Journal of Veterinary Internal Medicine
Open Access

J Vet Intern Med 2015;29:893–899

Effect of Screening Abdominal Ultrasound Examination on the Decision to Pursue Advanced Diagnostic Tests and Treatment in Dogs with Neurologic Disease

N.M. Tong, A.L. Zwingenberger, W.H. Blair, S.L. Taylor, R.X. Chen, and B.K. Sturges

Background: Abdominal ultrasound examinations (AUS) are commonly performed before advanced neurodiagnostics to screen for diseases that might affect diagnostic plans and prognosis.

Objectives: Describe the type and frequency of abnormalities found by AUS in dogs presenting with a neurological condition, identify risk factors associated with abnormalities, and evaluate treatment decisions based on findings.

Animals: Seven hundred and fifty-nine hospitalized dogs.

Methods: Retrospective study. Medical records of dogs presented from 2007 to 2009 for neurologic disease were searched for signalment, neuroanatomic localization, and AUS findings. Whether dogs had advanced neurodiagnostics and treatment was analyzed.

Results: Fifty-eight percent of dogs had abnormal findings on AUS. Probability of abnormalities increased with age ($P < 0.001$). Nondachshund breeds had higher probability of abnormal AUS than dachshunds (odds ratio [OR] = 1.87). Eleven percent of dogs did not have advanced neurodiagnostics and in 1.3%, this was because of abnormal AUS. Dogs with ultrasonographic abnormalities were less likely than dogs without to have advanced neurodiagnostics (OR = 0.3 [95% confidence interval [CI]: 0.17, 0.52]), however, the probability of performing advanced diagnostics was high regardless of normal (OR = 0.95 [95% CI: 0.92, 0.97]) or abnormal (OR = 0.85 [95% CI: 0.81, 0.88]) AUS. Treatment was more often pursued in small dogs and less often in dogs with brain disease.

Conclusions and Clinical Importance: Findings from screening AUS had a small negative effect on the likelihood of pursuing advanced neurodiagnostics. Although it should be included in the extracranial diagnostic workup in dogs with significant history or physical examination abnormalities, AUS is considered a low-yield diagnostic test in young dogs and dachshunds.

Key words: Ultrasonography; Magnetic resonance imaging; Computed tomography; Myelogram.

Before imaging the brain or spinal cord in dogs, complete blood count, serum biochemistry panel, urinalysis, thoracic radiographs, and abdominal ultrasound examinations (AUS) are often performed to rule out causes of neurologic disease originating from outside the central nervous system and to screen for conditions that might affect the decision to pursue diagnosis and treatment as well as the outcome of treatment. Supposedly, fewer abnormalities are identified on AUS in younger dogs presenting with neurologic disease in comparison to geriatric neurologic dogs which more often have comorbid disease conditions. However, these apparent relationships have not been quantitatively assessed. Compared with the large body of literature from human medicine exploring the role of preoperative testing,[1–12] there are few veterinary studies[13–18] evaluating the value of screening tests as a tool. To the authors' knowledge, there are no studies that evaluate the role of an AUS in dogs with neurologic disease.

The core purpose of screening tests is to identify clinically important conditions that could benefit the dog by early detection, but for which a physical abnormality is not necessarily expected based on clinical examination.[10,19] The primary flaws of screening are overdiagnosis, false positive results, incidental findings, and increased costs that do not lead to medical benefit.[1] These troublesome outcomes cause anxiety, increase exposure to risks associated with follow-up procedures,

Abbreviations:

AUS	abdominal ultrasound examination
CT	computed tomography
MRI	magnetic resonance imaging
CSF	cerebrospinal fluid
C1-C5	neuroanatomic localization from first cervical to fifth cervical segment
C6-T2	neuroanatomic localization from sixth cervical to second thoracic segment
T3-L3	neuroanatomic localization from third thoracic to third lumbar segment
L4-caudal	neuroanatomic localization from fourth lumbar segment to the caudal segments
CI	confidence interval
OR	odds ratio
Kg	kilogram

From the William R. Pritchard Veterinary Medical Teaching Hospital, (Tong, Blair); the Department of Surgical and Radiological Sciences, University of California School of Veterinary Medicine, Davis, CA (Zwingenberger, Sturges); and the Clinical and Translational Science Center, School of Medicine, University of California, Sacramento, CA (Taylor, Chen).

This project was completed at the William R. Pritchard Veterinary Medical Teaching Hospital, University of California School of Veterinary Medicine, Davis, CA.

Corresponding author: Allison Zwingenberger, 1 Shields Drive, 2112 Tupper Hall, Davis, CA 95616; e-mail: azwingen@ucdavis.edu.

Submitted December 9, 2014; Revised February 3, 2015; Accepted March 24, 2015.

DOI: 10.1111/jvim.12602

and could affect the decision to proceed with further diagnostics and treatment to address the primary condition.[2,4,5,7–9,18–20]

When faced with the high cost of neurodiagnostics and surgery, owners and clinicians alike might find themselves questioning the risk-to-benefit ratio of performing an AUS and the implications of significant abnormalities being found. The objectives of this study are to: (1) describe the type and frequency of abnormalities found by AUS in dogs presenting with a neurological condition, (2) quantitate the odds of an abnormality being discovered on an AUS based on age, breed, and neuroanatomic localization of the lesion, (3) evaluate diagnostic and treatment decisions in light of the ultrasound findings and other covariates.

The hypothesis of the study was that in certain subpopulations of dogs presenting with neurological disease, including young chondrodystrophic dogs, the AUS is not likely to identify an abnormality that would prevent the client from going forward with advanced neurodiagnostics, and surgical treatment for their dog.

Materials and Methods

Medical records of dogs presented to the Neurology/Neurosurgery Service at the UC Davis William R. Pritchard Veterinary Medical Teaching Hospital for a neurologic condition between the years 2007 and 2009 were reviewed. This included internal and external referrals. Dogs that had an AUS as part of medical screening before planned advanced neurodiagnostics including vertebral column radiographs, myelogram, computed tomography (CT), magnetic resonance imaging (MRI) and cerebrospinal fluid (CSF) analysis were included. The medical screening tests included complete blood count, serum biochemistries, urinalysis, and thoracic radiographs. For dogs with multiple visits, only the first visit was included in order meet independence assumptions for the statistical analyses.

Signalment data included age, weight, sex, and breed. Individual breeds were recorded and classified as dachshund or nondachshund as well as chondrodystrophic or nonchondrodystrophic. To the authors' knowledge, there is no comprehensive list of chondrodystrophic breeds, so the existing literature was evaluated for breeds that have been identified as chondrodystrophic or included in studies of chondrodystrophic dog breeds,[21–30] resulting in the following list: dachshund (miniature, standard, long hair, wire hair), Pekingese, West Highland white terrier, corgi, Japanese chin, bassett hound, shih tzu, Lhasa apso, bichon frise, beagle, pug, Boston terrier, Cavalier King Charles spaniel, French bulldog, English bulldog, miniature schnauzer, Tibetan spaniel, Jack Russell terrier, miniature poodle, Yorkshire terrier, border terrier, coton du tulear.

For all cases included in the study, the neurological examinations had been performed by faculty-supervised neurology residents and board certified neurologists. The neuroanatomic localizations based on the neurological examinations that were noted in the medical record were recorded. The categories were brain, neuroanatomic localization from first cervical to fifth cervical segment (C1-C5), neuroanatomic localization from sixth cervical to second thoracic segment (C6-T2), neuroanatomic localization from third thoracic to third lumbar segment (T3-L3), and neuroanatomic localization from fourth lumbar segment to the caudal segments (L4-caudal). All AUS had been performed and reports written by faculty-supervised radiology residents and board certified radiologists. The reports were reviewed retrospectively and if an abnormality was identified in the report, the abnormal organ system was recorded (liver, spleen, urinary, gastrointestinal, adrenal, lymph nodes, pancreas, reproductive), and categorized according to one of the following descriptors: nodule/mass, degenerative change, inflammation, enlargement, reduction in size, mineralization, hypoechoic, hyperechoic, or other. In those dogs that had a nodule or mass identified, the maximum dimension based on ultrasound images was recorded. If cytology or histopathology had been performed on the ultrasonographically abnormal organ, the results were recorded as well. Dogs were then categorized according to which, if any, advanced diagnostics were performed (vertebral column study, myelogram, CT, MRI, CSF analysis). The decision to treat medically or surgically, to not treat, or to euthanize was recorded. For those that were not treated, the primary reason was noted and assigned to one of the following categories: declined by owner, improved with conservative management, abnormal AUS findings, other disease, or increased anesthetic risk preventing safe performance of the neurological disease workup, unknown, died, or other. Clients who failed to follow up on recommendations for advanced neurodiagnostics or did not show for scheduled procedures were included in the "declined by owner" category.

Logistic regression analysis was used to identify significant predictors of the probability of a dog having an abnormal ultrasound result. The effects of demographic predictors consisting of age, weight, sex, and breed type were considered first. Then the relationship between the probability of an abnormal ultrasound and the neuroanatomic localization of the lesion was evaluated. Age groups were 0–6 years, >6–12 years, and >12 years. Weight groups were 0–10 kg, >10–25 kg, and >25 kg. As noted previously, breed type was classified into chondrodystrophic or nonchondrodystrophic breeds, and dachshund or nondachshund breeds.

For significant main effects, Tukey's Honestly Significant Differences method was used to identify significant group differences while maintaining the family-wise type I error at 0.05. A Chi-square test was used to determine whether conducting advanced neurologic diagnostics was associated with the presence of an abnormal ultrasound. Logistic regression also was used to model the probability that a neurologic disorder was treated as a function of age group, occurrence of an abnormal ultrasound, and the location of the neurologic disorder.

Results

Seven hundred and fifty-nine dogs met inclusion criteria, consisting of 324 (42.7%) females and 435 (57.3%) males. Three hundred and eighteen (41.9%) dogs were classified as chondrodystrophic breeds and 441 (58.1%) as nonchondrodystrophic breeds. Recategorizing the same 759 dogs, there were 139 (18.3%) dachshunds and 620 (81.6%) nondachshund breeds. Dachshund breeds, therefore, comprised 43.7% (139/318) of the total chondrodystrophic population. Age was recorded for 754 dogs (99.3%) ranging from 0.27 to 17 years old. Weight was recorded for 665 animals (87.6%), ranging from 0.66 to 90.4 kg. Of the 759 dogs studied, 444 (58.5%) had abnormal ultrasound examinations and 315 (41.5%) had normal examinations. Most dogs (675, 88.9%) underwent advanced neurodiagnostic procedures.

The probability of abnormal AUS examination findings increased with age ($P < 0.0001$). The mean probability of detecting an ultrasonographic abnormality for the 0–6 year old age group was 0.42 (95% confidence interval [CI] 0.36–0.49). For the >6–12 year old age group the mean probability was 0.65 (95% CI

0.60–0.70), and for the >12–17 year old age group it was 0.93 (95% CI 0.84–0.97). Other demographic variables evaluated (sex, weight, chondrodystrophic versus nonchondrodystrophic breed) were not significant, with the exception that dogs weighing between 10–25 kg had a higher probability of an abnormal AUS finding than dogs weighing <10 kg ($P = 0.04$) (Table 1).

We then considered the effect of the location of the neurologic lesion on the probability of a dog having an abnormal AUS with inclusion of age and weight as covariates. Age remained significant in this modeling ($P < 0.001$), but weight and neuroanatomic localization of disease were not significant predictors of the probability of a dog having an abnormal AUS finding.

Logistic regression was used to evaluate the probability of an abnormal AUS for dachshunds versus other breeds. Fifty-nine of 139 dachshunds (42.4%) and 385/620 nondachshunds (62.1%) had an abnormality identified on AUS. Age and dachshund versus nondachshund breed status were significant predictors of whether a dog had an abnormal AUS ($P < 0.001$ and $P = 0.012$, respectively). Among dachshunds, all age groups differed significantly from each other, showing again by virtue of increasing odds ratios (OR) with age, that the probability of an abnormal AUS examination increased with age (Table 1). Nondachshunds had higher probability of having an abnormal AUS than dachshunds ($P = 0.01$, OR = 1.87) after accounting for age as a factor.

In the 444 dogs with an abnormal AUS, 1,184 ultrasound abnormalities were identified; the abnormal organ system involved and the abnormal ultrasound characteristic were tabulated (Table 2). In total, 844 organ systems were affected: the urinary tract (220), liver (186), spleen (153), adrenal glands (81), reproductive system (60), other (48), lymph node (37), pancreas (30), and gastrointestinal tract (29). In these affected organ systems, 1,184 abnormalities were identified: enlargement (312), other (249), nodule/mass (175), hyperechoic (157), hypoechoic (107), degenerative change (74), mineralized (69), reduction in size (29), inflammation (12). The five most common combinations of organ and abnormality were urinary + other (126), liver + enlargement (110), spleen + nodule (78), liver + hyperechoic (64), spleen + enlargement (62).

Table 1. Pairwise comparisons from logistic regressions of the likelihood of ultrasound abnormalities between age groups and between weight groups with Tukey–Kramer Adjustment (Adj *P*).

	Group 1	Group 2	Adj *P*	OR
Age groups (years)	(12, 17)	(6, 12]	<0.001*	6.9
	(12, 17]	[0, 6]	<0.001*	17.8
	(6, 12]	[0, 6]	<0.001*	2.6
Weight groups (kg)	(10, 25]	(25, 81]	0.734	1.2
	(10, 25]	[0, 10]	0.0311*	1.8
	(25, 81]	[0, 10]	0.285	1.5
Age groups (years), dachshunds only	(12, 17)	(6, 12]	<0.001*	6.5
	(12, 17]	[0, 6]	<0.001*	16.3
	(6, 12]	[0, 6]	<0.001*	2.5

Adj *P*, adjusted *P*-value. OR, odds ratio.

Odds of an ultrasound abnormality were higher in the older age groups. Dogs were divided into the following age groups: 0–6 years old, >6–12 years old, >12–17 years old. The weight groups were 0–10 kg, >10–25 kg, >25–81 kg.

Asterisks denote significant difference between groups.

Table 2. Screening ultrasonographic abnormalities among all dogs.

	E	HO	HR	M	N	OT	R
A	54	1	2	0	24	1	9
G	1	2	3	0	1	23	0
L	110	29	64	1	37	39	13
LN	32	10	0	0	0	3	1
OT	1	4	7	0	14	28	0
P	13	6	11	0	4	7	0
R	37	3	15	10	6	20	0
S	62	51	23	0	78	14	0
U	2	1	32	58	11	200	6

Ultrasound abnormalities (rows): E, enlargement; HO, hypoechoic; HR, hyperechoic; M, mineralization; N, nodule/mass; OT, other; R, reduction in size, NA, not available. Organ systems (columns): A, adrenal gland; G, gastrointestinal; L, liver, LN, lymph node; P, pancreas; R, reproductive; S, spleen; U, urinary.

The decision to pursue advanced neurodiagnostics was significantly associated with an abnormal AUS finding ($P < 0.001$). The OR of conducting advanced testing for dogs with an abnormal ultrasound versus those with a normal ultrasound was 0.30 (95% CI: 0.17, 0.52), indicating that the presence of abnormalities reduced the likelihood of conducting advanced testing. However, the probability of a dog undergoing advanced testing was high regardless of whether the ultrasound revealed an abnormality. The estimated probability of advanced testing being conducted for dogs with abnormal AUS was 0.85 (95% CI: 0.81 and 0.88) versus 0.95 (95% CI: 0.92 and 0.97) for dogs with normal results. The type of abnormality did not significantly influence whether advanced neurologic testing was performed.

The most common reason among the 85 dogs that did not have advanced diagnostics performed was "Declined by owner" (29/85 = 34%). "Improvement with conservative management" was the second most common reason (20/85 = 23%), followed by "Other disease conditions or anesthetic risks" (17/85 = 20%). The findings from an abnormal AUS examination were the primary reason for not pursuing further neurodiagnostics in 10/85 (11%) dogs, constituting 1.3% of the total study population. In the subpopulation of dogs that did not have advanced diagnostics because of the abnormal findings from AUS, the most significant ultrasonographically abnormal organ systems affected were: liver (3), spleen (3), lymph node (1), reproductive tract (1), adrenal glands (2). The histopathologic, cytologic, or presumptive diagnoses were identified from the medical records. Of these dogs with the most significant abnormality identified in the liver, two had an enlarged liver with nodules—the first was diagnosed with hepatocellular carcinoma (based on histopathology) and the second

had a suppurative hepatitis (based on cytology). The third dog with liver changes had nodules that were diagnosed as lymphoma (histopathology). Splenic nodules were present in two of the dogs that did not have advanced diagnostics. One had histiocytic sarcoma (cytologic and histopathologic diagnosis), and two had presumptive hemangiosarcoma (hemoabdomen with splenic and hepatic nodules identified in one dog, previous history of histopathologically diagnosed vertebral hemangiosarcoma in the second dog). One dog with enlarged lymph nodes had a cytologic diagnosis of histiocytic sarcoma. One dog with prostatic enlargement, nodules and mineralization had a cytologic diagnosis of prostatic transitional cell carcinoma followed by histopathologic confirmation. Two dogs had an adrenal nodule/mass that had no histopathologic or cytologic diagnosis, but were presumed malignancies because of vascular invasion.

Factors influencing decisions to treat a neurological disease were investigated. Neither age nor abnormal AUS findings were significant predictors of the decision of whether to treat a neurological disease. However, weight was a significant predictor of not treating a disease ($P = 0.015$–0.035, depending on the lesion localization). Compared with small dogs (under 10 kg), larger dogs had a lower probability of being treated (OR = 0.37–0.42, $P = 0.01$–0.05; variation based on neuroanatomic localization). In addition, the neuroanatomic location of disease, either in the brain or the C6-T2 spinal cord segment was associated with the probability of treating the dog. The estimated probability of treating a C6-T2 localization was higher (0.93 [95% CI: 0.84 and 0.97]) than for other spinal cord localizations collectively (0.81 [95% CI: 0.71 and 0.89]). The estimated probability of treating a dog with neurological disease localizing to the brain was lower (0.54 [95% CI: 0.27 and 0.78]) than for all other neuroanatomic localizations collectively (0.85 [95% CI: 0.75 and 0.91]).

Discussion

The majority of dogs in the study population had an abnormality identified on AUS and these dogs were less likely to go on to advanced neurodiagnostics than those with normal AUS. However, overall, the probability of moving forward with advanced neurodiagnostics was high regardless of a normal or abnormal AUS. As hypothesized, young dogs and dachshunds were less likely to have an abnormal AUS; surprisingly, chondrodystrophic breeds as a group were not. The percentage of dogs that did not move on to advanced neurodiagnostics primarily because of AUS findings was quite small, suggesting a limited effect of the abnormal findings on the decisions to proceed with advanced diagnostics and treatment.

The AUS for neurological dogs serves a dual role of identifying an intra-abdominal cause of the neurological disease and to screen for the presence of concurrent, undiagnosed disease. Our study's finding that older dogs have a higher likelihood of AUS abnormalities parallels the findings of several prospective human and veterinary studies[15,16,20,31,32] and, when applied to older dogs, adds strength to the recommendation that AUS should be performed to look for extracranial neoplasia before advanced imaging of the brain or intracranial surgery.[33] The costs and risks associated with AUS in these dogs can be justified since it is sensitive for detection of intra-abdominal abnormalities, but because the ultrasonographic changes are rarely specific for disease etiology, biologic sampling is required for diagnosis.

Young dogs and dachshunds presenting with neurologic disease are less likely to have an abnormal AUS compared with others. This suggests relatively lower intra-abdominal disease prevalence in these two groups. When disease prevalence is low, there is higher likelihood of false positive results. If the incidental abnormal AUS findings in these dogs are more likely to be false positives or of low clinical significance, the risks associated with follow-up testing for these types of findings—complications from invasive procedures (biopsy, surgery, endoscopy), increased stress to the owner and dog and increased costs that do not lead to medical benefit—might not be worth assuming. As such, a routine screening AUS could be considered a less critical component of the extracranial workup for a young dog or dachshund presenting for neurologic signs. At the very least, owners of these dogs should be advised beforehand that the abdominal ultrasound exam is likely to be low yield and could identify incidental abnormalities.

Although dachshunds as a group and chondrodystrophics as a group share an increased risk of intervertebral disk herniation at a young age,[28,29] our study demonstrated they do not share a decreased risk of having abnormal AUS findings. Early investigations into the tendency of some breeds to intervertebral disk disease identified only the dachshund, Pekinese, and French bulldogs as a "chondrodystrophoid breed group."[34] Furthermore, the correlation between chondrodystrophy and intervertebral disk disease has not been established for all breeds.[29] The list of breeds categorized as chondrodystrophic for this study was collated from lists from many publications that spanned several decades, since universal agreement on this is lacking. Perhaps inclusion of so many breeds in the chondrodystrophic group negated the protective effect of the dachshunds.

Although the likelihood of a dog with an abnormal AUS proceeding to advanced neurodiagnostics was lower than a dog with a normal AUS, the overall likelihood that a dog with an abnormal AUS had advanced neurodiagnostics was still quite high. This is most likely because of the tertiary referral institution population studied. Clients presenting to our referral institution are more willing to proceed with advanced neurodiagnostics despite an abnormal AUS finding, which could bias our study population and results. Whether a willingness to proceed with advanced diagnostics and treatment would hold true in a nontertiary referral practice remains to be determined.

In a study of 53 mature, healthy golden retrievers undergoing screening AUS, 64.2% had AUS

abnormalities.[18] Two studies have explored the role of AUS before treatment for oncologic disease. Fifty seven percent of 118 dogs diagnosed with osteosarcoma had AUS abnormalities,[17] while among 101 dogs who were candidates for radiation therapy because of diagnosis of one of three different types of neoplasms with low metastatic potential (soft tissue sarcoma, primary brain tumor, intranasal tumors) there was a 78–87% frequency of abnormal AUS.[14] Our study's finding of a frequency of 58% of AUS abnormalities is similar to these three studies, and strengthened by our large study population.

Although not direct comparisons to the aforementioned studies, our study's finding of 1.3% of the study population not moving on to advanced neurodiagnostics primarily because of abnormal AUS findings is lower than the rates of 6.4% for the frequency of AUS abnormalities deemed capable of changing the prognosis or therapeutic recommendations in dogs with osteosarcoma, and 9% for serious comorbidities identified by thoracic radiographs, AUS, or both that resulted in alteration in treatment plans in dogs with neoplasms with low metastatic potential. Perhaps the reason why our study had such low percentage of cases with the diagnostic or treatment plan altered by AUS findings was the categorization scheme we used. Retrospectively categorizing the rationale for why advanced neurodiagnostics and treatment were not pursued is difficult, as the reasons are often multifactorial. It is possible that a fair number of the cases in our study, where advanced neurodiagnostics and treatment were "declined by owner" were because of significant comorbidities identified on abdominal ultrasound, but was not clearly expressed as such by the owner or in the medical record.

In evaluating the role of the screening AUS on likelihood of proceeding to advanced neurodiagnostics and treatment, another parallel is the routine preanesthetic blood work. No consensus opinion on the utility of preanesthetic screening in dogs has been reached, but in a large-scale retrospective study of 1,537 dogs, the changes revealed by preoperative hematologic and biochemical screening rarely prompted major changes to anesthetic technique. The authors of the study concluded that in dogs without abnormalities identified in careful clinical history taking or physical examination, the screening preanesthetic blood work is often clinically irrelevant.[13] This is similar to the literature in human medicine, where multiple studies have shown and many reviews and guidelines state that routine preoperative screening tests are of questionable benefit, and rarely change anesthetic management or improve surgical outcome for human surgery patients. Rather, decisions about ordering selective or directed preoperative tests should be guided by the clinical history, physical exam findings, and comorbid conditions.[1–3,7–11,35] We propose that similar logic should be employed in determining the necessity of the AUS in neurological dogs before advanced imaging and treatment.

Those smaller dogs were more likely to be treated than larger dogs could be because of the fact that smaller dogs with neurologic dysfunction would be less difficult for the client to manage at home than larger dogs and the difference in differential diagnoses and associated prognoses for small versus large breed dogs. The fact that the brain was treated surgically less often than lesions in other neuroanatomic localizations might be because of the nature of the disease, the invasiveness of the treatment procedures, potential complications, high cost, and variable prognoses based on lesion type and location. Somewhat surprisingly, we found C6-T2 lesions were more likely to be treated surgically than lesions with other neurolocalizations even though intervertebral disk extrusions are most common in the cervical and T11-L3 regions. This could be because of the comparative severity of myelopathic signs seen in the C6-T2 region versus the T3-caudal segments with intervertebral disk disease. Complete paralysis and loss of pain sensation are neurological findings that are associated with a guarded to poor prognosis for recovery.[36] These clinical signs are rare neurological findings in lesions affecting the cervical spinal cord, whereas they are commonly seen in the T3-L3 region of the spinal cord. Owners given an overall poorer prognosis for recovery based on the neurological signs of paralysis and loss of pain sensation might be less likely to move forward with diagnosis and treatment. Also, the inclusion of dogs with suspected degenerative myelopathy, which characteristically presents with signs of T3-L3 myelopathy and has no MRI changes or specific treatment,[37] could have negatively affected the percentage of dogs with T3-L3 myelopathy that are treated.

The primary limitation of this study is the retrospective nature. Although certain assumptions and interpretations had to be made from the medical records and were unavoidable, these were kept to a minimum by limiting the amount of data that were collected and using a systematic approach to categorization. Including dogs which were internal referrals within the hospital could have included a population, that is, less likely to pursue advanced neurodiagnostics because of other more critical medical conditions that require attention first. This internal referral population could also have biased the results toward more abnormal AUS examinations. Although some degree of error and bias is inherent in retrospective studies, this might be minimized by the large number of dogs reported in this study. Also, while ultrasonography is sensitive for lesion detection, the changes are rarely specific for disease etiology.[38] A prospective study with histopathologic correlation for abnormal AUS findings could better elucidate the effect of the findings on further diagnostics and treatment, but is impractical, as there is little justification for biopsy specimen collection in dogs with no clinical signs associated with the AUS finding.

In summary, abnormal findings from screening AUS had a small negative effect on the likelihood of pursuing advanced neurodiagnostics. The use of AUS as a directed preoperative test in dogs with historical or physical examination data that suggest an intra-abdominal comorbid condition or potential cause of the neurologic signs should still be performed, particularly in older

dogs, but an AUS is a low-yield screening test for neurological young dogs and dachshunds. These data could help clinicians and clients in their decision-making process as to whether the AUS is included as part of a diagnostic evaluation before advanced neurodiagnostics and treatment.

Acknowledgments

This project was supported by the National Center for Advancing Translational Sciences (NCATS), National Institutes of Health (NIH), through grant #UL1 TR000002.

Conflict of Interest Declaration: Authors disclose no conflict of interest.

Off-label Antimicrobial Declaration: Authors declare no off-label use of antimicrobials.

References

1. Bryson GL, Wyand A, Bragg PR. Preoperative testing is inconsistent with published guidelines and rarely changes management. Can J Anaesth 2006;53:236–241.

2. Chung F, Yuan H, Yin L, et al. Elimination of preoperative testing in ambulatory surgery. Anest Analg 2009;108: 467–475.

3. Haug RH, Reifeis RL. A prospective evaluation of the value of preoperative laboratory testing for office anesthesia and sedation. J Oral Maxillofac Surg 1999;57:16–20.

4. Hepner DL. The role of testing in the preoperative evaluation. Clevel Clin J Med 2009;76(Suppl 4):S22–S27.

5. Katz RI, Dexter F, Rosenfeld K, et al. Survey study of anesthesiologists' and surgeons' ordering of unnecessary preoperative laboratory tests. Anest Analg 2011;112:207–212.

6. Czoski-Murray C, Lloyd Jones M, McCabe C, et al. What is the value of routinely testing full blood count, electrolytes and urea, and pulmonary function tests before elective surgery in patients with no apparent clinical indication and in subgroups of patients with common comorbidities: a systematic review of the clinical and cost–effective literature [executive summary]. Health Technol Assess 2012;16:i–v.

7. Feely MA, Collins CS, Daniels PR, et al. Preoperative testing before noncardiac surgery—guidelines and recommendations. Am Fam Physician 2013;87:414–418.

8. Johansson T, Fritsch G, Flamm M, et al. Effectiveness of non-cardiac preoperative testing in non-cardiac elective surgery: a systematic review. Br J Anaesth 2013;110:926–939.

9. Keay L, Lindsley K, Tielsch J, et al. Routine preoperative medical testing for cataract surgery. Cochrane Database Syst Rev 2012;3:1–36.

10. Michota FA. The preoperative evaluation and use of laboratory testing. Clevel Clin J Med 2006;73(Suppl 1):S4–S7.

11. Reynolds TM. National Institute for Health and Clinical Excellence guidelines on preoperative tests: the use of routine preoperative tests for elective surgery. Ann Clin Biochem 2006;43:13–16.

12. Solca M. Evidence-based preoperative evaluation. Best Pract Res Clin Anaesthesiol 2006;20:231–236.

13. Alef M, von Praun F, Oechtering G. Is routine pre-anaesthetic haematological and biochemical screening justified in dogs? Vet Anaesth Analg 2008;35:132–140.

14. Bigio Marcello A, Gieger TL, Jiménez DA, Granger LA. Detection of comorbidities and synchronous primary tumours via thoracic radiography and abdominal ultrasonography and their influence on treatment outcome in dogs with soft tissue sarcomas, primary brain tumours and intranasal tumours. Vet Comp Oncol. 2013;DOI:10.1111/vco.12063.

15. Davies M. Geriatric screening in first opinion practice—results from 45 dogs. J Small Anim Pract 2012;53:507–513.

16. Joubert KE. Pre-anaesthetic screening of geriatric dogs. J S Afr Vet Assoc 2007;78:31–35.

17. Sacornrattana O, Dervisis NG, McNiel EA. Abdominal ultrasonographic findings at diagnosis of osteosarcoma in dogs and association with treatment outcome. Vet Comp Oncol. 2012;11:199–207.

18. Webb JA, Kirby GM, Nykamp SG, Gauthier MJ. Ultrasonographic and laboratory screening in clinically normal mature golden retriever dogs. Can Vet J 2012;53:626–630.

19. Berland LL, Berland NW. Whole-body computed tomography screening. Semin Roentgenol 2003;38:65–76.

20. Furtado CD, Aguirre DA, Sirlin CB, et al. Whole-body CT screening: spectrum of findings and recommendations in 1192 patients. Radiology 2005;237:385–394.

21. Braund KG, Ghosh P, Taylor TK, Larsen LH. Morphological studies of the canine intervertebral disc. The assignment of the beagle to the achondroplastic classification. Res Vet Sci 1975;19:167–172.

22. Martínez S, Fajardo R, Valdés J, et al. Histopathologic study of long-bone growth plates confirms the basset hound as an osteochondrodysplastic breed. Can J Vet Res 2007;71:66–69.

23. Martínez S, Valdés J, Alonso RA. Achondroplastic dog breeds have no mutations in the transmembrane domain of the FGFR-3 gene. Can J Vet Res 2000;64:243–245.

24. Bergknut N, Auriemma E, Wijsman S, et al. Evaluation of intervertebral disk degeneration in chondrodystrophic and non-chondrodystrophic dogs by use of Pfirrmann grading of images obtained with low-field magnetic resonance imaging. Am J Vet Res 2011;72:893–898.

25. Blaser A, Lang J, Henke D, et al. Influence of durotomy on laser-doppler measurement of spinal cord blood flow in chondrodystrophic dogs with thoracolumbar disk extrusion. Vet Surg 2011;41:221–227.

26. Forterre F, Gorgas D, Dickomeit M, et al. Incidence of spinal compressive lesions in chondrodystrophic dogs with abnormal recovery after hemilaminectomy for treatment of thoracolumbar disc disease: a prospective magnetic resonance imaging study. Vet Surg 2010;39:165–172.

27. Parker HG, VonHoldt BM, Quignon P, et al. An expressed Fgf4 retrogene is associated with breed-defining chondrodysplasia in domestic dogs. Science 2009;325:995–998.

28. Priester WA. Canine intervertebral disc disease—occurrence by age, breed, and sex among 8,117 cases. Theriogenology 1976;6:293–303.

29. Smolders LA, Bergknut N, Grinwis GCM, et al. Intervertebral disc degeneration in the dog. Part 2: chondrodystrophic and non-chondrodystrophic breeds. Vet J 2013;195:292–299.

30. Willis MB. Genetics of the Dog. New York: Howell Books; 1989.

31. McKee RF, Scott EM. The value of routine preoperative investigations. Ann R Coll Surg Engl 1987;69:160–162.

32. Velanovich V. The value of routine preoperative laboratory testing in predicting postoperative complications: a multivariate analysis. Surgery 1991;109:236–243.

33. Snyder JM, Shofer FS, Van Winkle TJ, Massicotte C. Canine intracranial primary neoplasia: 173 cases (1986–2003). J Vet Intern Med 2006;20:669–675.

34. Hansen HJ. A pathologic-anatomical interpretation of disc degeneration in dogs. Acta Orthop 1951;20:280–293.

35. Committee on Standards and Practice Parameters, Apfelbaum JL, Connis RT, Nickinovich DG, American Society of

Anesthesiologists Task Force on Preanesthesia Evaluation, Pasternak LR, et al. Practice advisory for preanesthesia evaluation: an updated report by the American Society of Anesthesiologists Task Force on Preanesthesia Evaluation. Anesthesiology 2012;116:522–538.

36. Oliver JE, Lorenz MD, Kornegay JN. Handbook of Veterinary Neurology, 3rd ed. Philadelphia, PA: Saunders; 1997:138.

37. Coates JR, Wininger FA. Canine degenerative myelopathy. Vet Clin North Am Small Anim Pract Elsevier Ltd 2010;40:929–950.

38. Withrow SJ, Vail DM. Withrow and MacEwen's Small Animal Clinical Oncology. 4th ed. St. Louis, MO: Elsevier Health Sciences; 2007:99.