EQUINE

Factors predictive of abnormal results for computed tomography of the head in horses affected by neurologic disorders: 57 cases (2001–2007)

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Objective—To determine neurologic indications associated with abnormal results for computed tomography (CT) imaging of the head of horses affected by neurologic disorders.

Design—Retrospective case series.

Animals—57 horses.

Procedures—Signalment, history, clinical abnormalities, and clinicopathologic findings were obtained from medical records of horses examined because of neurologic disorders, and precontrast and postcontrast CT images of the head were reviewed. Data were analyzed by use of univariate and multivariate logistic regression.

Results—For a horse with abnormal mentation, odds of having abnormal results for CT imaging of the head was 30 times (95% confidence interval [CI], 2.36 to 374.63) the odds for a similar horse without abnormal mentation. For a horse with cranial nerve deficits, odds of having abnormal results for CT imaging of the head was 11 times (95% CI, 1.00 to 127.96) the odds for a similar horse without cranial nerve deficits. For a horse with seizure-like activity, odds of having abnormal results for CT imaging of the head was 0.05 times (95% CI, 0 to 0.90) the odds for a similar horse without seizures.

Conclusions and Clinical Relevance—These results suggested that alterations in consciousness and cranial nerve deficits were strong predictors of abnormal CT findings for the head of affected horses. Thus, CT can be a useful complementary diagnostic test in horses with these neurologic deficits. In contrast, alternative diagnostic tests (eg, electroencephalography and magnetic resonance imaging) should be considered in horses with seizure-like activity that do not have head trauma or cranial nerve deficits. (*J Am Vet Med Assoc* 2009;235:176–183)

Computed tomography of the head of horses allows excellent determination of the anatomy of bony structures, and it is primarily conducted to identify and define fractures (and their extent) of the skull; temporohyoid osteoarthropathy; diseases of the sinuses; dental diseases; diseases of the inner, middle, and outer ear; diseases of the auditory tube diverticulum (ie, guttural pouch); and periorbital masses.[1–4] In human patients, CT of the head is also a sensitive diagnostic method for the detection of mineralization and acute hemorrhage of the brain.[5] In addition, brain lesions detectable by use of CT include intracranial masses, such as cholesterol granulomas, neoplasms and abscesses, ischemic areas, pituitary adenomas, hydrocephalic regions, and brain malformations.[5–10] Furthermore, IV administration of contrast medium during CT is used to identify inflammation and breakdown of the blood-brain barrier associated with brain lesions and to enhance vascular lesions.[2,7,10]

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Abbreviations

CI	Confidence interval
CT	Computed tomography
EEG	Electroencephalography
MRI	Magnetic resonance imaging
OR	Odds ratio

Except for subarachnoid hemorrhages, mineralized lesions, skull fractures, sinus abnormalities, and craniofacial abnormalities, CT is less sensitive than MRI for detecting lesions in the CNS.[2,5] Furthermore, MRI is superior to CT for use in evaluating soft tissue because of the improvement in contrast that can be achieved between tissues.[3] Despite these limitations, CT has been incorporated at many referral centers as one of the diagnostic tools used to evaluate equine patients with a wide array of neurologic conditions. However, to our knowledge, no studies have been conducted to define the neurologic indications that most warrant CT of the head in horses. Therefore, the purpose of the study reported here was to validate the use of CT imaging of the head of horses affected by neurologic disorders by determining the neurologic indications and clinical predicting factors associated with abnormal results for CT imaging

in this population, and evaluating the diagnostic use of CT (including IV administration of contrast medium) in relation to that of other ancillary tests.

Materials and Methods

Criteria for selection of cases—Medical records of horses affected by neurologic disorders that underwent CT of the head between January 2001 and August 2007 at The Ohio State University Veterinary Teaching Hospital were reviewed. Fifty-seven horses were identified for use in the study. One horse underwent 2 CT scans of the head, both of which yielded positive findings. The first was performed because of suspected vestibular disease, and the second was to evaluate the severity of head trauma after a fall while hospitalized. For the purpose of this study, only the information from the initial visit for that horse was used.

Medical records review—For each horse, signalment, historical information obtained from the owner or referring veterinarian, results of physical and neurologic examinations, results of CSF analysis, CT evaluations, and results of any additional diagnostic tests (such as EEG recordings, endoscopic examinations of pharynx and guttural pouches, and skull radiographs) were reviewed. Data were categorized for breed, sex, age, duration of clinical signs, history of head trauma or posttraumatic loss of consciousness, type and frequency of seizure-like activity, mentation, cranial nerve deficits, menace response, gait deficits, and CSF analysis. Only information related to moderate to severe gait deficits (grade ≥ 2 on a scale of 0 to 5 reported elsewhere[11]) was retained for the study.

Continuous and categoric variables were used to facilitate logistic regression. Horses were classified for sex (female, sexually intact male, or gelding), breed (Quarter Horse and Quarter Horse–crossbred horses, Thoroughbred, Arabian and Standardbred, and other), and age (< 1 year, 1 to 4 years, 5 to 15 years, and > 15 years). Duration of clinical signs was defined as acute-subacute (duration of ≤ 10 days) or chronic (> 10 days). History of head trauma or posttraumatic loss of consciousness was defined as detected or not detected.

Seizures were defined as detected or not detected and further classified on the basis of type and frequency. Type of seizures was defined on the basis of historical information, follow-up telephone communications with referring veterinarians, EEG interpretation (when available), and evaluation of seizures by at least 1 clinician when the horse had a seizure during hospitalization. As a result, seizures were grouped into 5 general categories (primary generalized seizures, secondary generalized seizures, simple and complex partial seizures, neonatal seizures, and unclassified seizures, including suspected behavioral changes and possible syncopal episodes) by use of a standardized classification used in humans and small animals.[12,13] Seizures generalized from the onset were defined as primary generalized seizures. Seizures with a focal onset were classified as partial seizures (simple partial seizures when consciousness was not impaired and complex partial seizures when consciousness was impaired).[12] Secondary generalized seizures could originate from both types of partial seizures. On the basis of historical information, clinical signs, or a combination of both, horses with posttraumatic seizures were included in the secondary generalized group. Because seizure-like activity results in grouping of horses with many clinical signs, horses with suspected behavioral changes were included in the category of horses with seizure-like activity. Seizures were further classified on the basis of frequency (≤ 2 and > 2 episodes), which included all of the episodes reported before referral and during hospitalization.

Mentation was classified as normal or abnormal, which included horses with primary clinical signs of altered consciousness (signs of depression, obtundation, stupor, coma, or anxiety-overreactivity) or narcolepsy-like episodes. Cranial nerve deficits were defined as detected or not detected. Horses with vestibular syndrome were included in the group of horses with cranial nerve deficits. Menace response was classified as normal or abnormal; it was grouped in a separate category from cranial nerve deficits because this test evaluates brainstem, cerebrum, and cerebellum pathways in addition to cranial nerves II and VII. Results for the CSF analysis were classified as normal or abnormal.

CT—Acquisition of CT images, which was accompanied by CSF collection in 55 horses and EEG recordings in 14 horses, was performed in anesthetized horses. Most horses were premedicated with xylazine hydrochloride[a] (0.6 mg/kg [0.27 mg/lb], IV). Anesthesia was induced by administration of guaifenesin[b] (55 mg/kg [25 mg/lb], IV) and thiopental sodium[c] (5.5 mg/kg [2.5 mg/lb], IV). Horses were then endotracheally intubated, and anesthesia was maintained by administration of isofluorane[d] or sevoflurane.[e] Horses were symmetrically positioned in dorsal recumbency on a CT table. The CT scans were acquired with a fourth-generation helical CT scanner[f] by use of conventional settings (ie, display field of view, 26, 32, or 35 cm; peak, 130 kV; 200 mA•s) and a slice thickness of 5 mm. A preliminary scan (topogram) was completed at the beginning of each examination. The CT images were initially acquired transverse to the long axis of the head and were reformatted into sagittal planes. Window width and level were adjusted as necessary to highlight the osseous or soft tissue structures on the CT images. The CT images were examined by board-certified veterinary radiologists. Anatomic references for the head of adult and neonatal horses have been published elsewhere.[14–16] Information recorded for CT images included area of abnormal density within the brain parenchyma, evidence of the effect of a mass (midline shift of the third ventricle and septum pellucidum, asymmetry of the 2 sides of the brain, or pronounced asymmetry of the lateral ventricles), enlargement of the ventricles, and anatomic site of any lesions.[17] Contrast medium was used to evaluate integrity of the blood-brain barrier. Approximately 300 mL of iodinated contrast medium[g] was injected into the jugular vein of a typical adult horse (approx 450 kg). Contrast enhancement was defined as absent, minimal, mild, or marked.

Statistical analysis—A preliminary univariate analysis of all 14 variables was performed to select the variables for inclusion in the final multivariate analysis.

Significance of univariate associations was determined by the use of χ^2 tests and univariate logistic regression analysis. To evaluate predictive factors while controlling for potential confounding factors, a multivariate logistic regression analysis was developed on the basis of results for the univariate analysis. A critical value of $P < 0.05$ was used as a criterion for inclusion of the variables in the multivariate model. Adjustments were made for heteroscedasticity of data. All variables chosen for the multivariate logistic regression analysis were also analyzed by use of a Pearson correlation test to determine interactions of dependency among variables; results of that analysis did not reveal any strong (ie, $r > 0.6$) correlations among the chosen variables. In the final model, only data for 53 horses could be included because one of the variables (CSF or menace response) was missing for 4 horses. Results of EEG and other ancillary tests were not included in the statistical analysis because these tests were performed only in a limited number of horses. The OR was used to measure the association between each independent variable and the outcome of interest (ie, abnormal results for CT imaging of the head), and 95% CIs were calculated. Values of $P \leq 0.05$ were considered significant. Data were analyzed by the use of commercially available statistical software.[h]

Results

Animals—The study population consisted of 57 horses with a primary problem of neurologic disorders that underwent CT of the head. The horses comprised 18 females, 12 sexually intact males, and 27 geldings. There were 19 Quarter Horses and Quarter Horse–crossbred horses, 16 Thoroughbreds, 7 Arabians, 4 Standardbreds, and 11 other breeds (warmblood, Friesian, Paso Fino, Morgan, Rocky Mountain, and pony). Horses ranged from 1 day to 23 years of age (mean ± SE, 10.5 ± 6.8 years). On the basis of analysis of the historical information, horses were examined because of seizure-like activity (39/57 [68%]), cranial nerve deficits (8/57 [14%]), abnormal mentation (6/57 [11%]), and tetraparesis and tetra-ataxia of acute onset (4/57 [7%]). Four horses were also examined because of a history of head trauma (3/4 had posttraumatic loss of consciousness and seizures).

At the time of admission, results of a neurologic examination were interpreted as abnormal in 34 of 57 (60%) horses. Notably, all horses with abnormal results for CT had abnormal results for the neurologic examination.

Among 39 horses examined initially because of seizure-like activity, 16 (41%) had abnormal results of a neurologic examination conducted at the time of admission. Abnormalities included generalized seizures, complex partial seizures, neonatal seizures, excitement and hypersensitivity to stimuli, star-gazing behavior, and signs of depression and obtundation; signs of depression or obtundation were detected in all horses with acute seizures. Abnormal behavior was suspected in 5 horses on the basis of historical information (n = 4 horses) or results of clinical examination at the time of admission (1). In addition to the 39 horses initially examined because of seizure-like activity, 5 other horses developed seizures while hospitalized; thus, there were 44 horses with seizure-like activity. Among the 44 horses with seizure-like activity, 32 (73%) had a history of multiple episodes (> 2 episodes), including 5 horses with repeated episodes of seizures with acute onset, and 12 (27%) horses had a history of 1 or 2 episodes of seizures. Furthermore, 11 (25%) horses were examined because of an acute onset of seizures (ie, episodes first observed during a period of < 48 hours), 5 (11%) horses had episodes during a period of 2 to 10 days, and 28 (64%) horses had recurring episodes during a period of > 10 days. On the basis of the historical information, clinical observations, and EEG results (when available), seizures in the 44 horses were defined as primary generalized in 4 (9%), secondary generalized in 13 (30%), simple and complex partial in 13 (30%), neonatal in 2 (5%), and unclassified or suspected intermittent behavioral changes in 12 (27%).

Results of cytologic evaluation of CSF were considered abnormal in 10 of 43 (23%) horses with seizures or intermittent behavioral changes (CSF was not collected from 1 horse with seizure-like activity). In particular, results of cytologic evaluation of CSF were abnormal in 2 horses with abnormal EEG results but normal results for CT of the head. Cytologic abnormalities were described as albuminocytologic dissociation (n = 5 horses), lymphocytic pleocytosis (2), neutrophilic pleocytosis (2), and evidence of past hemorrhage (2), with 1 horse having both past hemorrhage and albuminocytologic dissociation.

An EEG was recorded in 14 horses with seizure-like activity; results were abnormal in 10 horses (indicative of focal lesion in 8 horses) and unremarkable in 4 horses. All horses for which the EEG recording had normal results also had normal results for CT of the head. Strikingly, all 10 horses for which the EEG recording had abnormal results had normal results for CT of the head. Overall, CT of the head revealed abnormal findings in only 5 of 44 (11%) horses. In 1 of the 2 neonates, there was evidence of meningoencephalitis on CT imaging, and postmortem examination revealed congestion of meningeal vessels. Among the 13 horses with secondary generalized seizures, 4 (31%) had abnormal results for CT of the head, including an effect of a mass within the right caudal portion of the cerebrum attributed to posttraumatic cerebral edema in a 4-year-old Arabian. Notably, all 3 horses that had seizures secondary to head trauma had abnormal results for CT of the head. In contrast, CT of the brain was interpreted as unremarkable in all the horses with primary generalized (n = 4 horses), partial (13), and unclassified (12) seizures.

Ten of 57 (18%) horses had cranial nerve deficits, which included impaired function of cranial nerves II, III, V, VII, VIII, or XII; laryngeal hemiplegia; and dysphagia. Five of these 10 horses had vestibular syndrome (4/5 had central vestibular disease), and 1 horse had cauda equina syndrome. Results of cytologic examination of CSF were abnormal in 6 of the 10 horses and included neutrophilic pleocytosis in 2 horses. Western blot analysis for *Sarcocystis neurona* in serum or CSF yielded positive results for 6 horses (which was confirmed during postmortem examination in 1 horse with

normal results for CT of the head). Overall, results for CT imaging were abnormal in 7 of the 10 horses with cranial nerve deficits. The CT findings included temporohyoid osteoarthropathy (n = 2 horses), fractures of the petrous temporal bone (2), multiple skull fractures (1; **Figure 1**), a nasal neoplastic mass (ie, adenocarcinoma) invading the ventral calvarium (1), and a brainstem hyperdense structure likely associated with an acute vascular event (1). Among the 5 horses with vestibular syndrome, use of CT imaging identified lesions in 4 horses (3 of which had central vestibular disease). Computed tomographic findings included the following: a right-sided temporohyoid osteoarthropathy (peripheral vestibular disease [n = 1 horse]), a left-sided temporohyoid osteoarthropathy with findings compatible with osteomyelitis and a fracture of the petrous temporal bone (1), a brainstem lucent focus containing gas density associated with a fracture of the right petrous temporal bone (1), and a hyperdense lesion in the left lateral portion of the brainstem (1). For all of the horses with temporohyoid osteoarthropathy identified by use of CT, stylohyoid thickening was also recognized during endoscopic examination of the guttural pouches. Horses with central vestibular signs, accompanied by signs of depression and obtundation, had temporal bone fractures or brainstem lesions. Fractures of the petrous temporal bone visible on CT scans were not identified during examination of skull radiographs. Finally, 7 horses had an abnormal menace response or impaired vision; 4 of these had abnormal results for CT of the head.

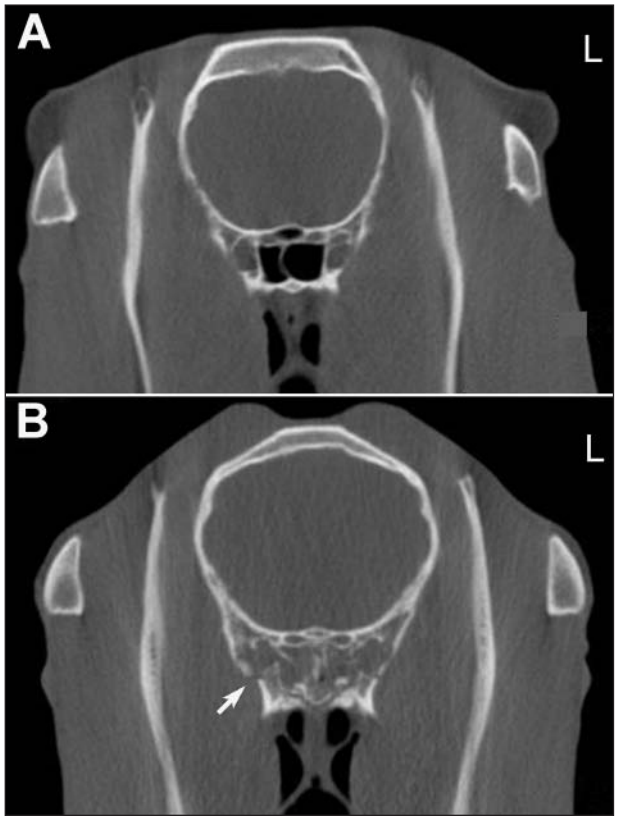

Figure 1—Transverse CT images of the skull of a horse with normal structure (A) and a horse that had signs of depression, occulomotor nerve dysfunction, and ataxia attributable to multiple fractures in the sphenoid bone (B). The images were obtained by use of a bone window (window width, 2,000; window level, 400) at approximately the same plan section. In panel B, 2 fragments of the sphenoid bone are displaced in an abaxial direction. The optic canals and orbital fissures are intact. Notice the fractures through the round foramen and alar canals (arrow). L = Left side.

Abnormal mentation was the primary problem for 6 horses and was detected in 16 other horses during hospitalization. Results of CSF analysis were abnormal in 10 of 20 (50%) horses and revealed neutrophilic pleocytosis (n = 4 horses), albuminocytologic dissociation (3), lymphocytic pleocytosis (1), and a combination of abnormalities (2). Eleven of 22 (50%) horses with abnormal mentation had abnormal CT findings, which included suspected cholesterol granulomas, a forebrain mass, hydrocephalus, cerebral edema, skull fractures, and temporohyoid osteoarthropathy. Cholesterol granulomas had differing CT densities that varied from hyperdense to hypodense, compared with the density of brain tissue. Hydrocephalus was recognized in 3 horses, with a suspected obstructive origin in 2 horses (oligodendroglioma and cholesterol granuloma were found during postmortem examination). In contrast, mentation at the time of admission was normal in 2 horses in which use of CT revealed cholesterol granulomas.

Four horses were referred because of acute onset of tetraparesis and tetra-ataxia, with normal mentation and unremarkable results for a cranial nerve examination at the time of admission. Computed tomography of the head was performed to rule out skull fractures or intracranial lesions when trauma was suspected, when the horse had a rapid progression of neurologic signs and became recumbent, or when the horse developed abnormal mentation or seizure-like activity. All brain CT images were interpreted as normal. Moderate to severe gait deficits were detected in 10 other horses during neurologic examinations, including all of the horses admitted because of partial seizures or secondary generalized seizures of acute onset, and 6 of these 10 had abnormal CT findings.

Comparison of precontrast and postcontrast images with abnormal CT findings—A total of 57 CT scans of the head were performed, 13 of which revealed abnormal findings. Abnormal findings detected on precontrast images included asymmetry of the lateral ventricles, hydrocephalus, effect of a mass in the cerebrum (shift of the midline, distortion of the lateral ventricles, and bone lysis), focal hyperdense structures, temporohyoid osteoarthropathy, skull fractures, and fluid-filled densities in the internal and middle ear. Contrast medium was injected IV in 12 of 13 horses with abnormal results for CT. Postcontrast enhancement of vascular and nonvascular structures within the brain was recorded in 6 of the 12 horses. In 2 of these horses, abnormal findings (which included meningeal congestion [interpreted as meningoencephalitis] and enhancement of the pituitary gland region) were detected only after injection of iodinated contrast medium. The horse with contrast enhancement of the pituitary gland region had a history of narcolepsy, and a suspected cholesterol granuloma was detected during CT examination; dysfunction of the pituitary pars intermedia was confirmed by further testing after completion of the CT examina-

tion. In 5 postcontrast examinations, there was minimal to mild enhancement of the area of interest identified during the precontrast examinations. Postcontrast CT findings included neoplastic masses (adenocarcinoma and oligodendroglioma; **Figure 2**), suspected cholesterol granulomas, and soft tissue uptake (compatible with focal meningitis) adjacent to temporohyoid osteomyelitis. Pooling of contrast medium in vertebral sinuses, choroidal plexuses, and soft tissues on the same side of the jugular injection site was interpreted as an incidental finding. Mild asymmetry of the lateral ventricles was interpreted as an anatomic variation.

Factors associated with abnormal CT findings—On the basis of results of χ^2 tests and the univariate logistic analysis, no association was detected between age, breed, sex, and CT results (**Table 1**). All 13 horses with abnormal results for CT of the head had neurologic deficits (12 horses had abnormal results for a neurologic examination performed at the time of admission, and 1 horse had a history of narcolepsy-like episodes as determined by evaluation of video recordings). In the univariate logistic model, neurologic deficits that were strong indicators of abnormal CT findings included abnormal mentation ($P = 0.001$), cranial nerve deficits ($P = 0.001$), abnormal menace response ($P = 0.027$), and moderate to severe gait deficits ($P = 0.047$). Furthermore, horses admitted because of a history of head trauma were more likely to have abnormal results for CT, compared with the likelihood for horses without this primary problem (OR = 12.9; 95% CI, 1.21 to 137.37; $P = 0.034$). Posttraumatic loss of consciousness was a perfect predictor of abnormal results of CT because all 3 horses that had this clinical sign also had abnormal CT findings. Consequently, this variable was not included in the final logistic regression model. In contrast, the detection and frequency of seizures, irrespective of their types, were significantly ($P \leq 0.003$) lower in horses with abnormal CT findings, compared with the detection and frequency of seizures in horses with normal CT findings. Furthermore, all horses admitted because of abnormal behavior had normal CT findings. An abnormal result of CSF analysis was significantly ($P = 0.009$) more prevalent in horses with abnormal CT findings, compared with that for horses with normal CT findings (7 horses had both abnormal results for CSF analysis and abnormal CT findings).

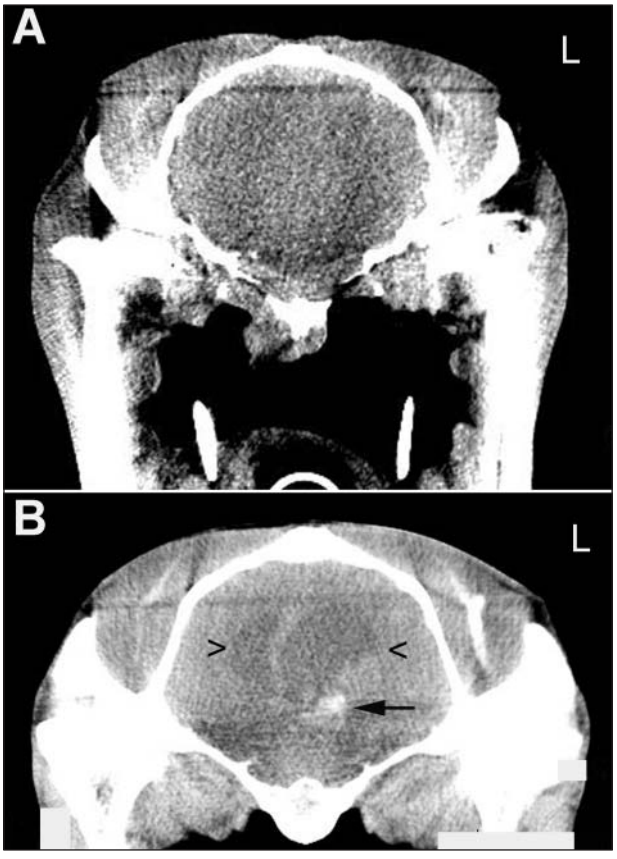

Figure 2—Transverse CT images, after IV injection of iodinated contrast medium, at the level of the stylohyoid bones and vertical portion of the mandibular rami in a horse with normal brain structure (A) and a horse that had abnormal mentation attributable to an intracranial mass (B). The image in panel A was obtained by use of a soft tissue window (window width, 150; window level, 40), and the image in panel B was obtained at approximately the same plan section by use of a soft tissue window (window width, 250; window level, 25). In panel B, notice the irregular hyperattenuating focus (suspected dystrophic mineralization or focal hemorrhage [arrow]) associated with the suspected mass lesion originating from the ventral portion of the left temporal lobe. Margins of the mass are not clearly defined, and there is minimal contrast enhancement. A diagnosis of oligodendroglioma was made during postmortem examination. Other abnormalities resulting from the large intracranial mass included distortion and dilatation of both ventricles (more pronounced in the left side [arrowheads]) and a severe shift of the falx cerebri to the right and lateral deviation of the right ventricle. *See* Figure 1 for remainder of key.

Overall, the initial evaluation identified 11 variables significantly associated with abnormal results of CT of the head, and 8 of the variables (duration of clinical signs, head trauma, detection of seizures, abnormal mentation, cranial nerve deficits, abnormal menace response, gait deficits, and abnormal results of CSF analysis) satisfied the criteria for inclusion in the final multivariate logistic regression model (**Table 2**). When adjusted for the effects of confounding factors in the multivariate logistic regression model, 4 variables were significantly associated with abnormal CT findings. Horses with a duration of clinical signs < 10 days were more likely to have abnormal CT findings (OR = 44; 95% CI, 1.32 to 1,445.00; $P = 0.034$), compared with the odds for horses with chronic clinical signs. For a horse with abnormal mentation, the odds of having abnormal results for CT of the head was 30 times (95% CI, 2.36 to 374.63; $P = 0.009$) the odds for a similar horse without abnormal mentation. For horses with cranial nerve deficits, the odds of having abnormal results for CT of the head were 11 times (95% CI, 1.00 to 127.96; $P = 0.050$) the odds for similar horses without cranial nerve deficits. Seizure-like activity was negatively associated with abnormalities detected on CT. For horses with seizure-like activity, the odds of having abnormal CT findings were 0.05 times (OR = 0.05; 95% CI, 0 to 0.90; $P = 0.042$) the odds for similar horses without seizure-like activity. Although not significant, horses with a history of head trauma were 87 times (95% CI, 0.95 to 7,916.28; $P = 0.053$) as likely to have abnormal CT findings, compared with the odds for similar horses without head trauma. Finally, abnormal results of CSF analysis, abnormal menace response, and gait deficits were not significantly associated with abnormal results of CT of the head.

Table 1—Results of univariate analysis of predictive factors for abnormal results of CT in 57 horses with neurologic deficits.

Variable	Category	No. of horses with abnormal CT results	No. of horses with normal CT results	OR	95% CI	*P* value*
Sex	Sexually intact male	2	10	1.00	Referent	NA
	Gelding	6	21	1.43	0.24–8.37	0.693
	Female	5	13	1.92	0.31–12.05	0.485
Breed	Quarter Horse†	7	12	1.00	Referent	NA
	Thoroughbred	3	13	0.40	0.08–1.89	0.245
	Arabian and Standardbred	1	10	0.17	0.02–1.64	0.126
	Other	2	9	0.38	0.06–2.29	0.292
Age (y)	< 1	1	4	1.00	Referent	NA
	1–4	4	6	2.67	0.21–33.50	0.447
	5–15	6	19	1.26	0.12–13.59	0.847
	> 15	2	15	0.53	0.04–7.49	0.641
Duration of clinical signs (d)	≤ 10	9	15	1.00	Referent	NA
	> 10	4	29	0.23	0.06–0.87	0.31
Head trauma	No	10	43	1.00	Referent	NA
	Yes	3	1	12.9	1.21–137.37	0.034
Seizure-like activity	No	8	5	1.00	Referent	NA
	Yes	5	39	0.08	0.02–0.34	0.001
Frequency of seizures	0–2	11	14	1.00	Referent	NA
	> 2	2	30	0.08	0.17–0.44	0.003
Mentation	Normal	2	33	1.00	Referent	NA
	Abnormal	11	11	16.50	3.16–86.25	0.001
Cranial nerves	Normal	6	41	1.00	Referent	NA
	Abnormal	7	3	15.94	3.21–79.905	0.001
Menace response‡	Normal	8	40	1.00	Referent	NA
	Abnormal	4	3	6.67	1.24–35.71	0.027
Gait	Normal	7	36	1.00	Referent	NA
	Abnormal	6	8	3.86	1.02–14.62	0.047
Results of CSF analysis‡	Normal	4	35	1.00	Referent	NA
	Abnormal	7	9	6.81	1.63–28.45	0.009

*Values were considered significant at $P \leq 0.05$. †Includes Quarter Horses and Quarter Horse–crossbred horses. ‡Data were obtained for only 55 horses.
NA = Not applicable

Table 2—Results of multivariate analysis of predictive factors for abnormal results of CT of the head in 53 horses with neurologic deficits.

Predictive factor	Z	OR	95% CI	*P* value*
Duration of clinical signs	2.11	43.64	1.32–1,445.00	0.034
Head trauma	1.94	86.84	0.95–7,916.28	0.053
Seizures	–2.03	0.05	0–0.90	0.042
Abnormal mentation	2.62	29.74	2.36–374.63	0.009
Cranial nerve deficits	1.96	11.31	1.00–127.96	0.050
Abnormal menace response	1.23	6.57	0.33–130.86	0.218
Gait deficits	0.27	1.55	0.06–38.02	0.788
Results of CSF analysis	1.86	11.58	0.88–152.01	0.062

See Table 1 for key.

Discussion

Computed tomography is commonly used to obtain images of the skull and brain in horses with a wide array of neurologic conditions. The main objective of the study reported here was to define the neurologic indications for which CT of the head in horses would be most warranted. Identification of predictive factors for abnormal CT findings of the head in affected horses could provide valuable information for practitioners, especially because cost and the need for anesthesia could limit its use in some circumstances.

The majority (44/57 [77%]) of horses in which CT of the head was performed had seizure-like activity. Most common in this study were simple or complex partial seizures (13/44 [30%]) or secondary generalized seizures (13/44 [30%]). Primary generalized seizures (4/44 [9%]) were less common than partial seizures and secondary generalized seizures. In this study, seizures (regardless of type, except for posttraumatic seizures) were negatively associated with abnormal CT results. Furthermore, 10 of 14 horses with seizure-like activity had abnormal results for an EEG. Remarkably, all of these horses with seizure-like activity and abnormal EEG results had normal CT results. Furthermore,

although focal lesions were determined in 8 of the 10 horses with abnormal EEG results, use of CT was not able to identify any focal lesion in these horses. Although no postmortem examination was available for these horses, these data strongly suggest that EEG appears to be a more sensitive method than CT to confirm seizure activity.[18] Although abnormal mentation was, overall, positively correlated with abnormal results of CT, depressed mentation in horses with acute partial or primary generalized seizures was not associated with CT findings in the brain of horses in our study. Seizures were significantly negatively associated with intracranial lesions detectable by use of CT. This result is consistent with reports in humans,[19,20] for whom EEG and MRI have mainly replaced the use of CT for the diagnosis of generalized and partial seizures. However, analysis of our data suggests that CT is still a valuable diagnostic tool in horses with seizures secondary to head trauma and is warranted to rule out structural cerebral lesions as an etiologic diagnosis, especially when associated with other neurologic signs such as cranial nerve deficits. Similarly, in human patients affected by seizures, CT is mainly used to exclude head trauma and skull fractures[21] and is considered appropriate when focal forebrain or brainstem lesions are suspected, although MRI is preferred in such instances.[19]

In contrast to results for horses with seizure-like activity, CT of the head appeared useful to detect skull and intracranial lesions in horses with abnormal mentation or cranial nerve deficits because these variables were strong positive predictors of abnormal CT findings in our referral population. Overall, CT aided in detection of skull or intracranial lesions in 11 of 22 horses with abnormal mentation. In particular, use of CT identified forebrain (cerebrum and diencephalon) lesions in 5 of 6 horses with a primary problem of abnormal mentation. In contrast, 2 of 3 horses with suspected cholesterol granulomas on the basis of CT findings had an owner history and video recordings of abnormal mentation but normal mentation at the time of admission. This finding is consistent with results of another report.[22] Indeed, it is believed that cholesterol granulomas, which are more commonly found in the lateral ventricles, generally do not cause clinical signs until they become large enough to obstruct CSF flow[23]; however, in the study reported here, one of the horses with normal mentation at the time of admission had evidence of hydrocephalus on the basis of CT findings. Among 10 horses with cranial nerve deficits, lesions were detected by use of CT in 7; findings included temporohyoid osteoarthropathy, skull fractures, space-occupying masses, and suspected acute vascular events in the brainstem.

Four of 5 horses with vestibular signs had central vestibular disease, and use of CT revealed abnormal findings in 3 of these 4 horses. In particular, horses with central vestibular signs associated with alterations in consciousness should undergo CT to rule out temporal skull fractures that may remain undetected during conventional radiography of the skull (because of potential superimpositions of bony structures) or during endoscopic examination of the guttural pouches. This is particularly germane to horses with vestibular signs without evidence of temporohyoid osteoarthropathy because in the study reported here, all horses with temporohyoid osteoarthropathy recognized by use of CT had also been identified by use of endoscopic examination of the guttural pouches, as reported elsewhere.[24] Furthermore, inflammation detected during CSF analysis (eg, neutrophilic pleocytosis) was supportive of skull fractures or brainstem lesions in horses with vestibular signs.

Finally, we detected a significant ($P = 0.034$) positive correlation between head trauma and abnormal CT findings in the univariate analysis; however, this correlation was not significant ($P = 0.053$) in the multivariate model. This result may have been related to a lower statistical power because only 53 horses could be included in the final model. Thus, consistent with results for other species, CT should be considered as a useful diagnostic technique to evaluate the location, extent, and number of skull fractures in horses with suspected head trauma.[2,5]

Despite the superior diagnostic capabilities of CT for bony structures, this technique has several limitations. In this study, brain parenchyma or meningeal inflammation (such as parasitic infection by *S neurona* or *Halicephalobus gingivalis*) could not be identified during CT, and brain abscesses, neoplasms, and infarcted areas could not be distinguished from each other. In such cases, age, progression of clinical signs, and interpretation of results of CSF analysis may be helpful in determining the primary differential diagnosis. Our study also revealed the diagnostic limitations of CT, which were mainly related to its low sensitivity to detect brain lesions in horses with seizure-like activity and to the potential of false-positive findings. For instance, we reported overinterpretation of CT findings in 1 horse for which meningeal congestion was misinterpreted as a sign of meningoencephalitis. Overall, CT findings seldom offer a definitive etiologic diagnosis and should be interpreted with caution.[25] Other potential overinterpretations include the difference in uptake of contrast medium in venous sinuses and choroidal plexuses and asymmetry of the lateral ventricles. In our study, these findings were interpreted as incidental, and the asymmetry of lateral ventricles was considered a normal anatomic variation, similar to the results in humans[26] and dogs[27]; however, to our knowledge, no data on asymmetry of the lateral ventricles in horses are available.

Finally, although IV infusion of iodinated contrast medium could be used to identify breakdown of the blood-brain barrier associated with brain lesions, the use of contrast medium administered at the dosage described did not aid in identifying cerebral lesions in most of the horses. Many factors influence uptake of iodinated contrast medium, which may have limited our ability to detect lesions on postcontrast images. For example, variables such as heart rate and blood pressure during anesthesia as well as recumbency affect the distribution of contrast medium.[28,29] In addition, variables for the contrast medium, such as volume per body weight, iodine dosage, osmolarity, viscosity, and rate of injection, also influence contrast enhancement.[28] These factors may have limited the availability and distribution of the iodinated contrast medium administered to the horses and therefore may have potentially compro-

mised the interpretation of our postcontrast images. In particular, it should be mentioned that the dose of iodinated contrast medium per kilogram of body weight varied slightly among the clinicians (approx 300 mL for a typical adult horse) because a standard dose has not yet been established in equine medicine.

In the study reported here, we identified neurologic indications that warrant use of CT of the head of affected horses. These predictive factors included cranial nerve deficits and altered consciousness, whereas seizure-like activity was negatively associated with abnormal CT findings of the head in horses. Thus, CT can be a useful diagnostic test in horses with abnormal mentation and cranial nerve deficits and in horses with a history of head trauma followed by a loss of consciousness. Furthermore, use of CT aided in identification of lesions in most of the horses with central vestibular disease and may also be useful in detecting skull fractures that are not visible on plain radiographs. In contrast, analysis of our data suggested that CT of the equine head was not a useful diagnostic tool in horses with a primary problem of seizure-like activity and that do not have a history of head trauma or cranial nerve deficits. Alternative diagnostic tests (ie, EEG and MRI) should be considered in those horses.

a. Rompun, Miles, Shawnee, Kan.
b. Guailaxin, A-H Robins, Richmond, Va.
c. Pentothal, Abott/Ceva Laboratories, North Chicago, Ill.
d. Aerrane, Anaquest Inc, Liberty Corner, NJ.
e. Bio-Tal, Bio-Ceutic, St Joseph, Mo.
f. Picker PQS, Philips Medical Systems, Bothell, Wash.
g. Omnipaque, Nycomed Amersham, Princeton, NJ.
h. Stata, StataCorp LP, College Station, Tex.

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