ORIGINAL RESEARCH

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Bowel Pathologies Caused by the Use of Electrocautery Knife in Spinal Surgery with Facet Denervation: The First Experimental Study

Faset Denervasyonu Olan Omurga Cerrahisinde Elektrokoter Bıçağı Kullanımının Neden Olduğu Bağırsak Patolojileri: İlk Deneysel Çalışma

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Abstract

Objective: Monopolar electrocautery (MEC) or bipolar electrocautery (BEC) are surgical instruments commonly used in spinal surgery. Our study aimed to determine the bowel end pathologies induced by sacral parasympathetic network degeneration due to the use of MEC or BEC in spinal surgery.

Method: Twenty male hybrid rabbits were used in the study, including 5 in the control group, 7 in the BEC group, and 8 in the MEC group. We used the thoracic vertebra 11-lumbar vertebra 2 (T11-L2) spinal laminectomy for the operation technique. After one week, the animals' abdominal organs were examined on computerized tomography, and then the animals were sacrificed. The descending colon and Onuf's nucleus/S4 spinal ganglia were histopathologically examined. The colonic degeneration scores were numbered as follows: Normal (0P), vasospasm (1P), endothelial injury (2P), thrombus (3P), colonic wall injury (4P), inflammation (5P), colonic mucosal degeneration (6P), Auerbach myenteric ganglion degeneration (7P), and necrosis (8P). The groups were scored according to 36 points, and the results were compared with the number of degenerated pudendal ganglion neurons.

Results: The mean numbers of normal neurons/degenerated neurons were 22.610±962/5±2, 21.617±890/103±21, and 16.692±641/345±62 in the control, BEC, and MEC groups, respectively. The colonic degeneration score was <8 points in the control group, 9-30 points in the BEC group, and >31 points in the MEC group. Our results were statistically significant ($p<0.05$ for all).

Conclusion: In this study, we have found that high-voltage electrical devices such as MEC/BEC may cause bowel pathologies due to their harmful effects on the Adamkiewicz artery/sacral parasympathetic network and should not be used in spinal surgery unless necessary.

Keywords: Electrocauterization, facet denervation, neuronal injury, rabbit, spinal surgery

Öz

Amaç: Monopolar elektrokoter (MEC) veya bipolar elektrokoter (BEC), spinal cerrahide yaygın olarak kullanılan cerrahi aletlerdir. Çalışmamızda spinal cerrahide MEC veya BEC kullanımına bağlı sakral parasempatik ağ dejenerasyonunun neden olduğu bağırsak patolojilerini belirlemeyi amaçladık.

Yöntem: Çalışmada, kontrol grubunda 5, BEC grubunda 7 ve MEC grubunda 8 olmak üzere toplam 20 erkek hibrid tavşan kullanıldı. Ameliyat tekniği olarak torasik vertebra 11-Lomber vertebra 2 (T11-L2) spinal laminektomi uygulandı. Bir hafta sonrasında, hayvanların karın organları bilgisayarlı tomografi ile incelendi ve ardından hayvanlar sakrifiye edildi. İnen kolon ve Onuf çekirdeği/S4 spinal gangliyonları histopatolojik olarak incelendi. Kolonik dejenerasyon skorları: Normal (0P), vazospazm (1P), endotelyal hasar (2P), trombüs (3P), kolonik duvar hasarı (4P), inflamasyon (5P), kolonik mukozal dejenerasyon (6P), Auerbach miyenterik ganglion dejenerasyonu (7P) ve nekroz (8P) olarak skorlandı. Gruplar toplamda 36 puana göre puanlandı ve sonuçlar dejenere olmuş pudendal ganglion nöronlarının sayısı ile karşılaştırıldı.

Bulgular: Kontrol, BEC, MEC gruplarında sırasıyla ortalama normal nöron/dejenere nöron sayıları 22,610±962/5±2, 21,617±890/103±21 ve 16,692±641/345±62 idi. Kolonik dejenerasyon skoru kontrol grubunda <8 puan, BEC grubunda 9-30 puan ve MEC grubunda >31 puandı. Sonuçlarımız istatistiksel olarak anlamlıydı.

Sonuç: Bu çalışmada, MEC/BEC gibi yüksek voltajlı elektrikli cihazların Adamkiewicz arter/sakral parasempatik ağ üzerindeki zararlı etkileri nedeniyle bağırsak patolojilerine neden olabileceği ve gerekli olmadıkça omurga cerrahisinde kullanılmaması gerektiği sonucuna ulaştık.

Anahtar kelimeler: Elektokoterizasyon, faset denervasyonu, nöronal hasar, spinal cerrahi, tavşan

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Introduction

Parasympathetic innervation of the bowels is maintained by the lumbosacral plexus and blood supply provided by the Adamkiewicz artery (AKA), which was first described in 1882 by Adamkiewicz (1). Onuf's nucleus is a small group of neurons in the sacral spinal cord's ventral horns that provide parasympathetic innervation to the bowel, centralized in the sacral parasympathetic network (2). AKA provides the arterial circulation of the lower spinal cord; as a result, the arterial nutrition of the Onuf's nucleus and dorsal root ganglia (DRG) is also provided by AKA. DRG contains pseudounipolar neurons that convey sensory information from the colon to the spinal cord (3). DRG neurons innervate the large intestines of rats (4).

Bilateral segmental occlusion of AKA causes spinal cord ischemia-related dysfunctions of the lower extremities (5). Spinal subarachnoid hemorrhage may cause vasospasm in AKA (6). AKA vasospasm leads to degenerations in Onuf's nucleus/pudendal ganglia induced by urinary retention (7). Intestinal distension may occur secondary to DRG degeneration due to AKA spasm during SAH (8). These studies showed the importance of AKA in the functions of the abdominopelvic organs.

Electrical energy can cause nerve damage due to its thermal properties (9). The electric current's direction, location, and application time contribute to the amount of damage (10). A low-voltage electrical injury can cause arterial thrombosis, while a higher voltage electrical current can cause tetraplegia (11). Electrical injury results in vascular impairment, histological and electrophysiological changes in peripheral nerves (12).

Although electrical energy is known to cause tissue damage, it is frequently used in surgical applications. Especially in spinal surgery, monopolar electrocoagulation (MEC) or bipolar electrocoagulation (BEC) is preferred.

We aimed to reveal the neurovascular damage and adverse events caused by MEC and BEC, used mainly at high voltages in spinal surgery in the intestine, by conducting an experimental study.

Materials and Methods

Twenty male hybrid rabbits (age: 2 years; mean ± standard deviation weight: 3.5±0.4 kg) were used. The experiments were conducted with the approval by the Ethics Committee of Atatürk University (06.01.2004, no:17, number: B30.2.ATA.0.01.00/2). Rabbits are frequently used in such studies because they are suitable for experimental analyses. The effects of AKA-insult-related intestinal pathologies after MEC/BEC have not been studied yet in an experimental model.

In our study, five animals were assigned to the control group to estimate the normal neuron density in Onuf's nucleus/S4 spinal ganglia and colonic degeneration score. In the remaining animals, general anesthesia was induced with 25-mg/kg ketamine hydrochloride, 15-mg/kg lidocaine hydrochloride, and 1-mg/kg acepromazine. After the required surgical cleaning of the operation site, we cut the skin and subcutaneous tissue with a median skin incision adequate for the thoracic vertebra 10-lumbar vertebra 3 in the animals. The paraspinal muscles were removed subperiosteally from the spinous processes, laminae, and facet joints of the vertebrae by using a scalpel in the control group. We used MEC and BEC in the other groups for this purpose. Then, thoracic 11-lumbar two vertebrae (T11-L2) laminectomy was performed, and the facets were denervated with BEC (n=7) and MEC (n=8) using electrocoagulation using 220 V and 50 Hz. Fascia and skin were sutured with 3-0 cotton sutures. The animals were postoperatively followed up in their cages for 7 days without antibiotic/analgesic treatment. All the animals were subjected to multislice computed tomography (CT) to observe the abdominopelvic organs and then sacrificed. The S4 DRG ganglia neuron density, volumes of the descending colon sections, and colonic degeneration scores were determined. The colonic intestinal degeneration criteria we developed are as follows: Normal (0P), vasospasm (1P), endothelial injury (2P), thrombus (3P), colonic wall injury (4P), inflammation (5P), colonic mucosal degeneration (6P), Auerbach myenteric ganglion degeneration (7P), and necrosis (8P). The groups were scored according to 36 points, and the results were compared with the number of degenerate pudendal ganglion neurons. The tissues were preserved in paraffin blocks, and sections were stained with hematoxylin and eosin, aldehyde fuchsin, vanGieson, and terminal deoxynucleotidyl transferase UTP nick-end labeling. To estimate the numbers of degenerated neurons of the S4 ganglia, the physical dissector method was used as described by Yolas et al. (7).

The accepted neuronal degeneration criteria are cellular angulations, peri-cytoplasmic halo formation, cytoplasmic condensation, and nuclear shrinkage. Our former method to estimate the degenerated neuron density of the S4 ganglia (13) and the AKA degeneration criteria were used (6).

Statistical Analysis

Statistical analysis was performed in the SPSS 11.0 software for Windows. The volumetric changes of the colon and

the numbers of alive and degenerated neurons of S4 DRG were compared between the groups using a two-tailed t-test. Non-parametric relationships were examined with the Mann-Whitney U tests. For the analyses in which non-parametric tests were used, the differences between the groups were evaluated with the Tukey HSD post-hoc test. A p-value <0.05 was considered significant.

Results

Two animals with MEC and one animal with BEC showed wound problems at the thoracic operation level. The distended abdomen was detected in most animals in the MEC group (n=5) and a few in the BEC group (n=3). The animals showed defecation problems with cardiorespiratory disturbances secondary to abdominal swelling.

Radiological examination determined segmentary colonic dilatation, excessive intraluminal gas collection, and diaphragmatic elevation. It was found in the morphological examination that perivertebral duro-ligamentary adhesions, fibrosis, vascular congestion, and scar formation were more prominent in the MEC group than in the BEC group. Colonic examination revealed colonic dilatation, wall edema, hemorrhage, and scattered necrosis.

Mononuclear infiltration, neurovascular disarrangements, perineural capsule thickening, venous dilatations, arterial thinning, ligamentous rigidity, laminary burning scars, and spinal canal narrowing by intracanalicular tissues were more severe in the MEC group, moderately severe in the BEC group and absent in the control group. The spinal cord, nerve roots, evacuated intervertebral disk space, and denervated facets were visualized during the operation. After the operation, peridural adhesions and fibrotic tissue development were found in the denervated rabbits. Angulation, cytoplasmic condensations, flattening, elongations, vascular wall degeneration with atrophy/necrosis, and thrombus with intimal infiltrations in the AKA or branches were moderately severe in the BEC group and most severe in the MEC group.

An enlarged gaseous descending colon was detected in the multi-slice CT evaluation in the MEC group, and a necrotic descending colon was found in the macroscopic pathological evaluation (Figure 1). We detected the histopathological appearance of the degenerated/scaled endothelium and muscles, AKA, and dorsal root ganglion in an animal undergoing MEC (Figure 2). The S4 dorsal root ganglion and spinal cord degenerated or lost axons, and apoptotic neurons of the S4 roots in a MEC-treated animal were histopathologically evaluated (Figure 3). In an animal treated with MEC, the secretory cells, myenteric ganglia, and the histopathological appearance of the intestine and degenerated part of the intestine were detected (Figure 4). Histopathological appearance of colonic mesenteric artery branches is seen in control, with moderate BEC, and severe degenerated/desquamated endotheliums and muscles are seen in a MEC applied animal (Figure 5). The damaged intestinal wall was detected in the dilated segment of the MEC-treated animal (Figure 6).

The numbers of normal and degenerated neurons, and the colonic degeneration scores are given in Table 1. The mean number of the alive/normal and degenerated neurons were 22,610±962/5±2, 21,617±890, and 16,692±641/345±62 in the control, BEC, and MEC groups, respectively. There were significant differences among the groups (p<0.001). The values in the MEC group were significantly lower than in the other two groups (p<0.001 for both).

The mean colonic degeneration scores were <8, 9-30, and >31 in the controls, BEC, and MEC groups. The score in the

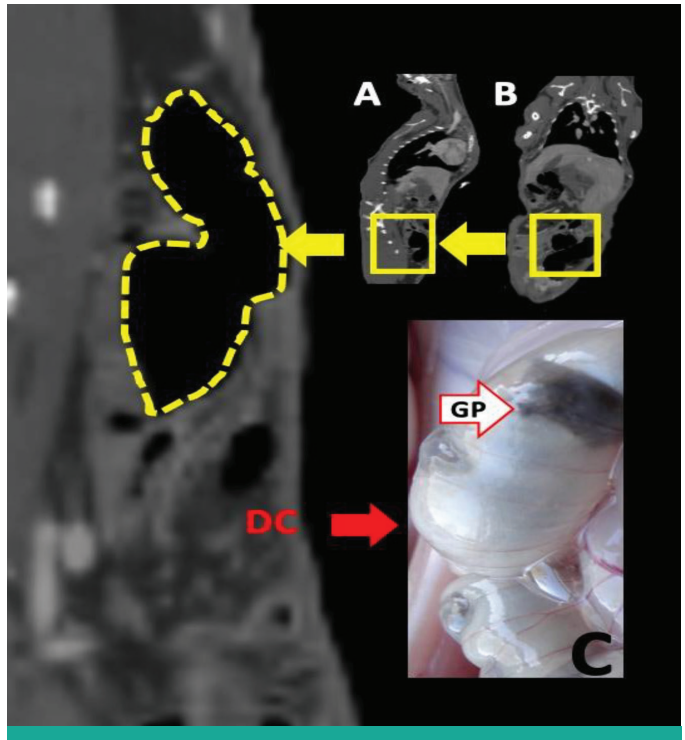

Figure 1. Multislice computed tomography image of a rabbit's abdomen in the sagittal (A) and coronary planes (B), showing an enlarged gaseous descending colon (yellow sguaresin A and B) and the anatomical appearances of the descending colon (DC) and gangrenous necrotic colon part (GP) (C) in a rabbit treated with monopolar electrocautery

MEC group was statistically higher than in the other groups (Table 1).

Discussion

Although MEC/BEC has hazardous effects on neurovascular tissues, it is used mainly in spinal surgery (13). Vascular deformities, myoendothelial degeneration, and thrombus in most spinal radicular arteries and the AKA were most severe in the MEC group and moderately severe in the BEC group (14).

The sacral parasympathetic fibers originating from Onuf's nucleus innervate the distal colon, and peripheral axons of the DRG travels through the pudendal, pelvic, and hypogastric nerves (15). Peripheral axons originating from sacral cord ganglion cells, named "pudendal nerves,'' course into the urethra and distal colon (16). The sacral parasympathetic nucleus originates from fibers innervating the contractor smooth muscle of the bladder, colon descendants, and rectum (17). With the activation of Onuf's nucleus, the pelvic floor sphincters relax during micturition or defecation, or sexual activity (18). The DRG contains pseudounipolar neurons that convey sensory information from the colon to the spinal cord and central nervous system. DRG or nerve root compression is an essential factor causing intestinal problems due to neuronal insensitivity to ectopic discharges of target organs (19). As a result, the sacral parasympathetic network provides parasympathetic innervation of the lower abdominal and pelvic organs.

Facet denervation may be related to the higher incidence of postoperative complications after the spinal surgery (14). We may think that the intestinal complications are related to the harmful effects on the sacral parasympathetic in facet denervation animals. We did not analyze its effect on the development of intestinal pathologies due to the lack of animals without facet denervation. So, future

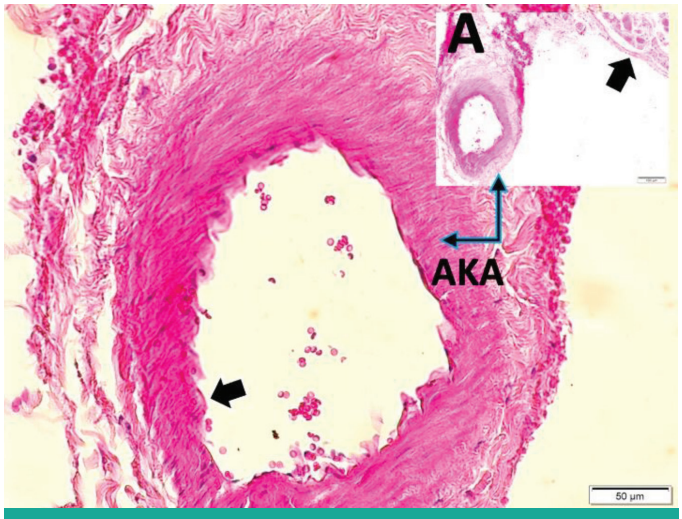

Figure 2. Histopathological appearance of the Adamkiewicz artery (AKA) and dorsal root ganglion [black arrow/light microscopy (LM), hematoxylin&eosin (H&E) staining, original magnification' 4/A] and magnified form of the AKA with degenerated/desquamated endothelium and muscles in a monopolar electrocautery-treated rabbit (LM; H&E, original magnification '20/base)

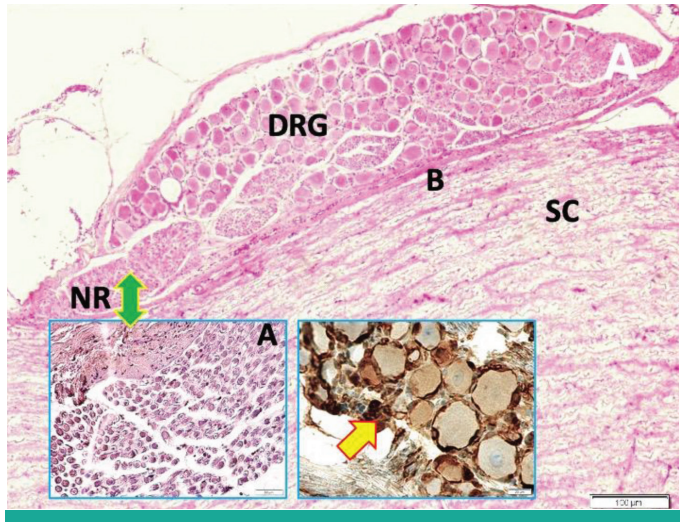

Figure 3. Histopathological appearance of the L4 dorsal root ganglion, nerve root (NR), and spinal cord [SC; light microscopy (LM), hematoxylin and eosin staining, original magnification '10/base]. Degenerated or lost axons (Pale) and apoptotic neurons of the L4 roots can be observed in a monopolar electrocautery-treated rabbit (LM; terminal deoxynucleotidyl transferase dUTP nick-end labeling, original magnification '10/B)

Table 1. NND/DND of S4 ganglia (n/mm^3) and CDS

	Control (n=5)	BEC (n=7)	MEC (n=8)	p1	p2	p3
NND †	22.610±962	21.617±890	16.692±641	0.125	<0.001	<0.001
DND †	5±2	103±21	345±62	0.003	<0.001	<0.001
CDS ‡	<8	9-30	>31	<0.05	<0.001	<0.001

†: Mean ± standard deviation, †: n, (min-max)

p1: Between control and BEC, p2: Between control and MEC, p3: Between BEC and MEC. NND: Normal neuron densities, DND: Degenerated neuron densities, CDS: Colonic degeneration scores, BEC: Bipolar electrocautery, MEC: Monopolar electrocautery

experimental studies are needed to evaluate the impact of facet denervation and sacral parasympathetic injuries.

The effect of MEC on the number of degenerated neurons after experimental spinal surgery has been studied previously. Aydin et al. (13) found that MEC application caused significantly higher numbers of degenerated neurons. They concluded that neuronal degeneration was directly related to the impact of the electric current. Our study is the first to use both MEC and BEC applications in experimental spinal injuries. The present findings may be regarded as evidence for the harmful effects of MEC applications on the neurovascular tissues.

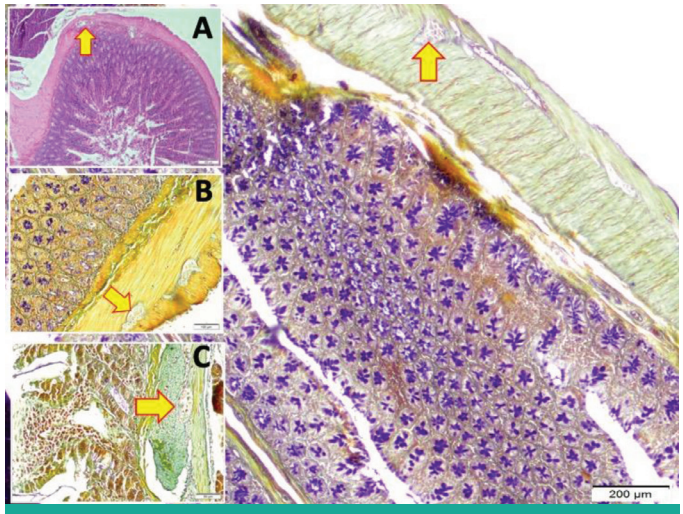

Figure 4. Histopathological appearance of the bowel with normal [light microscopy (LM), hematoxylin and eosin staining, original magnification '4/A] secretory cells and myenteric ganglia (LM, aldehyde fuchsin, original magnification' 4/base; magnified form, original magnification '10/B), and degenerated part of the bowel is a monopolar electrocautery-treated rabbit (LM, aldehyde fuchsin, original magnification '10/C)

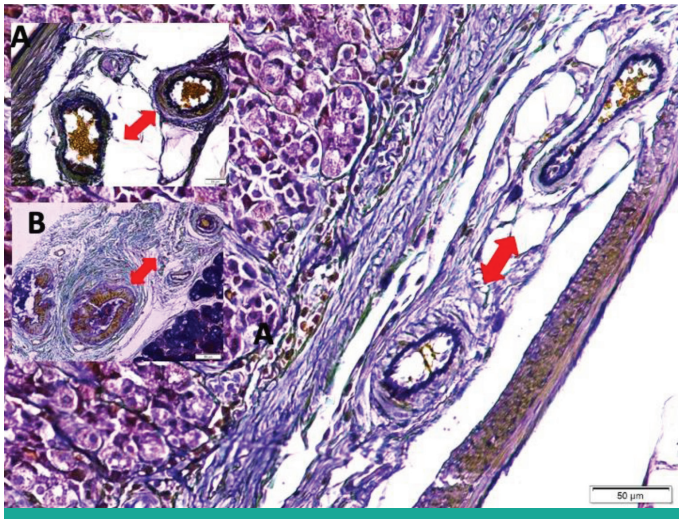

Figure 5. Histopathological appearance of colonic mesenteric artery branches (arrows) are seen in control (LM, Aldeyde fuchsine, x20/base), with moderate (LM, Aldeyde fuchsine, x20/A) in BEC and severe degenerated/desquamated endotels and muscles (LM, Aldeyde fuchsine, x20/B) are seen in a MEC applied animal

The association of electricity and neurovascular injury is another speculated issue. Longer contact time and higher voltage cause severe injuries than brief contact with low voltages (13,14). The non-thermal mechanisms can be questioned, leading to the reversible cell damages in such injuries. Besides, electrical burn also causes arterial injuries and consequently the development of thrombosis (14). Therefore, even in direct contact with the neuronal tissues, an electric current may be hazardous if used in spinal surgery incautiously.

Our study experimentally determined that the AKA could be seriously damaged by high-voltage electrocautery applications, which can cause sacral parasympathetic network dysfunction and bowel paralysis. Although we investigated bowel involvement due to parasympathetic damage in our study, parasympathetic damage will cause changes in much lower abdominal and pelvic organs. Ozturk et al. (8) showed that AKA vasospasm was seen after spinal subarachnoid hemorrhage secondary to the neurodegeneration of the dorsal root ganglion. They also reported the coexistence of bowel dilatation with subarachnoid hemorrhage in association with AKA vasospasm. Our study provides a better understanding of the mechanism of abdominopelvic complications of unknown causes after a safe spinal surgery. The effects on other abdominopelvic organs can also be investigated.

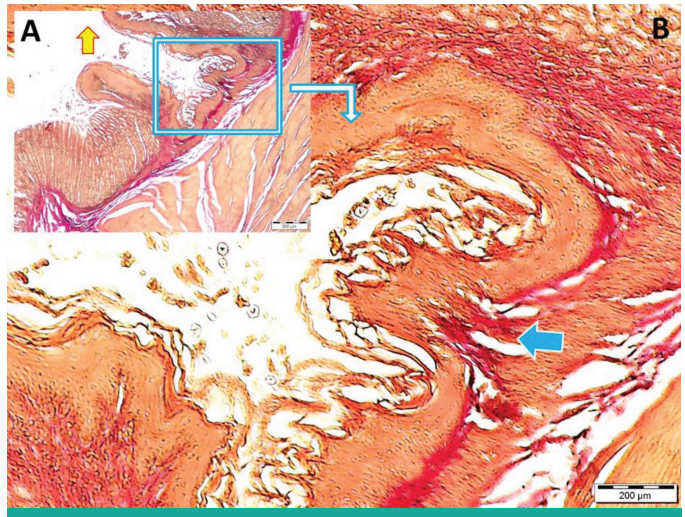

Figure 6. Histopathological appearance of destructed bowel wall at the dilated segment in Figure 1C of a MEC applied animal (LM, Van Gieson, xx4/A; x10 B)

In this sense, it will also benefit clinicians. We think that better results will be obtained with angiography and electrophysiological examinations.

Conclusion

The lack of experimental groups without facet degeneration and functional motor testing of the urinary bladder were the major limitations of the present study.

Our results show that electrocautery knives such as BEC/MEC should not be used in spinal surgery, unless necessary, to avoid neurovascular tissue damage.

Ethics

Ethics Committee Approval: The experiments were conducted with the approval by the ethics committee of Atatürk University (06.01.2004, no:17, number: B30.2.ATA.0.01.00/2).

Informed Consent: It is an experimental study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: M.K.K., A.Y., A.A., Design: M.K.K., A.Y., A.A., Data Collection or Processing: M.K.K., A.Y., M.D.A., Analysis or Interpretation: M.K.K., A.Y., M.D.A., A.A., Critical Review of the Manuscript: M.D.A., A.Y., A.A., Final Approval: M.K.K., A.A., A.Y., M.D.A.

Conflict of Interest: No conflict of interest was declared by the authors.

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