Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Adjunctive acupuncture improves postoperative pain control and early functional recovery after stifle joint surgery in dogs: a prospective randomized controlled clinical trial

shuman Liu
China Agricultural University
Han Zhang
China agricultural university veterinary teaching hospital
Zhihui Hao
China Agricultural University
Gebin Li
China Agricultural University
Kai Fan
China Agricultural University
Zhankui Yuan
China Agricultural University
Shuaiyu Wang
wangshuaiyu2016@cau.edu.cn
China Agricultural University

Research Article

Keywords: Acupuncture, electroacupuncture, postoperative pain, multimodal analgesia, canine, stifle surgery

Posted Date: July 30th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10151414/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Adjunctive acupuncture improves postoperative pain control and early functional recovery after stifle joint surgery in dogs: a prospective randomized controlled clinical trial

Shuman Liu,Han Zhang,Zhihui Hao,Gebin Li,Kai Fan,Zhankui Yuan,Shuaiyu Wang(corresponding author)，College of Veterinary Medicine, China Agricultural University, Beijing, China,e-mail:wangshuaiyu2016@cau.edu.cn

Abstract

Background: Postoperative pain management remains a major challenge in canine orthopedic surgery. Although acupuncture has demonstrated analgesic effects in both human and veterinary medicine, high-quality clinical evidence in dogs remains limited. This study evaluated whether adjunctive acupuncture could improve postoperative pain control and early functional recovery in dogs undergoing stifle joint surgery.

Results: Dogs receiving adjunctive acupuncture showed significantly lower CMPS-SF scores at 12 h and 48 h postoperatively, lower CSU-CAPS scores at 24 h, and lower joint manipulation scores at 3 h compared with controls ($P < 0.05$). Significant improvements were also observed in changes in stifle circumference at T48 – T0 and ROM at T72 – T0 ($P < 0.05$). No significant differences were detected in lameness scores or serum β-endorphin concentrations. Only one dog in the acupuncture group required rescue analgesia. No acupuncture-related adverse events were observed.

Conclusions: Adjunctive acupuncture may improve postoperative pain management and early functional recovery in dogs undergoing stifle joint surgery when combined

with multimodal analgesia. Acupuncture appears to be a safe complementary intervention for perioperative pain management in veterinary clinical practice.

Keywords: Acupuncture;electroacupuncture;postoperative pain; multimodal analgesia; canine; stifle surgery

Introduction

Postoperative pain remains a major clinical challenge in veterinary orthopedic surgery and has important implications for animal welfare and recovery outcomes [1]. Dogs undergoing stifle joint surgery commonly experience moderate to severe postoperative pain, particularly within the first 24 – 48 h after surgery [2]. Inadequate pain control may contribute to delayed functional recovery, impaired mobility, prolonged hospitalization, and adverse neuroendocrine and inflammatory responses [3, 4]. Therefore, effective perioperative analgesia is considered a fundamental component of contemporary veterinary practice [5].

Because animals cannot verbally communicate pain, behavioral assessment tools remain the primary method for evaluating postoperative pain in veterinary patients [6]. Among the currently available instruments, the Glasgow Composite Measure Pain Scale – Short Form (CMPS-SF) and the Colorado State University Canine Acute Pain Scale (CSU-CAPS) are widely used and clinically validated for assessing acute pain in dogs [7].

Multimodal analgesia, which combines analgesic agents with different mechanisms of action, is currently regarded as the standard approach for perioperative pain

management in veterinary medicine [8].Commonly used protocols may include opioids, nonsteroidal anti-inflammatory drugs (NSAIDs), local anesthetics, and adjunctive analgesics. However, pharmacological analgesia alone may not always provide optimal pain control and can be associated with adverse effects such as gastrointestinal disturbances, sedation, cardiovascular depression, and delayed recovery [9]. Consequently, increasing attention has been directed toward complementary non-pharmacological interventions that may enhance analgesic efficacy while reducing drug-related complications.

Acupuncture has been increasingly incorporated into veterinary rehabilitation and pain management programs. Previous experimental and clinical studies have suggested that acupuncture and electroacupuncture may exert analgesic effects through multiple mechanisms, including modulation of endogenous opioid release, regulation of neurotransmitters such as serotonin and norepinephrine, and attenuation of inflammatory responses [10–13]. In veterinary medicine, acupuncture has shown potential benefits in dogs undergoing spinal surgery and in patients with neurologic or musculoskeletal disorders [14–16]. In addition, electroacupuncture has been associated with reduced postoperative analgesic requirements in several animal studies [17].

Despite these promising findings, high-quality prospective controlled clinical studies evaluating acupuncture for postoperative pain management in dogs remain limited. Many previous studies have been constrained by small sample sizes, heterogeneous methodologies, inconsistent outcome measures, or limited assessment of functional

recovery [18]. Furthermore, objective biomarkers potentially associated with acupuncture-mediated analgesia, such as β-endorphin, have not been sufficiently investigated in canine surgical patients.

Therefore, the present study was designed as a prospective randomized controlled clinical trial to evaluate the efficacy of adjunctive acupuncture in dogs undergoing stifle joint surgery. We hypothesized that acupuncture combined with standardized multimodal analgesia would reduce postoperative pain and improve early functional recovery compared with multimodal analgesia alone. To comprehensively assess clinical outcomes, both subjective pain scoring systems and objective recovery-related indicators, including range of motion, stifle circumference, and serum β-endorphin concentrations, were evaluated.

2. Materials and Methods

2.1 Study design and ethical approval

This study was designed as a prospective randomized controlled clinical trial. The study protocol was approved by the Institutional Animal Care and Use Committee (IACUC) of China Agricultural University (approval number: XXX). Written informed consent was obtained from all owners prior to enrollment.

Client-owned dogs presented to the Veterinary Teaching Hospital of China Agricultural University between June 2021 and March 2022 for unilateral stifle joint surgery were considered eligible for inclusion.

2.2 Animals

Twenty dogs diagnosed with patellar luxation and/or cranial cruciate ligament disease and scheduled for elective unilateral stifle surgery were initially enrolled.

The inclusion criteria were as follows:

1. Requirement for unilateral stifle joint surgery;
2. American Society of Anesthesiologists (ASA) physical status I – II;
3. No previous acupuncture treatment within 30 days before surgery;
4. Owner consent for participation.

The exclusion criteria included:

1. Severe systemic disease, including cardiac, hepatic, or renal dysfunction;
2. Neurological disorders;
3. Skin infection or dermatitis at acupuncture sites;
4. Pregnancy or lactation;
5. Coagulation abnormalities.

Four dogs were excluded during the study because of postoperative stress, loss to follow-up, or protocol deviations. Consequently, 16 dogs completed the study and were included in the final analysis (8 dogs per group).

2.3 Randomization and blinding

Dogs were randomly allocated to either the acupuncture group or the control group using a computer-generated randomization sequence.

Pain and functional assessments were performed by a single investigator who was blinded to treatment allocation throughout the study period. Dog owners were not informed of group assignment during postoperative evaluation.

2.4 Anesthesia and perioperative management

Food was withheld for 6-8 h before anesthesia, while water was available until 2 h preoperatively.

All dogs underwent standardized anesthetic and perioperative management. Premedication consisted of opioid and sedative administration according to institutional protocols. General anesthesia was induced intravenously and maintained using inhalational anesthesia with endotracheal intubation.

2.5 Multimodal analgesic protocol

All dogs received a standardized multimodal analgesic regimen consisting of:

1. Lidocaine constant-rate infusion (50 μg/kg/min, intravenous);
2. Carprofen (4.4 mg/kg, subcutaneously, once daily);
3. Gabapentin (10 mg/kg, orally, twice daily);
4. Cryotherapy applied to the surgical site three times daily.

The analgesic protocol was maintained for 72 h postoperatively.

2.6 Acupuncture treatment

In addition to multimodal analgesia, dogs assigned to the acupuncture group received adjunctive acupuncture treatment immediately after extubation and subsequently every 24 h for 72 h.

The selected acupoints included ST-34 (Liangqiu), SP-10 (Xuehai), GB-34 (Yanglingquan), KID-10 (Yingu), Baihui, ST-36 (Zusanli), GV-14 (Dazhui), KID-3 (Taixi), and BL-23 (Shenshu), based on established veterinary acupuncture references and clinical experience.

Sterile disposable acupuncture needles were inserted using standard veterinary acupuncture techniques. Manual acupuncture stimulation was applied to all acupoints except Baihui and ST-36, which were connected to an electroacupuncture device (2/100 Hz dense-disperse wave; stimulation intensity 0.5 – 1.5 mA). Electrical stimulation intensity was gradually increased until mild visible muscle contraction was observed.

Each treatment session lasted 20 min and was performed by the same experienced veterinary acupuncturist.

2.7 Outcome assessment

The observation period extended to 72 h postoperatively. Baseline measurements were obtained 1 h before surgery (T0). Subsequent assessments were performed at 3, 6, 12, 24, 36, 48, 60, and 72 h after extubation.

The primary outcome was postoperative pain intensity, assessed using:

- Glasgow Composite Measure Pain Scale – Short Form (CMPS-SF);
- Colorado State University Canine Acute Pain Scale (CSU-CAPS).

Secondary outcomes included:

- Joint manipulation score;
- Lameness score;
- Stifle circumference;
- Range of motion (ROM);
- Physiological variables;

- Requirement for rescue analgesia;
- Postoperative complications;
- Serum β-endorphin concentration.

2.8 Rescue analgesia

Rescue analgesia was administered when the CMPS-SF score reached ≥ 10/24. Butorphanol (0.2 mg/kg, subcutaneously) was used as rescue analgesia. Continuous-rate infusion of dexmedetomidine (0.1 μg/kg/h) was permitted if clinically indicated because of excessive agitation or stress.

2.9 Serum β-endorphin Measurement

Venous blood samples were collected at baseline (T0) and 72 h postoperatively (T72). Samples were centrifuged, and serum was stored at −20 ℃ until analysis. Serum β-endorphin concentrations were measured using a commercially available enzyme-linked immunosorbent assay (ELISA) kit according to the manufacturer's instructions.

2.10 Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA) and GraphPad Prism version 8.0 (GraphPad Software, San Diego, CA, USA).

Data distribution was evaluated using the Shapiro–Wilk test. Normally distributed continuous variables were expressed as mean ± standard deviation (SD), whereas non-normally distributed variables were presented as median and range.

Between-group comparisons at individual time points were performed using the

177 independent-samples t-test or Mann–Whitney U test, as appropriate.

178 Repeated-measures data were analyzed using linear mixed-effects models with
179 treatment group and time as fixed effects and subject as a random effect. Bonferroni
180 correction was applied for post hoc multiple comparisons.

181 Categorical variables were analyzed using the chi-square test or Fisher's exact test. A
182 value of $P < 0.05$ was considered statistically significant.

183

184 **3. Results**

185 **3.1 Study population and baseline characteristics**

186 Twenty dogs were initially enrolled in the study. Four dogs were excluded because of
187 postoperative stress, loss to follow-up, or protocol deviations. Consequently, 16 dogs
188 completed the study and were included in the final analysis, with 8 dogs allocated to
189 each group.

190 No significant differences were identified between the acupuncture and control groups
191 regarding age, body weight, body condition score (BCS), disease characteristics, or
192 baseline outcome measurements ($P > 0.05$; Table 1).

193 Table 1 Baseline demographic and clinical characteristics of dogs included in the
194 study

Variable	Acupuncture Group	Control Group	*P* value
Breed			
Yorkshire Terrier	—	1	

Poodle	2	1	
Bichon Frise	2	—	
Shiba Inu	—	2	
Corgi	—	1	
Pug	—	1	
Samoyed	—	1	
Labrador Retriever	4	1	
Sex			
M (Male)	1	7	
MC (Neutered Male)	4	1	
F (Female)	2	—	
FS (Spayed Female)	1	—	
Age (y)	7(4,11)	3.5(1.5,8)	0.371
Weight (kg)	21.4(5.5,41.7)	11.7(2.8,50.7)	0.382
BCS (/9)	6.5(4,7)	5(4,9)	0.117
Affected Joint(s)			
Unilateral MPL	3	4	
Bilateral MPL	1	—	
Unilateral CCLD	—	2	
Bilateral CCLD	2	1	
Unilateral MPL + Unilateral CCLD	1	—	
Bilateral MPL + Unilateral CCLD	2	—	

Baseline Measurements			
CMPS-SF Score (/24)	1(1,2)	1(1,9)	0.645
CSU-CAPS Score (/4)	0(0,0)	0(0,4)	0.721
Joint Manipulation Score (/4)	0(0,0)	0(0-4)	0.721
Lameness Score (/5)	2(2,4)	3(1,5)	0.645
Knee Joint Diameter (cm)	25.1(14,34.0)	19.0(12.1,35.2)	0.721
Range of Motion (°)	93(30,120)	105(88,124)	0.645
Temperature (°C)	38.2(37.9,38.7)	38.6(37,40)	0.574
Heart Rate (bpm)	98(78,120)	110(90,160)	0.195
Respiratory Rate (bpm)	33(16,60)	60(24,60)	0.161
Blood Pressure (mmHg)	151.5(124,210)	155(128,175)	0.721

Note: Baseline characteristics of dogs in the acupuncture and control groups. Data are presented as median (minimum, maximum). *P* values were calculated using the Mann-Whitney U test.

3.2 Postoperative pain assessment

3.2.1 Glasgow Composite Measure Pain Scale – Short Form (CMPS-SF)

Postoperative CMPS-SF scores were generally lower in the acupuncture group throughout the observation period. Significant between-group differences were

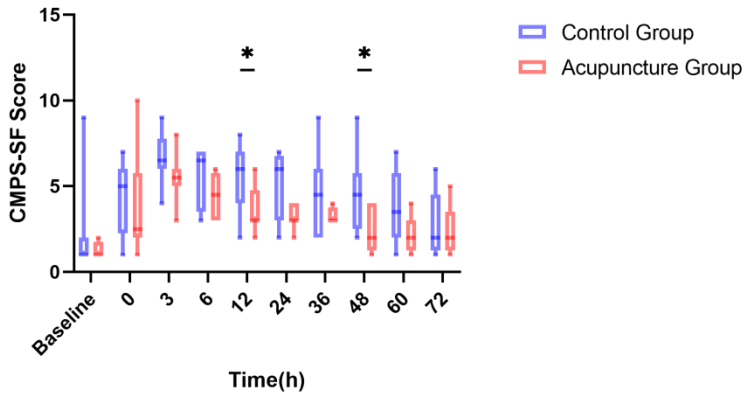
identified at 12 h and 48 h postoperatively, with dogs receiving acupuncture showing lower pain scores compared with controls ($P < 0.05$; Table 2, Figure 1).

Table 2 Comparison of postoperative CMPS-SF scores between groups

Time Point(h)	CMPS-SF Scores		*P* value
	Acupuncture Group	Control Group	
T0	2.5(1,10)	5.0(1,7)	0.505
T3	5.5(3,8)	6.5(4,9)	0.130
T6	4.5(3,6)	6.5(3,7)	0.130
T12	3.0(2,6)	6.0(2,7)	0.050*
T24	3.0(2,4)	6.0(2,7)	0.083
T36	3.0(3,4)	6.0(2,9)	0.505
T48	2.0(1,4)	4.5(2,9)	0.038*
T60	2.0(1,4)	3.5(1,7)	0.161
T72	2.0(1,5)	2.0(1,6)	0.721

Note: Data are presented as median (minimum, maximum). *$P < 0.05$ compared with the control group.

Figure 1 Boxplots of CMPS-SF scores over time in the two groups.



Note: Data are presented as median, interquartile range, and range. Significant between-group differences were observed at 12 h and 48 h postoperatively ($P < 0.05$).

3.2.2 Colorado State University Canine Acute Pain Scale (CSU-CAPS)

Dogs in the acupuncture group demonstrated lower CSU-CAPS scores than control dogs during the postoperative period. A statistically significant difference between groups was observed at 24 h postoperatively ($P = 0.028$; Table 3, Figure 2).

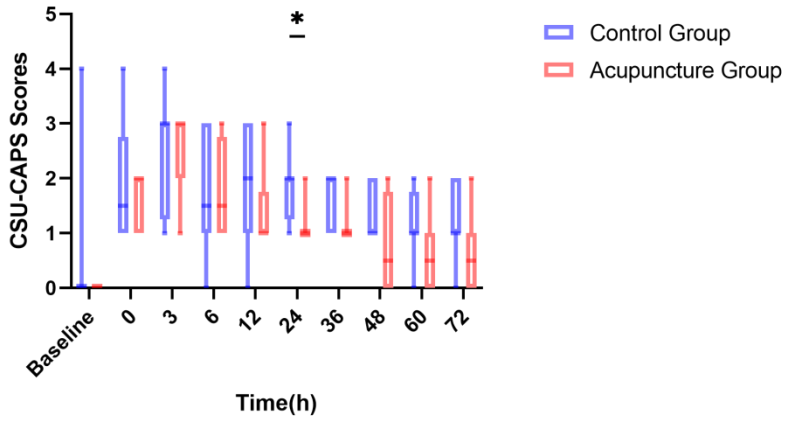
Table 3 Comparison of postoperative CSU-CAPS scores between groups

Time Point(h)	CSU-CAPS scores		*P* value
	Acupuncture Group	Control Group	
T0	2.0(1,2)	1.5(1,4)	0.959
T3	3.0(1,3)	3.0(1,4)	0.959
T6	1.5(1,3)	1.5(0,3)	1.000
T12	1.0(1,2)	2.0(0,3)	0.328
T24	1.0(1,2)	2.0(1,3)	0.028*
T36	1.0(1,2)	2.0(1,2)	0.105
T48	0.5(0,2)	1.0(1,2)	0.161

T60	0.5(0,2)	1.0(0,2)	0.195
T72	0.5(0,2)	1.0(0,2)	0.130

Note: Data are presented as median (minimum, maximum). *$P < 0.05$ compared with the control group.

Figure 2 Boxplots of CSU-CAPS scores over time in the two groups



Note: Data are presented as median, interquartile range, and range. A significant between-group difference was identified at 24 h postoperatively ($P < 0.05$).

3.2.3 Joint Manipulation Scores

Joint manipulation scores were lower in the acupuncture group during the early postoperative period. A significant between-group difference was detected at 3 h postoperatively, with lower scores observed in dogs receiving acupuncture ($P = 0.010$; Table 4, Figure 3).

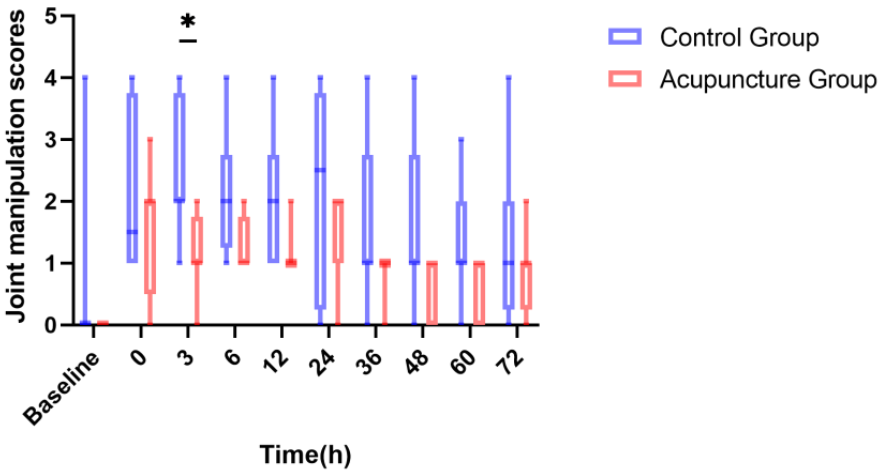
Table 4 Comparison of postoperative joint manipulation scores between groups

Time Point(h)	Joint manipulation Scores		*P* value
	Acupuncture Group	Control Group	
T0	2(0,2)	1.5(1,4)	0.721

T3	1(0,2)	2(1,4)	0.010*
T6	1(1,2)	2(1,4)	0.065
T12	1(1,2)	2(1,4)	0.083
T24	2(0,2)	2.5(0,4)	0.382
T36	1(0,1)	1(0,4)	0.279
T48	1(0,1)	1(0,4)	0.105
T60	1(0,1)	1(0,3)	0.105
T72	1(0,2)	1(0,4)	0.505

Note: Data are presented as median (minimum, maximum). *$P < 0.05$ compared with the control group.

Figure 3



Note: Data are presented as median, interquartile range, and range. A significant between-group difference was observed at 3 h postoperatively ($P < 0.05$).

3.3 Functional recovery outcomes

3.3.1 Lameness Score

There were no significant between-group differences were detected at any time point

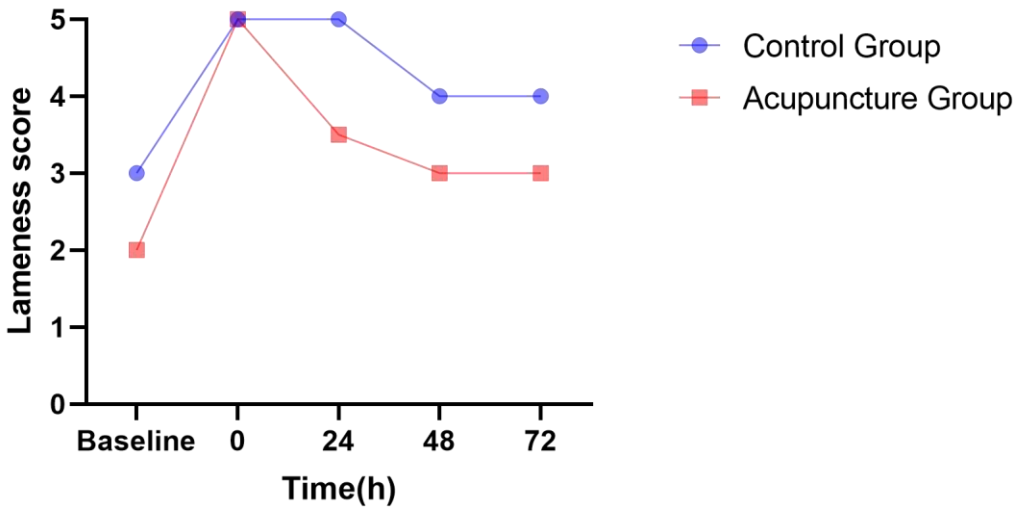
($P > 0.05$; Table 5, Figure 4).

Table 5 Comparison of postoperative lameness scores between groups

Time Point(h)	Lameness Scores		*P* value
	Acupuncture Group	Control Group	
T0	5(5,5)	5(5,5)	1.000
T24	3.5(3,5)	5(3,5)	0.130
T48	3(3,4)	4(2,5)	0.328
T72	3(2,4)	4(2,5)	0.195

Note: Data are presented as median (minimum, maximum). No significant difference between groups at any time point.

Figure 4 Median lameness scores over time in the two groups



Note:Data are presented as median and range. No significant between-group differences were observed.

3.3.2 Knee Joint Diameter

There were no significant differences at any of the individual time points ($P > 0.05$;

249 Table 6). However, the change from T0 to T48 was significantly greater in the
250 acupuncture group ($P < 0.05$; Table 7, Figure 5).

251 Table 6 Statistical description of knee joint diameters scores of affected dogs in the
252 two groups

Time Point(h)	Knee Joint Diameters Scores		*P* value
	Acupuncture Group	Control Group	
T0	26.3(16.0 34.5)	20.5(12.8,35.7)	0.878
T24	28.2(16.5,34.8)	22.3(13.7,38.3)	0.798
T48	27.0(15.7,35.7)	22.7(13.7,37)	1.000
T72	26.6 (15.0, 35.2)	21.5(12.8,36.5)	1.000

253 Note: Data are presented as median (minimum, maximum). No significant difference
254 between groups at any time point.

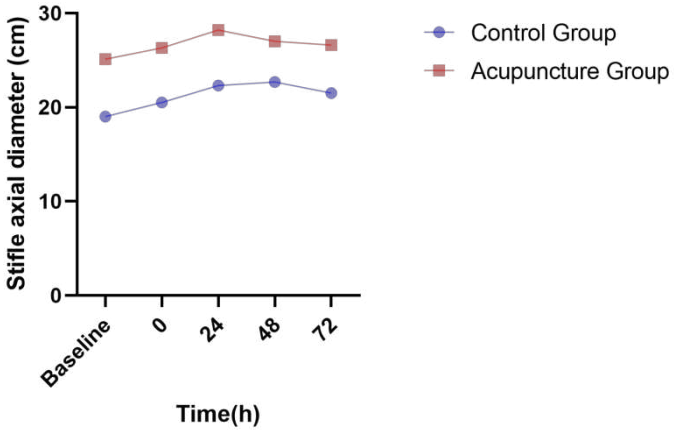
255 Table 7 Comparison of changes of knee joint circumference between the two groups

	Change in Knee Joint Circumference (cm)		
	T24-T0	T48-T0	T72-T0
Acupuncture group	0.5(-0.1,3.5)	-0.25(-0.6,2)	-0.75(-1.1,1.6)
Control group	1.75(0.3,3.3)	1.5(0.5,2.5)	0.75(-0.2,2.7)
P value	0.083	0.015*	0.083

256 Note: Data are presented as median (minimum, maximum). *$P < 0.05$ compared with
257 the control group.

258

259 Figure 5 Median knee joint circumference over time in the two groups.



3.3.3 Range of Motion (ROM)

No significant differences were found at any of the individual time points ($P > 0.05$; Table 8). However, the change from T0 to T72 was significantly greater in the acupuncture group ($P < 0.05$; Table 9, Figure 6).

Table 8 Comparison of postoperative stifle range of motion between groups

Time Point(h)	Joint Range of Motion		*P* value
	Acupuncture Group	Control Group	
T0	79.50(45,89)	96.00(14,115)	0.328
T24	77.50(60,90)	73.50(62,121)	0.798
T48	83.50(73,97)	82.50(66,100)	1.000
T72	96.50(88,106)	83.00(70,105)	0.083

Note: Data are presented as median (minimum, maximum). No significant difference between groups at any time point.

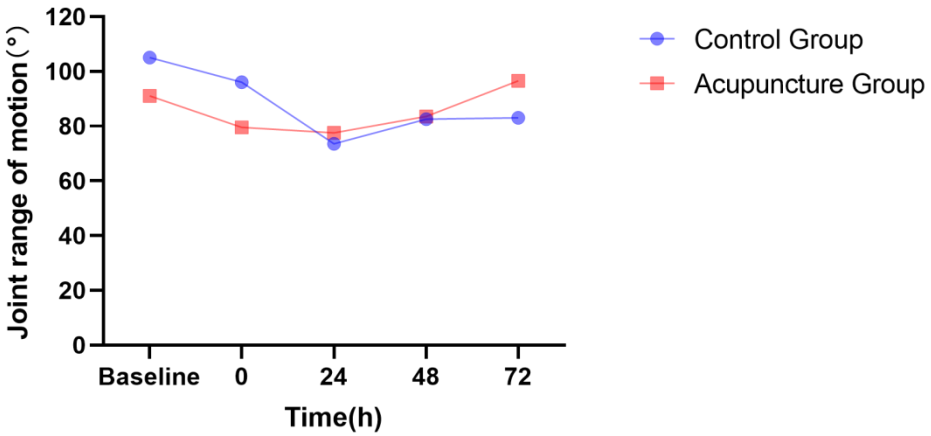
Table 9 Comparison of changes in stifle range of motion between groups

	Change in Stifle Range of Motion (°)

	T24-T0	T48-T0	T72-T0
Acupuncture group	-4(-15,26)	4.5(-11,28)	15(5,55)
Control group	-11(-39,54)	-7(-49,48)	-1(-29,80)
P value	0.721	0.505	0.021*

Note: Data are presented as median (minimum, maximum). *$P < 0.05$ compared with the control group.

Figure 6 Comparison of stifle range of motion between the two groups



Note:Data are presented as median and range. A significantly greater improvement in ROM from T0 to T72 was observed in the acupuncture group ($P < 0.05$).

3.4 Physiological variables

3.4.1 Body Temperature

There were no significant differences between groups at any time point ($P > 0.05$; Table 10, Figure 7).

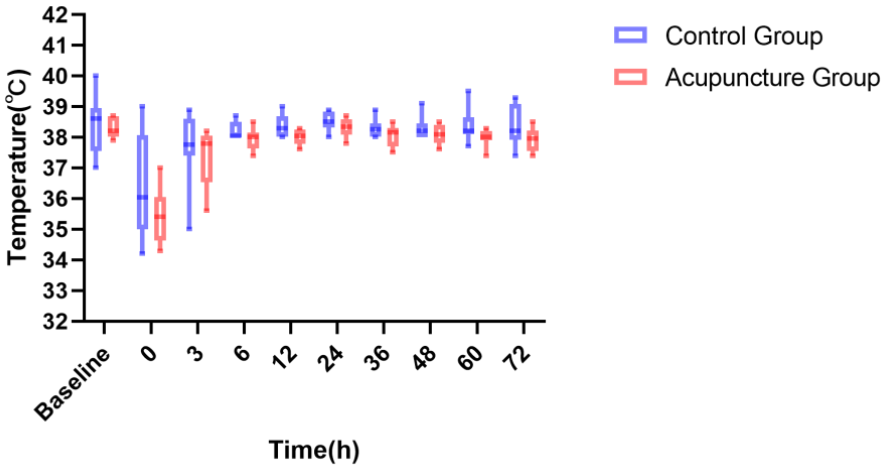
Table 10 Comparison of postoperative body temperature between groups

Time Point(h)	Body Temperature (℃)	*P* value

	Acupuncture Group	Control Group	
T0	35.4(34.3,37.0)	36.1(34.2,39.0)	0.279
T3	37.8(35.6,38.2)	37.8(35.0,38.9)	0.959
T6	38.0(37.4,38.5)	38.1(38.0,38.7)	0.195
T12	38.1(37.6,38.3)	38.3(38.1,39.0)	0.083
T24	38.4(37.8,38.7)	38.5(38.3,38.9)	0.279
T36	38.2(37.5,38.5)	38.3(38.0,38.9)	0.382
T48	38.2(37.6,38.4)	38.3(38.0,39.1)	0.382
T60	38.0(37.4,38.3)	38.2(38.1,39.5)	0.195
T72	38.0(37.4,38.5)	38.2(37.4,39.3)	0.161

Note: Data are presented as median (minimum, maximum). No significant difference between groups.

Figure 7 Boxplots of body temperature at each time point



Note:Data are presented as median, interquartile range, and range. No significant between-group differences were identified.

289 3.4.2 Heart Rate

290 There were no significant differences between groups ($P > 0.05$; Table 11, Figure 8).

291 Table 11 Comparison of postoperative heart rate between groups

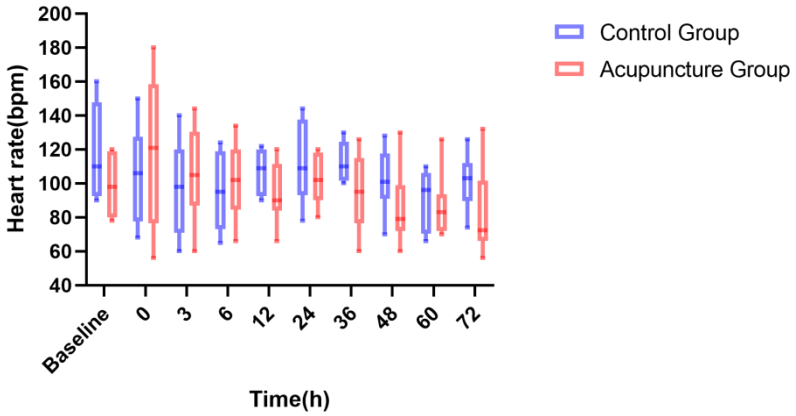
Time Point(h)	Heart Rate(bpm)		*P* value
	Acupuncture Group	Control Group	
T0	121(56,180)	106(68,150)	0.505
T3	105(60,144)	98(60,140)	0.574
T6	102(66,134)	95(65,124)	0.574
T12	90(66,120)	109(90,120)	0.105
T24	102(80,120)	109(78,144)	0.574
T36	95(60,126)	110(100,130)	0.065
T48	79(60,130)	101(70,128)	0.161
T60	83(70,126)	96(66,110)	0.645
T72	72(56,132)	103(74,126)	0.130

292 Note: Data are presented as median (minimum, maximum). No significant difference

293 between groups.

294 Figure 8 Boxplots of heart rate at each time point

295



296

297 Note:Data are presented as median, interquartile range, and range. No significant

298 between-group differences were observed.

299 3.4.3 Respiratory Rate

300 The respiratory rate was significantly lower in the acupuncture group at 12 hours and

301 24 hours ($P < 0.05$; Table 12, Figure 9).

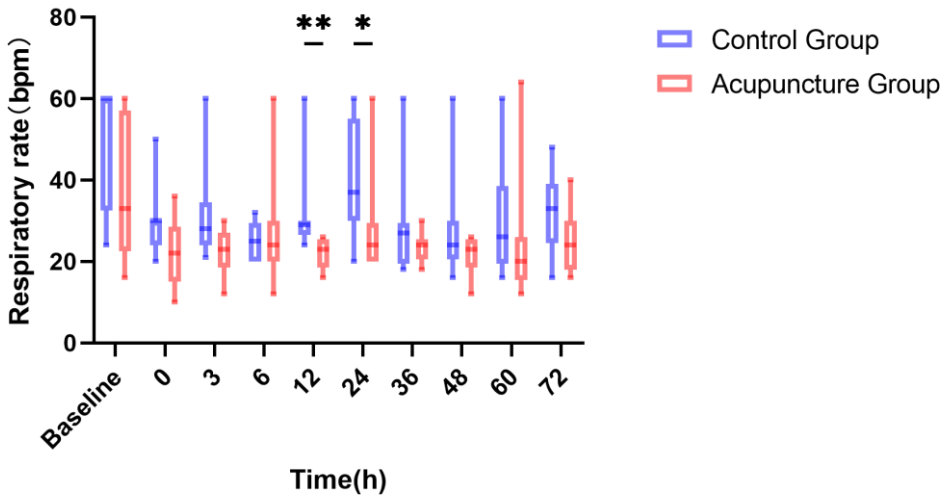
302 Table 12 Comparison of postoperative respiratory rate between groups

Time Point(h)	Respiratory Rate(bpm)		*P* value
	Acupuncture Group	Control Group	
T0	22(10,60)	30(20,50)	0.105
T3	23(12,30)	28(21,60)	0.065
T6	24(12,30)	25(20,32)	0.959
T12	23(16,26)	29(24,60)	0.002**
T24	24(20,60)	37(20,60)	0.050*
T36	24(18,30)	27(18,60)	0.328
T48	23(12,26)	24(16,60)	0.382
T60	20(12,60)	26(16,60)	0.328

T72	24(16,40)	33(16,48)	0.234

Note: Data are presented as median (minimum, maximum). **$P < 0.01$, *$P < 0.05$ compared with the control group.

Figure 9 Boxplots of respiratory rate at each time point



Note:Data are presented as median, interquartile range, and range. Significant between-group differences were observed at 12 h and 24 h postoperatively ($P < 0.05$).

3.4.4 Blood Pressure

The acupuncture group had significantly lower blood pressure at 24 hours ($P < 0.05$; Table 13, Figure 10).

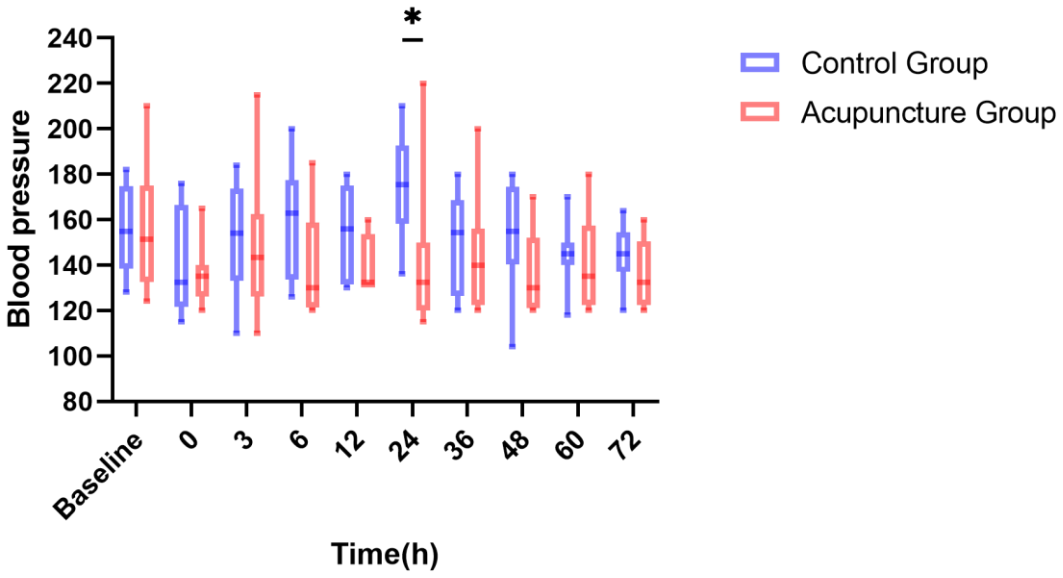
Table 13 Comparison of postoperative blood pressure between groups

Time Point(h)	Blood Pressure(mmHg)		*P* value
	Acupuncture Group	Control Group	
T0	135(120,165)	132.5(115,174)	1.000
T3	143.5(110,215)	154(110,184)	0.442
T6	130(120,185)	163(126,200)	0.105

T12	132.5(115,220)	156(130,180)	0.161
T24	132.5(115,220)	175(136,210)	0.015*
T36	140(120,200)	154.5(120,180)	0.382
T48	130(120,170)	155(104,180)	0.105
T60	135(120,180)	145(118,170)	0.645
T72	132.5(120,160)	145(120,164)	0.234

313 Note: Data are presented as median (minimum, maximum). *$P < 0.05$ compared with
314 the control group.

315 Figure 10 Boxplots of blood pressure at each time point



316

317 Note:Data are presented as median, interquartile range, and range. A significant
318 between-group difference was observed at 24 h postoperatively ($P < 0.05$).

319 **3.5 Postoperative Use of Additional Analgesics**

320 During the study period, there was no significant difference between the groups with
321 regard to the requirement for rescue analgesia. Of the dogs in the acupuncture, only

one dog required rescue analgesia.

3.6 Postoperative Complications

Transient anesthesia-related complications, primarily hypothermia, and mild gastrointestinal adverse effects, including vomiting and regurgitation, were observed in both groups. All complications resolved with supportive care.

No acupuncture-related adverse events were identified during the study period.

3.7 Serum β-Endorphin Concentration Levels

Serum β-endorphin concentrations increased postoperatively in both groups. Although the increase appeared greater in the acupuncture group, the between-group difference did not reach statistical significance ($P = 0.056$; Table 14).

Table 14 Comparison of serum β-endorphin concentrations between groups

	β-endorphin Concentration (pg/mL)			
	n	T0	T72	T72-T0
Acupuncture group	7	131.30(112.08,139.29)	149.78(142.82,159.18)	20.04(10.48,30.74)
Control group	2	134.87(101.40,168.34)	137.54(99.22,175.85)	2.66(-2.18,7.51)
P value	-	-	-	0.056

4. Discussion

The present study evaluated the effects of adjunctive acupuncture on postoperative pain management and early functional recovery in dogs undergoing stifle joint surgery.

The findings suggest that acupuncture combined with multimodal analgesia may provide additional benefits in reducing postoperative pain and improving selected recovery-related outcomes during the early postoperative period.

Dogs receiving adjunctive acupuncture demonstrated significantly lower CMPS-SF, CSU-CAPS, and joint manipulation scores at several postoperative time points compared with dogs receiving multimodal analgesia alone. These findings are consistent with previous veterinary studies reporting analgesic effects of acupuncture and electroacupuncture in surgical and neurologic conditions [13, 15, 16]. Electroacupuncture has previously been associated with reduced postoperative opioid requirements and improved perioperative analgesia in dogs undergoing hemilaminectomy and other surgical procedures [17]. The present results further support the potential role of acupuncture as a complementary component of perioperative analgesic protocols in veterinary orthopedic patients.

In addition to pain reduction, acupuncture-treated dogs showed greater improvements in postoperative stifle circumference and ROM over time. These findings may indicate improved early functional recovery following surgery. Similar observations have been reported in both veterinary and human rehabilitation studies, where acupuncture has been associated with reduced inflammation, improved circulation, and enhanced joint mobility [18, 19]. Although lameness scores did not differ significantly between groups, functional recovery after orthopedic surgery is influenced by multiple factors, including surgical trauma, preoperative disease severity, muscle atrophy, and patient compliance. Therefore, short-term lameness

assessment alone may not fully reflect subtle differences in postoperative recovery.

The mechanisms underlying acupuncture-induced analgesia are likely multifactorial. Experimental studies have suggested that acupuncture may modulate endogenous opioid pathways and influence neurotransmitters involved in nociceptive processing, including serotonin and norepinephrine [20]. In the present study, serum β-endorphin concentrations increased to a greater extent in the acupuncture group, although the difference did not reach statistical significance. This lack of statistical significance may be related to the limited sample size and substantial biological variability among clinical patients. In addition, circulating β-endorphin concentrations may not fully represent local or central neurochemical changes associated with acupuncture-mediated analgesia.

Interestingly, respiratory rate and blood pressure were lower in the acupuncture group at selected postoperative time points. Although these physiological variables are influenced by multiple perioperative factors and cannot be interpreted as direct indicators of pain, the findings may be consistent with reduced sympathetic activation and improved postoperative comfort in dogs receiving acupuncture. Similar physiological responses have been reported in previous acupuncture studies in both animals and humans.

Importantly, no acupuncture-related adverse events were observed during the study period, supporting the safety and tolerability of acupuncture when performed by trained veterinary practitioners. This finding is consistent with previous reports describing acupuncture as a minimally invasive and low-risk complementary therapy

[21, 22].

Several limitations of this study should be acknowledged. First, the sample size was relatively small, which may have limited statistical power for detecting differences in some variables, particularly serum β-endorphin concentrations and rescue analgesia requirements. Second, despite efforts to maintain assessor blinding, complete blinding in clinical acupuncture studies may be difficult to achieve. Third, the study population included dogs with different orthopedic conditions and potentially variable surgical procedures, which may have introduced heterogeneity into postoperative recovery outcomes. Finally, the postoperative observation period was limited to 72 h, and long-term functional recovery was not evaluated.

Future studies with larger sample sizes, standardized surgical procedures, longer follow-up periods, and objective gait analysis methods are warranted to further clarify the role of acupuncture in canine postoperative rehabilitation and pain management.

5. Conclusion

Adjunctive acupuncture combined with multimodal analgesia was associated with lower postoperative pain scores and improved selected indicators of early functional recovery in dogs undergoing stifle joint surgery. Although further large-scale studies are required, acupuncture may represent a safe and clinically useful complementary strategy for perioperative pain management in canine orthopedic patients.

Abbreviations

CMPS-SF: Glasgow Composite Measure Pain Scale–Short Form

CSU-CAPS: Colorado State University Canine Acute Pain Scale

ROM: Range of motion

NSAIDs: Nonsteroidal anti-inflammatory drugs

CRI: Constant-rate infusion

ASA: American Society of Anesthesiologists

ELISA: Enzyme-linked immunosorbent assay

BCS: Body condition score

Declarations

Ethics approval and consent to participate

Written informed consent was obtained from all owners prior to enrollment of their dogs in the study.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This work was supported by National Natural Science Foundation of China under

Grant No. 32473076.

Authors' contributions

Shuman Liu:Writing-original draft, Visualization, Investigation, Data curation.Han Zhang: Writing-review & editing, Software, Formal analysis, Conceptualization.conducted statistical analysis.Zhihui Hao:Validation.Gebin Li:Validation. Kai Fan:Validation.Zhankui Yuan:Writing-review & editing.Shuaiyu Wang:Project administration, Conceptualization.

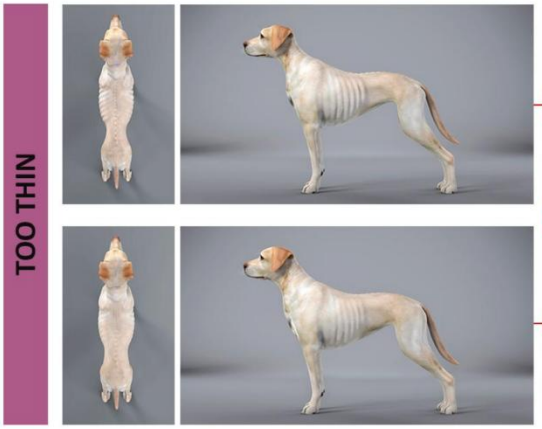
Acknowledgements

The authors thank the staff of the Veterinary Teaching Hospital of China Agricultural University for their assistance during clinical case management and postoperative monitoring.

458 Supplementary materials S1

PURINA Institute
Advancing Science for Pet Health

BODY CONDITION SYSTEM



TOO THIN

1 Ribs, lumbar vertebrae, pelvic bones and all bony prominences evident from a distance; no discernible body fat; obvious loss of muscle mass.

2 Ribs, lumbar vertebrae, pelvic bones easily visible; no palpable fat; some evidence of other bony prominence; minimal loss of muscle mass.

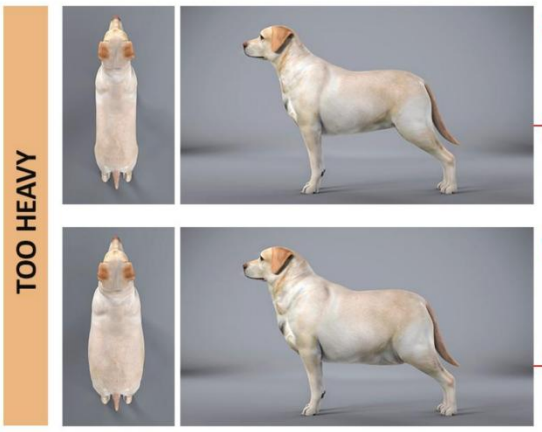
3 Ribs easily palpated and may be visible with no palpable fat; tops of lumbar vertebrae visible; pelvic bones becoming prominent; obvious waist and abdominal tuck.



IDEAL

4 Ribs easily palpable, with minimal fat covering; waist easily noted when viewed from above; abdominal tuck evident.

5 Ribs palpable without excess fat covering; waist observed behind ribs when viewed from above; abdomen tucked up when viewed from the side.



TOO HEAVY

6 Ribs palpable with slight excess fat covering; waist is discernible viewed from above, but is not prominent; abdominal tuck apparent.

7 Ribs palpable with difficulty; heavy fat cover; noticeable fat deposits over lumbar area and base of tail; waist absent or barely visible; abdominal tuck may be present.

8 Ribs not palpable under very heavy fat cover, or palpable only with significant pressure; heavy fat deposits over lumbar area and base of tail; waist absent; no abdominal tuck; obvious abdominal distention may be present.

9 Massive fat deposits over thorax, spine and base of tail; waist and abdominal tuck absent; fat deposits on neck and limbs; obvious abdominal distention.

The BODY CONDITION SYSTEM was developed at the Nestlé Purina Pet Care Center and has been validated as documented in the following publications:
LaFlamme DP. Development and Validation of a Body Condition Score System for Dogs. *Canine Practice July/August 1997; 22: 10-15.*
Mawby DI et al. Comparison of Various Methods for Estimating Body Fat in Dogs. *J Am Anim Hosp Assoc 2004; 40: 109–114.*
German AJ et al. A Simple, Reliable Tool for Owners to Assess the Body Condition of Their Dog or Cat. *J. Nutr. 2006; 136: 2031S–2033S.*
German AJ et al. Comparison of a Bioimpedance Monitor with Dual-energy X-ray Absorptiometry for Noninvasive Estimation of Percentage Body Fat in Dogs. *AJVR April 2010; Vol 71, No. 4.*

459
460
461

Supplementary materials S2

SHORT FORM OF THE GLASGOW COMPOSITE MEASURE PAIN SCALE

Dog's name _ **Date** / / **Time**

Hospital Number _____

Procedure or Condition_____

_____

In the sections below please circle the appropriate score in each list and sum these to give the total score

A. Look at dog in Kennel

Is the dog

(i)		(ii)	
Quiet	0	Ignoring any wound or painful area	0
Crying or whimpering	1	Looking at wound or painful area	1
Groaning	2	Licking wound or painful area	2
Screaming	3	Rubbing wound or painful area	3
		Chewing wound or painful area.	4

In the case of spinal, pelvic or multiple limb fractures, or where assistance is required to aid locomotion do not carry out section **B** and proceed to **C**
Please tick if this is the case ☐ then proceed to C

B. Put lead on dog and lead out of the kennel

When the dog rises/walks is it?

(iii)	
Normal	0
Lame	1
Slow or reluctant	2
Stiff	3
It refuses to move	4

C. If it has a wound or painful area including abdomen, apply gentle pressure 2 inches round the site

Does it?

(iv)	
Do nothing	0
Look round	1
Flinch	2
Growl or guard area	3
Snap	4
Cry	5

D. Overall

Is the dog? *(v)*		*Is the dog?* *(vi)*	
Happy and content or happy and bouncy	0	Comfortable	0
Quiet	1	Unsettled	1
Indifferent or non-responsive to surroundings	2	Restless	2
Nervous or anxious or fearful	3	Hunched or tense	3
Depressed or non-responsive to stimulation	4	Rigid	4

Total Score (i+ii+iii+iv+v+vi) = _____

Supplementary materials S3

Colorado State University

Date _____

Time _____

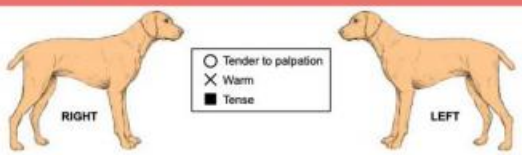
Colorado State University Veterinary Medical Center

Canine Acute Pain Scale

Rescore when awake

- ☐ **Animal is sleeping, but can be aroused - Not evaluated for pain**
- ☐ **Animal can't be aroused, check vital signs, assess therapy**

Pain Score	Example	Psychological & Behavioral	Response to Palpation	Body Tension
0		☐ **Comfortable** when resting ☐ **Happy, content** ☐ Not bothering wound or surgery site ☐ Interested in or curious about surroundings	☐ **Nontender** to palpation of wound or surgery site, or to palpation elsewhere	Minimal
1		☐ **Content to slightly unsettled** or restless ☐ **Distracted easily** by surroundings	☐ **Reacts to palpation** of wound, surgery site, or other body part by **looking around, flinching,** or **whimpering**	Mild
2		☐ Looks **uncomfortable** when resting ☐ May **whimper** or cry and may **lick or rub wound** or surgery site when unattended ☐ Droopy ears, **worried facial expression** (arched eye brows, darting eyes) ☐ **Reluctant to respond** when beckoned ☐ **Not eager to interact** with people or surroundings but will look around to see what is going on	☐ Flinches, whimpers cries, or guards/pulls away	Mild to Moderate **Reassess analgesic plan**
3		☐ **Unsettled, crying, groaning, biting or chewing** wound when unattended ☐ **Guards or protects** wound or surgery site by altering weight distribution (i.e., limping, shifting body position) ☐ **May be unwilling to move** all or part of body	☐ May be **subtle** (shifting eyes or increased respiratory rate) if dog is too painful to move or is stoic ☐ May be **dramatic**, such as a sharp cry, growl, bite or bite threat, and/or pulling away	Moderate **Reassess analgesic plan**
4		☐ **Constantly groaning or screaming** when unattended ☐ May bite or chew at wound, but unlikely to move ☐ **Potentially unresponsive** to surroundings ☐ **Difficult to distract** from pain	☐ **Cries at non-painful palpation** (may be experiencing allodynia, wind-up, or fearful that pain could be made worse) ☐ May react aggressively to palpation	Moderate to Severe **May be rigid to avoid painful movement** **Reassess analgesic plan**



Comments _____

© 2006/PW Hellyer, SR Uhrig, NG Robinson

Supported by an Unrestricted Educational Grant from Pfizer Animal Health

Supplementary materials S4

Response of the dog following joint manipulation	Score
No awareness of the procedure	0
Turns attention to the area during manipulation, but does not resist	1
Turns attention to the area, may lick the site, and shows mild resistance to manipulation	2
Resists manipulation, may vocalize, and excessively licks the site	3
Attempts to escape or block the manipulation, may bite or show aggression	4

Supplementary materials S5

Lameness Severity	Gait and Grading	Score
Clinically normal	No lameness; equal weight bearing when standing	0
Barely detectable lameness	Lameness may be present when walking or trotting, with equal weight bearing on both hind limbs when standing	1
Mild lameness	There may be mild but definite lameness when walking or trotting, with mild non-weight bearing on the affected limb when standing	2
Moderate lameness	There may be obvious lameness when walking or trotting, with definite non-weight bearing on the affected limb when standing	3
Severe lameness	There may be non-weight bearing when trotting, but at least occasional weight bearing when walking or standing	4
Most severe lameness	There may be complete non-weight bearing when walking or standing	5

Supplementary materials S6

Evaluation Metric	Baseline Period	Intervention Period (h)							
	Preoperative	T0	T3	T6	T12	T24	T36	T48	T60	T72
Glasgow Composite Measure Pain Scale-Short Form(CMPS-SF)	√	√	√	√	√	√	√	√	√	√
Colorado State University Canine Acute Pain Scale (CSU-CAP)	√	√	√	√	√	√	√	√	√	√
Joint Manipulation Score	√	√	√	√	√	√	√	√	√	√
Lameness Score	√	√				√		√		√
Knee Joint Circumference	√	√				√		√		√
Range of Motion (ROM)	√	√				√		√		√
Physiological Parameters	√	√				√		√		√
Postoperative Use of Additional Analgesics		√	√	√	√	√	√	√	√	√
Postoperative Complications		√	√	√	√	√	√	√	√	√
Canine β-Endorphin Concentration		√								√

Reference

1. __, __, Hellyer P, Rodan I, Brunt J, Downing R, et al. AAHA/AAFP Pain Management Guidelines for Dogs & Cats. J Am Anim Hosp Assoc. 2007;43:235–48. https://doi.org/10.5326/0430235.

2. Raja SN, Carr DB, Cohen M, Finnerup NB, Flor H, Gibson S, et al. The revised International Association for the Study of Pain definition of pain: concepts, challenges, and compromises. Pain. 2020;161:1976–82. https://doi.org/10.1097/j.pain.0000000000001939.

3. Sun E, Dexter F, Macario A. Can an Acute Pain Service Be Cost-Effective? Anesth Analg. 2010;111:841–4. https://doi.org/10.1213/ANE.0b013e3181f33533.

4. Proceedings of the Anaesthetic Research Society Meeting, Cardiff Meeting, July 11–12, 2002. Br J Anaesth. 2002;89:670P-681P. https://doi.org/10.1093/bja/Abstracts.

5. Gruen ME, Lascelles BDX, Colleran E, Gottlieb A, Johnson J, Lotsikas P, et al. 2022 AAHA Pain Management Guidelines for Dogs and Cats*. J Am Anim Hosp Assoc. 2022;58:55–76. https://doi.org/10.5326/JAAHA-MS-7292.

6. Holton LL, Scott EM, Nolan AM, Reid J, Welsh E. Relationship between physiological factors and clinical pain in dogs scored using a numerical rating scale. J Small Anim Pract. 1998;39:469–74. https://doi.org/10.1111/j.1748-5827.1998.tb03681.x.

7. Reid J, Nolan A, Hughes J, Lascelles D, Pawson P, Scott E. Development of the short-form Glasgow Composite Measure Pain Scale (CMPS-SF) and derivation of an analgesic intervention score. Anim Welf. 2007;16:97–104. https://doi.org/10.1017/S096272860003178X.

8. Tomas A, Bledsoe D, Wall S, Davidson G, Lascelles BDX. Initial evaluation of a canine stifle arthrotomy post-operative pain model. Vet J. 2015;204:293–8. https://doi.org/10.1016/j.tvjl.2015.03.010.

9. Friton G, Thompson CM, Karadzovska D, King S, King JN. Efficacy and safety of oral robenacoxib (tablet) for the treatment of pain associated with soft tissue surgery in client-owned dogs. BMC Vet Res. 2017;13:197. https://doi.org/10.1186/s12917-017-1100-x.

10. Szabo SD, Levine D, Marcellin-Little DJ, Sidaway BK, Hofmeister E, Urtuzuastegui E. Cryotherapy Improves Limb Use But Delays Normothermia Early After Stifle Joint Surgery in Dogs. Front Vet Sci. 2020;7:381. https://doi.org/10.3389/fvets.2020.00381.

11. Mingfu L, Xiaotong D, Xiaojing S, Jin J, Jinling Z, Ying H. Study on the Dynamic Compound Structure Composed of Mast Cells, Blood Vessels, and Nerves in Rat Acupoint. Evid Based Complement Alternat Med. 2013;2013:1–4. https://doi.org/10.1155/2013/160651.

12. Yoo Y-C, Oh JH, Kwon TD, Lee YK, Bai SJ. Analgesic Mechanism of Electroacupuncture in an Arthritic Pain Model of Rats: A Neurotransmitter Study. Yonsei Med J. 2011;52:1016. https://doi.org/10.3349/ymj.2011.52.6.1016.

13. Machin H, Taylor-Brown F, Adami C. Use of acupuncture as adjuvant analgesic technique in dogs undergoing thoracolumbar hemilaminectomy. Vet J. 2020;264:105536. https://doi.org/10.1016/j.tvjl.2020.105536.

14. Liu CM, Lin CT. Retrospective Study of a New Standardized Acupuncture

Treatment Protocol on Thoracolumbar Spinal Cord Diseases in 84 Dogs. Pak Vet J. 2015.

15. Gakiya HH, Silva DA, Gomes J, Stevanin H, Cassu RN. Electroacupuncture versus morphine for the postoperative control pain in dogs. Acta Cir Bras. 2011;26:346–51. https://doi.org/10.1590/S0102-86502011000500004.

16. Laim A, Jaggy A, Forterre F, Doherr MG, Aeschbacher G, Glardon O. Effects of adjunct electroacupuncture on severity of postoperative pain in dogs undergoing hemilaminectomy because of acute thoracolumbar intervertebral disk disease. J Am Vet Med Assoc. 2009;234:1141–6. https://doi.org/10.2460/javma.234.9.1141.

17. Groppetti D, Pecile AM, Sacerdote P, Bronzo V, Ravasio G. Effectiveness of electroacupuncture analgesia compared with opioid administration in a dog model: a pilot study. Br J Anaesth. 2011;107:612–8. https://doi.org/10.1093/bja/aer199.

18. 陈钢, 辜锐鑫, 徐丹丹. 电针疗法在全膝关节置换术后康复中的应用. 中国针灸. 2012;32:309–12. https://doi.org/10.13703/j.0255-2930.2012.04.008.

19. 徐燕, 王斌, 钟洪菊. 电针腰夹脊穴结合康复训练对脑卒中后恢复期病人步态与平衡能力的影响. 中西医结合心脑血管病杂志. 2018;16:2225–8.

20. Zhao Z-Q. Neural mechanism underlying acupuncture analgesia. Prog Neurobiol. 2008;85:355–75. https://doi.org/10.1016/j.pneurobio.2008.05.004.

21. MacPherson H, Thomas K, Walters S, Fitter M. The York acupuncture safety study: prospective survey of 34 000 treatments by traditional acupuncturists. BMJ. 2001;323:486–7. https://doi.org/10.1136/bmj.323.7311.486.

22. Ernst E, White AR. Prospective studies of the safety of acupuncture: a systematic

review. Am J Med. 2001;110:481–5. https://doi.org/10.1016/S0002-9343(01)00651-9.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementarymaterial.xlsx