Confirmation of epidural anesthesia with bupivakain in cats by infrared thermographic imaging and SEP

Muammer Ayberk KARA[1,a], Özlem ŞENGÖZ ŞİRİN[2,b,✉]

[1]Mehmet Akif Ersoy University, Faculty of Veterinary Medicine,Department of Veterinary Surgery, Burdur, Türkiye; [2]Mehmet Akif Ersoy University, Faculty of Veterinary Medicine,Department of Veterinary Surgery, Burdur, Türkiye

[a]ORCID: 0009-0002-3316-352X; [b]ORCID: 000-0002-2232-6349

ARTICLE INFO

Article History
Received : 13.03.2024
Accepted : 16.11.2024
DOI: 10.33988/auvfd.1452503

Keywords
Bupivacaine
Epidural anesthesia
Somatosensory Evoked Potential
Thermal Camera

✉Corresponding author
ozlemsirin@mehmetakif.edu.tr

How to cite this article: Kara MA, Şengöz Şirin Ö (2025): Confirmation of epidural anesthesia with bupivakain in cats by ınfrared thermographic imaging and SEP. Ankara Univ Vet Fak Derg, 72 (2), 165-173. DOI: 10.33988/auvfd.1452503.

ABSTRACT

In this study, the usability of electromyography and infrared thermography was tested to confirm the success of epidural anesthesia. The cats were randomly divided into 2 groups as experimental and control groups. The cats were intubated and placed under inhalation anesthesia using an anesthesia device. SEP (Somatosensory Evoked Potentials) recordings were obtained at the L7-S1, L6-L7, L6-L5, and L5-L4 intervals before epidural injection. Before epidural injection, infrared thermographic images and rectal temperatures were taken from a distance of 50 cm, where the areas where surface temperatures were to be measured were clearly visible. Following asepsis and antisepsis, 0.5% bupivacaine in the experimental group and saline in the control group were injected into the lumbosacral region. Infrared thermograms and rectal temperatures were obtained from each cat seven times (0.min, 5.min, 10.min, 15.min, 20.min, 25.min and 30.min) for 30 min at 5 min intervals after injection. After the last infrared thermogram was recorded, post-epidural SEP was recorded. Rectal temperature values decreased gradually in all cats throughout the anesthesia period, and no difference was observed between the groups. A decrease in potential duration and an increase in latency values were recorded in 10 cats administered epidural 0.5% bupivacaine compared with 10 cats administered epidural saline. Although there were only statistically significant values, the amplitude values were not kinetically significant. No clinically or statistically significant difference was observed in the infrared thermograms obtained before and 5 min after epidural injection in both groups.

Introduction

It is a common technique used to perform surgical procedures in veterinary medicine since the 1950s in North America and Europe (15, 27). In the late 1980s, with the recognition of the analgesic effects of opioids on the spinal cord, the use of epidural analgesia became an important re-emerging tool in intra- and postoperative epidural techniques to provide analgesia and anesthesia in veterinary medicine (27).

The efficacy of epidural anesthesia in cats was first confirmed experimentally in 1969 (9). Epidural anesthesia has been used successfully in cats for a variety of purposes (27). Epidural injections are most easily and safely performed in the lumbosacral (L7-sacrum [L-S]) intervertebral space in small animals because the spinal cord and dura end cranially in this region. Although it is optional to perform the technique under general anesthesia in the dog, general anesthesia is considered indicated in the cat (15). Considered by some to be the gold standard for preemptive analgesia, epidural anesthesia reduces central sensitization, intraoperative inhalant and opioid requirements, and stress responses during surgery (21, 25). The most commonly used agents were bupivacaine and lidocaine (15).

Infrared thermography has been used in many veterinary medicine studies, such as for inflammation detection and herd inspection, and its use is expanding. (5, 13, 20, 29). Infrared thermographic changes after epidural

bupivacaine injection have been investigated in various animals and humans (4, 5, 10, 12, 16, 17, 28). However, the use of thermography to confirm the efficacy of epidural administration has not been widely studied in veterinary medicine (5).

Electrodiagnostic methods have been used in the field of neurology for approximately 70 years, and have been used in veterinary neurology since the 1960s and are now developing as a sub-branch. In the field of veterinary neurology, it was first isolated from a dog in 1966 (6). Somatosensory evoked potentials (SEP) have been routinely used for many years to evaluate the somatosensory pathway and thus complete the diagnostic process when history, neurological examination, and imaging are not entirely conclusive (11, 19, 22). The effects of epidural bupivacaine administration on SEP have been investigated in humans (18).

This study aimed to evaluate the somatosensoryevoked potential and segmental warming of cats epidurally anesthetized with bupivacaine using infrared thermography and to confirmepidural anesthesia because failure of the epidural technique was estimated to be as high as 9% in cats (27). Techniques that demonstrate the accuracy of epidural injection may be useful.

Materials and Methods

The study subjects were 20 2-5 years old and 3-4 kg mongrel cats, which were brought to Burdur Mehmet Akif Ersoy University of Veterinary Medicine Animal Hospital for castration, were in class I or II according to ASA classification, and no hind limb or spine fracture or cardiovascular disease was detected in the clinical examination. Before the operation, all patients were premedicated with intravenous diazepam (Diazem, Deva Holding A.Ş., Türkiye) at a dose of 0.5 mg/kg by opening the vascular access with an appropriately sized intravenous catheter. After premedication, anesthesia was induced with intravenous propofol (Propofol® 1% Fresenius, Fresenius Kabi) at a dose of 4 mg/kg. Following induction, the patient was intubated with an endotracheal tube (Bıçakçılar A.Ş., Istanbul) of the appropriate size, and the patient was connected to the anesthesia device (Dräger, Primus, Lübeck, Germany). Until the end of the operation, sevoflurane (Sevorane®, Abbott Laboratuvarları İthalat İhracat Tic. Ltd. Şti. Istanbul, Türkiye) was used to maintain anesthesia with mechanical ventilation. Also, the oxygen concentration was maintained at 100%.

A 22G spinal needle (MediSpine, Olgun Medikal İNŞ ve TİC. LTD.ŞTİ) was used for the epidural catheterization. For epidural anesthesia, 0.5% bupivacaine (Marcaine 0.5%, Zentiva Sağlık Ürünleri Sanayi ve Ticaret A.ş., Türkiye) was administered at a dose of 1 mg/kg.

With an electromyography (EMG) device (Synergy CareFusion 5-channel EMG-EP®), SEP parameters were evaluated and recorded with Teflon-coated stainless-steel needles in the S1-L7, L7-L6, L6-L5, and L5-L4 intervals before epidural anaesthesia and at 30 minutes after epidural injection.

Immediately before epidural anesthesia, an infrared thermographic image was taken with an infrared thermal camera (FLIR® C5, USA) using a tripod at a right angle at a distance of 50 cm from the operating table and rectal temperature was recorded (Figure 1). Subsequently, infrared thermographic images and rectal temperature measurements were obtained seven times (0. minute, 5. minute, 10. minute, 15. minute, 20. min, 25. min, and 30. min) at 5-minute intervals after epidural anesthesia. The thermal images were evaluated using the Flir Ignite application and superficial temperature values of seven different regions (Figure 2., Figure 3.) in each image was recorded.

Figure 1. Taking thermographic images.

DOI: 10.33988/auvfd.1452503

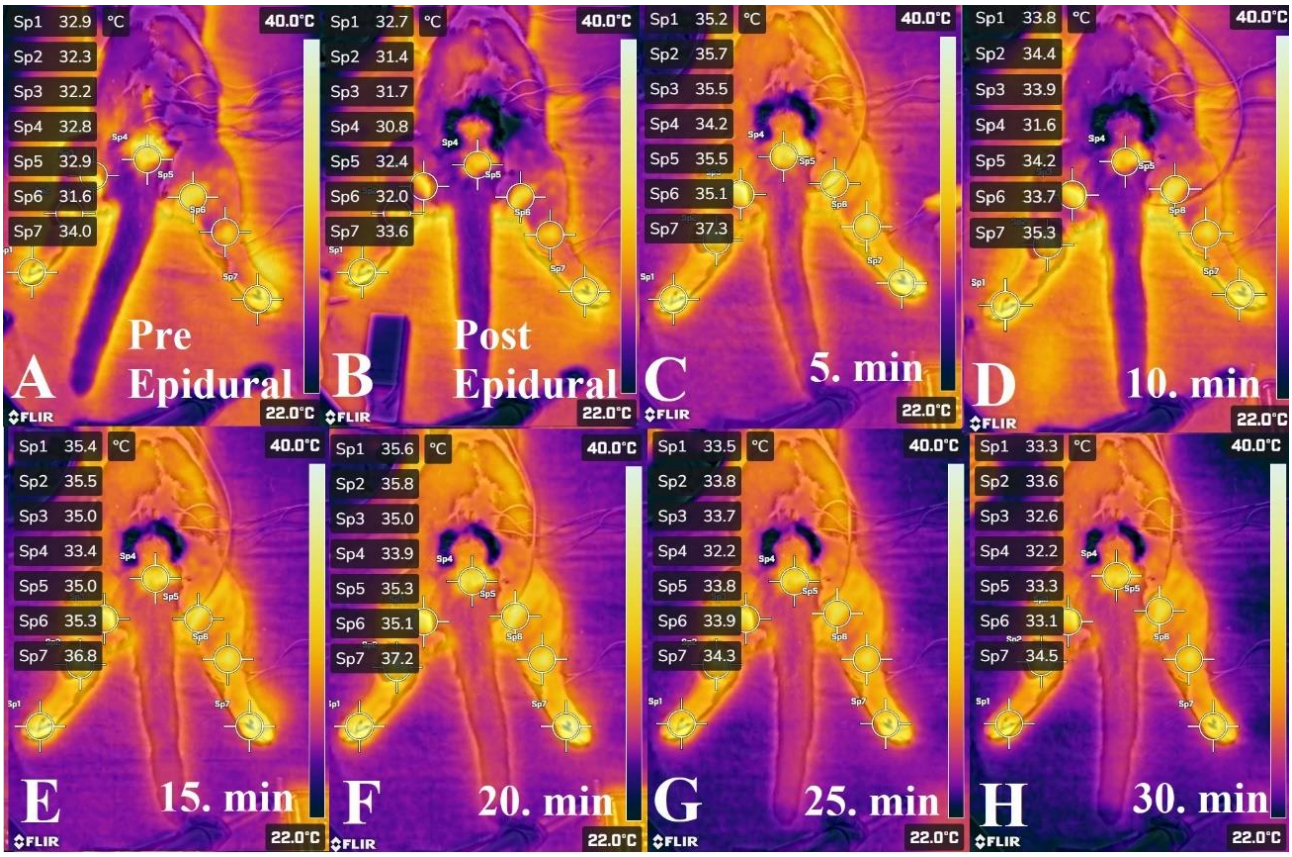

Figure 2. Infrared thermographic images of experimental group, 2-year-old female cat with epidural injection of bupivacaine.
(A) Thermography taken before epidural injection. (B, C, D, E, F, G, H) Thermographic images taken 5 minutes after epidural injection, respectively.

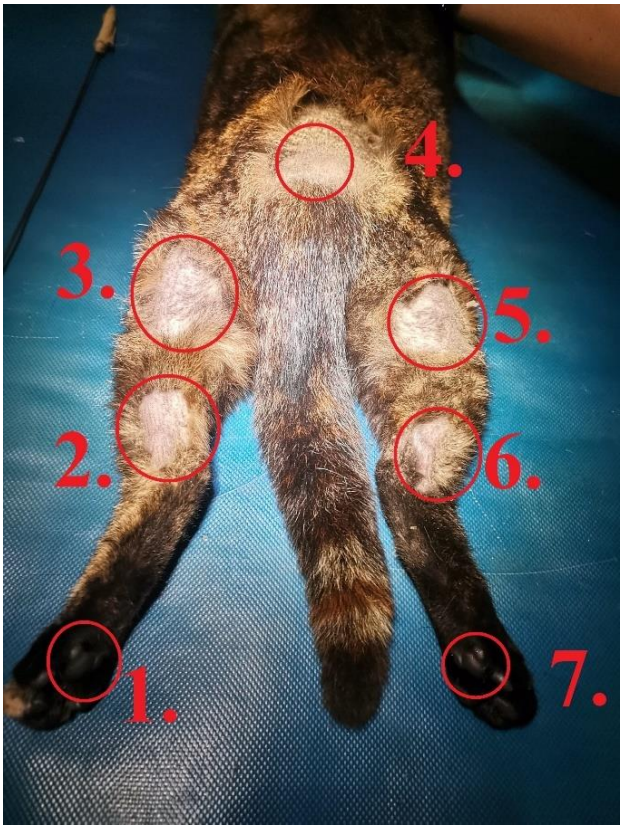

Figure 3. Regions to measure temperature in Infrared Thermographic images.

In all cases, after the radiopaque material was injected into the epidural catheter, radiography of the region in the laterolateral position was performed to confirm whether the needle was in the right place. In the experimental group, 0.5% bupivacaine (Marcaine 0.5%, Zentiva Sağlık Ürünleri Sanayi ve Ticaret A. Ş., Türkiye) at a dose of 1.0 mg/kg was used to induce epidural anesthesia. The total amount of fluid administered into the epidural space was limited to 0.4 ml/kg. If the drug dose did not meet the total amount of fluid administered, 0.9% isotonic NaCl (Polifarma İlaç San. ve Tic. A.Ş., Tekirdağ, Türkiye) was added, not exceeding 1 ml in total. After confirming that the spinal needle was in the epidural space, the control group received 1 mL 0.9% isotonic NaCl.

Statistical Analysis: The Shapiro-Wilk test was used to test whether the variables fit a normal distribution. Variables conforming to normal distribution are given as mean±standard deviation, and an independent sample t-test was used for comparisons between two independent groups. Variables that did not fit the normal distribution were presented as median (minimum-maximum) values, and the Mann-Whitney U test was used for comparisons between two independent groups. Statistical analyses were performed using the IBM SPSS Statistics 22.0 program. The significance level was set at α=0.05.

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Results

This study tested the usefulness of EMG and infrared thermography in confirming the success of epidural anesthesia. Rectal temperature values decreased gradually during the anesthesia period in all cats, and no difference was observed between the groups. Epidural administration of 0.5% bupivacaine decreased the potential duration and increased the latency values in 10 cats compared to 10 cats receiving epidural saline, but the amplitude values were not clinically and statistically significant. No clinically or statistically significant difference in temperature change was observed in the infrared thermograms taken beforeand 30 min after epidural injection in either group.

The groups within the scope of the study showed statistically significant differences in terms of the amount of change in pre-test, post-test amplitudes S1-L7, L7-L6, and L5-L4 ($P<0.05$). The decreases in amplitude S1-L7, amplitude L7-L6, and amplitude L5-L4 values of the cats in the experimental group were higher than those in the control group. The change in pre-test, post-test amplitude L6-L5 values did not show a statistically significant difference between the groups ($P>0.05$) (Table 1).

When we consider the amplitude values, we see that the L6-L7 and L4-L5 potentials recorded in the experimental group decreased, as expected, at the 30th minute of epidural bupivacaine administration. However, a decrease in the 3rd and 1st potentials. The potentials recorded in the control group showed a slight increase 30 min after saline injection. (Figure 4.)

Table 1. Examination of pre-test - post-test amplitude change amounts of the cats included in the study.

	Group	N	Avarage.±SS*/Median(Min-Maks)**	t*/Z**	P
Amplitud S1-L7 yd*	Test	10	-0.23±0.24	-2.784	0.012*
	Control	10	0.15±0.36		
Amplitud L7-L6 yd**	Test	10	-0.24(-0.33-0.12)	-2.57	0.010*
	Control	10	0.05(-0.19-0.50)		
Amplitud L6-L5 yd**	Test	10	-0.13(-0.61-0.47)	-1.470	0.141
	Control	10	0.01(-0.09-0.17)		
Amplitud L5-L4 yd*	Test	10	-0.23±0.15	-3.292	0.004*
	Control	10	0.07±0.25		

*P<0.05, yd: Percentage Change, *Independent Sample t-Test, **Mann Whitney U Test*

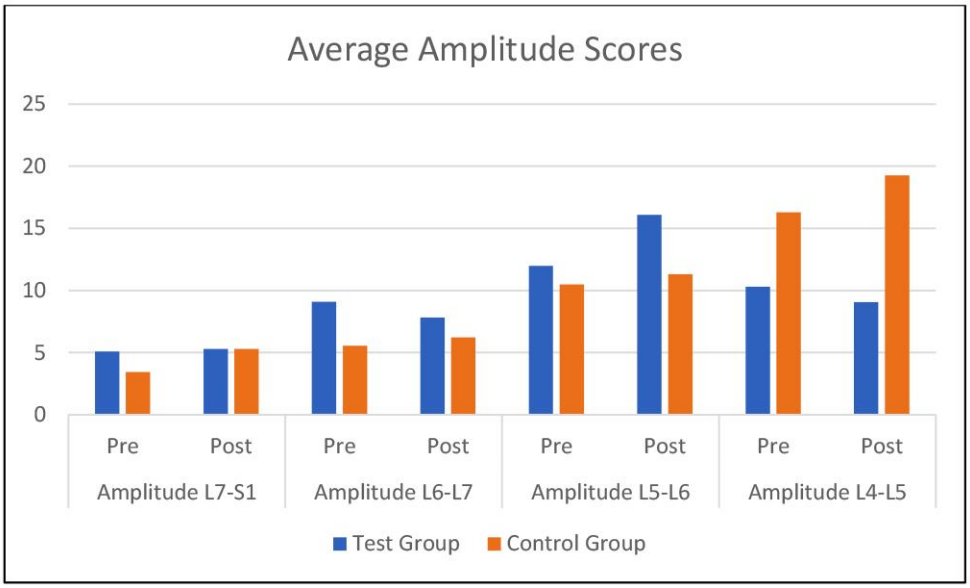

Figure 4. The bar graph shows average amplitude scores for both pre and post epidural injection SEP measurement.

The groups within the scope of the study did not show statistically significant differences in terms of the amount of change in pre-test,post-test latency S1-L7, L7-L6, L6-L5, and L5-L4. (P>0,05) (Table 2).

In the experimental group, the potential latencies measured at each interval after the epidural bupivacaine injection increased, as expected. However, the control group did not show such a significant increase, as observed in the experimental group (Figure 5). When changes in the mean potential duration were examined, a decrease was observed in the measurements obtained from the experimental group. In contrast, an increase was recorded in the control group measurements, except for the second interval (Figure 5). However, the groups within the scope of the research did not show statistically significant differences in terms of the pre-test-post-test duration S1-L7, duration L7-L6, duration L6-L5, and duration L5-L4 change amounts (P>0,05) (Table 3).

Table 2. Examination of the pre-test, post-test latency change amounts of the cats included in the study.

	Group	N	Average.±SS*/Median(Min-Maks)**	t*/Z**	P
Latans S1-L7 yd**	Test	10	0.13(-0.20-0.30)	-0.267	0.796
	Control	10	0.04(0-0.31)		
Latans L7-L6 yd**	Test	10	0.09(-0.20-0.14)	-1.328	0.218
	Control	10	0(-0.06-0.10)		
Latans L6-L5 yd**	Test	10	0.08(-0.19-0.33)	-2.061	0.052
	Control	10	0(-0,11-0)		
Latans L5-L4 yd*	Test	10	0.04±0.13	-0.558	0.584
	Control	10	0.07±0.12		

*P<0.05, yd: Percentage Change, *Independent Sample t-Test, **Mann Whitney U Test*

Table 3. Examination of the pre-test - post-test duration change amounts of the cats included in the study.

	Group	N	Average.±SS*/Median(Min-Maks)**	t*/Z**	P
Duration S1-L7 yd**	Test	10	-0.002(-0.26-0.33)	-0.982	0.356
	Control	10	0.03(-0.11-1.19)		
Duration L7-L6 yd**	Test	10	-0.08(-1.2-0.52)	-1.063	0.315
	Control	10	0(-4.77-1.4)		
Duration L6-L5 yd**	Test	10	-0.07(-0.21-0.25)	-1.798	0.079
	Control	10	-0.001(-0.7-0.05)		
Duration L5-L4 yd*	Test	10	-0.09±0.32	-0.753	0.462
	Control	10	-0.009±0.14		

*P<0.05, yd: Percentage Change, *Independent Sample t-Test, **Mann Whitney U Test*

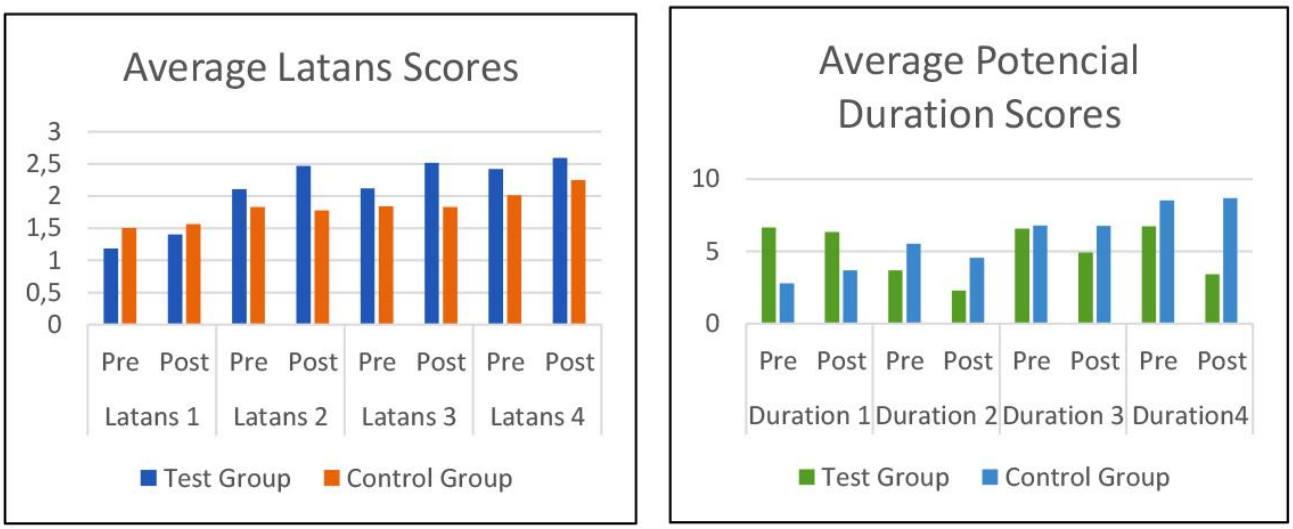

Figure 5. Column graph showing the comparison of latency (Left) and potencial duration (Right) values before and after epidural injection.

Rectal temperature values decreased in both groups during 30 min of anesthesia. In the experimental group, a significant decrease of 2° was observed at 10 min, whereas a difference of more than 1° was recorded at the end of 30 min. In the control group, a steady and slow decrease was observed, and again, a difference of more than 1 ° between the last and first measurements was observed. The groups within the scope of the study did not show statistically significant difference in terms of the amount of change in rectal temperature at 0. min, 5. min, 10. min, 15. min, 20. min, 25. min and 30. min after epidural injection compared with the rectal temperatures before epidural injection (P>0.05) (Figure 6) (Table 4.).

The groups within the scope of this research did not show statistically significant differences in terms of the amount of change in the temperatures of 0. min, 5.min, 10.min, 15.min, 15.min, 20.min, 25.min and 30.min after epidural injection in all seven regions compared with pre-epidural temperatures (P>0.05) (Table 5., Table 6.).

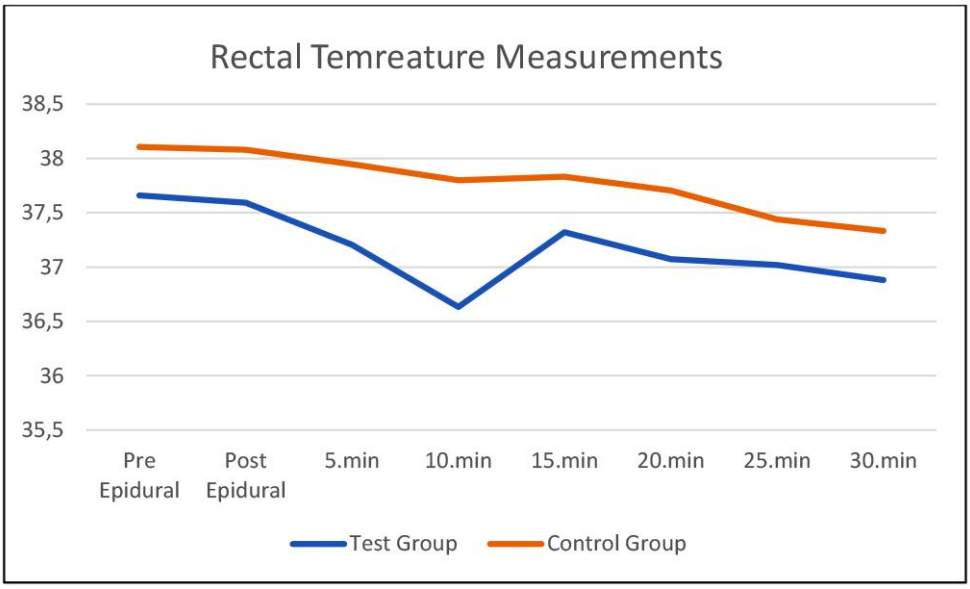

Figure 6. Graph of mean rectal temperature measurements.

Table 4. Examination of the amount of change in the rectal temperatures of the groups included in the study at 0. min, 5. min, 10. min, 15. min, 20. min, 25. min and 30. min after epidural compared to the rectal temperatures before epidural.

	Group	N	Average.±SS*/(Median(Min-Maks)**	t*/Z**	P
Post Epidural 0.min yd**	Test	10	0(-0.03-0)	-0.927	0.354
	Control	10	0(-0.01-0)		
Post Epidural 5.min yd*	Test	10	-0.02±0.01	-1.952	0.074*
	Control	10	-0,01±0,01		
Post Epidural 10.min yd**	Test	10	-0.02(-0.05-0.53)	-0.265	0.791
	Control	10	-0.01(-0.27-(-0.01))		
Post Epidural 15.min yd*	Test	10	-0.02±0.01	-1.323	0.202
	Control	10	-0.02±0.01		
Post Epidural 20.min yd**	Test	10	-0.02(-0.06-(-0.01))	-1.512	0.131
	Control	10	-0.02(-0.03(-0.01))		
Post Epidural 25.min yd*	Test	10	-0.03±0.02	-1.224	0.237
	Control	10	-0.02±0.01		
Post Epidural 30.min yd*	Test	10	-0.04±0.02	-1.369	0.188
	Control	10	-0.03±0.01		

*P<0.05. yd: Percentage Change, *Independent Sample t-Test, **Mann Whitney U Test*

DOI: 10.33988/auvfd.1452503

Table 5. To examine the amount of change in the temperatures of the groups within the scope of the research at 0. min, 5. min, 10. min, 15. min, 20. min, 25. min and 30. min after the 1st region epidural compared to the pre-epidural temperatures.

	Group	N	Mean ..SS	T	P
Post Epidural 0.min yd**	Test	10	0.04±0.06	0.271	0.789
	Control	10	0.04±0.03		
Post Epidural 5.min yd*	Test	10	0.06±0.06	-0.119	0.907
	Control	10	0.06±0.04		
Post Epidural 10.min yd**	Test	10	0.06±0.04	-0.161	0.874
	Control	10	0.06±0.06		
Post Epidural 15.min yd*	Test	10	0.07±0.04	-0.592	0.561
	Control	10	0.08±0.05		
Post Epidural 20.min yd**	Test	10	0.07±0.04	-0.247	0.808
	Control	10	0.07±0.06		
Post Epidural 25.min yd*	Test	10	0.07±0.05	-0.286	0.778
	Control	10	0.08±0.06		
Post Epidural 30.min yd*	Test	10	0.07±0.05	-0.549	0.589
	Control	10	0.08±0.05		

*P<0.05. yd: Percentage Change, *Independent Sample t-Test, **Mann Whitney U Test*

Table 6. To examine the amount of change in the temperatures of the groups within the scope of the research at 0. min, 5. min, 10. min, 15. min, 20. min, 25. min and 30. min after the 6th region epidural compared to the pre-epidural temperatures.

	Group	N	Mean.±SS	T	P
Post Epidural 0.min yd**	Test	10	0.02±0.06	-0.31	0.760
	Control	10	0.03±0.05		
Post Epidural 5.min yd*	Test	10	0.05±0.05	0.415	0.683
	Control	10	0.04±0.05		
Post Epidural 10.min yd**	Test	10	0.05±0.05	0.005	0.996
	Control	10	0.05±0.04		
Post Epidural 15.min yd*	Test	10	0.04±0.04	-1.941	0.068
	Control	10	0.08±0.04		
Post Epidural 20.min yd**	Test	10	0.05±0.04	-0.884	0.338
	Control	10	0.07±0.06		
Post Epidural 25.min yd*	Test	10	0.05±0.05	-0.257	0.800
	Control	10	0.06±0.08		
Post Epidural 30.min yd*	Test	10	0.05±0.05	-0.842	0.411
	Control	10	0.08±0.07		

P<0.05. pd: Percentage Change, Independent Sample t-Test

Discussion and Conclusion

It is recommended that bupivacaine be administered epidurally in cats and dogs at a dose of 1-1.65 mg/kg (15, 26, 27). It has also been reported that the duration of action of bupivacaine administered by epidural injection is 15-30 minutes (15, 26, 27). Di Filippo et al. (8) reported in their study on humans that 0.5% bupivacaine, 0.5% ropivacaine and 0.75% ropivacaine rapidly increased skin temperature after epidural injection, reaching a peak of 1 to 1.80 ° 30 minutes after the block. In this study, cats in the experimental group received bupivacaine at a dose of 1 mg/kg. In addition, measurements were continued for 30 min following epidural injection so that data could be collected during the onset of the duration of action.

In a similar study by Xu et al. (28) examining surface temperature changes in experimental mice after epidural injection, the change in thermography over time after epidural bupivacaine administration was significant for the lower extremities (RM-ANOVA, P<0.001), but not in the upper extremities (RM-ANOVA, P=0.78). After epidural saline administration, there was no significant effect on thermography of the extremities. Compared with bupivacaine, epidural saline was a significant between-subject variable (RM-ANOVA, P<0.001). After epidural bupivacaine, the mean (±SD) Emax for the lower extremities was +3.73 °C ± 1.56. After epidural saline, the mean Emax for the lower extremities was -0.88 °C ± 0.28. No significant effect of epidural saline was observed in

any of the regions. In contrast to the study by Xu et al. (28), there was no significant difference in infrared thermographic analysis of cats before and after epidural bupivacaine or saline administration. It was thought that the reason for this may be the difference in sensitivity of the infrared thermal cameras used in data collection.

Epidural administration of low-concentration local anesthetics in humans has been shown to cause significant changes in surface skin temperature, as measured by infrared thermography (2). Epidural administration of bupivacaine has been shown to cause a gradual increase in foot skin temperature, taking more than 15 minutes to reach a 50% maximal increase (12). Furthermore, epidural sympathetic blockade at the thoracic and lumbar levels with low concentrations of bupivacaine was found to cause changes in the skin temperature in the thorax and feet (16). Thoracic epidural analgesia with low concentrations of bupivacaine has been shown to induce thoracic and lumbar sympathetic blocks, supporting the effect of bupivacaine on skin temperature (10). However, in this study, no significant difference was found between the two groups before and after epidural in the 2 groups.

Available references indicate that epidural anesthesia may ffect skin temperature. Küls et al. (17) described and compared two blockade methods (epidural and sciatic) in dogs undergoing orthopedic surgery. They reported that only four out of 12 animals (33%) receiving epidural analgesia and one out of eight animals (12.5%) receiving sciatic block showed an increase in temperature in the plantar pad. Other studies have reported that hyperthermia is associated with prolonged epidural analgesia (23), while others have found that epidural anesthesia may cause a decrease rather than an increase in skin temperature (3). Di Filippo et al. (8) reported in their study in humans that epidural 0.5% bupivacaine rapidly increased skin temperature after injection, reaching a peak of 1–1.8C 30 min after the block. In these studies, there was no statistically significant difference between the group that received 0.5% bupivacaine injection into the epidural region and the two groups that received saline injection at 30 min.

Loughnan et al. (18) evaluated the effects of epidural bupivacaine 0.75% on epidural somatosensory evoked potential (SEP) after posterior tibial nerve stimulation and found that the most prominent change was the decrease in the amplitude of the second and third peaks with a decrease in the overall amplitude. Similar but less pronounced changes were found with 0.5% bupivacaine administration, as in our study.

The maximum conduction velocity of a nerve decreases with decreasing temperature (7, 14). A 1 °C decrease in skin temperature causes a 1.3-2.4 m/s decrease in motor and sensory nerve conduction velocities (1). Şirin et al. reported that a 1 °C change in temperature caused a decrease of 1.7-1.8 m/s (24). In this study, a decrease of 1 °in rectal temperature and an average increase of 1 ° in skin temperature were recorded at the end of the 30-minute period in the two groups. However, a decrease in potential duration was recorded only in the experimental group. The reason for this difference is thought to be the vasodilation effect of 0.5% bupivacaine applied from the lumbosacral region to the epidural space.

The infrared thermal camera could not confirm the success of epidural anesthesia. When the available data and the literature were examined, it was thought that SEP analysis performed before and after the application could confirm the success of epidural 0.5% bupivacaine application, albeit with a small difference. Although a slight clinical difference was noted in the experimental group, no statistically significant difference was found. The reason for the failure of our method to confirm the accuracy of epidural bupivacaine administration was thought to be that the thermal camera we used for recording was not sensitive enough, or that epidural administration of bupivacaine may not have a recordable effect on skin temperature in cats. Further studies on this subject are recommended.

Acknowledgements

This study was derived from the MSc thesis of the first author.

Financial Support

This research received no grant from any funding agency/sector.

Ethical Statement

This study was conducted after the animal experiments were approved by the Burdur Mehmet Akif Ersoy University Local Ethics Committee (Decision number: 1182).

Conflict of Interest

The authors declared that there is no conflict of interest.

Author Contributions

ÖŞŞ and MAK conceived and planned the experiments. MAK carried out the experiments. ÖŞŞ and MAK planned and carried out the simulations. MAK contributed to sample preparation. ÖŞŞ and MAK contributed to the interpretation of the results. MAK took the lead in writing the manuscript. All authors provided critical feedback and helped shape the research, analysis and manuscript.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Animal Welfare

The authors confirm that they have adhered to the ARRIVE Guidelines to protect animals used for scientific purposes.

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