Spinal Dysraphism in a Newborn Holstein–Friesian Calf

S. OHFUJI

Abstract. Spinal dysraphism, not associated with vertebral defect or arthrogryposis, was found in a 3-day-old Holstein–Friesian calf that was clinically diagnosed as having encephalopathy. The dysraphic lesion occurred in the sixth (C6) and seventh (C7) segments of the cervical spinal cord. Microscopically, the lesion was characterized by hydromyelia, syringomyelia, anomaly of the ventral median fissure, abnormal running of the myelinated nerve fibers in the white column, and absence of the central canal due to a developmental defect of the ependymal cells.

Key words: Calf; dysraphism; histology; spinal cord.

Spinal dysraphism, a congenital defect defined as a midline lesion due to incomplete closure of the neural tube,1,4,10 is uncommon in cattle.1 There are no recent descriptions of the pathology of this condition in cattle. This report describes an additional case of spinal dysraphism in a newborn calf.

A 3-day-old Holstein–Friesian bull calf had been unable to rise since birth. The calf lay with the limbs and neck stiffly extended and showed sudden convulsive seizures at intervals of a few minutes. Padding movements of the limbs were seen between spontaneous convulsions. The calf was euthanatized because of a suspected brain lesion with poor prognosis. The 4-year-old dam of the calf had given birth to another normal calf previously. Pedigree information about the sire was unavailable.

At necropsy, the vertebral column, including cervical vertebrae, joints, and skeletal muscles, appeared normal; however, the C6 and C7 segments of the spinal cord had a centrally located spindloid cavity, measuring 1.2-cm long, 4 mm in diameter transversely, and 3.5 mm in diameter dorsoventrally at its maximum dimension. In addition, bilateral and roughly symmetric, smaller, cystic cavities filled with a clear fluid were in the dorsal septal region of the segment C7. Otherwise, there were no significant lesions.

Microscopically, the central cavity at the C6 and C7 segments of the spinal cord was partially lined by ependymal cells, indicating its central canal origin; hence, the hydromyelia (Fig. 1). The central canal through C6 and C7 had a variation in size and shape (Fig. 2); a dilated canal partially lined by pseudostatified ependymal cells whose nuclei were significantly smaller in size than those of the ependymal cells that lined the canal of the unaffected spinal segments (Fig. 3, Table 1); central microrosette formation (Fig. 4); and complete absence of the canal (Fig. 5), without evidence of preexisting inflammatory, traumatic, or neoplastic changes. The dorsal and ventral horn neurons appeared normal. In addition to the aberrations of the central canal, there were two cystic cavities in the dorsal funiculi, lined by parenchymal glial fibers; hence, the syringomyelia (Fig. 1). Dilated myelin sheaths with swollen axons or macrophages were scattered around the cavities. Proliferation of astrocytes was not found; Holzer stains did not reveal any fibrillar gliosis in medullary tissue. Direct communication between hydromyelic and syringomyelic cavities was undetectable; however, the neuropil between these cavities was edematous or malacic and stippled with fine periodic acid–Schiff-positive granules. In addition, there were dilated perivascular spaces, which contained weakly staining eosinophilic fluid and a few gitter cells. There were a variety of alterations to the anatomy of the ventral median fissure, including a complete absence of fissure formation without blood vessels (Fig. 5), short penetration with poor vascularization, or partial duplication, in which many small blood vessels (probably branches of the ventral spinal artery and vein) were found, associated with proliferation of fibrous connective tissue (Figs. 6, 7). There were also aberrant bundles of myelinated nerve fibers across the lateral and ventral white column. No deficiency of myelin was observed in myelin stains; however, the variation in the diameter of axons was prominent throughout the length of the spinal cord. Sometimes swollen eosinophilic (dystrophic) axons were observed in the lateral and ventral funiculi. Oligodendrocytes often had pyknotic nuclei.

The brain revealed markedly swollen axons scattered in the median lemniscus of the pons (Fig. 8), bilateral dilatation of many myelin sheaths in the nucleus gracilis and cuneate nucleus of the medulla oblongata, and passive congestion in the medulla of the cerebellum. The ependymal cells that lined the lumen of the ventricular system in the brain were cuboidal to columnar, with a proportionate arrangement. The only other lesion observed was acute focal bronchiolitis.

The dysraphic lesion described here was consistent, in most respects, with that described in standard veterinary texts.3,7 It seems unusual, however, that the lesion occurred in the cervical intumescence of the spinal cord and without vertebral defect in this calf, because spinal dysraphism in calves usually involves the caudal thoracic and lumbar spinal cord segments2 and is often associated with spina bifida, arthrogryposis, or both.2,7,9

The hydromyelia observed could have been caused by a dilatation of the central canal in association with obstruction of cerebrospinal fluid flow5,7 due to central canal agenesis. The lack of evidence of direct connection between the hydromyelic and syringomyelic cavities suggested that the syringomyelia was not caused by an extension of the hydromyelic cavity into the cord parenchyma. Instead, it seems probable that the syringomyelia was associated with the increased cerebrospinal fluid pressure, which could have resulted in the rupture of the central canal, dissection of parenchyma, tracking of the cerebrospinal fluid with consequent edema and malacia, and formation of secondary sy-
Fig. 1. The sixth segment of the cervical spinal cord; calf. Bilateral syringomyelic cavities are found in the dorsal funiculi, and the hydromyelic cavity has a partial ependymal lining (arrowhead). HE. Bar = 1.5 mm.

Fig. 2. The sixth segment of the cervical spinal cord; calf. The distorted central canal has unequal ependymal cells. HE. Bar = 60 μm.

Fig. 3. The sixth segment of the cervical spinal cord; calf. The hydromyelic central canal is partially lined by pseudostratified ependymal cells, all of which have uniformly small nuclei. HE. Bar = 60 μm.

Fig. 4. The seventh segment of the cervical spinal cord; calf. The central canal is characterized by a microrosette composed of a single layer of ependymal cells. HE. Bar = 20 μm.

Fig. 5. The seventh segment of the cervical spinal cord; calf. Neither the central canal nor the ventral median fissure can be found. Note the edematous area in the dorsal funiculi. HE. Bar = 1.5 mm.

Fig. 6. The seventh segment of the cervical spinal cord; calf. In addition to the hydromyelia and syringomyelia, the ventral median fissure is incompletely developed and bifurcated dorsally (arrowhead). HE. Bar = 1.5 mm.

Fig. 7. The seventh segment of the cervical spinal cord; calf. Higher magnification of Fig. 6. The bifurcated ventral median fissure is composed of many small blood vessels accompanied by fibrous connective tissue. HE. Bar = 110 μm.

Fig. 8. Pons; calf. The medial lemniscus has a swollen axon (arrow). Luxol fast blue–HE. Bar = 30 μm.
Table 1. Nuclear size* of ependymal cells lining hydromyelic or nonhydromyelic central canal of the cervicothoracic spinal cord segments in a calf with spinal dysraphism.

<table>
<thead>
<tr>
<th>Segment</th>
<th>Axial Length (μm)</th>
<th>Width (μm)</th>
</tr>
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<tbody>
<tr>
<td>Hydromyelic segments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C6</td>
<td>6.08 ± 1.05†</td>
<td>3.55 ± 0.85†</td>
</tr>
<tr>
<td>C7</td>
<td>5.84 ± 1.06†</td>
<td>4.26 ± 0.66</td>
</tr>
<tr>
<td>Nonhydromyelic segments</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>9.63 ± 1.69</td>
<td>4.74 ± 0.91</td>
</tr>
<tr>
<td>C8</td>
<td>9.00 ± 1.05</td>
<td>4.89 ± 0.89</td>
</tr>
</tbody>
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* Values are mean ± standard deviation.
† Significantly different from C1 and C8 at P < 0.01, t-test (n = 10).

ringomyelic cavitations. Topographically, syringomyelia bilaterally involved the whole of the fasciculus gracilis and a portion of the fasciculus cuneatus. The general proprioceptive axons pass cranially in these fascicles to the nucleus gracilis and medial cuneate nucleus of the medulla oblongata, and axons from these nuclei course through the medial lemniscus to the thalamus. Thus, it is conceivable that axonal or myelin-sheath changes found in the medulla oblongata and pons could have been associated with those in the perisyringomyelic nerve fibers, which were probably damaged by the expanding cavitations.

Persistence of the pseudostratified ependymal cells that partially lined the hydromyelic central canal may indicate immaturity of the cells, because this feature is seen during the embryonic development of the spinal cord. Ependymal cells were of unequal shape, and the morphometry revealed that their nuclei were significantly smaller than normal, suggesting not only nondifferentiation but also inactivity of the cells. Additionally, an ependymal microrosette and agenesis of ependymal cells/central canal were in the same spinal segment, which probably showed the presence of a blind canal. Thus, the central canal abnormality was considered to have been related to arrest or delay of ependymal cell development. There are two major theories on the pathogenesis of dysraphic lesions: they may be caused by the failure of the neural tube to close or they may be due to a reopening or secondary rupture of a previously closed tube. It seems likely that the dysraphic lesion in this calf was due to a failure of the neural tube to maintain normal ependymal development from the germinal layer of proliferating neuroepithelial cells during the embryonic development of the C6 and C7 spinal cord segments. Here, noticeable change was an abnormal pattern of vascularization topographically associated with an anomaly in the ventral median fissure. The degrees of vascular abnormalities that were characterized by a deficient penetration of the ventral spinal artery/vein paralleled those associated with developmental anomalies of the ventral median fissure; indeed, the ventral funiculi, with a complete absence of the ventral median fissure, had no more intramedullary vasculature, upon which they are dependent for blood supply. Thus, the ventral median fissure aplasia was probably due to poor vascularization. The pathogenesis of vascular anomalies was unknown; however, the possibility that these anomalies were responsible for ischemia within the central zone of the C6 and C7 spinal cord segments, leading to a failure to complete development of the ependymal cells and the ventral median fissure, may be suggested.

Acknowledgements

I thank Dr. T. Matsui, Dr. J. Yasuda, Dr. H. Isogai, Dr. I. Kawase, and Mr. S. Mori for their considerable help in preparing this paper.

References


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