoregional anaesthesia of the pelvic limb. For the saphenous nerve block, animals were positioned in lateral recumbency with the surgical limb uppermost, and a linear ultrasound transducer was placed on the medial aspect of the mid-thigh to identify the femoral neurovascular bundle. The saphenous nerve was visualized as a hypoechoic structure caudal to the femoral artery, and a 22 G echogenic needle was advanced in-plane until positioned adjacent to the nerve. For the sciatic nerve block, the transducer was placed on the lateral aspect of the thigh, distal to the greater trochanter and ischiatic tuberosity, allowing identification of the sciatic nerve as a hypoechoic double-discoid structure. The needle was advanced in-plane toward the nerve under continuous ultrasound visualization. Animals in the lidocaine and bupivacaine groups received their respective local anesthetics at a total dose of 1 mg/kg, divided between the two nerve blocks. No locoregional anaesthesia was performed in the control group.

2.2.3. Maintenance of Anaesthesia

Anaesthesia was maintained with sevoflurane in oxygen delivered via a rebreathing system. Mechanical ventilation using pressure support ventilation was applied throughout surgery. Lactated Ringer's solution was administered intravenously at 3 mL/kg/h. Heart rate, respiratory rate, arterial blood pressure, oxygen saturation, and rectal temperature were continuously monitored and recorded every five minutes. An increase of $\geq 25\%$ in heart rate or mean arterial pressure compared with baseline values was considered indicative of nociception and treated with intravenous butorphanol (0.05 mg/kg) as rescue analgesia. Supportive measures were provided as required based on individual physiological responses.

2.2.4. Recovery and Postoperative Care

Following surgery, all animals underwent postoperative radiographic evaluation to confirm implant positioning and were then transferred to individual recovery pens, where they were positioned in sternal recumbency as soon as possible. Extubation was performed after the return of swallowing reflexes. Postoperative treatment consisted of a single subcutaneous dose of meloxicam (0.2 mg/kg) and long-acting oxytetracycline (20 mg/kg), both administered immediately after extubation. Animals were continuously monitored postoperatively using a video surveillance system, allowing real-time remote observation and detection of abnormal behaviour or signs of discomfort.

2.3. Pain Assessment

Pain assessment was performed using an adapted version of the Melbourne Pain Scale incorporating the modifications proposed by Ahern [18]. This multidimensional scale is suitable for the evaluation of both conscious and semi-conscious animals and allows standardized quantification

of nociceptive responses before and after surgical procedures. The assessment included physiological variables such as heart rate, respiratory rate, rectal temperature, and arterial blood pressure, together with biological indicators including pupillary dilation and salivation. Behavioural responses, namely reaction to palpation, locomotor activity, mental status, posture, and vocalisation, were also considered. In its original formulation, the Melbourne Pain Scale yields a maximum score of 27 points, with pain intensity classified as absent, mild, moderate, or severe according to established thresholds. In the present study, the maximum achievable score was reduced to 22 points due to the exclusion of components not applicable under general anaesthesia. All pain evaluations were conducted by the same trained and blinded observer in order to minimize inter-observer variability and ensure consistency in scoring.

Reference Physiological Parameters

Interpretation of physiological variables required consideration of normal reference values in sheep, as well as individual and environmental variability such as temperament, nutritional status, ambient temperature, or circadian influences [21,22]. Bradycardia was defined as HR < 55 bpm and tachycardia as HR > 140 bpm, considering the average baseline HR in adult sheep to be approximately 75 bpm [23]. Normal reference values for arterial blood pressure in sheep are as follows: SAP: 90–120 mmHg, DAP: 60–80 mmHg and MAP: 75–100 mmHg. Hypotension under general anaesthesia was defined as MAP < 65 mmHg, and hypertension as SAP > 120 mmHg or MAP > 100 mmHg [6,24]. Oxygen saturation (SpO₂) values above 95% were considered acceptable, with optimal ranges between 98% and 100%, as reported in veterinary anaesthesia guidelines [25–28].

3. Results

The anesthetic parameters evaluated throughout the procedure demonstrated notable differences between the treatments (lidocaine, bupivacaine, and control) (Table 1). The SpO₂ values remained relatively stable in all groups, with no clinically relevant desaturation observed at any timepoint. Significant differences were found in HR, particularly at baseline (T0), where the control group showed markedly higher values compared to lidocaine and bupivacaine groups ($p < 0.05$). This trend was generally maintained throughout the monitoring period, with the lowest HR observed in the bupivacaine group. Likewise, the RR was significantly lower in the bupivacaine group across all timepoints, while the control group exhibited consistently higher values ($p < 0.05$). Animals in the lidocaine group showed intermediate RR values. Regarding SAP, all groups experienced a progressive increase over time; however, animals treated with bupivacaine presented the highest SAP values, particularly from T2 onward. Both DAP and MAP increased steadily throughout the procedure. The control group tended to present higher values, especially for DAP, while pressure values in the lidocaine group were consistently lower

Table 1. Anesthetist parameters evaluated between different groups.

Anesthetic parameters		LIDO	BUPI	CONTROL
SPO2	T0	94.233	94.467	97.8
	T1	93.260	96.267	96.067
	T2	92.293	95.900	94.983
	T3	92.570	96.850	94.733
	T4	94.375	96.167	95.291
HR	T0	96.470 ^a	101.800 ^b	13.367 ^c
	T1	114.457	92.533	121.883
	T2	100.247	92.367	117.917
	T3	102.140	92.400	122.500
	T4	99.550	90.400	116.600

RR	T0	25.740 ^a	20.250 ^b	36.667 ^c
	T1	37.483 ^a	17.063 ^b	38.312 ^c
	T2	32.587 ^a	17.183 ^b	34.417 ^c
	T3	30.810 ^a	19.783 ^b	33.967 ^c
	T4	30.760 ^a	33.967 ^b	36.033 ^c
SAP	T0	99.753	106.133	112.767
	T1	103.857	118.050	124.083
	T2	117.330	123.267	128.483
	T3	122.230	125.667	124.333
	T4	1212.630	125.500	123.333
DAP	T0	54.967	54.133	68.100
	T1	59.703	67.833	74.450
	T2	69.473	69.333	75.650
	T3	74.850	71.967	79.767
	T4	79.660	72.733	72.933
MAP	T0	70.277	71.500	83.067
	T1	74.167	83.350	96.117
	T2	85.587	89.283	99.600
	T3	89.430	89.450	97.400
	T4	93.940	91.200	95.500

Different letters (a, b, c) denote significant differences between treatment groups ($p < 0.05$).

The analysis of HR, RR, and MAP revealed distinct patterns among the three anesthetic protocols evaluated (lidocaine, bupivacaine, and control), as summarized in Figure 1. The control group consistently presented the highest HR, with mean values ranging from 117.91 to 122.50 bpm across timepoints, while the bupivacaine group maintained significantly lower and stable HR values (92.37–92.53 bpm). In the lidocaine group, HR values were intermediate and showed slightly greater variability (100.25–114.46 bpm). Regarding respiratory rate, bupivacaine-treated animals exhibited the lowest RR throughout anesthesia (17.18–19.78 bpm), with very narrow variation, suggesting stable respiratory depression. The control group showed the highest RR, especially during the initial timepoints (33.96–38.00 bpm). Lidocaine-treated animals had intermediate and slightly fluctuating RR values (30.81–33.93 bpm). In terms of mean arterial pressure (MAP), all groups showed relatively stable trends. However, the control group exhibited the highest MAP values (96.12–99.60 mmHg), while both bupivacaine and lidocaine groups showed lower pressures, ranging from 83.35 to 89.45 mmHg in bupivacaine and 74.17 to 89.43 mmHg in lidocaine.

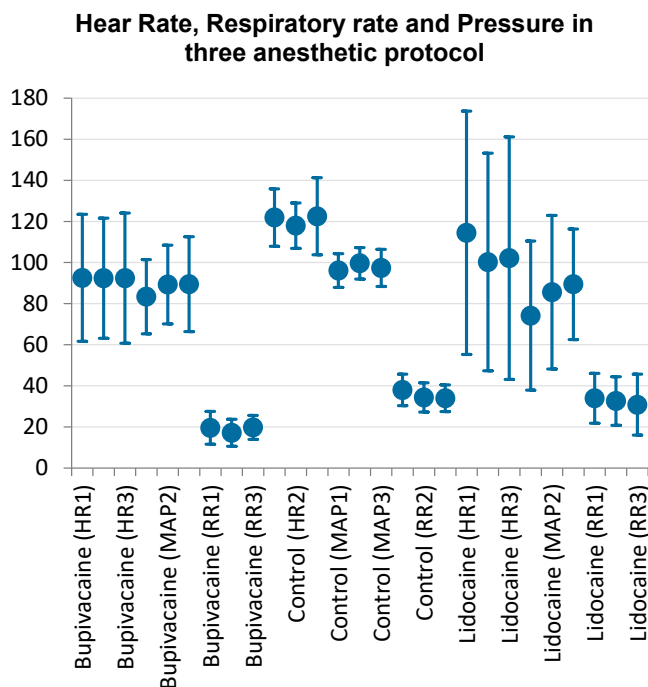


Figure 1. Heart rate (HR), respiratory rate (RR), and mean arterial pressure (MAP) measured at three different timepoints across treatment groups: lidocaine, bupivacaine, and control.

Data are presented as mean \pm SD.

Pain evaluation at two postoperative timepoints revealed significant differences among treatment groups (Table 2). Animals in the control group exhibited the highest pain scores at both timepoints (8.0 and 8.2, respectively), followed by the lidocaine group and the bupivacaine group, which consistently showed the lowest scores ($p < 0.05$). In the lidocaine group, a significant increase in pain score was observed between the two timepoints ($p < 0.05$), whereas pain scores remained stable in the bupivacaine and control groups.

Table 2. Pain scores (mean values) at two postoperative timepoints (Pain-1 and Pain-2) in animals treated with lidocaine, bupivacaine, or control.

	PAIN-1	PAIN-2
LIDOCAINE	6.8 ^{a1}	7.4 ^{a2}
BUPIVACAINE	4 ^b	4.2 ^b
CONTROL	8 ^c	8.2 ^c

Different letters (a, b, c) denote significant differences between treatment groups ($p < 0.05$), while different numbers (1, 2) within the same treatment indicate significant differences over time.

Pearson's correlation analysis between pain scores (Pain-1) and physiological parameters at corresponding intraoperative timepoints revealed several statistically significant associations (Table 3). Notably, moderate to strong positive correlations were identified between Pain-1 and RR at T1, T2, and T3, indicating that increased pain was associated with higher respiratory activity. A weaker but significant correlation was also observed between Pain-1 and heart rate (HR) at T3 ($r = 0.521$, $p = 0.05$). In contrast, no significant correlations were found between pain scores and MAP at any of the evaluated timepoints.

Table 3. Pearson's correlation coefficients (r) between Pain-1 scores and physiological parameters (heart rate, respiratory rate, mean arterial pressure) at different intraoperative timepoints (T1–T3).

	Corr	p-value
PAIN 1 – HR (T1)	0.386	0.06
PAIN 1 – HR (T2)	0.388	0.07
PAIN 1– HR (T3)	0.521*	0.05
PAIN 1– RR (T1)	0.662***	0.001
PAIN 1– RR (T2)	0.760***	0.001
PAIN 1– RR (T3)	0.694**	0.005
PAIN 1 – MAP (T1)	0.034	0.908
PAIN 1 – MAP (T2)	0.093	0.750
PAIN 1 – MAP (T3)	0.160	0.58

Correlation was significant at 0,5 % (p <0.005), *Correlation was significant at 1% (p <0.01),

*Correlation was significant at 5% (p <0.05).

Further correlation analysis between Pain-2 scores and physiological parameters at intraoperative timepoints revealed patterns broadly consistent with those observed for Pain-1 (Table 4). Significant moderate positive correlations were observed between Pain-2 and respiratory rate (RR) at T1 (r = 0.658, p = 0.01) and T2 (r = 0.574, p = 0.03), indicating an association between higher pain scores and increased respiratory activity at these timepoints. No statistically significant correlations were found between Pain-2 and either heart rate or mean arterial pressure (MAP).

Table 4. Pearson's correlation coefficients (r) between Pain-2 scores and physiological parameters (heart rate, respiratory rate, mean arterial pressure) at different intraoperative timepoints (T1–T3).

	Corr	p-value
PAIN 2 – HR (T1)	0.419	0.135
PAIN 2 – HR (T2)	0.316	0.271
PAIN 2– HR (T3)	0.371	0.190
PAIN 2– RR (T1)	0.658**	0.01
PAIN 2– RR (T2)	0.574*	0.03
PAIN 2– RR (T3)	0.465	0.09
PAIN 2 – MAP (T1)	0.309	0.282
PAIN 2 – MAP (T2)	0.304	0.289
PAIN 2 – MAP (T3)	0.290	0.314

***Correlation was significant at 0,5 % (p <0.005), **Correlation was significant at 1% (p <0.01),

*Correlation was significant at 5% (p <0.05).

4. Discussion

The present study demonstrates that the incorporation of ultrasound-guided combined sciatic and saphenous nerve blocks into a multimodal anaesthetic protocol significantly improves perioperative stability and postoperative analgesia in Hair Canarian Sheep undergoing invasive orthopaedic surgery. These findings reinforce the growing evidence supporting the use of peripheral nerve blocks (PNBs) as refinement strategies in veterinary anaesthesia [29].

Ultrasound-guided sciatic and femoral/saphenous nerve blocks have been anatomically validated in sheep and shown to provide reliable limb desensitization [31]. Furthermore, ultrasound guidance improves block accuracy and reduces the risk of complications compared with landmark-based techniques [30]. The physiological stability observed in the present study aligns with previous reports demonstrating that regional anaesthesia reduces intraoperative stress responses and inhalant requirements in veterinary patients [32].

Pain assessment in sheep is inherently challenging due to their prey-species behaviour and tendency to mask clinical signs of discomfort. Recent literature highlights persistent gaps and

opportunities in ovine pain management strategies [33]. The present findings suggest that respiratory rate may represent a more sensitive intraoperative marker of nociceptive activation than cardiovascular parameters alone.

These results are consistent with the pharmacological properties of the two agents. Lidocaine is characterized by rapid onset and intermediate duration, whereas bupivacaine provides prolonged sensory blockade due to its higher lipid solubility and protein binding [34]. Comparative pharmacological discussions support the preferential use of longer-acting local anaesthetics when sustained postoperative analgesia is required [34].

Sheep are widely used in translational orthopaedic research due to anatomical and biomechanical similarities to humans [35,36]. Their cortical bone structure, load-bearing characteristics, and bone remodelling dynamics make them valuable large-animal models for implant evaluation and regenerative strategies. However, perioperative nociception and postoperative severity may influence physiological responses capable of affecting experimental outcomes [37]. The implementation of ultrasound-guided sciatic and saphenous nerve blocks therefore represents both an ethical refinement aligned with the 3Rs framework and a methodological strategy to enhance experimental reproducibility.

5. Conclusions

This Ultrasound-guided combined sciatic and saphenous nerve blocks significantly improved intraoperative physiological stability and postoperative analgesia in Hair Canarian Sheep undergoing invasive orthopaedic hindlimb surgery. The incorporation of locoregional anaesthesia reduced nociceptive responses compared to general anaesthesia alone, as evidenced by lower heart rate, respiratory rate, and postoperative pain scores. Among the local anaesthetics evaluated, bupivacaine provided superior and longer-lasting analgesia compared to lidocaine, resulting in more consistent intraoperative stability and sustained postoperative comfort. These findings support the inclusion of long-acting local anaesthetics in multimodal anaesthetic protocols for sheep, contributing to improved animal welfare and refinement of experimental orthopaedic models.

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