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Hazardous Effects of Lumbar Somatosensitive Dorsal Root Ganglion Ischemia on Abdominal Skin Following Spinal Subarachnoid Hemorrhage: The First Experimental Study

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Abstract: Somatosensitive innervation of lower abdominal region skin region (LARS) is mainly managed by somatosensitive fibers of lumbar spinal dorsal root ganglions (DRG). We investigated if there is a relationship between the degenerated neuron densities (DND) of the first lumbar DRG (L1) and LARS' total tissue viability score (TVS) following subarachnoid hemorrhage (SAH). Study was conducted on 20 rabbits. All animals divided in three groups as Control group (n=5), SHAM group (n=5) and study group (n=10). For SHAM group 0,5 cc saline solution injected into lumbar spinal subarachnoid space and for study group, 0.5cc autolog blood injected into lumbar spinal subarachnoid space under general anesthesia. All animals were followed up three weeks and sacrificed. DND of L1 DRG (n/mm3) and the histopathological changes of LARS examined histopathologically. A value determined for hair loss per square millimeter (n): 1 point(P); if n<5, 2P if 10>n>5; 3P if n>10. For skin thickness as micrometer (T□m), it was scored as 1P if T>700□m, 2P if 600□m <T>400□m, and 3P if T<400□m. Evaluation was made on their total 12-points tissue viability score (TVS). If TVS>10, the skin is considered as normal; If 10<TVS>6, the moderately damaged; if TVS < 7, the was severely damaged. DND and TVS values analyzed by Mann Witney U test. The mean DND of LI DRG (n/mm3) and TVS values were determined as 13±3/11±1 in control; 34±8/8±2 in SHAM and 263±44/<6 in the study group. Statistical values were: p<0.05 (Control/SHAM), p<0.0005 (SHAM/Study) and p<0.0001 (Control/Study). Somatosensitive innervation deficiency resulting from DRG ischemia following SAH may lead to deterioration of LARS which may be important in reconstructive surgery. © 2022 NTMS.

Keywords: Abdominal Skin; Dorsal Root Ganglion Ischemia; Spinal Subarachnoid Hemorrhage.

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1. Introduction

The LARS is innervated by somatosensitive spinal nerves, sacral parasympathetic and thoracolumbar sympathetic nerves. Tissue viability of LARS depends on the normal formation of the intercostal, superior epigastric, external and internal epigastric arteries feeding these areas (1). Abdominal wall blood supply is maintained by internal thoracic, internal iliac, external iliac arteries and some branches of aorta (2). Experimental and clinical studies shown that histoanatomical characteristic of recipient and donor sites' viabilities are important for surgical outcome. Or else, tissue reject/necrosis or dehiscence in surgical area could be inevitable. Vasodilators have wound healing potential (3). It is well known that DRG neurons secrete vasodilators and play major roles on wound healing (4). SAH can lead decreased spermatogenesis (5), Hirschsprung-like diseases (6), second motor neuron degeneration (7), urinary retention (8), descending colon dilatation (9). These experiments have shown that spinal subarachnoid hemorrhages can cause cutaneous ischemia and necrosis in related dermatomes with their degenerative effects in dorsal root ganglia, in addition to chronic complications in visceral organs as well as paraparesis-paraplegia. The pearl of our study is that denervation injury cause memory loss in tissue and causes of organ or flap rejection and even dehiscence. In current plastic surgery principles, it is known that adequate vascular flow is generally considered in flap design for the area to be reconstructed. However, the neglected importance of the neural network is that it also innervates the vessels and that its neovascularization originates from the arteria nervorum rather than the arteries, and it seems to open a new horizon for all surgeons in this field.

2. Material and Methods

This experimental study was performed with 20 rabbits. Ethical approval obtained from The Ethical Committee of Ataturk University. Five rabbits (n=5) were used to determine the normal structure of the L1DRG and LARS. The remainder animals (n=15) were anaesthetized by 25 mg/kg ketamine hydrochloride, 15 mg/kg lidocain hydrochloride and 1mg/kg acepromasine combination. After required thoracolumbar cleaning, SHAM group (n=5) received 0,5 cc saline and 0.5 cc autolog blood injected into lumbar spinal subarachnoid space of study group (n=10). After followed-up three weeks, they were sacrificed under general anesthesia following intracardiac formaline injection. Their L1DRG and rots complexes at the level of L1 and LARS were removed and preserved in 10 % formalin solution for four days. Tissues were stained with hematoxylene and eosin (H&E) and analysed by Stereological and cavaliery methods. Histopathologically, condensed cytoplasmic, shrinkaged nucleus, angulated neurons and halo formation covered cytoplasm and regressed cytoplasm accepted as neuro-degeneration criteria of dorsal root ganglion neurons. Physical dissector method was used to evaluate the numbers of neurons in DRG. A value determined for deformed hair follicles numbers per square millimeter (n): 1 point(P); if n<5, 2P if 10>n>5; 3P if n>10. For skin thickness as micrometer (Tμm), it was scored as 1P if T>700 μm, 2P if 600 μm <T>400 μm, and 3P if T<400 μm. Evaluation was made on their total 12-points tissue viability score (TVS). If TVS>10, the skin is considered as normal; If 10<TVS>6, the moderately damaged; if TVS<7, the was severely damaged. DND and TVS values analyzed by Mann Witney U test.

2.1. Statistical Analysis

All values are expressed as the mean±SD. The differences between the TVS and the DND compared statistically. Mann-Whitney U nonparametric test used for statistical comparisons. Differences were considered to be significant at $p<0.05$.

3. Results

Two animals dead with surgery and SAH complications within the first week. Intestinal and bladder distenions, paraparesia, spastic or flask gait disturbances an limitations of tail movements were observed in some surviving animals of study grup. Histopathologicaly, notified severe vasospasm of Adamkiewicz artery branches and arteria nervorums, neuronal degeneration was observed in the Onuf's nucleus and dorsal root ganglia of pudendal nerves in SAH group. Macroscopical appearances of spinal cords shown subaracnhnoid hemorrhage induced spinal cord edema, clot formation in subarachnoid spaces and nerve roots in the study group.

3.1. Histopathological Results

Histopathological appearances of spinal cord and L1 DRG, DRG with normal and degenerated neurons in a SHAM and study animal (Figure 1). Histopathological appearances of spinal cord and L1 DRG with normal and degenerated neurons, spinal cord and nerve roots are seen in a study animal (Figure 2). Histopathological appearances of skiin and normal and degenerated hair follicles with normal skin in a normal, DH and thinned skin in a SHAM and many numbers of DH and very tinned and fragmented skiin in a study animal (Figure 3).

3.2 Numerical Results

The mean DND of LI DRG (n/mm3) and TVS values were determined as 13±3/11±1 in control; 34±8/8±2 in SHAM and 263±44/<6 in the study group. Statistical values were: $p<0.05$ (Control/SHAM), $p<0.0005$ (SHAM/Study) and $p<0.0001$ (Control/Study).

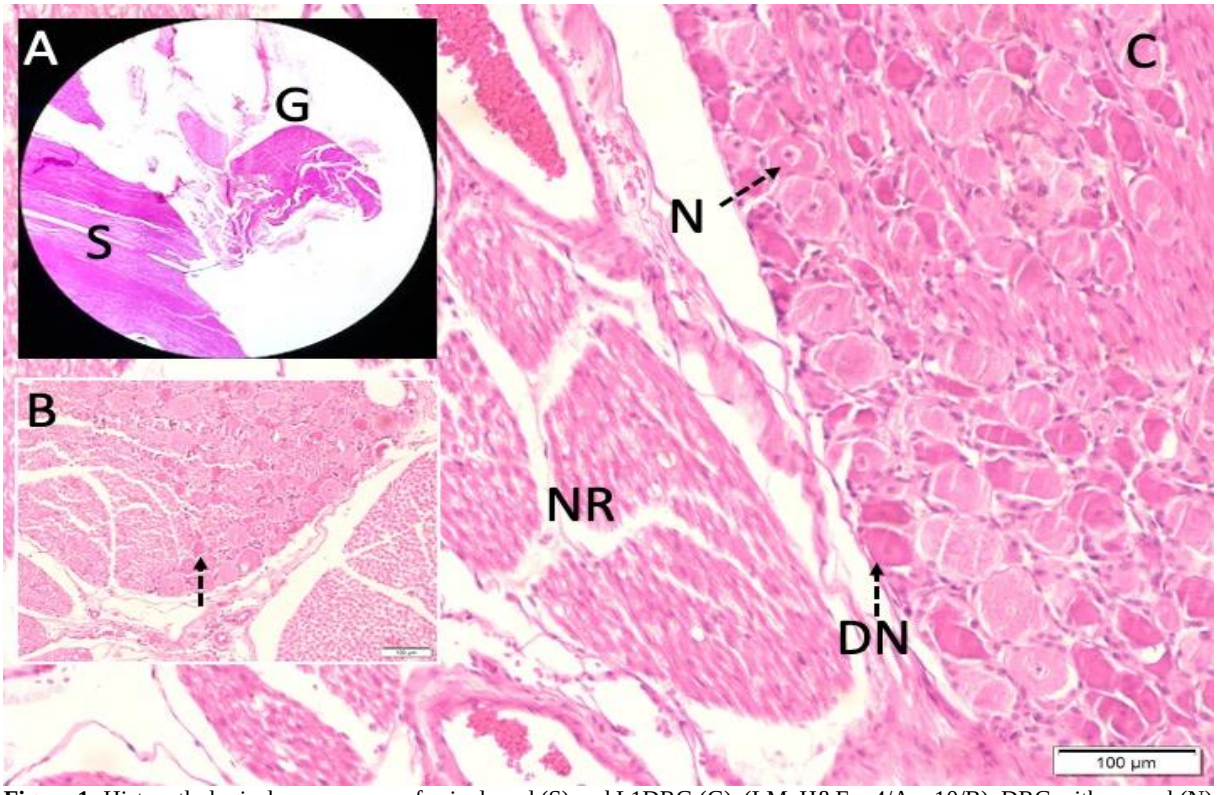

Figure 1: Histopathological appearances of spinal cord (S) and L1DRG (G) (LM, H&E, x4/A; x10/B), DRG with normal (N) and degenerated neurons (DN) in a SHAM (A,B) and study animal (C) are seen.

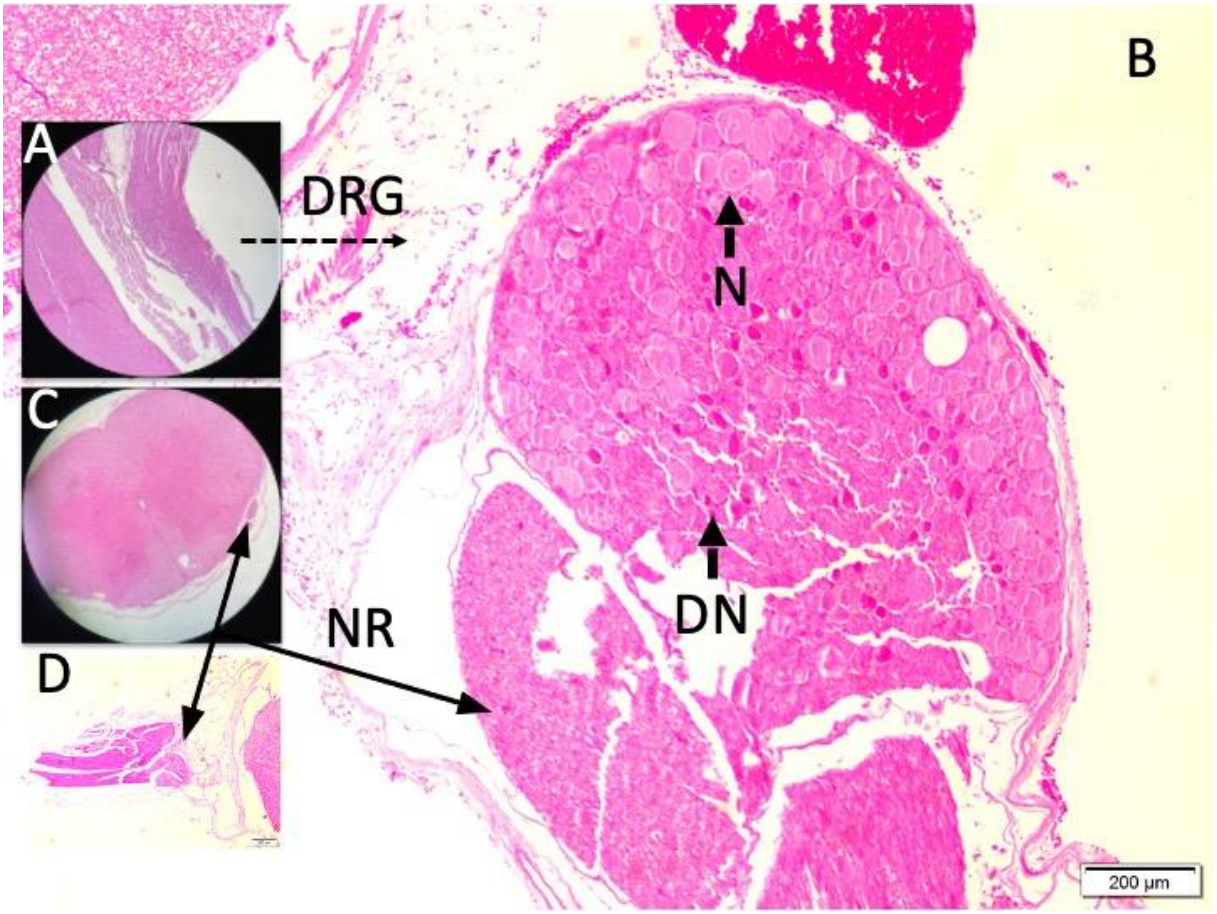

Figure 2: Histopathological appearances of spinal cord and L1DRG with normal (N) and degenerated neurons (DN) (LM, H&E, x4/B), spinal cord (LM, H&E, x4/C) and nerve roots are seen in a study animal are seen (LM, H&E, x4/B,C.D).

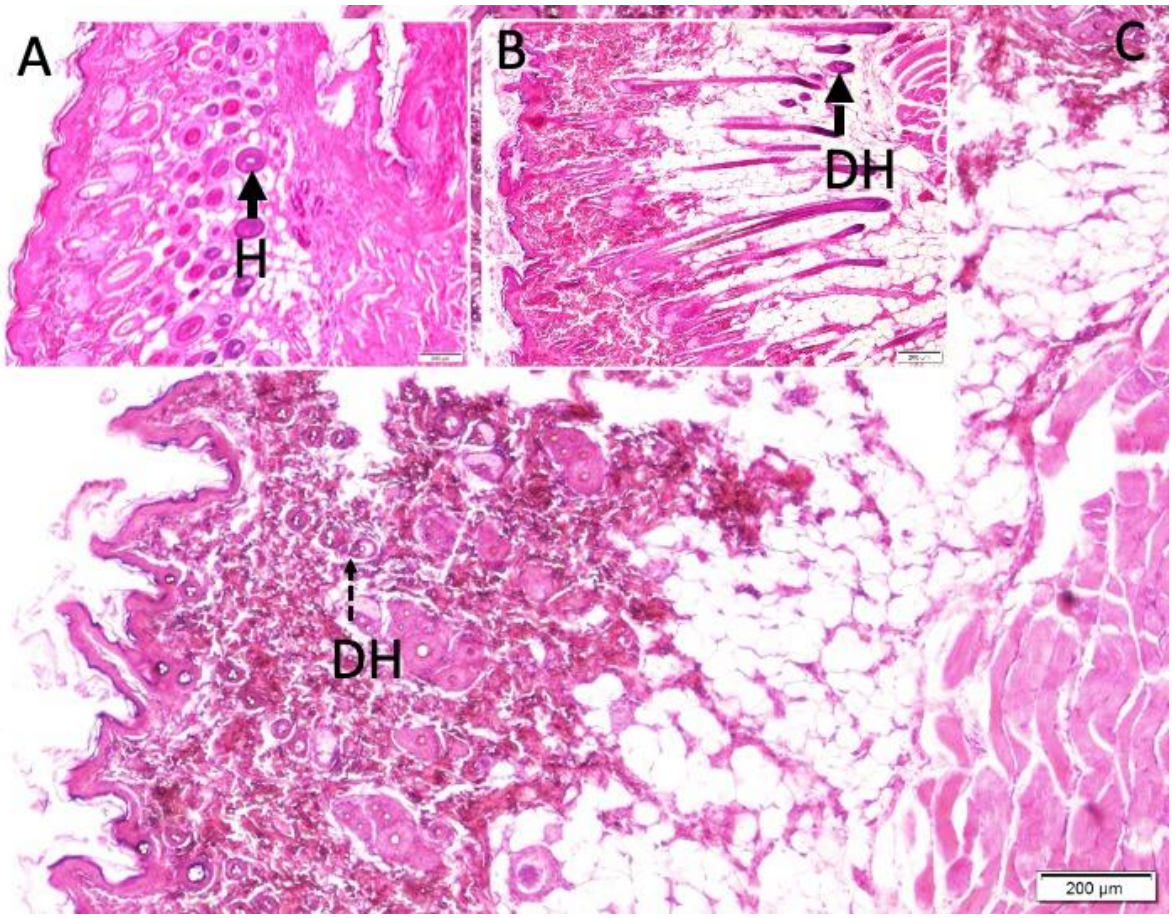

Figure 3: Histopathological appearances of skiin and normal (H) and degenerated hair follicles (DH) with normal skiin in a normal (A), DH and thinned skiin in a SHAM (B) and many numbers of DH and very tinned and fragmented skiin in a study animal (LM, H&E, x20).

4. Discussion

The vitality of the histological units in the abdominal skin and surrounding organs are related to the somatosensitive spinal nerves innervating these areas, the parasympathetic fibers originating from Onuf's nucleus and thoracolumbar sympathetic nerves. It also depends on the normal circulation of the intercostal, superior epigastric, external and internal epigastric arteries of LARS. Any damage of neurovascular network impairs the health of the abdominal structures. Especially neurovascular network diasabilities lead to poor prognosis following reconstructive surgical interventions. Here, we examined the neurodegenerative changes in the L1 root of the lumbar somatosensitive nerve network induced by spinal SAH and the microanatomical changes in the LARS innervated by this roots.

4.1. Innervation of Lower Abdominal Skin

Lower abdomen is inervated by L1-S1 spinal nerve roots, sacral parasympathetics and abdominopelvic sympathetic nerves (1). It has been reported that examining of afferent cutaneal sensory discharges are important indicator for tissue strength and viability. Because tissue sensation measurement is required for not only donor site but also recipient site preoperatively. Altough doppler USG examination is essential for determination of tissue viability, but it not adequately be alone. It should not be forgotten that neurophysiological studies of related nerves certainly required (10).

Abdominal wall weakness occurs due to decreased strength of muscles (11). So, DRG degeneration may be rely on decreased strength of muscles. Cutaneous microcirculatory regulation is maintained by vibration sensing mechanoreceptors innervated by somatosensitive fibers arisig from segmental DRG (12). Because the skin innervating nerves of abdominal wall travel around of epigastric arteries; injury of that neurovascular tree associated with hair loss (1). For obtaining of excellent result, neural-vascular and related tissues should be transferred together (13).

4.2. Arteries of The Lower Abdominal Skin

Abdominal wall blood supply is maintained by internal iliac artery and it’s branches such as umbilical artery, ductus deferentis artery, superior vesical artey, prostatic artery, superior gluteal artery, iliolumbal

artery, obturatory artery and inferior gluteal artery. The other main arterial tree is external iliac artery and it's branches such as inferior epigastric artery and deep circumflex iliac artery and superior epigastric artery branch of internal thoracic artery (2).

Epidemiological studies have suggested that histoanatomical architectures of recipient and donor site-supplying arteries should be normal range (14). Or else, tissue reject/necrosis could be inevitable. Nitric oxide-like vasodilators producing nerves have wound healing potential (3). It is well known that DRG neurons secrete copious amounts vasodilators. For example, nitric oxide is a vasodilatory neurotransmitter in the mesenteric artery (4).

It is known that long vein grafts used to maintain flow continuity in the flap pedicle will have negative consequences on flap viability (15). In our opinion, although long vein grafts are considered appropriate in terms of vascular anatomy, segmental neural innervation of such a long flap will be unsuccessful due to insufficient innervation because it is made from more than one root. As a new idea, we can say that although the hardware of the vascular structures are in-house, the software comes from the neural tissues. In summary, a graft tissue that is used without its neural components has a memory loss due to neural software insufficiency. As a team, we have studies on this subject that are still in the publication stage. Memory loss in tissue may be one of the most important causes of organ or flap rejection and even dehiscence.

4.3. Spinal SAH Induced Somatovisceral Disorders

Lumbosacral pathologies can lead to infertility due to decreased sperm number following spinal SAH induced by testiculary artey spasm due to parasympathetic innervation deficiency (5). Onuf's nucleus insults could rely on Hirschsprung-like diseases and vascular insufficiency (6). Gray matter ischemia may lead to second motor neron degeneration (7). Adamkiewicz artery spasm lead to dorsal root ganglion degeneration (16), Onuf's nucleus-pudendal nerve ganglia insult and urinary retention (8), descending colon dilatation (9). In summary, the sacral parasympathetics, the parasympathetic innervaters of the arteries supplying the lower abdomen, arise from Onuf's nucleus and supply the Adamkiewicz artery. Ischemic damage to the Adamkiewicz artery after SAH invites all the somatic and autonomic pathologies mentioned in this section.

5. Conclusion

These experiments have revealed the importance of DRGs in maintaining skin viability, which has not received much attention in clinical practice. The spinal cord takes the necessary precautions about the source that sends the signal by transmitting the decisions it makes about the skin according to the mechanosensitive signals it receives from the skin through DRGs, both to the skin and to the entire nervous system. Interruption of this information in pathological conditions may be an overlooked cause of non-healing wounds and decubitus ulcers.

Future Insight

DRGs, each containing neurons, a neurochip yet to be identified, are actually a miniature memory store that records signals from tissue. Damage to these neurochips may impair tissue memory, leading to a loss of identity in the tissue. The solution of this extremely dangerous darkness with digital logic may herald great revolutions that cannot be imagined yet in the illumination of unknown medical problems, especially the rejection process seen in reconstruction and transplantation surgery.

Limitations of the Study

This study doesn't include electrophysiological studies.

Acknowledgement

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Conflict of Interests

There is no conflict of interest.

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Author Contributions

Conceived and designed the analysis: AO, MHS, MZ, MKK, RD, OC, MDA Collected the data: AO, MHS, MZ, RD. Contributed data or analysis tools: AO, MHS, MKK, RD, MDA. Performed the analysis: OEY, YK. Wrote the paper: AO, MHS, MZ, MKK, RD, OC, MDA

Ethical Approval

Ethics committee approval was received for this study from the ethics committee of Atatürk University

Data sharing statement

All data relevant to the study are included in the article.

Consent to participate

None

Informed Consent

None

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