

## II: The Diseased Spinal Cord

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### 1. Introduction

A recent PubMed search of the literature for “horse OR equine AND spinal OR vertebral” revealed 462 citations relevant to equine spinal cord disease. I have circa 500 additional papers, many of which are in languages other than English and in nonrefereed journals, that relate to equine vertebral and spinal cord disease. Finally, several contemporary texts review our understanding of equine spinal cord disease.<sup>1-4</sup> Thus, this paper is not intended to exhaustively review all such information but to highlight recent trends and personal observations on interesting aspects of the diseased equine spinal cord. It will be obvious that I find all the diseases discussed here to be biologically fascinating, a criterion for inclusion that Dr. Frank Milne would be pleased with. Particular attention will be given to diseases wherein I can add new data and commentary, and to publications originating from studies in non-English-speaking countries. If some aspects of this paper are provocative (or even wrong), I will at least have achieved one aim—to stimulate interest in equine neurology!

At the conclusion of a neurological examination (see part I), the equine practitioner should be able to identify any evidence of spinal cord disease.<sup>5</sup> When the signs are subtle, it is always preferable to perform an orthopedic examination to help rule in or

rule out the possibility of musculoskeletal involvement that might contribute to the syndrome. Lameness due to orthopedic disease frequently mimics and sometimes accompanies neurological disease and some very confusing “neurological” syndromes can result.

One example of this is bilateral hindlimb laminitis markedly altering the mildly ataxic hypermetric gait in a yearling with C3–4 cervical vertebral malformation (CVM) to one of hypometria. Also, a sole abscess in a hindlimb of a 4-year-old racehorse with a very asymmetrical C7 compression caused profound sideways (spider-like) walking, pivoting on the other hindlimb and circling. The underlying significance of these neurological syndromes was displayed after appropriate nerve blocks had been performed.

With mild cervical lesions, signs of ataxia and weakness may be evident in the pelvic limbs only especially if the patient is uncooperative. In this situation it is safest to conclude that the horse (with no head signs) has a lesion between C1 and S3. On the other hand, close scrutiny of the gait, posture and even postural reactions in the thoracic limbs, along with a search for findings that help localize a lesion, often is fruitful. A horse that “dog-sits” for perhaps a minute or so on repeated efforts to rise most likely (but not always) has a lesion caudal to T2.

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### NOTES

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By being able to define most accurately the site of the lesion(s), the clinician can reduce the number of possible etiologies and can help focus the ancillary testing available. Diagnostic aids are very useful.

Before discussing the evaluation of wobblers, it is very important to define terms. The term "wobbler" can be used to describe a clinical syndrome, suggesting that a horse has spinal cord disease. On the other hand, it has been used to describe a more specific diagnosis after high-quality cervical radiographs taken from the base of the skull to T1, and preferably a myelogram, have confirmed the presence of cervical vertebral malformation and spinal cord compression. In this discussion, the term will be used as a generic one simply indicating the clinical suspicion of spinal cord disease.

Finally, in presenting the following interesting and topical spinal cord disorders, particularly those for which new data are emerging, I have divided them up by causal mechanisms; thus no specific importance should be placed on the order of presentation.

## 2. Congenital and Familial Diseases

### A. Cervical Vertebral Malformation

Spinal cord trauma is probably the most frequently suspected and diagnosed cause of acute recumbency and the equine wobbler syndrome throughout the world. Possibly the next most frequently occurring disease is cervical vertebral malformation (CVM).<sup>5-11</sup> In this disease the neurological signs stem from progressive cervical spinal cord compression that is not the result of a single episode of contemporaneous trauma. It can be convenient to divide CVM into 2 pathophysiological types, although a continuum does exist.

#### i. Type I CVM

*Description:* This type of CVM tends to occur in younger animals, typically from weaning until 2 years of age. The underlying developmental vertebral changes certainly begin in the formative first months of life and likely can begin in utero. Several or all of the following cervical vertebral changes (Figs. 1-3) may be present.<sup>5,12-16</sup>

- Malformation with stenosis of the vertebral canal. This may be absolute, occurring with the neck in any position, or dynamic, occurring more on flexion (usually C2-C6) or on extension (C6-T1).
- Malformation with abnormal formation of and alterations to the articular processes. These degenerative changes include osteochondrosis.
  - Malformation with kyphosis and further canal narrowing on flexion (C2 - C6).
  - Further canal narrowing with extension (C5 - T1) of the neck.
  - Enlarged vertebral physal growth regions that are equivalent to physitis in the long bones of rapidly growing young horses.

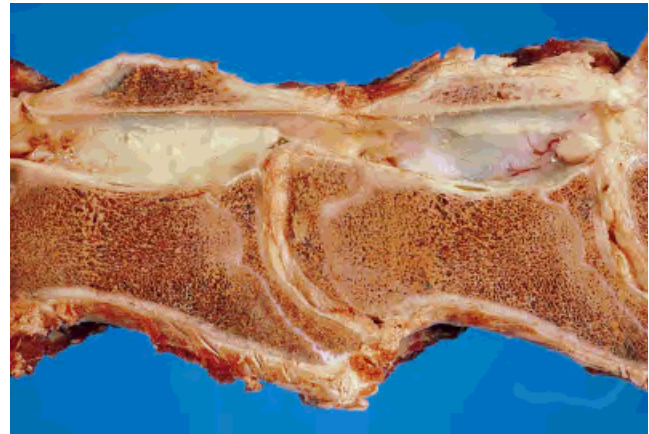
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Fig. 1. Median section of C4 and C5 from a young Thoroughbred horse with Type I CVM. Many of the vertebral changes seen in this disease are present (see Fig. 2).

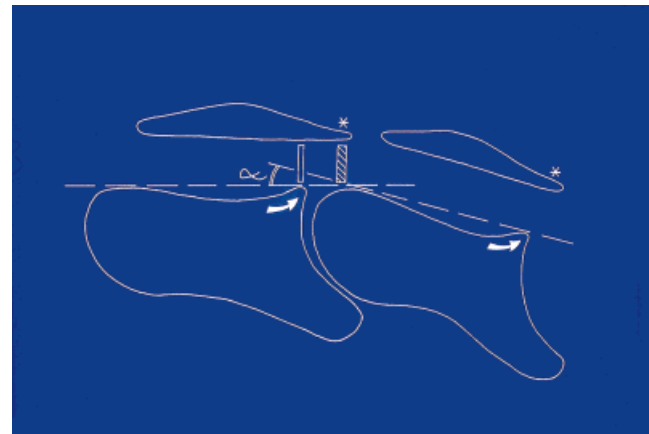
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Fig. 2. Line drawing to match Fig. 1 depicting intravertebral stenosis (open bar), intervertebral stenosis (hatched bar), kyphosis (dashed lines), enlarged caudal physal growth regions with encroachment into the vertebral canal (curved arrows), and caudal extension of the dorsal rim of the caudal arch of the canal to lie dorsal to the cranial physis of the next caudal vertebra (stars). Compare with Fig. 3.

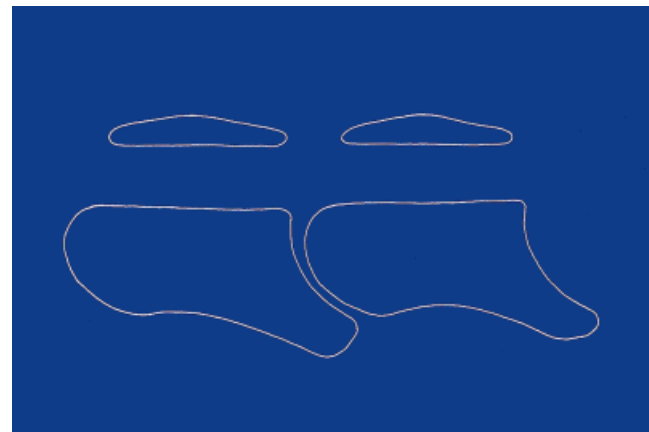
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Fig. 3. Line drawing of normal midcervical vertebrae.

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**Table 1. Sagittal Vertebral Measurements and Likelihood Ratios from Cervical Radiographs That Are Useful in Confirming the Site of Compression in Cases of CVM**

Value	Body Weight (kg)	C2	C2-3	C3	C3-4	C4	C4-5	C5	C5-6	C6	C6-7	C7	
MSD* (mm)	<320	20.8	—	18.1	—	16.7	—	17.3	—	18.3	—	19.8	
	>320	21.1	—	18.5	—	17.7	—	18.7	—	19.0	—	22.2	
MFDD* (mm)	<320	—	11.3	—	9.0	—	9.9	—	11.9	—	17.3	—	
	>320	—	12.9	—	10.5	—	10.8	—	11.4	—	17.6	—	
Sagittal ratio†	>0.56	>320	NA	—	NA	—	0	—	<1	—	<1	—	<1
	0.52	>320	NA	—	NA	—	2	—	2	—	2	—	>35
	<0.50	>320	NA	—	NA	—	>25	—	>25	—	>40	—	>35

NA, not applicable.

\*MSD, minimal sagittal vertebral canal diameter with neck in neutral position (plain films); MFDD, minimal sagittal dural diameter with neck flexed (myelogram). (Data from Mayhew et al.<sup>93</sup>)

†These figures represent the likelihood ratios for each sagittal ratio, i.e., the risk factor for having spinal cord compression due to vertebral canal stenosis in comparison to the normal population. (Data from Moore et al.<sup>14</sup>)

- Caudal extension of the dorsal aspect of the vertebral arch over the cranial physis of the next caudal vertebral body. This is particularly associated with cases demonstrating dynamic stenosis with flexion between C2 and C5.

- External trauma plays a variable role but may be the factor that initially precipitates the clinical syndrome.

**Diagnosis:** It appears that radiographic evidence of stenosis is the singularly most important factor in diagnosing type 1 CVM. Figures for the normal ranges of canal diameters are available for foals.<sup>12</sup> The most clinically useful data for sagittal measurements taken from plain and myelographic radiographs for horses are summarized in Table 1. Using these figures an individual horse can usually be identified as having CVM or not. By using measurements from standing cervical radiographs of the intravertebral minimal sagittal diameter as a ratio of the maximal height of the cranial physis (Fig. 4) it is possible to give a likelihood ratio as to the probability that an individual horse has spinal

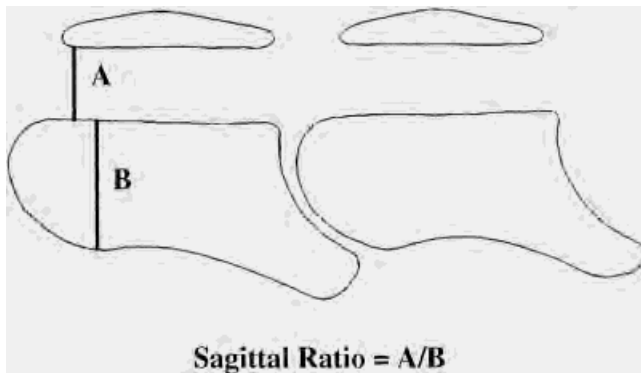


Fig. 4. Line drawing to indicate the site to measure and calculate the sagittal ratio from plain standing radiographs. Note that in stenotic vertebral canals the narrowest sagittal diameter may be at the caudal orifice and that measurement should be used in calculations.

cord compression.<sup>17</sup> A sagittal ratio % at any vertebra from C3 – C7 of <50% is a strong predictor (likelihood ratio of 20–40) of spinal cord compression. However, a few horses have been found to have sagittal ratios of <50% at multiple sites in the cervical vertebrae with no pathological evidence of spinal cord compression; a myelogram must be used to obtain the best evidence of compression.

The overall assessment is that most young horses with CVM have various manifestations of developmental orthopedic disease/osteochondrosis with rapidly growing physal growth plates and physal enlargements combined with effects of external forces applied at these sites. A degree of familial predisposition almost certainly occurs in this juvenile form of CVM. Certainly, many wobblers if left alone will not improve. Also, it is reasonable to ask whether a wobbler that recovers from a neurological deficit following conservative or surgical therapy and/or rest can ever reach one hundred per cent of its phenotypic potential.

**Treatment:** Surgical treatment should only be considered in specifically selected cases following a thorough neurological and radiographic evaluation.<sup>18</sup> Some quite dramatic clinical improvements in cases suffering from spinal cord disease have occurred following cervical vertebral fusion surgery. This form of stabilization of cervical vertebrae in the horse has been popularized in North America and many surgeons now have considerable experience with the surgical approach and hundreds of cases have been followed for many years post surgery. Following the grading system of wobblers from 1+ being mild to 4+ being profound, an improvement of 1 to 2 grades can be offered in up to 50% of specifically selected cases that are operated on. Occasionally an improvement will occur over three grades, but it is rare for a horse suffering from cervical vertebral malformation to improve four grades and become neurologically normal following surgery. Rarely, a “domino effect” can occur following surgical fusion of two cervical vertebrae (Fig. 5). Surgery

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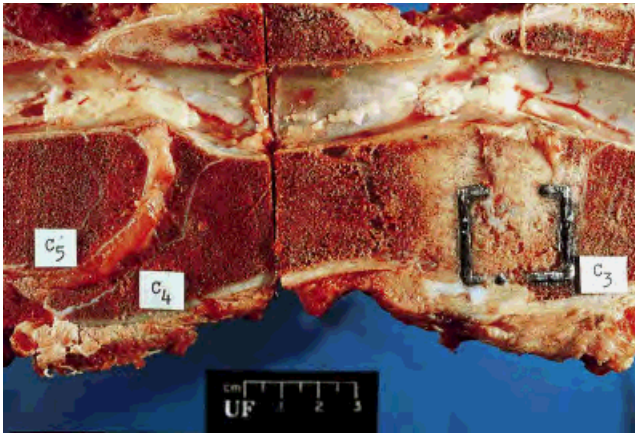
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Fig. 5. The domino effect. Successful fusion using a stainless steel basket has been performed at C3-4 in this foal with Type I CVM. Clinical signs improved for several months but then deteriorated rapidly. The second episode was due to compression at C4-5, a site that did not have narrowing and spinal cord compression at the time of surgery. It is assumed that the added forces applied to C4-5 in this young horse because of fusion at C3-4 promoted a Type I malformation to develop at C4-5. (Courtesy A. J. Nixon, Ithaca, NY.)

may or may not be acceptable to many owners, trainers and veterinary surgeons. Therefore, alternative approaches at predicting and treating the disease have been looked into.

One group of workers has investigated groups of foals on particular farms on which cervical vertebral malformation had been occurring with a relatively high frequency.<sup>19</sup> Figures for measurements taken from plain radiographs, of the sagittal diameters of vertebral canals of horses and foals that do not have CVM, have been incorporated into a semi-quantitative grading of the contributing structural changes (see above) evident on plain cervical radiographs. The resulting scoring system has been used to predict the status of an individual foal with respect to the likelihood of it developing CVM. This semi-quantitative CVM score has a maximum value of 35 points and the higher the value the greater the expected likelihood of CVM occurring. This weighted score is detailed elsewhere.<sup>12</sup> Using this CVM score it does seem possible to predict the onset of signs of spinal cord compression in Thoroughbred foals less than a year of age. Those that have been radiographed and graded with a CVM score of 12 or above consistently had clinical signs of spinal cord disease. This scoring system is not a statistically proven diagnostic test for CVM. It is intended to be a system that better predicts the presence of spinal cord compression associated with bony changes in the neck of Thoroughbred foals, using evidence taken only from plain lateral radiographs.

In this study there were 142 foals at risk of CVM. After analyses of feeding and management practices, a program involving a strict, well-balanced, "paced" (with growth) diet, along with exercise restriction was developed. A total of 18 foals (15 colts and 3

fillies) had CVM scores over 12. Twelve had clinical signs of spinal cord disease and 6 more were predicted to be at high risk for CVM and were also placed on the program. The 12 foals showing clinical signs of CVM and with high (>12) radiographic CVM scores were followed for up to 5 years after completing the program. On neurological examination all horses showed a marked improvement in their clinical signs with most returning to being neurologically normal and all having CVM scores less than 12. Nine of the 12 raced in a total of over 100 starts. These observations must be tempered by the fact that no age-matched affected cases remained on normal feeding and management regimens to determine whether or not this marked improvement may have occurred anyway. In spite of this drawback, the findings are sufficiently rewarding to suggest that this devastating disease can be predicted. It was also determined that neurological examinations performed in young foals can detect mild signs of spinal cord disease. Finally, these signs can be reversed with the institution of early nutritional and management restriction.

Interestingly, 11 mares produced these 18 foals and of these, 6 mares produced 13 of the foals. Also the average age of all mares at the time each of their foals were born was 13.6 years, and the average of mares producing more than 1 of these 18 foals was 16.9 years.

#### ii. Type II CVM

*Description:* Cases of Type II CVM tend to be older patients with severe osteoarthritic enlargement of cervical vertebral articular processes<sup>7,20</sup> and no evidence of developmental defects as with Type I CVM. These horses more likely have an acquired traumatic cervical vertebral disease (Fig. 6). Cranial and

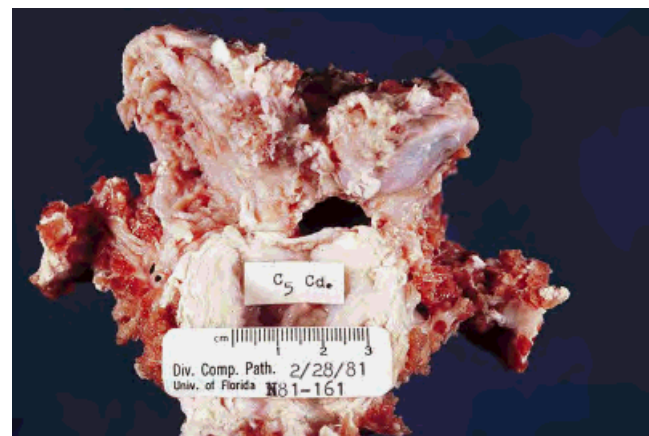


Fig. 6. Typical Type I CVM malformation at caudal C5 articular processes. It is not so much the enlarged left articular process that is important but the encroachment into the vertebral canal of the proliferating bone and soft tissues associated with this degenerative joint disease. The relatively normal right articular process (and other cervical articulations) is very consistent with the lesion being traumatic in origin rather than associated with osteochondrosis.

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ventral extension of the craniodorsal edge of the vertebral arch (“wedging”) results in absolute stenosis of the vertebral canal and allows dynamic stenosis to occur, particularly during extension, of vertebral bodies C6–T1. There can be proliferation of articular and peri-articular soft tissues with impingement upon the spinal cord. This includes formation of epidural and peri-articular (synovial) cysts.<sup>2,6,7,11</sup> Such synovial cysts can result in sudden onset of signs without a contemporaneous episode of external injury. Also, clinical signs can be very asymmetrical. These cysts can be shown at necropsy examination to be able to swell up suddenly and push against the cord with movement of the vertebrae, perhaps explaining such clinical features. One case was seen where the cystic structure suddenly filled with blood (Fig. 7).

I have also seen 2 cases in which severe signs of spinal cord disease occurred, only to abate completely in several hours. In both cases the signs reappeared within a few weeks and both were shown to have synovial cysts associated with the dorsal articulations at C6–7.

*Cause:* The genesis of severe degenerative joint disease in Type II CVM is speculative; the bone and joint disease process having started weeks to years prior to the onset of neurological signs. Many horses have had follow-through evaluations after having sustained trauma to their neck, with radiographic evidence of fracture to articular processes with or without neurological signs. Several of these horses have gone on to develop marked degenerative joint disease of cervical intervertebral processes with or without persisting neck pain or delayed signs of Type II CVM. These cases have convinced me that external injury is the most important factor in the genesis of Type II CVM (Fig. 6).

*Treatment:* Surgical fusion is indicated in selected cases (see above).<sup>18,21</sup>

### iii. Accuracy of Diagnosing CVM from Radiographs

Tomizawa et al. in Japan have studied detailed relationships between morphologic measurements taken from cervical vertebrae in normal and CVM-affected young Thoroughbred horses.<sup>22</sup> These workers then correlated their measurements as previously used by me<sup>1</sup> with histological lesions and found that the accuracy of radiographically diagnosing CVM was very good but not completely precise.<sup>23</sup> Finally, they developed complex measurements of “Ratios of Stenosis” from plain survey radiographs (Ss) and from myelograms (Sm).<sup>9</sup> The Ss compared the average sagittal diameter of the vertebral canal measured in the middle of each of two adjacent vertebrae with the hypothetical “dural height” between these vertebrae as measured from extensions of lines drawn along each dorsal lamina of the vertebral canals in each vertebra. Likewise the Sm compared the average sagittal diameter of the dural space measured in the middle of each of 2 adjacent vertebrae with the minimal flexed dural sagittal diameter (MFDD) between these adjacent vertebrae. The conclusions were that such measurements were useful for the clinical diagnosis of CVM and better than the poorly documented diagnostic criterion of “50% reduction in height of dorsal myelographic dye column”.<sup>24</sup> Unfortunately no correction for size of animal or for radiographic enlargement<sup>12,17</sup> was made.

The inclusion of intervertebral measurements for canal diameters (Fig. 1) taken from standing survey radiographs is likely to increase the discrimination of Types I and II CVM cases from non-CVM cases. These measurements can be corrected for horse size and radiographic magnification as has been done for the intravertebral sagittal ratios. Preliminary new data for intravertebral and intervertebral sagittal ratios for 19 control horses are given in Table 2. These horses had neurological signs of spinal cord disease and had a full series of cervical radiographs taken. However, on scrutinizing the brain and spinal cords there was no histological evidence of compression of the cervical spinal cords from C2 to T1; a final diagnosis of other than CVM was made in each case. Notably, some of the minimum sagittal ratio values for these control data would give odds ratios for CVM of >1.0.<sup>14</sup>

Table 2 also includes data from radiographs of wobblers that have a final pathologic diagnosis of CVM confirmed with compression at one or two sites. Study of these data and reference to Fig. 8 reveals that the addition of intervertebral sagittal ratio measurements is likely to improve the accuracy of using plain radiography in diagnosing CVM. It will be noted that in all cases the values fall below the minimum values at 4–8 sites. Also, the low intervertebral values tend to be considerably lower than their minimal control values than the intravertebral values are from their control minimal values. Further analysis of these data will give even more

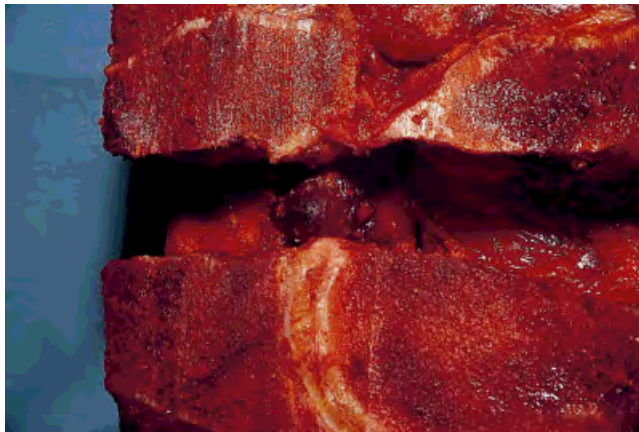


Fig. 7. Median section of the C6–7 vertebrae from a horse that had a sudden onset of severe ataxia and weakness. There was prominent degenerative joint disease at this site, and a synovial cyst filled with blood can be seen bulging into the canal at the site of the right intervertebral foramen. This accounted for abrupt onset of severe spinal cord disease.

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Table 2. Cervical Vertebral Sagittal Ratio Measurements for 18 Non-CVM Cases and Sites of Compressive Lesions in 8 Cases of CVM

	C2	C2-3	C3	C3-4	C4	C4-5	C5	C5-6	C6	C6-7*	C7	Lesion Site†
Control values												
Median	73	93	60	71	58	73	60	81	58	71	62	NA
Maximum	83	108	70	92	83	90	75	100	75	86	72	NA
Minimum	55	63	52	60	49	56	52	63	54	58	55	NA
CVM cases												
1	70	74	48	42	46	56	47	58	46	62	48	C4
2	65	87	52	64	55	53	51	48	52			C6
3	85	75	44	41	44	63	46	38	43			C4, C6
4	51	69	43	41	46	59	50	56	44			C4, C6
5	45	25	48	67	49	64	52	71	53			C3
6	61	80	50	64	50	50	48	64	45	52	46	C5, C7
7	66	66	51	48	44	49	45	56	46	67	50	C4, C5
8	61	82	51	70	49	62	51	72	54	55	47	C7

NA, not applicable.

\*Taken in reverse from dorsocaudal aspect of the body of C6 to the cranial aspect of the dorsal lamina of the vertebral arch of C7.

†Spinal cord segment.

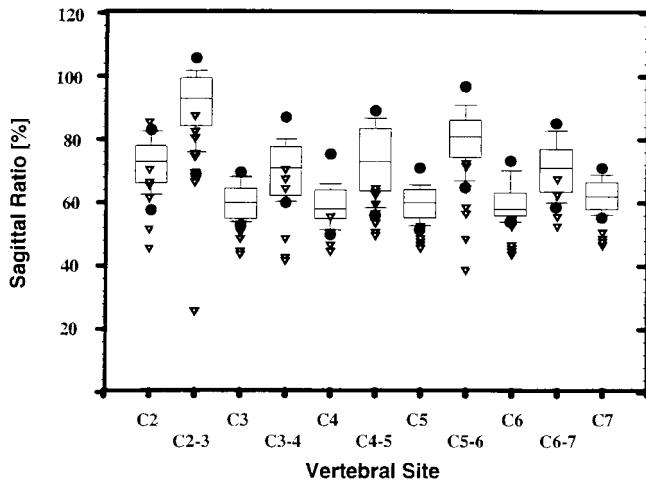


Fig. 8. Graphical representation of cervical vertebral sagittal ratios for horses with and without CVM (data in Table 2). The box-and-whisker plots represent the median and the 5th and 95th percentiles with outliers marked as black dots. Data points taken from radiographs from 8 cases of CVM are represented by triangles.

accurate objective diagnostic criteria for the diagnosis of CVM from plain radiographs.

Occasionally the compression in both Type I and Type II CVM cases can be transverse rather than dorsoventral. In Type I cases this is usually due to a kyphotic angular deformity between C2-3, C3-4 or occasionally C4-5 and an associated ventral positioning of the pedicles and articular processes bringing the latter level with the lateral aspects of the spinal cord. Many times the intervertebral sagittal ratio will still be abnormal even if the intravertebral measurement is not. Likewise, in Type II cases with transverse compression the intervertebral sagittal ratios are often small and prominent arthropathy is present. On lateral myelography of these cases the dorsal and ventral dye columns may not appear compressed and the MFDD value may not be too small. However, a blanching of the overall dye

column, widening of the sagittal shadow of the spinal cord and sometimes the presence of 2 dorsal borders to the dye column (due to asymmetrical dorsolateral compression) indicates spinal cord compression.

B. Occipitoatlantoaxial Malformation (OAAM)

This uncommon disease usually affects Arabian foals.<sup>25</sup> Affected foals may be still-born, ataxic at birth or show progressive ataxia as weanling foals (i.e., are wobblers). Cases in other breeds have shown ataxia from birth or signs began within the first year of life. An extended neck posture is often seen and a malformed atlas and axis often can be palpated. Reduced flexion of the atlantooccipital joint is demonstrable and clicking sounds may be heard as the animal moves its head and neck or when they are manipulated. Scoliosis may be present. It is possible to have no neurological abnormality but usually varying degrees of tetraparesis and ataxia, to tetraplegia exist.

Various anomalies involving the occiput, atlas and axis are present, including atlantooccipital fusion, hypoplasia of the dens and additional bony pieces. A diagnosis is confirmed by radiography. As the disease is most likely inherited in Arabian foals, breeding from the same family lines should be discouraged.

Two unusual variations of cranial cervical malformations of Arabian foals have been reported. The first involved a 15-mo-old Arabian gelding that had one atlas fused to the occiput, an additional free atlas and an axis with elongated dens.<sup>26</sup> This horse compressed its spinal cord at C6-7 with a CVM Type I malformation. The other involved a tetraplegic neonatal Arabian colt foal.<sup>27</sup> It had one atlas fused to the occiput, one free atlas and an axis with greatly elongated dens. The 7 ossification centers in this axis indicated embryological duplication of the axis. The elongated dens compressed the spinal cord at the level of the atlas that was fused to the occiput.

Particularly in non-Arabian adult horses interpre-

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tation of the origin of marked malformations of the cranio-vertebral region, including atlantooccipital fusion should be made cautiously; healed traumatic lesions can mimic congenital malformations.<sup>28</sup>

### C. Neonatal Thoroughbred Foal Ataxia Syndrome

Recently, an unusual, apparently familial, neurological syndrome was described in new-born Thoroughbred foals.<sup>29</sup> Three foals from the same dam but by different and unrelated sires born on different properties were normal at birth but between 2 and 4 d old developed severe ataxia that was exacerbated by voluntary effort and excitement. There was no weakness. A poor menace response, dysmetria of the thoracic and pelvic limbs and ataxia was noted in one of the foals. No intention tremor or visual deficits were evident in the affected foals. The clinical syndrome was consistent with symmetrical cerebellar or spinocerebellar dysfunction. An acquired (in utero or neonatal) mechanism, possibly of toxic or viral etiology, was suggested to be the most likely cause. They were all treated with box rest and diazepam and the syndrome resolved completely between 2 weeks and 2 mo.

### 3. Physical Mechanisms

In a survey of neurological diseases in Australian horses, 26% of 450 horses with neurological signs had disease due to trauma to the brain, cranial nerves or spinal cord. Cervical vertebral fractures/trauma were the most common injury.<sup>10</sup> Interesting single cases of spinal cord injury are regularly presented in veterinary journals e.g. *J Am Vet Med Assoc.*<sup>21,30-35</sup>

#### A. Spinal Cord Trauma

External injury is probably the cause of spinal cord disease (wobblers) that is most frequently suspected in clinical practice.<sup>2,10,11,36</sup> This affects horses of all ages and breeds, particularly those that are easily frightened and those that have the ability and space to reach high speeds.

*History:* There most often will be a sudden onset of reluctance to move, ataxia and weakness, or recumbency. Signs usually are peracute and nonprogressive, often with some improvement occurring. With focal hemorrhage, structural instability or subsequent callus formation there can be progression of signs in minutes to years later.

Apparently innocuous falls during performances, rearing and falling over backwards while being handled, and thunderstorms, may be historical factors of significance in resultant spinal cord trauma.

*Syndromes:* There are not always neurological signs with vertebral damage and the neurological syndromes are very variable. The C1-T1 region is the most frequently affected especially the occipitoatlantoaxial site. Signs varying from degrees of tetraparesis to recumbency can result. Thoracolumbar vertebral involvement can result in paraparesis to recumbency and the patient may "dog-sit". Sacral

fractures (usually S2) produce urinary and fecal incontinence, loss of use of the tail and anus, mild sacral muscle atrophy and minimal abnormalities in pelvic limb gait. Sacrococcygeal fractures produce signs varying from hypalgesia, hypotonia and hyporeflexia of the perineum, tail and anus to total analgesia and paralysis of these structures. All affected animals may be frantic as a result of pain and the inability to stand.

*Acute recumbency after major injury:* Particularly because of the adrenalin domination phase it can be extremely difficult to localize spinal cord injury in a horse, immediately following major trauma. Thus, it is difficult to identify a clear border between normal sensation and analgesia at the site of a spinal cord lesion and artery forceps alone may be insufficient to test normal reflexes let alone superficial sensation.

Because of the strength of the vertebral column and protective axial musculature, it usually takes high energy, low velocity injury to damage the vertebral column enough to then damage the spinal cord. Thus, horses that remain tetraplegic or paraplegic but attempt to rise after one or two hours following a fall most often have a severe and usually unstable vertebral column injury causing the spinal cord lesion. Recent fractures can be stabilized by muscle spasm and thus evidence of vertebral instability with neurological deterioration may only occur hours to days after the initial injury, when such muscle spasm subsides.

The three predilection sites for spinal cord injury and vertebral fractures and luxations are the occipitoatlanto-axial region, the caudal cervical region and the mid-back. Occipitoatlanto-axial damage often occurs as tearing or avulsion of the ligaments of the dens particularly following neck hyperflexion. This is one site where spinal cord compression can occur without a vertebral fracture but sometimes the associated pain can make evaluation of such cases extremely difficult. Caudal cervical (C5-T1) damage often results from neck hyperflexion when a horse nose-dives with the head under the body. Because of the strength of equine intervertebral disks, even if there is damage to the articular processes, pedicles or arches there may not be instability associated with the damage to the adjacent spinal cord. Affected horses may get back up following the fall to continue running, only to show progressive neurological signs in minutes to hours because of associated hemorrhage. The majority of fractured backs resulting from major trauma occur between the mid-thoracic to cranial lumbar region and particularly result from a massive force such as a horse landing on its back. Such fractures usually are unstable even though muscle spasm may temporarily stabilize the lesion.

After recovery of reflexes and responses that may be obscured because of adrenalin release and concussion the syndrome of spinal shock may (or may not!) occur in a horse following a fall. Spinal shock

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results in a suppression of all reflexes caudal to a lesion and if it does occur in horses it is short-lived. It has been said that tail and anal reflexes have been found to be completely absent in horses later confirmed to have suffered a profound thoraco-lumbar spinal cord lesion and this may well represent spinal shock. If this is so, then other reflexes (e.g. flexor reflex and patella reflex) also should be absent. On the other hand such a syndrome may result with one severe lesion at (say) T10 and another at S2. Whether spinal shock occurs or not, it is still better to base any prognosis and any major decisions on results of as full a neurological examination as can be undertaken rather than on results of one single (e.g., anal) reflex.

Thus, with acute recumbency following suspected major spinal trauma, the phase of adrenaline domination must pass before sensible interpretation of neurological examination findings can be made. This may take in the order of 30–120 min. If after that time the horse is either paraplegic or tetraplegic in spite of reasonable efforts to rise, the prognosis is bad (but not necessarily grave!) for survival. Preferably, a decision on the quality of survival from spinal cord injury is best delayed for 24 h. Father Time and Mother Nature can be extremely valuable healing influences.

The following unusual case of spinal cord injury highlights the above point and raises the issue of vestibular-like signs resulting from C1–2 nerve root lesions introduced in Paper 1. A 10 year old Connemara mare was found recumbent but alert on the other side of her paddock fence. She remained recumbent for 1 h then rose, was given 500 mg of flunixin meglumine IV and referred. The mare had a severely staggy gait in all 4 limbs. She stood and walked with a very wide-based stance in all 4 limbs and would stagger to either side, stopping herself falling by quick, hypometric ataxic movements of the limbs. Limb weakness was graded mild. Examination revealed an extremely painful neck, a firm swelling over the left cranial neck and hyporeflexia and analgesia of the C2 dermatome bilaterally. There were no eye position or movement abnormalities and the head was held on a median plain. A blindfold was not applied for fear that the mare would fall. Radiographs of the neck revealed a piece of the spine of the axis avulsed cranially (Fig. 9). Therapy consisted of box rest, and by 3 mo no gait abnormalities were present. There remained bilateral atrophy of the muscles over C1, particularly the caudal capital oblique muscle and bilateral areflexia and analgesia over the C2 dermatome (Fig. 10).

The clinical picture in this case was due to mild spinal cord disease and total loss of function of the C2 nerve roots. It was characterized by a gait that mimicked bilateral peripheral vestibular disease or central vestibulocerebellar disease such as is seen with rye grass staggers (see below). It certainly

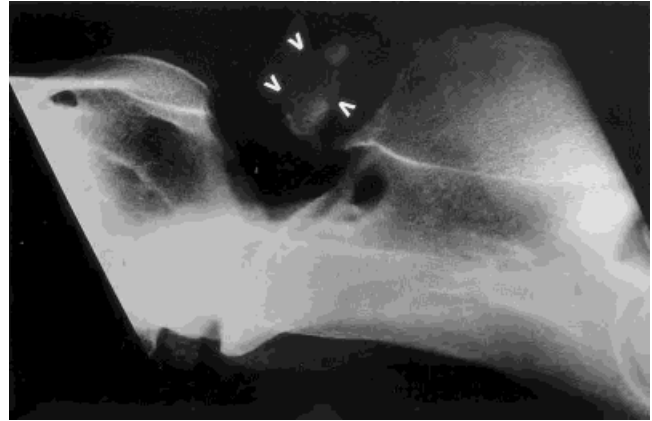


Fig. 9. Cervical radiograph of 10-year-old mare who had severe trauma and had become recumbent, showing a bone fragment (arrowheads) separated off the spine of the axis.



C  
O  
L  
O  
R

Fig. 10. Same mare as in Fig. 9, about 3 mo after the accident. There is muscle atrophy between the atlas and axis and areflexia and analgesia over the C2 dermatome. This was bilateral.

appears that the cranial cervical nerves have a prominent input into the vestibular system.

**Diagnosis:** Radiography is indispensable, particularly if fixation or surgery is contemplated. When the patient is able to walk however, this can be delayed for hours to even weeks until the patient is stable. Also, radiography is useful to detect chronic osteoarthropathy (CVM Type II) with precipitating external injury resulting in spinal cord compression.

**Therapy:** The immediate care of patients suffering severe neurological injuries consists of firstly attending to preservation of a patent airway, stopping bleeding and treating shock.<sup>2,36</sup> If there is no other major damage that must be evaluated, such as fractured long bones, fractured ribs and ruptured lung, then therapy for CNS injury should be instituted. Sedation of a delirious, thrashing patient is preferably performed with low doses of guaifenesin, diazepam or acetylpromazine. For convenience, detomidine and other  $\alpha_2$ -adrenergist agonist drugs often are dosed to effect, but should be used cau-



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tiously because they result in a transient hypertension that may exacerbate nervous tissue hemorrhage.

Consideration should probably be given to administering glucocorticosteroids to all horses with prominent signs of spinal cord disease following trauma.<sup>36</sup> A dose of 0.1–0.2 mg/kg dexamethazone probably decreases spinal cord swelling and edema. This dose can be repeated q 4–6 h for 1–4 d.

If the patient is recumbent then intravenous hyperosmolar fluids are theoretically indicated. The best of these appears to be 20% mannitol given IV at 0.25 g/kg over 20 min. This may also be repeated every 4–6 h for 24 h if there is neurological improvement following its use. One g/kg, 10% DMSO in 5% dextrose, given slowly IV, and repeated 1–6 times in 72 h has been purported to be beneficial.

Renal diuretics such as frusemide are probably not as effective as corticosteroids and mannitol in the therapy of swollen CNS tissue, although their hypotensive effect may be useful if the patient is not in shock. Prostaglandin synthetase inhibitors (phenylbutazone and flunixin) symptomatically do appear to be useful, probably by their analgesic action and should always be considered.

Many large animal clinicians are quite conservative in all such medical management partly because of side effects of drugs and of recumbency in big horses. Such complications include laminitis, necrotic cystitis, decubital sores, and super-infections that are frequently lethal. The problem really is that without intensive monitoring of central venous pressure, intracranial pressure, and cerebral blood flow and accurate morphological information of the exact brain and calvarial lesions from CT and MR surveying studies, we have no idea whether any of these drugs are doing any good at all!

*Surgery:* Selection of patients for surgery is vital to success.<sup>2,21</sup> Surgery is probably indicated if a horse's neurological condition deteriorates after appropriate medical therapy, and decompression of the spinal cord and stabilisation of luxations is feasible. Essentially, the only option for adult horses is vertebral fusion. Successful internal fixation of a fractured C2 guided by computed tomography has been reported.<sup>30</sup>

*Prognosis:* Repeated neurological examinations are the best guide to prognosis. Time alone can be the most beneficial factor to influence the final quality of survival. It is probably helpful to indicate that the decision points to continue to wait for improvement are at 1–2 h, 24 h, 3 mo, and 12 mo postinjury. As long as improvement continues it may well be worthwhile giving the patient more time to recover and compensate, depending on the minimal quality of survival that is acceptable to the owner.

#### B. Diskospondylitis

Degrees of subclinical thoracolumbar spondylosis are common and this process is linked to back pain quite frequently. Also, compared with bacterial diskospondylitis that can be treated successfully,<sup>37</sup> de-

generative disk disease is regarded as a rare (but possible) disorder in horses. Unfortunately, there is no evidence that such disk disease is primary rather than secondary to external trauma.<sup>38</sup> A distinct pathological entity is emerging that may well account for a proportion of clinical cases of locomotor problems in horses that involves secondary disk degeneration.

The hypothesis developed here and in Figs. 11–16 is that trauma from strenuous exercise and injuries due to falls causes damage to caudal cervical and thoracolumbar intervertebral disks and associated subchondral bone plates and epiphyseal cortical bone. Hemorrhagic and/or ischemic necrosis of disks, fractures of the vertebral bodies and a foreign body reaction to fibrocartilage in the epiphyseal bone occurs (Figs. 11, 14, and 16). This results in degrees of progressive spondylosis and instability of intervertebral joints, that is self-perpetuating if exercise continues. Such a process might well account for some of the subclinical ventral spondylosis of the back that is referred to as ageing changes.<sup>39</sup>

The presenting clinical syndromes have included acute and chronic neck pain, acute ataxia and tetraparesis, severe back pain and acute paraplegia. Radiography can detect the collapsed disk space and spondylosis (Figs. 12, and 13) depending on location. Scintigraphy is useful but with both these imaging techniques it is extremely difficult to accurately differentiate this traumatically induced degenerative process from bacterial diskospondylitis (Fig. 12) without a histological diagnosis or compelling systemic and therapeutic evidence of infection.<sup>37</sup>

#### 4. Inflammatory, Infectious and Immunity-Mediated Conditions

##### A. Equine Protozoal Myeloencephalitis

Considerable advances have been made in the understanding of equine protozoal myeloencephalitis (EPM) over the last 5 years by researchers in the United States. Although I am far from an expert in this disease, it would be an oversight to not discuss it in this paper.

*Epidemiology:* This disease, caused by *Sarcocystis neurona*, is a very common disease of horses in the eastern United States, although it occurs in horses that have spent some time in any part of the American continent.<sup>40</sup> The disease has been confirmed in horses that have come from the Americas in at least the United Kingdom, Ireland, and South Africa, making this disease of international importance. Most breeds of horses have been affected, but it most frequently affects Standardbred and Thoroughbred horses between 1 and 4 years of age in racing or breeding establishments in the midwestern, eastern, northeastern, and southern states of the United States, during the spring and summer in particular. Outbreaks are not seen, and the disease is not contagious from horse to horse. Clusters of cases on single properties are, however, found over

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COLOR



Fig. 11. Diskospondylosis at C7–T1 in an aged horse with spinal cord compression. The necrotic disk material has been washed out. Note the dense adjacent cancellous bone that contains cartilage-like material.



Fig. 12. Caudal cervical radiograph from another case of diskospondylosis. The disk space at C7–T1 is collapsed and very indistinct, with sclerosis of surrounding bone (arrowheads). Diskospondylosis remains a compelling differential diagnosis until a histological diagnosis is obtained.

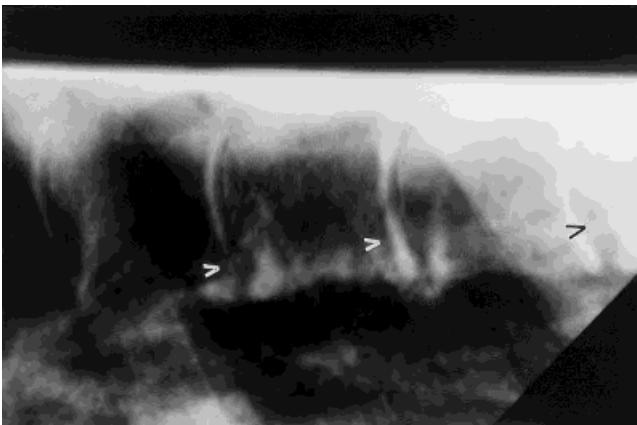


Fig. 13. Radiograph of the midthoracic vertebrae of a 20-year-old mare with profound back pain. Spondylosis is evident at several sites, with sclerosis of adjacent vertebral bone (arrowheads).

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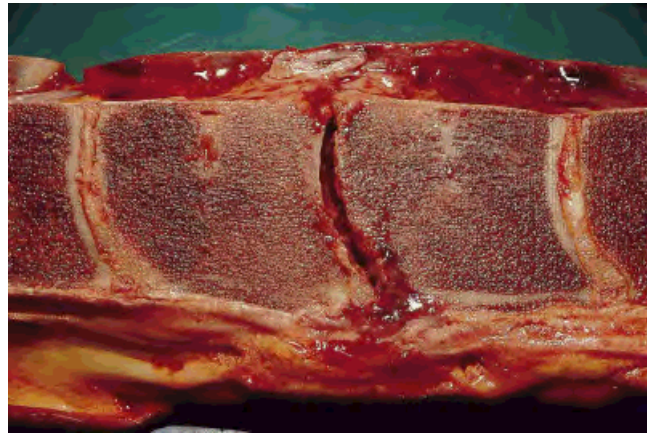


Fig. 14. Same case as in Fig. 12. The mare became suddenly paraplegic and was euthanized. Hemorrhaging from the T18–L1 disk site was shown to compress the spinal cord. The necrotic disk material has been washed out. Again there is dense adjacent cancellous bone that contains cartilage-like material.

COLOR

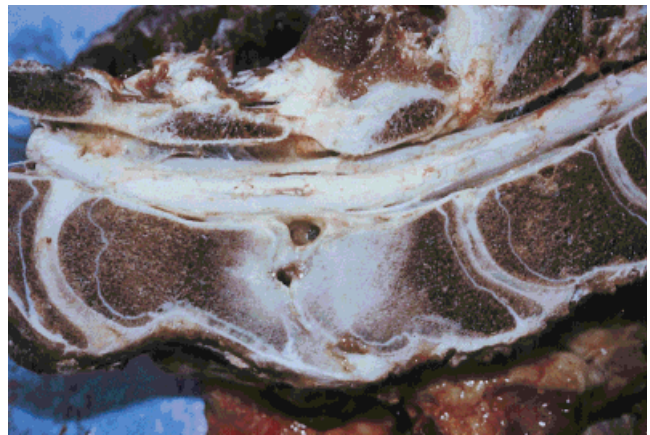


Fig. 15. The end stage of diskospondylosis is fusion of vertebrae with bony sclerosis, as shown in this horse with an extremely stiff neck. (Courtesy of K. E. Whitwell.)

COLOR

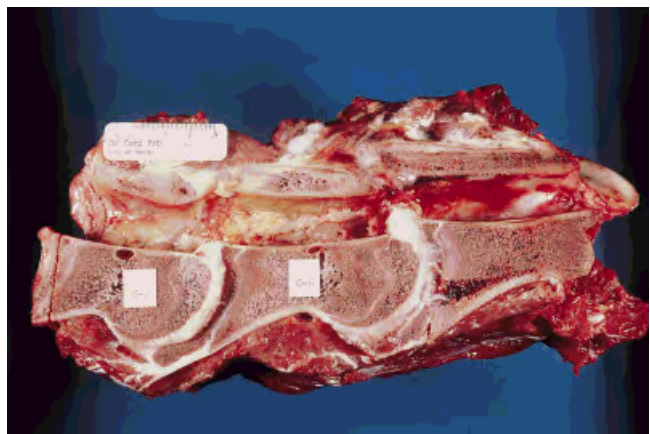


Fig. 16. The role of injury in the genesis of diskospondylosis is strongly suggested by this case of acute cervical injury. There is an obvious fracture of the caudal aspect of C5. Disk material can be seen in the cancellous bone of the caudal region of C5.

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periods of weeks to years; for example, an epizootic of EPM occurred with 12 of 21 horses on one farm having EPM for more than 6 mo.<sup>41</sup>

**Cause:** The complete life cycle for *S. neurona* is not known, although its definitive host is the North American opossum, *Didelphis virginiana*.<sup>42,43</sup> There appear to be three distinct Sarcocysts affecting this opossum; *S. neurona*, *S. falcatula*, and a third unnamed *Sarcocystis* sp.<sup>44-47</sup> Suspected intermediate hosts for *S. falcatula* are several species of birds including the North American cowbirds and grackles. The horse acts as a dead-end aberrant intermediate host for *S. neurona* but the true intermediate host(s) remains to be determined.

At least one species of *Neospora*, *N. hughesi*, also produces protozoal myeloencephalitis.<sup>48-50</sup> One case was found in an aged mare with Cushing's disease.<sup>51</sup> This disease is rare, and the life cycle is not known. *Neospora* antibodies probably can react with *S. neurona* proteins<sup>50</sup> currently used in testing for antibodies; thus clinical differentiation between these two protozoal diseases is problematic.

**Clinical Syndromes:** Signs vary tremendously, and it has been said that EPM can mimic essentially any central and peripheral neurological disease and syndrome in horses.<sup>40</sup> There can be a per-acute or extremely subtle onset of a neurological abnormality, most often involving the gait. Signs usually are progressive over hours to months or years, often with static periods. Muscle atrophy anywhere is a common finding and on neurological examination asymmetrical ataxia, weakness and stiffness in 1, 2, 3, or all 4 limbs often can be found. Selective muscle wasting, sensory deficits, localized sweating, and profound weakness, being evidence of gray matter involvement (Fig. 17), and evidence of more than one lesion, help distinguish EPM from most other equine neurological diseases including those causing ataxia and weakness. Asymmetrical cranial nerve deficits are a common finding and occasionally cerebral signs, even epilepsy, occur.

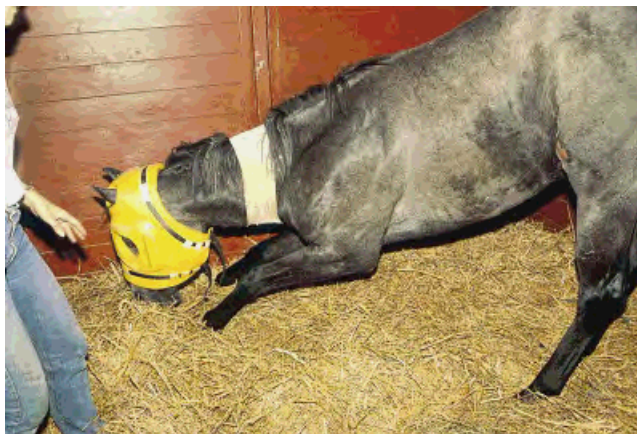


Fig. 17. Horse with EPM showing the unusual syndrome of bilateral, brachial, lower motor neuron deficits and apparently normal pelvic limb strength. The lesion was confined to the ventral horn gray matter at C7-T2.

**Lesions:** Pathologically EPM consists of focal, multifocal or diffuse, asymmetrical, nonsuppurative inflammatory lesions in the brain and particularly the spinal cord. Gray and white matter is involved and the lesions can be exquisitely localized and selective to involve, for example, just the motor nucleus of the trigeminal nerve or gray matter supplying the cranial gluteal nerve from L6.

**Diagnosis:** Diagnostically cerebrospinal fluid (CSF), especially from the lumbosacral site, may contain increased numbers of mononuclear cells, and some increase in protein along with xanthochromia but this is very inconsistent. Rarely there can be a spectacular mononuclear or granulocytic pleocytosis. Of most use is detecting antibodies to *S. neurona* in serum and CSF using a Western immunoblot test. Although 50% of randomly selected horse sera from some parts of the United States will contain antibodies,<sup>52</sup> a positive test on CSF from a horse showing neurological signs is probably 90% accurate for the diagnosis of EPM. Electromyography can help confirm lower motor neuron involvement but is of course not specific for the disease. Migrating parasites can be the differential diagnosis most difficult to rule out. This is particularly so if there has been leakage of serum across the blood-CSF barrier in a horse with a positive serum antibody test, effecting a positive immunoblot test result in CSF.

**Therapy:** Alternatives to the traditional treatment protocol of a sulfadiazine (20 mg/kg/d) and pyrimethamine (1 mg/kg/d) are emerging. Thus, 2 triazine-based anticoccidial agents, diclazuril and toltrazuril, are being investigated as therapy for EPM at doses of approximately 5 mg/kg/d. Another broad spectrum antimicrobial agent, nitazoxanide, is being used to treat cryptosporidiosis in human patients<sup>53</sup> and is on trial for EPM therapy (R. J. MacKay, personal communication). Almost certainly, a vaccine will one day be available as is the case for toxoplasmosis in sheep in some countries.

**Word of caution:** One final word of caution regards the overdiagnosis of EPM.<sup>54</sup> Certainly EPM can result in some very subtle and unusual, gait, postural, and behavioral abnormalities. However, there occurs an equally wide range of subtle and unusual syndromes in the United Kingdom in horses that have never been to the Americas; but there is no indigenous EPM in Europe.

#### B. Equine Herpesvirus Myeloencephalopathy

**Clinical syndrome:** The neurological form of infection with equine herpesvirus type 1 (EHV-1) and possibly EHV-4<sup>55</sup> is not common, but it has occurred as outbreaks in Europe, North America, and Australia. Usually adult horses of both sexes, and occasionally foals, are affected. There is an acute onset of ataxia or acute recumbency about 1 week after exposure to the virus. Limb edema is frequently seen in pregnant mares and stabled horses. Signs usually are static after 24 h, though they may fluctuate somewhat. Often in an outbreak there will be associated

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abortion and respiratory infection in horses in the herd. Some horses may have a fever (40.5°F) and transient ataxia. Occasionally cases occur following live virus EHV-1 vaccination. Hypothermia has been reported, as has diarrhea in foals, and a prominent keratoconjunctivitis may be present.

Neurological signs include pelvic limb ataxia and paresis that usually is symmetrical. Thoracic limbs can be involved, and occasionally asymmetry in gait abnormality is seen. Very frequently there is urinary bladder paralysis and overflow incontinence. Mild sensory deficits over the trunk and around the perineum are sometimes found. Infrequently, head signs such as depression and diffuse face, jaw, tongue, and pharyngeal weakness will be present.

**Lesions:** Vasculitis and associated ischemic necrosis of gray and particularly white matter is widespread. An acute vascular lesion of arterioles in the brain and especially in the spinal cord with resulting infarction of neural tissue explains the acute onset of the disease. The pathogenesis is suspected to be the direct effects of a neurotropic strain of EHV-1, perhaps associated with an immunity-mediated, Arthus-type reaction in vessel walls. Harvesting virus from the CNS of affected horses has been very difficult; even with *in situ* DNA-hybridization testing, results are conflicting.<sup>55-57</sup>

**Diagnostic aids:** The results of analysis of CSF, best obtained from the lumbosacral site often shows xanthochromia and elevated protein (1-3 g/l = 100-300 mg/dl) but usually very few cells.<sup>58</sup> Pre-existing EHV-1 serum neutralization titers are not protective and in fact probably are a prerequisite for the neurological form of the disease to occur. Substantial rises in EHV-1 serum (and possibly CSF) titers can be very helpful in making a diagnosis on a herd basis but in individual animals interpretation can be problematical. Viral isolation can be undertaken from nasal swabs, tracheal fluids and blood buffy coat taken from affected and unaffected horses in the herd. The rationale for corticosteroid therapy is debatable but appears to be clinically effective at least in the first 24-48 h. A dose of 0.1-0.25 mg/kg dexamethasone, IM, BID, for 3 d may be used. Vaccination may be deleterious during an outbreak.

**Prognosis:** Ambulatory horses usually improve<sup>58</sup> over a few days to a few months and often return to normal. Recumbent horses have recovered completely with dedicated nursing care and particular attention paid to preventing pressure sores and ensuring bowel and bladder evaluation.

#### C. Vertebral Osteomyelitis and Diskospondylitis

Unlike in ruminants, sepsis involving the vertebral column is uncommon in foals and rare in adult horses. Neck or back pain, and/or paresis, sometimes with ill thrift occur with this disorder. Often there is an acute onset of pain or stiffness progressing to paresis. Diarrhea or evidence of sepsis or lung abscesses are often coexisting problems in foals. Neurological evidence of focal spinal cord compres-

sion with para or tetraparesis may be found and the presence of localising signs of heat, pain and swelling involving vertebral and paravertebral tissues is very helpful. Osteomyelitis and diskospondylitis occur at variable sites in the vertebral column, especially C1-2, C6-7 and the lumbar region. Direct extension of sepsis from external wounds and from lung and abdominal abscesses occurs in both foals and adult horses. Many different organisms have been isolated, particularly *Streptococcus* spp., *Salmonella* spp., *Actinobacillus equuli* and *Rhodococcus equi* in foals and *Brucella abortus*, *Mycobacterium tuberculosis*, *Actinobaccillus* spp. and coagulase positive *Staphylococcus* in adults.<sup>2,59,60</sup>

Radiography, scintigraphy and electromyography are very helpful in localizing the lesion and helping make a diagnosis. Results of CSF analysis may be normal or have evidence of compression (xanthochromia, mononuclear cells and elevated protein). Occasionally neutrophils will be present, but rarely can the organism be cultured from CSF. Aerobic and anaerobic culture of material obtained from direct aspiration from the vertebral lesion has been very useful in determining an etiologic diagnosis. A tuberculin test, brucellosis titer and blood and urine cultures also may be indicated.

Prolonged antimicrobial therapy, preferably based on culture results. Surgical drainage and decompression if compression of the spinal cord is prominent is theoretically indicated but usually impracticable. The prognosis is guarded but can be fair to good if prolonged therapy is economically possible.<sup>37</sup>

#### D. Helminth and Fly Larval Myelitis

Various migrating parasites accidentally meander through the equine CNS infrequently and sporadically but may do so endemically in certain regions (e.g., Kumri in horses in India due to *Setaria* sp.).<sup>1,3</sup> Equids of any age are susceptible and there usually is an acute onset of signs with progression, though this varies tremendously. Signs usually reflect the tortuous, usually asymmetrical, random migrations (*Strongylus* sp., *Hypoderma* sp., *Habronema* sp., *Setaria* sp.) or diffuse spinal cord and/or brain involvement (*Setaria* sp., *Micronema* [*Halicephalobus*] *deletrix*). Circulating eosinophilia and especially CSF eosinophilic or neutrophilic leukocytosis with hemorrhage are helpful ancillary findings but are not always present.

Appropriate antiparasitic and anti-inflammatory therapy appears to be rewarding in some cases. Suggested doses are: ivermectin, 200µg/kg (may take several days to destroy the parasite); fenbendazole, 50 mg/kg; thiabendazole, 440 mg/kg; diethylcarbamazine, 50 mg/kg; and routine doses of organophosphates. Phenylbutazone, flunixin or even dexamethazone at routine anti-inflammatory levels should be included in therapy.

Corticosteroid therapy perhaps is more important with suspected *Angiostrongylus cantonensis*,<sup>61</sup> a para-

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site recently introduced to North America that has resulted in neural angiostrongylosis in the United States.<sup>62</sup>

Some amazing recoveries from acute spinal syndromes suspected to be caused by parasite migration have occurred, but the outlook for a chronic case or those showing recumbency must be bad.

## 5. Toxic Disorders

### A. Ryegrass Staggers and Related Syndromes

*Cause:* Staggers syndromes in horses are caused by a group of alkaloids produced by endophytes in feedstuff, particularly grasses. *Acremonium* (now *Neotyphodium*) *lolii* is the endophyte that grows in perennial ryegrass (*Lolium perenne*) and produces at least 3 neurotoxic alkaloids, the most potent of which is Lolitrem B.<sup>63</sup> This is the most understood of the various phyto-genous mycotoxicoses that result in ataxia in horses. The parasitic endophytes have symbiotic relationships with the grass, actually living within it. As such, they are passed through the seed to future generations and are consequently associated with particular strains of ryegrass. They are generally beneficial to the grass, improving growth and stress- and parasite- resistance. Under some adverse and ill defined weather conditions they produce neurotoxic alkaloids that reduce the likelihood of the grass becoming overgrazed through producing ryegrass staggers in the grazing animals. Sensitivity and resistance to ryegrass staggers is under genetic control, at least in sheep.<sup>63</sup>

*Clinical syndrome:* Particular clues to the diagnosis of this disease are the absence of weakness and presence of muscle tremor and fasciculation, ataxic eyeball movements and exacerbation of signs with effort, excitement and especially with blindfolding, all indicating a vestibulocerebellar component to the syndrome. On occasions these signs are so profound that the patients will become recumbent in a convulsive episode that can be repeated, mimicking cerebral seizures.

*Epidemiology:* Ryegrass staggers has been a problem in Australia and New Zealand<sup>63</sup> for many years and cases occur in horses every year. It also occurs in the United States<sup>64</sup> and Holland.<sup>65</sup> Until recently the disease has not occurred on a widespread scale in horses in the United Kingdom although sporadic cases have been diagnosed presumptively. A recent outbreak in the United Kingdom (Wood JLN and Mayhew IG, unpublished, 1994)<sup>66</sup> occurred in stabled animals in a variety of different yards in two counties. The only common factor in the outbreak was the single field from which the suspect hay being fed had been harvested. Clinical signs included an acute onset of ataxia, proprioceptive deficits and a wide-based stance in a high proportion of horses. In one yard, 42/48 horses were affected. They were apyretic and good appetites were retained. Once a diagnosis had been reached and the feed withdrawn,

recoveries were generally uneventful. The diagnosis was initially made on epidemiological grounds.

The hay in question was a by-product of a ryegrass seed crop (i.e. "thrashed" hay). The ryegrass variety (Yatsin) recently imported from New Zealand was known to have a high endophyte content and has caused staggers in that country. Although grasses are marketed in New Zealand labelled with the endophyte content, no such marking occurs in the United Kingdom. Being a seed crop, all the hay was this one variety, thereby being concentrated. Of grasses indigenous to the United Kingdom, some red fescues contain endophyte, however as they rarely make up more than a small proportion of meadow grass, the likelihood of problems is usually much lower. With new imported varieties of ryegrass being marketed internationally, ryegrass staggers forms an important differential diagnosis in any area or country where such outbreaks of neurological disease occur.

*Therapy and prognosis:* In horses affected severely acetylpromazine and diazepam given to effect have been useful to relieve spasticity and tremor. Of more importance is to remove the horses from the potential mycotoxin and allow time for the putative false neurotransmitter mycotoxins to be detoxified. Affected horses should be left undisturbed in a quiet environment, preferably outside where they have a wide horizon to orient to because of the vestibular component to the syndrome. If they must be housed then a light should be left on during darkness for the same reason.

In severe cases in horses a permanent ataxia can remain. In cases of wobblers with no other diagnosis evident, this disease should be considered. If such horses are necropsied and little evidence of spinal cord disease is evident, the cerebellum should be scrutinized for evidence of Purkinje axon swellings ("torpedoes") that can be seen in chronic cases (63).

### B. *Indigofera* spp. Toxicity and Grove Poisoning

Birdsville disease is seen in horses in Australia that consume *Indigofera linnaei* (Birdsville indigo). Signs include weight loss, progressive ataxia and weakness and the described signs suggest a high-striding, cerebellar-like gait abnormality. Stomatitis and conjunctivitis may also be present. Affected animals may collapse and show terminal convulsions. Complete recovery can occur but toe dragging may persist. The toxicity appears to be prevented by feeding arginine rich feeds such as alfalfa or gelatin.<sup>2</sup>

So-called grove poisoning has been recognized in horses in southern Florida for decades. It now appears that this is caused by an *Indigofera* sp. that grows well in the region. The signs appear essentially the same as Birdsville disease and on several detailed post-mortem examinations no CNS lesions have been identified. Large doses of gelatin (500 g BID) should probably be given by stomach tube to

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suspected cases (Z. Franklin and R. Mackay, personal communication, 1998).

## 6. Nutritional Conditions

### A. Equine Degenerative Myeloencephalopathy (EDM)

*Epidemiology:* Equine degenerative myeloencephalopathy (EDM) has been recognized as a clinical and pathological syndrome in various equidae for at least 20 years. It has been reported most often in North American horses,<sup>67-69</sup> but has occurred in Great Britain and Continental Europe.<sup>11,70</sup>

Most frequently signs are first seen in suckling and weanling foals. Rarely, if ever, are signs documented to begin after 2 years of age compared with cases of equine motor neuron disease that also is associated with a vitamin E-deficient state. Signs often are insidious in onset and slowly progressive, however a rather dramatic onset of severe ataxia and weakness in the pelvic limbs or all four limbs may be apparent. At that stage closer inspection of other foals on the farm may reveal further cases. Clinical signs occasionally progress to recumbency although most frequently they plateau with maturity. Although a wide variety of breeds of horses have been affected those in which clusters of cases have been observed include Arabian, Appaloosa, Thoroughbred, Standardbred, Przewalskii (Mongolian Wild Horse), Paso Fino and Morgan breeds as well as Grant Zebras.

*Clinical syndrome:* Neurological examination reveals essentially symmetrical ataxia, weakness and hypermetria usually affecting all four limbs often substantially worse in the pelvic limbs. Severely affected foals and zebras have been known to adopt a paraplegic (dog-sitting) posture. In moderately to markedly affected horses there can be rather prominent hyporeflexia or areflexia involving the thoracolumbar (slap), local cervical and cutaneous truncal reflexes. This hyporeflexia is in spite of absence of hypalgesia or lower motor neuron involvement (muscle atrophy) and probably relates to involvement of internuncial neurons in the intermediate columns of the spinal cord.

*Diagnostic aids:* Ancillary aids including routine laboratory blood tests, cervical radiography, cerebrospinal fluid analyses and electromyography do not help in the diagnosis. Early in the course of the disease young affected animals and unaffected foals on the same farm may have serum vitamin E concentrations below control values of 1-4 mg/l. Conversely, more mature animals with chronic disease can have normal serum vitamin E concentrations, particularly if they have access to fresh green forage.

*Lesions:* The underlying lesions that account for the clinical syndrome are degrees of neuroaxonal dystrophy affecting spinal cord and brain stem nuclei and neuronal fiber degeneration within ascending and descending spinal cord pathways, particularly prominent in the thoracolumbar region.

*Cause:* Access to dirt paddocks having no grass and use of heated, pelleted feed and sun baked forages with very low vitamin E contents are predisposing factors to the disease. Supporting evidence for vitamin E deficiency being involved is prominent neuroaxonal dystrophy recorded in spinal cord and brain stem nuclei in two foals that were subjected to vitamin E deprivation from the last trimester of pregnancy of their dams though 6 mo of age.<sup>71,72</sup> Also, a familial tendency has been observed<sup>69</sup> with foals from dams that have previously had an affected offspring being at a higher risk of developing the disease than foals from other dams.<sup>73</sup>

The above evidence strongly supports the hypotheses that EDM is a vitamin E deficiency that has a familial and likely genetic predisposition.<sup>69</sup> On the other hand, some chronically affected animals have been found to have normal serum vitamin E concentration<sup>68</sup> and affected horses have normal intestinal absorption of  $\alpha$ -tocopherol.<sup>74</sup> Also, prior use of insecticides and exposure to wood preservatives have been identified (with others) as risk factors in EDM. Thus, the hypothesis, which extends the pathophysiology to include exposure to environmental oxidants and lack of antioxidants including vitamin E, is tenable. Notwithstanding this, the evidence strongly indicates that supplementation of groups of horses, in which there has been a high prevalence of the disease, with adequate vitamin E (at least 2000 IU/d/horse) has been associated with cessation of new cases. Whether this has been replenishment of a vitamin E deficiency and/or an additional antioxidant effect is still unclear. Finally, therapy of chronically affected animals with vitamin E, up to 6000 units per day, may result in some, but not total, improvement in clinical signs.<sup>75</sup>

### B. Equine Motor Neuron Disease (EMND)

*Epidemiology:* Equine motor neuron disease (EMND) is a fascinating neuromuscular disorder of horses that does not appear to have been recognized prior to 1982 and was first described in 1990 by the late John Cummings and colleagues at Cornell University.<sup>75</sup> The majority of initial cases appeared to cluster in the Northeastern United States.<sup>76</sup> To date, circa 150 horses have been definitively diagnosed with EMND at Cornell University with another 50 or so cases reported worldwide.<sup>77-82</sup>

EMND bears a striking resemblance to progressive muscular atrophy (Lou Gehrig's disease), a form of human motor neuron disease. This increases the significance of the equine disease well above its relatively low incidence. The disease results from destruction of lower motor neurons in the brainstem and spinal cord leading to typical clinical signs characterized by postural weakness.

Quarterhorses, Appaloosas, and Standardbred horses appear to be more likely to develop the disease than other breeds and older horses are at a higher risk than young animals. The peak incidence occurs at 16 years of age and then declines.

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Most importantly, the vast majority of cases have no or little access to grass.<sup>83</sup>

*Clinical syndrome:* In early cases, weight loss in the face of a normal to increased appetite, increased recumbency and muscle tremors are consistent findings. Weight loss often precedes the onset of trembling by several weeks.<sup>83,84</sup> Trembling usually is exacerbated by forcing the horse to stand in a fixed location such as in stocks or in a trailer. Affected horses appear to be unable to lock their stifles and constantly shift weight from one hindlimb to another. They adopt a characteristic stance and frequently have an abnormally low head carriage (Fig. 18). Some affected animals rest their head on the ground when recumbent or rest it on a stable door or feed manger when standing. A short-strided gait is common, however there appears to be no loss of proprioception and they are not ataxic; *affected horses move better than they stand*. Many animals have a raised tail head and excessive sweating is seen in more than half of the patients.<sup>83</sup> In most chronic cases where signs are stable ophthalmic examination reveals varying degrees of a mosaic pattern of dark brown to yellow brown pigment deposited in the tapetal zone with a horizontal band of pigment at the junction of the tapetum and nontapetum.<sup>85,86</sup>

The clinical syndrome tends to stabilize or improve somewhat 1 or 2 mo after the onset of signs. These horses may not tremble or have muscle fasciculations or lie down frequently, but marked muscle wasting is common, particularly in neck, scapular, triceps, quadriceps and lumbar muscles.<sup>84</sup> Progression of signs after a period of stabilization does occur. Body weight may return to pre-disease levels as the horse accumulates fat but their athletic ability is permanently impaired to varying degrees.<sup>83</sup> Oral vitamin E supplementation (6–10,000 IU/d)

appears to have improved the clinical syndrome in a few cases.

*Diagnosis:* There are several important differential diagnoses that must be eliminated including botulism, organophosphate and other toxicities, myositis, malabsorptive disorders and neglect. The stance and muscle trembling is very similar to that seen in grass sickness. Laboratory findings do reflect a myopathy but are not specific for EMND. A survey of 28 horses showed the mean CK and AST activities were elevated to 1276 and 1367 IU/l respectively.<sup>83</sup> The CSF protein content and IgG index were slightly increased, a finding that did not seem to be associated with either duration or severity of disease. Although plasma glucose concentrations were normal in all horses, the mean peak value after an oral glucose absorption test was low in 7 cases (64 mg/dl = 6.33 mmol/l). In one study,<sup>87</sup> plasma vitamin E concentrations for 53 affected horses ( $0.76 \pm 0.70$  µg/ml) were significantly ( $p < 0.001$ ) lower than 69 control horses ( $2.15 \pm 1.66$  µg/ml). Interpretation of the odds ratios indicated that raising the plasma vitamin E concentration by 1 µg/ml reduced the risk of EMND 6-fold.

Needle electromyographic studies have proved to be a useful diagnostic test as they are consistently abnormal in affected animals but require general anesthesia for accurate interpretation. Prolonged insertional activity and positive sharp waves are frequently recorded, particularly in the proximal thoracic appendicular muscles.<sup>88</sup> The dorsolateral coccygeal muscle contains a high proportion of type I muscle fibers (postural or antigravity muscles) which makes it a convenient muscle to biopsy to confirm lower motor neuron disease in suspect cases.<sup>77</sup> Microscopic evaluation of a biopsy of the ventral branch of the spinal accessory nerve (cranial nerve XI) is another valuable antemortem diagnostic tool for the evaluation of horses suspected of having EMND (sensitivity 91%, specificity 92%).<sup>89</sup> Histological evidence of the degeneration of myelinated axons is present in both acute and arrested cases.

A definitive diagnosis can only be made by demonstrating degeneration and loss of neuronal cell bodies in the ventral horn of the spinal cord and some motor nuclei in the brain stem at postmortem examination.<sup>83,90</sup> Neuronal cell bodies swell, lose Nissl substance, become chromatolytic, and have perikaryal and proximal axonal accumulations of neurofilaments. There is concomitant degeneration of axons in the ventral nerve roots and neurogenic muscle atrophy, mainly of type 1 fiber.<sup>75,90</sup> Endothelial pigment is prominent in the small vessels of the spinal cord.<sup>85</sup>

*Cause:* Although the precise cause of EMND is not known, several aspects of it suggest the possibility of a deficiency of antioxidant activity in the central nervous system, as is the case in the familial human disease.<sup>83,90</sup> These include a predilection for the loss of highly oxidative, type I muscle fibers, the presence of endothelial lipopigment and the low

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Fig. 18. A 14-year-old gelding with EMND who had a voracious appetite associated with weight loss. The horse shows the characteristic tendency to have a low head carriage and to stand with all feet close together. This horse had prominent muscle tremors in the proximal limb muscles. He also had a mosaic pattern of brown pigment deposits in the tapetal zone typical of EMND.

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serum vitamin E levels found in many cases. A depleted vitamin E status is strongly incriminated as a causal factor in the disease, although other individual horse and farm-level factors contribute significantly to the risk of a horse developing EMND.<sup>92</sup>

### 7. Conclusion

In this paper I have attempted to highlight the most important, topical and interesting disorders affecting the equine spinal cord. New data and commentary have been included, particularly those from my clinical experience. If this paper sparks an interest in diseases of the spinal cord of horses in just one practitioner it will have been worthwhile; I am sure that Dr Frank Milne would agree with that.

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