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Evaluating the Tissue Safety of Epidural Lidocaine: A Radiological, Gross, and Histological Study in a Canine Model

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***Abstract*—** Epidural anesthesia is a technique widely practiced in veterinary medicine despite reservations about its probable local neurotoxic side effects. This study was undertaken to assess the clinical, radiological, gross, and histological changes following administration of epidural lidocaine in dogs. Twelve healthy male dogs were used for this study and were randomly assigned to two equal groups of six each. Group A (Control group) received distilled water while Group B received 2% lidocaine hydrochloride at a dose of 4.5 mg/kg. The body weight for each dog. Clinical observations were made during the period of anesthesia and after that period. Radiological examination was done before the injection and after 24 hours. Gross and histological examinations of the spinal cord were carried out 72 hours post-injection. Both groups showed transient ataxia. However, the treated group (lidocaine group) demonstrated additional transient motor dysfunction and vocalization, all of which resolved within one hour. Gross examination demonstrated focal redness with small hematomas at injection sites. The lidocaine group demonstrated significant histological alterations at 72 hours, including axonal degeneration, neuronal atrophy, Schwann cell swelling and vacuolation, pronounced perineuronal vacuolation, and early transient degenerative micro-lesion despite the transient nature of the clinical signs. Despite these tissue alterations, all clinical motor effects were fully reversible. The statistical analysis showed significant changes between groups at the level ($p < 0.05$). Epidural administration of lidocaine at 4.5 mg/kg induces transient and fully reversible clinical motor effects in dogs. However, the observed histological alterations at 72 hours suggest potential localized neurotoxicity. Therefore, while lidocaine remains a viable option for veterinary anesthesia, careful dosing, vigilant perioperative monitoring, and the consideration of neuroprotective strategies are recommended to mitigate potential tissue risks.

***Keywords* —** Epidural Anesthesia, Lidocaine, Tissue Integrity, Histopathology, Radiological Assessment.

INTRODUCTION

Epidural anesthesia is a widely popular technique employed in both human and veterinary medicine, offering effective regional analgesia for a variety of surgical and diagnostic procedures (1). This technique involves administering local anesthetics into the epidural space to achieve a reversible nerve blockade, primarily by inhibiting voltage-gated sodium channels and preventing the propagation of action potentials (2). Pain has physiologically different effects on the body system, especially on the respiratory and cardiovascular systems, in both intraoperative and postoperative monitoring (3,4).

Lidocaine hydrochloride is local anesthetic drug, very popular in use in medical branch both in human and animals is related to amino-amide class (5), has rapid onset with intermediate duration (1-2 hours), mostly used at concentrations 1% 2%, and when used in epidural anesthesia it recommended for short-duration operation (up to 1 hour), but in surgeries up to 2 hours, it recommended to use the combination with bupivacaine. The toxic effects of using lidocaine hydrochloride as local anesthesia may include drowsiness with hypotension, muscle tremors, nausea, and vomiting (6). Despite its widespread clinical use, few studies have systematically integrated clinical, radiological, gross, and histological assessments to characterize the complete tissue safety profile of epidural lidocaine in a controlled canine model. A comprehensive evaluation using a multimodal approach is critical for optimizing anesthetic protocols and ensuring patient safety in veterinary practice. Evidence from previous research highlights this need. Imani Rastabi *et al.* (7) reported that epidural lidocaine, when combined with general anesthesia in dogs, not only ensured effective analgesia but also influenced stress and immune responses, emphasizing that anesthetic intervention may exert effects extending well beyond immediate clinical outcomes. Therefore, the above project aimed to study the effect of epidural anesthesia with lidocaine hydrochloride anesthetic

administration on spinal cord integrity with surrounding tissues in dogs, compared to a distilled water control.

MATERIALS AND METHODS

Laboratory Animals and designed

Twelve apparently healthy male local-breed dogs were used in the study. Their average age was approximately 3.17± 0.15 years, and their average body weight was about 25±0.71 kg. The dogs were housed for 15 days in special cages prior to the procedure. The dogs were divided randomly into two groups, each containing the same number of animals (n=6):

I. Group (untreated control Group): Received an epidural injection of sterile distilled water at a volume equivalent to the treatment group.
II. Group Lidocaine Group: Received epidural injection 4.5 mg/kg. B. W. of 2% lidocaine hydrochloride (2).

Epidural Procedure

The experimental animals were fasted for six hours before the procedure. The surgical site was prepared at the end of the 7th lumbar vertebra (L7) and the 1st sacral vertebra (S1), known as the lumbosacral region, and aseptically prepared. A 22-gauge needle was inserted into the epidural space, and radiography using the hanging drop technique was used to confirm correct placement (Fig. 1). The designated solution was then injected slowly over 60 seconds (8).

Clinical Assessment

Dogs were continuously monitored during and after the procedure for clinical signs, including ataxia, vocalization, motor function of the hind limbs, and general alertness. The frequency of these signs was recorded and tabulated (Table 1). Recovery was defined by the ability to stand and walk without assistance (9).

Radiological Assessment

Ventro-dorsal and lateral radiographs of the lumbosacral region were obtained immediately after epidural administration and 24 hours post-injection. The radiographic images were examined for. This methodological approach was routinely used as a protocol in veterinary anesthesia scientific work; the radiographic image has been used effectively to monitor the dispersion of epidural injectates and detect anatomical changes (10).

Gross and Histological Assessment

All experimental dogs were euthanized seventy-two hours post-injection. The lumbosacral region was dissected and examined locally, macroscopically for redness, hematomas, or any abnormalities (Figure 3). Tissue samples were collected from the injection site, then the sample embedded (fixed) in 10% neutral buffered formalin for fixation. It was placed in formalin with the vertebrae and then extracted from the vertebrae because it is soft tissue (11).

Statistical Analysis

Statistical analysis was performed using SPSS (version 25.0). Categorical data were expressed as percentages and analyzed using Fisher's exact test or Chi-square test where appropriate. Statistical significance was set at $p < 0.05$. (12).

RESULT AND DISCUSSION

Clinical Findings

The clinical signs observed in both groups are summarized in Table 1. While all dogs in both groups exhibited transient ataxia, the Lidocaine Group displayed additional signs not seen in the control group, including shivering (33.33%), lameness (16.66%), and transient vocalization (16.66%). Furthermore, all dogs in the lidocaine group showed a temporary motor block of the hind limbs, with recovery of movement occurring between 30 and 60 minutes post-injection.

Table 1: Frequency of Clinical Signs Observed in Control and Lidocaine Groups.

Clinical Sign	Lidocaine Group (%)	Control Group (%)
Ataxia	100%	100%
Shivering	33.33%	0%
Lameness	16.66%	0%
Vocalization	16.66%	0%
Toe in Struggling (30-60 min)	100%	0%

Radiological Findings

The radiographic image analysis confirmed the actual placement of the spinal vertebrae for correct needle insertion into the lumbosacral space in all animals, as shown in Figure 1. No statistically significant radiographic changes were observed in the control group during the procedure. In the lidocaine-treated animals, radiographs taken immediately after injection showed minor displacement and mild distortion of the perispinal soft tissues at the injection site, consistent with a localized mechanical tissue response to the injected volume. These perispinal soft tissue changes were largely resolved on the 24-hour follow-up radiographs.

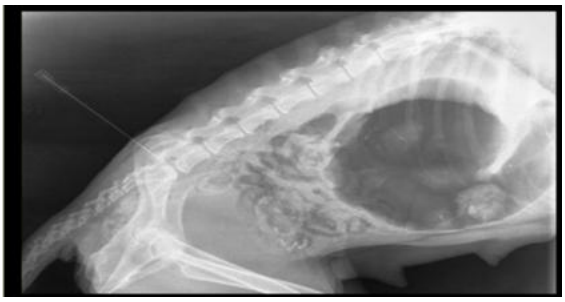

Figure 1. Representative radiograph demonstrating the correct placement of a 22-G spinal needle in the lumbosacral (L7-S1) epidural space of a dog. This confirms procedural accuracy for all animals in the study.

Gross Anatomical and Histopathological Findings

Gross examination revealed normal injection sites in the Control Group, whereas the Lidocaine Group showed temporary moderate redness and small hematomas at the injection site. However, the spinal cord and meningeal structures remained macroscopically intact in both groups without evidence of hemorrhage or direct trauma.

Histologically, the Control Group demonstrated normal spinal cord architecture with intact axons and normal Schwann

cells. In contrast, the Lidocaine Group exhibited sub-clinical microscopic alterations 72 hours after epidural administration, including localized structural compression consistent with post-injection edema (rather than true spinal cord atrophy), neuronal and axonal degeneration, Schwann cell swelling and vacuolation, pronounced perineuronal vacuolation, and early transient degenerative micro-lesions within the spinal tract. These sub-clinical microscopic findings suggest potential localized neurotoxic alterations associated with epidural lidocaine administration, while remaining below the functional threshold required to produce persistent neurological deficits.

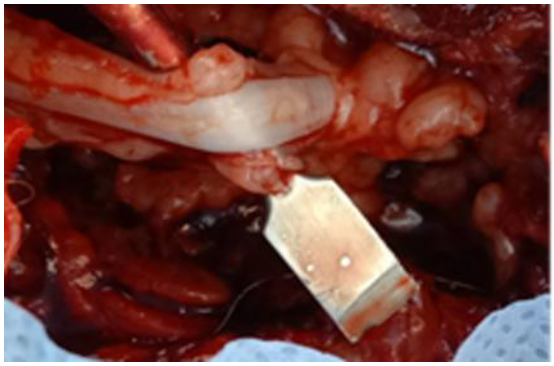

Figure 2. Gross anatomical dissection of the spinal cord post-euthanasia.

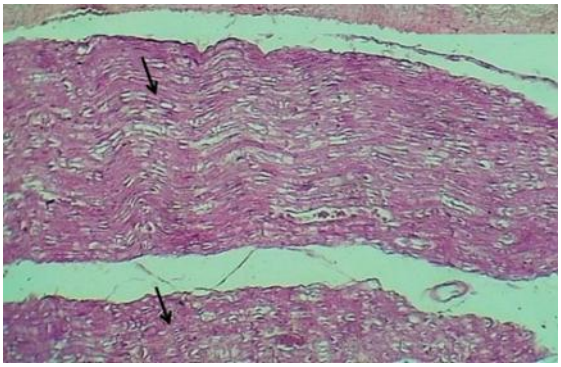

Figure 3. Longitudinal section of axon tract (Group A - Control) shows normal arrangement and appearance of axons and perineurium (Black arrows).H and E stain 100x.

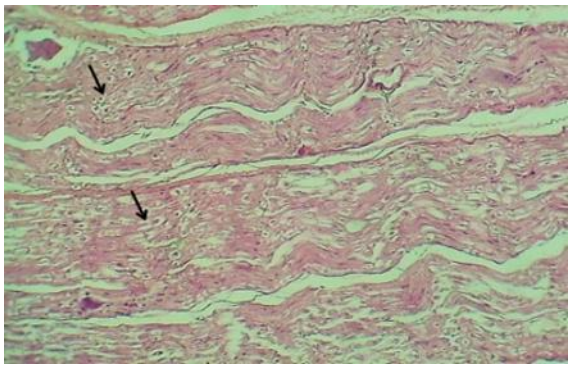

Figure 4. Longitudinal section of axon tract (Group A Control) shows normal arrangement and appearance of axons and Schwann cells (Black arrows). H and E stain 100x.

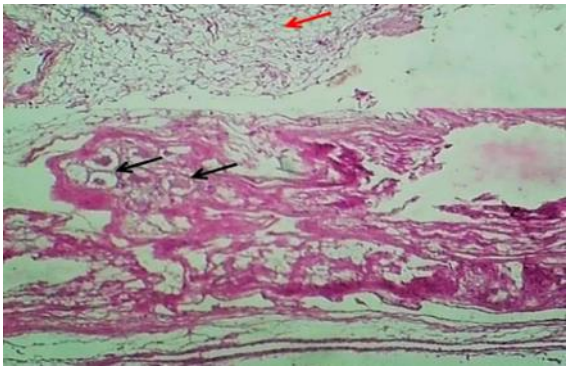

Figure 5. Histoparhological section (longitudinal) of axon Group B - Lidocaine) showing localized structural compression with perineuronal vacuolation and neuronal atrophy (Black arrows) and Degeneration tract of axons (Red arrows). H and E stain 100x.

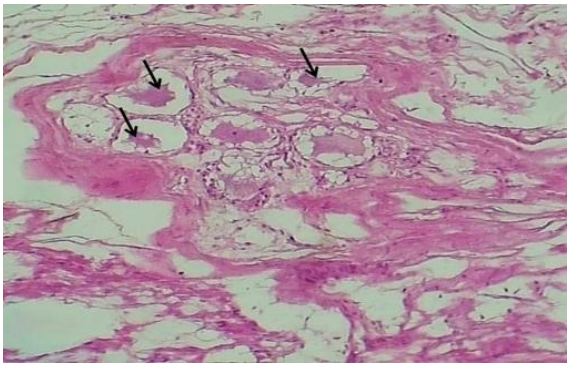

Figure 6. Histological section (longitudinal) of spinal cord segment (Group B – Lidocaine) showing pesrineuronal vacuolation and neuronal atrophy (Black arrows). H and E stain 400x. H and E stain 100x.

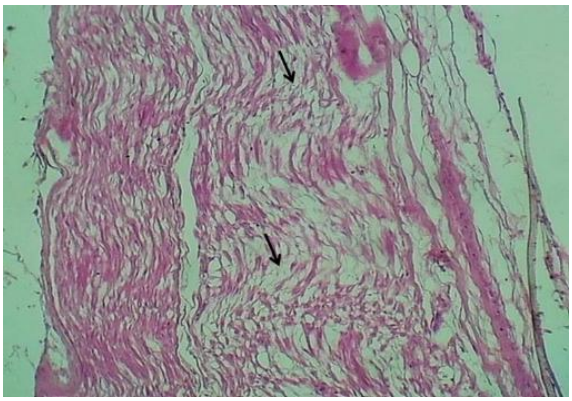

Figure 7. Histological section (longitudinal) of axon (Group B - Lidocaine) showing axonal and Schwann cell degeneration (Black arrows).H and E stain 100x.

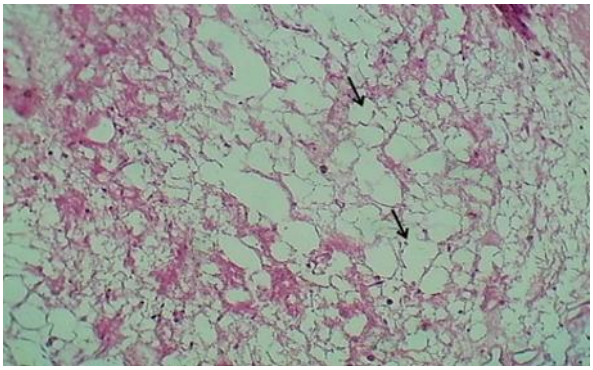

Figure 8. Histopathological section (cross) of the spinal tract (Group B - Lidocaine) showing early degenerative changes and scattered axonal alterations (Black arrows). H and E stain 100x.

The results of the present study revealed an apparent paradox in which clinical assessment indicated rapid and complete functional recovery, whereas histopathological examination demonstrated marked neural injury. This discrepancy suggests that the absence of persistent neurological deficits does not necessarily exclude the presence of underlying microscopic neurotoxic alterations. This dissociation between clinical recovery and histopathological injury is a recognized phenomenon in local anesthetic neurotoxicology, explicable through several well-established mechanisms. First, the nervous system maintains functional transmission even when a proportion of its axonal population is damaged; complete loss of motor function requires injury exceeding a critical threshold of fiber involvement, and focal or scattered lesions-as observed in the present study-may not reach this threshold Blight,)29); Sakura et al. (21). Second, the histopathological changes described in this study, including "focal necrosis" and "scattered axonal degeneration," represent localized, non-confluent lesions that differ fundamentally from the diffuse spinal cord destruction necessary to produce permanent paralysis, as confirmed by epidural lidocaine neurotoxicity studies in animal models Friederich and Schmitz, (20); Kirihara et al. (31). Third, Friederich and Schmitz, (20) demonstrated that lidocaine induces apoptotic cellular changes at the microscopic level that do not correlate with gross neurological deficits at clinically used concentrations. These documented precedents provide a sound scientific basis for the clinico-pathological divergence observed in our study.

The present study demonstrated that epidural administration of lidocaine hydrochloride induced transient neurological and motor disturbances in dogs, including ataxia, hind-limb motor block, shivering, lameness, and transient vocalization. Most of these clinical signs resolved within 30-60 minutes after injection, indicating that the observed effects were temporary and reversible.

These findings are consistent with those reported by Ghazy and Atiba, (14), who observed that epidural lidocaine administration in dogs produced effective analgesia associated with transient motor impairment and mild neurological effects without permanent complications. Similar observations were also reported by A. Ghazy *et al.* (15) in water buffalo calves, where epidural lidocaine induced reversible motor dysfunction and short-term neurological alterations related to its anesthetic action.

Gross anatomical examination in the current study revealed moderate redness and small hematomas at the injection site in the lidocaine-treated group, while the spinal cord and meningeal layers remained macroscopically intact without evidence of direct trauma or hemorrhage. In contrast, histopathological examination demonstrated sub-clinical microscopic alterations characterized by neuronal degeneration, perineuronal vacuolation, scattered axonal changes, Schwann cell swelling and vacuolation, and early transient degenerative micro-lesions within the spinal tract. In Group I (control group), the spinal cord architecture remained entirely intact, confirming that the epidural injection technique itself did not induce mechanical or structural injury. This information agrees with (16) that the earlier reports in dogs, where epidural administration of neutral solutions showed no evidence of neural damage. Another scientific report on histological analysis showed intact neural architecture in the control group, demonstrating that the epidural technique itself does not cause injury, consistent with previous findings in dogs and rabbits using neutral or saline solutions (17,18,19). The recorded lesions of dogs receiving lidocaine, which exhibited mild edema, inflammatory cell infiltration, axonal swelling, and early demyelination, are consistent with the transient neurotoxic effects previously reported for local anesthetics (20).

These manifestations likely arise from acute, temporary vascular and cellular stress rather than permanent structural devastation. However, the presence of localized axonal degeneration and neuronal atrophy in some sections aligns with literature linking higher concentrations of lidocaine to mitochondrial dysfunction and impaired axonal transport (21,22). Notably, the dose applied in this study (4.5 mg/kg. B. W.) falls within previously documented safe ranges, supporting the importance of careful dose selection.

The gross and radiological findings corroborated the histological findings, which showed localized redness and tissue swelling, with minor hematoma formation. All of these were transient, and motor function fully recovered within one hour. All animals resumed normal locomotion and behavior shortly after recovery, emphasizing the self-limiting nature of these tissue effects, as mentioned in (23,24).

The results which finding and records suggest that single epidural doses of lidocaine hydrochloride may cause mild side effects, transient neurotoxic changes without long-term functional deficits, as confirmed in long-term studies on dogs by (25,26).

The integration of clinical, imaging, and histological data strengthens the conclusion that epidural lidocaine is generally safe when used at therapeutic doses. Nevertheless, the occasional focal lesions underscore the need for cautious and carefully selected and calculated anesthetic drug dosing with caution and to justify the use of adjunctive neuroprotective strategies, such as dexmedetomidine, to further mitigate potential risks (27,28).

CONCLUSION

From the Current study, the conclusion demonstrates that administration of 4.5 mg/kg. B. W. of lidocaine hydrochloride in the epidural space leads to reversible clinical motor dysfunction, and it produces sub-clinical microscopic Histopathological neurotoxicity, which appears as axonal degeneration, neuronal atrophy, with early transient degenerative micro-lesions. These lesions reveal a critical divergence between clinical appearance and underlying neural pathology. Therefore, administration of lidocaine hydrochloride locally in the spinal space remains a clinically effective anesthetic drug; its potential for inducing iatrogenic spinal cord injury requires careful dose selection, with persistent monitoring, and the consideration of neuroprotective adjuncts to enhance its safety profile in the veterinary practice field.

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Conflict of Interest

The authors declare no conflict of interest.

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