

Configuration of sacral plexuses in Hasmer and Hasak sheep breeds: a comparative macro-anatomical approach

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Abstract

The aim of this study was to examine and compare the macro-anatomical structures and configurations of *plexus sacralis* in Hasmer and Hasak sheep breeds. For this purpose, 18 sheep (eight female Hasmer sheep, three male Hasak sheep and seven female Hasak sheep) were assessed. After induction of anesthesia, the body cavities were opened. The sheep were fixed with formaldehyde after draining of the blood. The nerves of the *plexus sacralis* were dissected separately and photographed. Both in Hasmer and Hasak sheep breeds, the *plexus sacralis* was a large anastomotic complex of nerves which gave rise to nerves distributed to pelvic cavity and pelvic limb. It was derived from the ventral branches of the six spinal segments. It was observed that this plexus was formed by the ventral rami of four (first to fourth) sacral spinal nerves as well as ventral ramus of the sixth and fifth lumbar nerves. The results of this study are believed to be improved further with the future morphometric studies and to make a contribution to future anatomical and surgical studies in this area.

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Introduction

Sheep have been a considerable component in Anatolian husbandry for almost 10,000 years from the Neolithic time; they also keep their importance in Türkiye's national economy at the present time.¹ In addition, ancient central Anatolia played a significant role in sheep taming process.²

In order to boost the sheep meat production in Türkiye, elaborate studies were launched in 1986. Some of these studies are still in process, such as pure breeding and cross-breeding of Britain, Germany and France mutton sheep breeds with Turkish indigenous breeds.³⁻⁵

Hasmer and Hasak are two different sheep breeds developed as a result of cross-breeding and selection studies at Bahri Dagdas International Agricultural Research Institute, Konya, Türkiye, between the years of 1989 and 2000. These studies were accomplished in order to create the new meat type sheep in Türkiye. Hasmer sheep breed contains 31.25% Hampshire Down, 31.25% German Black Head and 37.50% Merino genotypes. Hasak sheep type contains 31.25% Hampshire Down, 31.25% German Black Head and 37.50% Akkaraman genotypes.^{3,6}

Hasmer and Hasak sheep type names were created from the first syllables of the pure genotype names (based on Turkish pronunciation).⁷

According to the statement written in the 2,973rd issue of Turkish Official Newspaper (Statement Number: 2014/50), both sheep species are approved as official indigenous animal species of Türkiye.⁸

Nerve supply to the pelvic limb consists of the ventral branches from the last four lumbar nerves through the second sacral nerve (L4 - S2) of the lumbosacral plexus. The lumbosacral plexus is formed by *plexus lumbalis* and *plexus sacralis*. The nerves originating from *plexus sacralis* of mammals are *nervus gluteus cranialis*, *nervus gluteus caudalis*, *nervus cutaneus femoris caudalis*, *nervus ischiadicus*, *nervus pudendus* and *nervi rectales caudales*.^{9,10} In addition, the rectal and anal morphologies of the sheep and humans are comparable. In both species, *musculus sphincter ani externus* and anus are innervated by *nervi rectales caudales* originated from the *plexus sacralis*.¹¹

It was observed that studies about Hasmer and Hasak sheep breeds are generally used for zootechnical purposes, and no studies regarding the anatomy of the nervous system of these sheep breeds have been found in literature reviews.

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As in most other butchery animal species, hind limb and gluteal region muscles constitute the most important part of the carcass used as meat in Hasmer and Hasak sheep breeds. The innervation of these regions is mostly supplied by *plexus sacralis*, which is formed by union of ventral branches of sacral spinal nerves. The aim of this study was to compare the macro-anatomical structures and configurations of these nerves and their way of forming the plexus in these two different sheep breeds. The results of this study are believed to be improved further with the future morphometric studies and to make a contribution to future anatomical and surgical studies in this area.

Materials and Methods

In the current study, a total of 18 sheep (eight female Hasmer sheep, three male Hasak sheep and seven female Hasak sheep) obtained from Konya Bahri Dagdas International Agricultural Research Institute, Türkiye, were used. All procedures were carried out in exact accordance with the principles of the Ataturk University Local Ethical Committee of Animal Experiments, Erzurum, Türkiye. The present study was approved by the Ataturk University Local Ethical Committee for Animal Experiments, Erzurum, Türkiye (Approval Number: 8, 23 October 2015).

Under general anesthesia using 0.05 mg kg⁻¹ of xylazine (Alfasan, Woerden, The Netherlands) followed by 2.00 mg kg⁻¹ of ketamin (Alfasan), the neck regions of the sheep were dissected, and the *arteria carotis communis* was revealed and drained of the blood. An incision was then made from the pubis to the *processus xiphoideus* along the *linea alba* in all the sheep. The muscles were dissected, *symphysis pelvis* was cut with costatom and the *cavum pelvis* was opened. The organs of the *cavum abdominis* and *cavum pelvis* were removed without damage to the nerves forming the *plexus sacralis*, and the cadavers were fixed in 10.00% formalin solution. The 18 sets of pelvic limbs were thoroughly dissected. At the end of the dissection, the nerves of the *plexus sacralis* being in the pelvic cavity were photographed. The terminology used in this study was compatible with the *Nomina Anatomica Veterinaria*.¹²

Results

After all anatomical dissection, both in Hasmer and Hasak sheep breeds, the *plexus sacralis* was a large anatomical complex of nerves which gave rise to nerves distributed to the pelvic cavity and pelvic limb. It was derived from the ventral branches of the six spinal segments. It was observed that this plexus was formed by the ventral rami of four (first to fourth) sacral spinal nerves as well as ventral ramus of the fifth and sixth lumbar nerves (Figs. 1, and 2). In all of the specimens,

typical arrangements were observed with symmetry between right and left; also, no significant difference was observed between the males and females. In addition, the specimens had the similar arrangement among their own breed.

The plexus was formed by two major groups of nerves being divided macro-anatomically on the dorso-lateral and ventro-medial sides of the *ligamentum sacrotuberale latum*. The cranial group derived from the ventral ramus of the sixth lumbar nerve and the ventral rami of the first and second sacral spinal nerves ran laterally in a caudo-ventral course to the ventral surface of the *ala ossis sacri* and cranial border of the *ligamentum sacrotuberale latum*. *Nervus obturatorius*, *nervus gluteus cranialis*, *nervus ischiadicus* and *nervus gluteus caudalis* were originating from this cranial group. These nerves were innervating gluteal region and hind limb.

The caudal group was originated from the ventral rami of the second, third and fourth sacral spinal nerves. These nerves anastomosed on the ventral surface of *ligamentum sacrotuberale latum* in pelvic cavity and dispersed into the pelvic viscera and perineal region. We detected that the first root of the *plexus sacralis* is the branch of ventral ramus of the sixth lumbar nerve. This root immediately after its origin, gave a ventral thin branch from its ventral side in Hasmer sheep (Fig. 1: v) and from its lateral margin in Hasak sheep (Fig. 2: v). This ventral thin branch provided a connection between *plexus lumbalis* and *plexus sacralis* in both sheep breeds. After giving the thin branch, the first root of *plexus sacralis* coursed caudo-ventrally.

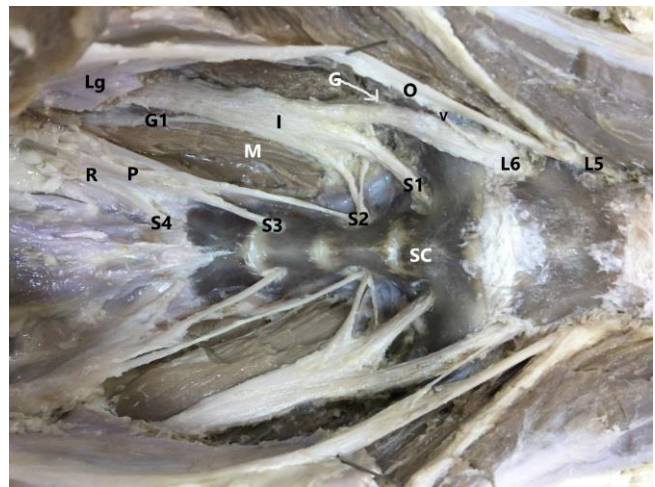


Fig. 1. *Plexus sacralis* of Hasmer sheep breed (ventral view). L5: Ventral branch of the fifth lumbar spinal nerve; L6: Ventral branch of the sixth lumbar spinal nerve; SC: Sacrum; S1: Ventral branch of the first sacral spinal nerve; S2: Ventral branch of the second sacral spinal nerve; S3: Ventral branch of the third sacral spinal nerve; S4: Ventral branch of the fourth sacral spinal nerve; R: *Nervi rectales caudales*; P: *Nervus pudendus*; O: *Nervus obturatorius*; G: *Nervus gluteus cranialis*; G1: *Nervus gluteus caudalis*; I: *Nervus ischiadicus*; v: Ventral thin branch of L6; Lg: *Ligamentum sacrotuberale latum*; M: *Musculus gluteus medius*.

After this course, just before joining the formation of the *nervus ischiadicus*, it emitted the *nervus gluteus cranialis* from its dorsal aspect in Hasmer sheep (Fig. 1: G) and from its dorso-lateral aspect in Hasak sheep (Fig. 2: G). While the ventral thin branch of this root was joining the *nervus obturatorius*, the *nervus gluteus cranialis* was passing through *foramen ischiadicum majus* innervating the muscles of the cranial gluteal region being termed as *musculus gluteus medius*, *musculus gluteus profundus*, *musculus gluteus superficialis* and *musculus tensor fascia latae* in both sheep breeds.

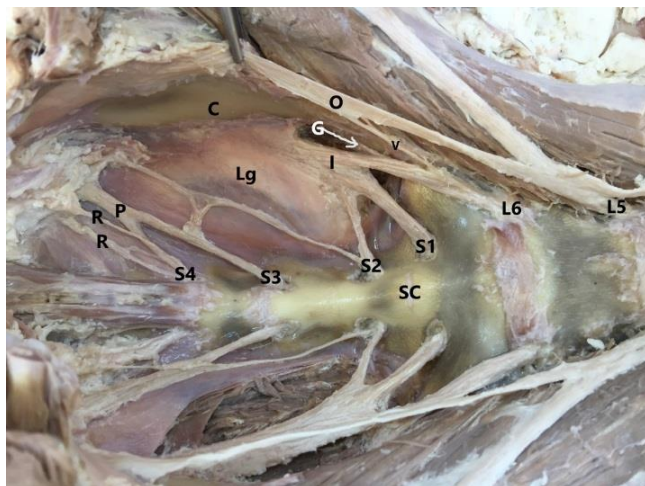


Fig. 2. Plexus sacralis of Hasak sheep breed (ventral view). L5: Ventral branch of the fifth lumbar spinal nerve; L6: Ventral branch of the sixth lumbar spinal nerve; SC: Sacrum; S1: Ventral branch of the first sacral spinal nerve; S2: Ventral branch of the second sacral spinal nerve; S3: Ventral branch of the third sacral spinal nerve; S4: Ventral branch of the fourth sacral spinal nerve; C: *Os coxae*; R: *Nervi rectales caudales*; P: *Nervus pudendus*; O: *Nervus obturatorius*; G: *Nervus gluteus cranialis*; I: *Nervus ischiadicus*; v: Ventral thin branch of L6; Lg: *Ligamentum sacrotuberale latum*.

In both sheep breeds, it was observed that the roots coming from ventral ramus of the sixth lumbar nerve and the ventral rami of the first and second sacral spinal nerves were united and formed the *nervus ischiadicus* between the *ligamentum sacrotuberale latum* and *musculus gluteus medius*, at the entrance of the *foramen ischiadicum majus* (Figs. 1: I, and 2: I). This nerve continued caudo-ventrally, and after a short course from its origin, just before passing through the *foramen ischiadicum majus*, gave off its first branch, *nervus gluteus caudalis* from its medial edge in Hasmer sheep (Fig. 1: G1). However, in Hasak sheep, the *nervus gluteus caudalis* was originated from *nervus ischiadicus* immediately after leaving the *foramen ischiadicum majus*.

By leaving the *canalis sacralis*, the ventral ramus of the first sacral spinal nerve joined the *nervus ischiadicus* in both sheep breeds. In Hasmer sheep, the ventral ramus of the second sacral spinal nerve ramified into three

branches just after its origin (Fig. 1:S2). The first two cranial branches, which were shorter than the third one, directed laterally; while, the third one directed caudally.

The first two cranial branches were determined to contribute to the formation of the *nervus ischiadicus* on the dorso-lateral aspect of *ligamentum sacrotuberale latum*. Together with the first root of *plexus sacralis* (branch of ventral ramus of the sixth lumbar spinal nerve) and the ventral ramus of the second sacral spinal nerve, these two branches were shown to form the cranial group nerves of *plexus sacralis* being mentioned above. However, the third branch of the ventral ramus of the second sacral spinal nerve was located on the ventromedial surface of the *ligamentum sacrotuberale latum* and adhered firmly to it in the *cavum pelvis*. This nerve was forming a caudal anastomosis by uniting with ventral rami of the third and fourth sacral spinal nerves. *Nervus pudendus* and *nervi rectales caudales* dispersed from this anastomotic complex (Fig. 1: R and P).

However, in Hasak sheep, the ventral ramus of the second sacral spinal nerve bifurcated after a short course following leaving the *canalis sacralis* (Fig. 2: S2). The cranial branch, which was shorter and thicker, directed laterally and joined to the formation of *nervus ischiadicus*. The caudal branch, which was longer and thinner, directed caudally and joined to the formation of *nervus pudendus* after uniting with ventral ramus of the third sacral spinal nerve. The ventral ramus of the fourth sacral spinal nerve was also joining to the formation of the *nervus pudendus*. While one of the ventral rami of the fourth sacral spinal nerve was joining to the formation of the *nervus pudendus*, the rest three generated *nervi rectales caudales* (Fig. 2: R and P).

Discussion

It was stated that the sacral and lumbar nerves united and formed *plexus sacralis* and *plexus lumbalis*, forming the *plexus lumbosacralis* together. The nerves emerged from the *plexus lumbosacralis* are responsible for the innervation of the lateral wall of the abdomen, pelvic region, hindlimbs and tail in animals.^{9,10,13,14} The plexus is an anatomical landmark during epidural anesthesia and rectal, obstetric and orthopedic operations.¹⁵ Similar to the findings of previous studies,^{9,10,13,14} we found that a thin branch provided a connection between *plexus lumbalis* and *plexus sacralis* both in Hasmer and Hasak sheep breeds.

Chauveau and Arloing¹⁶ have reported that in ruminants, *plexus sacralis* is constituted by three sacral nerves as in solipeds; but, the third sacral nerve reaches the second sacral spinal nerve only by a very thin filament passing cranio-ventrally. In the current study, contrary to the Chauveau and Arloing's¹⁶ findings, we found that this plexus was formed by the ventral rami of four (first to fourth) sacral spinal nerves as well as ventral ramus of the

sixth and fifth lumbar nerves in both sheep breeds. We also found that the third sacral spinal nerve, contrary to the Chauveau and Arloing report,¹⁶ passed caudo-ventrally as a single and thick branch and formed *nervus pudendus* after uniting with the branch from the second sacral spinal nerve.

According to the findings of some authors¹⁷⁻²⁴ the *nervus ischiadicus* in ruminants originated from the last lumbar and the first sacral spinal nerves. On the other hand, de Lima *et al.*²⁵ have reported that the ventral branch of the last lumbar spinal nerve and the ventral branches of the first and second sacral spinal nerves together form the *nervus ischiadicus* in Saanen goats. In the present study, in both sheep breeds, it was observed that the ventral ramus of the sixth lumbar spinal nerve and the ventral rami of the first and second sacral spinal nerves were united and formed the *nervus ischiadicus*. Vasconcelos *et al.*²⁶ have displayed that the *nervus ischiadicus* originates from the first, second and third sacral spinal nerves, and a thin branch of the sixth lumbar spinal nerve in mixed-breed sheep. In our study, in contrast with Vasconcelos *et al.*²⁶ the third sacral spinal nerve didn't contribute to the formation of the *nervus ischiadicus* in Hasmer and Hasak sheep breeds.

In Angora goat and Akkaraman sheep,²⁷ *nervus gluteus cranialis* emitted from *nervus ischiadicus*. In the current study, we observed that *nervus gluteus cranialis* branched from the *ramus ventralis* of the sixth lumbar spinal nerve in both sheep breeds. In the Hasmer and Hasak sheep breeds examined in this study, *nervus gluteus caudalis* was derived from *nervus ischiadicus*, in consistent with the results of Ghoshal and Getty¹⁹ in sheep. However, *nervus gluteus caudalis* originated from the last lumbar spinal nerve and the first and second sacral spinal nerves in Angora goats and Akkaraman sheep.²⁷

Vasconcelos *et al.*²⁶ have illustrated that the ventral ramus of the second sacral spinal nerve does not give any branch and it joins the *nervus ischiadicus* in mixed-breed sheep. In the current study, contrary to Vasconcelos *et al.*²⁶ findings, we found that the ventral ramus of the second sacral spinal nerve split into three and two branches in Hasmer and Hasak sheep breeds, respectively.

The *Nervus pudendus* emerges from the ventral rami of the third and fourth sacral spinal nerves in cattle²⁸ and from the second and third sacral spinal nerves in dromedary camels.²⁹ However, in the current study, we found that the *nervus pudendus* and *nervi rectales caudales* emerged from a plexus formed by the second, third and fourth sacral spinal nerves.

In conclusion, in the present study, the configurations of *plexus sacralis* in Hasmer and Hasak sheep breeds were determined. We consider that the current study will help to understand the phylogenetic and morphological varieties among different species. Additionally, the present findings will contribute to the future understanding of the

nerve organization in *plexus sacralis* of other species. This study on the Hasmer and Hasak sheep breeds will explain the configuration of pelvic region nerves and provide specific macro-anatomical data in this particular area.

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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