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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.

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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

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,