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Clinical presentations of naturally occurring canine seizures: similarities to human seizures☆

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Abstract

The clinical presentations of 119 canine seizures from 41 Standard Poodles and 11 Dalmatians were classified according to a modified version of the International League Against Epilepsy (ILAE) seizure classification system. Standardized use of the ILAE system with dogs not only should facilitate research in veterinary medicine, which has no standard criteria for seizure classification, but also should facilitate comparisons between canine and human seizures. We found that for more than 80% of both breeds, at least some of their seizures had partial onsets. However, because it was common for partial seizures to secondarily generalize, the majority of Poodles (81%) and Dalmatians (91%) experienced at least some generalized seizures. Among partial seizures, complex partial were more frequent than simple partial. For both breeds, two thirds of those with partial onset seizures had exclusively complex partial. Among dogs with primary or secondarily generalized seizures, 80% of both breeds had tonic–clonic seizures.

Keywords: Epilepsy; Canine; Seizure classification; Partial seizure; Generalized seizure; Animal model; Clinical presentations; Seizures; Genetics

1. Introduction

Seizures are the most common neurological problem reported in dogs that are owned as pets [1]. Some estimate that between 0.5 and 5.7% of all dogs have experienced seizures sometime in their lives [2]. However, this is likely to be an underestimate because owners sometimes do not realize that certain unusual behaviors can be seizures and because owners do not always seek veterinary care if their dogs' seizures are mild and/or infrequent (Licht et al., unpublished data). Importantly, the lifetime prevalence of seizures varies considerably across breeds. For example, a survey of Belgian Tervuren breeders suggests that as many as 17% of American-bred Belgian Tervurens have had at least one seizure in their lives [3]. In addition to Tervurens, 25–30 dog breeds (of approximately 150 breeds recognized by the American Kennel Club) are reported to have a higher than average prevalence of seizures. These include some popular breeds (e.g., Beagles, Cocker Spaniels, German Shepherds, Golden Retrievers, Labrador Retrievers, and Poodles), as well as less common ones (e.g., Bernese Mountain Dogs, Keeshonds, and Saint Bernards) [4,5].

A variety of factors, such as infectious and other inflammatory diseases, metabolic disorders, congenital anomalies, neoplasia, trauma, vascular disorders, and toxicity, can contribute to seizures in dogs [1,6]. However, the most commonly given diagnosis for canine seizures is idiopathic epilepsy [7]. Pedigree studies of a number of affected breeds indicate a high degree of heritability for canine idiopathic epilepsy [3,8,9], although to date, no causative genes or genetic markers linked to causative genes have been identified. Further, the genetic mechanisms are likely to vary across breeds, and perhaps even across bloodlines (i.e., families) within

☆ Supplemental video clips of canine seizures are included in the electronic version of this paper.

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a single breed. For example, the pattern of inheritance in British-bred Keeshonds was found to be most consistent with a single-gene, recessive trait [10], whereas several studies of Swiss-bred dogs (Bernese Mountain Dogs, Labrador Retrievers, and Golden Retrievers) found a pattern of inheritance that was most consistent with a polygenic, recessive trait [5,8,9].

Not only are there a variety of factors that can contribute to canine seizures, but dogs also can show a wide variety of seizure types [6,11,12]. However, currently there are no standard criteria in the veterinary literature for seizure classification, and relatively few empirical studies have systematically classified the clinical presentation of canine seizures beyond the overall distinction of generalized versus partial. Also, electroencephalograms (EEGs), which aid in seizure classification, are employed with dogs on an infrequent basis [13,14]. Thus, relatively little is known about the nature and frequencies of specific seizure types.

With respect to the broad distinction between generalized and partial, generalized seizures have been the most commonly reported in dogs [1,5,11,15]. However, because veterinary classification often does not take into consideration the initial clinical signs, it is likely that partial onset seizures are more common in dogs than previously reported. In fact, when researchers give careful consideration to the first clinical signs of an episode, their results suggest that partial onset seizures may be more common than generalized onset seizures. For example, a research group in Switzerland has reported "auras" or "preictal" signs in the majority of dogs with generalized seizures. In one study of idiopathic epilepsy that included 46 different breeds [16], the researchers reported that approximately two-thirds of the dogs had seizures with a "preictal phase" consisting of attention seeking, autonomic signs, restlessness, uncontrolled barking, staring, fear, or tremor lasting between a few seconds and 1 h. Further, in two additional studies of idiopathic epilepsy from the Swiss research group, which focused on Labrador Retrievers [8,17], the majority of dogs with generalized seizures were described as showing an "aura" (prior to seizure onset) consisting largely of unilateral motor movements beginning with the head and progressing to the limbs, and lasting approximately 30 s. Thus, many of the episode descriptions in these Swiss studies suggest that those episodes involved partial seizures that secondarily generalized, although the researchers did not use that terminology.

The findings of these Swiss studies are important because they suggest not only that partial onset seizures in dogs are more common than previously reported, but also that partial onset seizures are common in cases of canine *idiopathic* epilepsy, which often is assumed to involve almost exclusively generalized onset seizures [14,18]. Nonetheless, the specific results of these studies are difficult to interpret because while the researchers described an "aura" or "preictal" phase prior to most generalized seizures, they gave no description of the operational definitions they used to differentiate what they called generalized versus partial seizures or to differentiate simple partial from complex partial seizures.

Some researchers in Denmark also have given careful attention to the first clinical signs of seizures. In a recent study [18], they employed the system of the International League Against Epilepsy (ILAE) [19] to classify canine seizures. The dogs in this study included 26 breeds plus mixed breeds, and included those with symptomatic epilepsy as well as idiopathic epilepsy. The researchers reported that 65% of the dogs had partial onset seizures, and 32% had primary generalized seizures. (Three percent could not be classified.) Eighty-five percent of the partial onset seizures secondarily generalized. Of all partial onset seizures (with and without secondary generalization), 68% were classified as simple partial (consciousness unimpaired), 27% were classified as complex partial (impaired consciousness), and 5% were not classifiable. These results provide further evidence that partial onset seizures in dogs are more common than generally is reported and, importantly, that canine seizures can be classified according to the rules of the ILAE system. The authors concluded that standardized use of the ILAE system not only would increase comparability across studies examining canine epilepsy, but also would facilitate comparisons between the seizure types and epilepsy syndromes found in dogs with those found in humans.

While their findings are important, Berendt and Gram [18] did not explain how they modified the ILAE system to accommodate differences between dogs and people. For example, it is not clear how they operationally defined impaired versus unimpaired consciousness since it is not possible to assess the dog's memory of the seizure. They also did not indicate how they classified dogs that experienced multiple seizure types. Based on the human epilepsy literature [20,21] and our own prior experience with dogs, it is likely that at least some dogs would have had multiple seizure types. Thus, as was the case with the Swiss studies described earlier, it is very difficult to replicate their methodology and interpret their conclusions.

Like Berendt and Gram [18], we recognize the potential utility of comparing canine and human seizures. Indeed, in the context of our own research on the genetic basis of idiopathic epilepsy in Poodles, we have been struck by the similarities between the clinical presentations of seizures seen in Poodles (and some other breeds) and those seen in humans.

The purpose of this paper is to present descriptive analyses of canine seizures whose clinical presentations have been classified according to a modified version of the ILAE system. However, to increase the potential replicability and utility of our findings, and to facilitate appropriate comparisons with human seizures, we

developed a detailed manual in which we operationally defined each seizure type as it applies to canine seizures (see Section 2). Another difference between this study and the one prior study that used the ILAE system [18] is the type of dog studied. Berendt and Gram studied multiple breeds of dogs that all presented at a veterinary teaching college with the primary complaint of seizures. In contrast, the dogs described here are primarily Standard Poodles, with a small number of Dalmatians, and owners were recruited through national and regional breed clubs, dog fancier magazines, or the Internet. Each sampling strategy has the potential to provide useful data depending on one's goals. Including many different breeds might provide a broader range of seizure types seen in the canine population as a whole, while focusing largely on one breed will show the range of seizure types that can be found within a single breed. Additionally, it is likely that our sample of dogs will include a broader range of severity than will dogs presenting at a teaching hospital, with the latter likely to include a larger proportion of severe cases.

2. Methods

2.1. Selection and description of dogs

Fifty-two dogs with seizures were included in this study. Eleven (21.2%) were purebred Dalmatians and 41 (78.8%) were purebred Standard Poodles. While Poodles of all sizes are considered to be a single breed, they are divided into three "varieties" based on height, with Standards being the largest, followed by Miniatures, and Toys. The mean height of the Poodles in this study was 24.3 in., and the mean height of the Dalmatians was 22.9 in.

All dogs were owned as pets, and owners were recruited through national and regional breed clubs and, to a lesser extent, through dog fancier magazines and the internet. Between 1996 and 2001, owners of 183 Standard Poodles notified us that their dogs had one or more seizures. Of these, approximately 100 were mailed the initial questionnaire for this study, 84 of which were completed. Fifty of these dogs were selected for more detailed investigation, and data collection was completed on 41. Selection was largely random, but we also considered owners' expressed interest in participating. Also, Poodles were excluded if their veterinary records provided evidence that the dog had symptomatic epilepsy. Additionally, some dogs were excluded to ensure that no particular Poodle family was overly represented. Thus, the 41 Poodles do not represent any particular bloodline or geographical region (they were from 18 different states and Canada), although some were closely related by chance. All Dalmatians that were recruited and that did not meet the exclusion criteria for symptomatic epilepsy were included in this study. Dalmatians also did not represent any particular bloodline or geographical region (they were from eight states). All owners gave informed consent, and the study was approved by the institutional review boards at Florida State University for both human and animal subjects.

The most probable diagnosis for dogs in this study was idiopathic epilepsy. However, it was not possible to confirm the diagnosis for most of the dogs because only 10% had sufficient diagnostic testing and examination. (The neurological consultant for this research defined the minimal diagnostic workup as including physical and neurological examinations, complete blood count, fasting serum chemistry profile, urinalysis, fasting and postprandial bile acids, and tests for suspected toxin exposure, with further testing in the event that any of these yielded abnormal findings.) Based on anecdotal reports, insufficient diagnostics is the norm for canine seizures. Although insufficient testing does not allow us to confidently rule out the possibility that some of these dogs had symptomatic epilepsy, it is likely that most dogs did have idiopathic epilepsy based on the following. First, as previously indicated, all dogs with evidence of symptomatic epilepsy were excluded. Second, the vast majority of dogs had their first seizure more than $1\frac{1}{2}$ years prior to this study (mean duration of disorder at time of study was 3.3 years for Poodles and 4.9 years for Dalmatians), and the only neurological signs seen during this period were seizures. Third, the majority of Poodles came from bloodlines in which large numbers of other dogs with seizures were reported to us. (However, as indicated, we did not include most of their close relatives so that no one bloodline was overly represented.) Additionally, as presented in Section 3, the ages of onset were consistent with what commonly is reported for canine idiopathic epilepsy, and the majority of dogs taking anticonvulsant medication responded favorably. Nonetheless, our findings may reflect canine seizures in general and may not be specific to idiopathic epilepsy.

2.2. Obtaining seizure descriptions

First, owners completed a written questionnaire that provided preliminary information on the nature of the dog's seizures. The questionnaire also addressed the dog's medical and environmental histories. A follow-up structured telephone interview was conducted, generally several months after the questionnaire was returned. The interviewer began by asking the owner to give a detailed open-ended description of the dog's first observed seizure. Following that, a structured series of questions was asked. For example, if the only body movement the owner mentioned was rigidity, the interviewer asked whether there also was any "shaking, jerking, or paddling." Follow-up questions also focused on the very first signs of the seizure, the sequence of

seizure components, which part(s) of the body were involved, and the dog's "responsiveness" during the episode. The responsiveness question asked the owner to pick one of the three answers that best described his or her dog's attention during the episode. The answers varied in the degree to which the owner could get and keep the dog's attention. For partial onset seizures that progressed in severity over the course of the episode, owners were asked the responsiveness question twice—once for the onset and once for "the worst part of the episode." Next, the interviewer repeated back to the owner the entire description, including any additions that were made from the follow-up questions, and the owner was asked whether the final description was accurate. The owner was then instructed to describe any other seizures that the dog ever had that differed from the one already described. If the owner or interviewer had any question about whether another seizure differed in meaningful ways from those already described, the interviewer obtained a full description. The structured follow-up questions were asked separately for each type of seizure that was described.

Because of the structured follow-up questions, it is possible that some owners were influenced by "suggestion" and included some seizure components that did not actually occur, which potentially could have influenced how those seizures were classified. However, we chose to err in this direction because pilot testing indicated that owners' open-ended descriptions tended to be very brief and include only the most salient components.

All owners were encouraged to videotape an episode, but only a few were able to do so. Although the technical quality of these home videos is often poor, they still are illustrative, and are therefore included in this paper. Because we obtained only a few videos of Poodles, and none of Dalmatians, video clips of other breeds are included when they demonstrate the kinds of seizures we found in Poodles and/or Dalmatians.

2.3. Classification of seizure descriptions

Each description of a seizure or seizure type was classified based on a modified version of the ILAE seizure classification system [19]. A brief summary of the system we employed is presented in Table 1. The primary modifications addressed the inability to evaluate a dog's consciousness with the methods used for human patients (see Section IB of Table 1). Additional modifications were made to increase reliability among coders.

While we avoided making unwarranted inferences about what dogs were experiencing during seizures, we did allow certain inferences. For example, owners often reported that immediately prior to a generalized seizure, the dog would seek their attention with "fear in his/her eyes." When this was reported, we coded that seizure as having a partial onset with accompanying "psychic signs." Although owners are making an inference when they say that the dog was fearful, some human epilepsy researchers take a fearful expression shown by a child immediately prior to a generalized or complex partial seizure as evidence that the child is having an "aura" (simple partial seizure) [22]. It seems likely that dog owners learn to recognize signs of fear in their pets, just as parents learn to identify these signs in their children without them having to verbalize the fear.

2.4. Statistics

Although more than one seizure description was obtained for many of the dogs, all statistics are based on classifications at the level of dogs rather than seizures. All statistics in this paper (e.g., means, percentages) are descriptive rather than inferential. That is, we are not attempting to generalize our findings to either all Poodles or all Dalmatians with seizures. Our sample of Dalmatians is small ($N = 11$), yielding only suggestive results for this breed, and neither our Poodle nor Dalmatian sample was selected in a truly random fashion.

3. Results

3.1. Characteristics of seizures

Across the 52 dogs, 119 descriptions of seizures were obtained and classified. Table 2 presents the distribution of seizure onsets. For the vast majority of dogs, at least some of their seizures had a partial onset. As seen in the top half of Table 2, only 17.1% of the Poodles and 18.2% of the Dalmatians had exclusively *primary* generalized seizures (i.e., the first clinical signs were generalized).

It is common for owners to miss the first clinical signs of a seizure, particularly for the dog's first few episodes. Thus, we were concerned that some of the seizures that were classified as having a generalized onset might really have had a partial onset that was missed by the owner. In a similar vein, it seemed possible that an owner could miss a generalized seizure and see only the postictal disorientation, as, for example, if the owner arrived home or woke up right after the seizure terminated. If this occurred, the episode could mistakenly be seen as a complex partial seizure. To address this issue, we repeated the above analysis after omitting all seizure descriptions for which the owner was not highly confident that he or she saw the episode from the very beginning. The results of this more conservative analysis are presented in the bottom half of Table 2. Eight Poodles and one Dalmatian were omitted from this analysis because their owners were never highly confident that they saw the episodes from the very beginning. Further, three Poodles and four Dalmatians that were initially

Table 1
Seizure classification summary[a]

I. *Partial seizures*
(A) General criteria. Clinical signs suggest involvement of one part of one cerebral hemisphere. Motor signs are unilateral *or* asymmetric *or* involve only limited parts of the body (e.g., head only). May involve unusual behaviors (see Section IB2b).
(B) Distinction between SPS and CPS.[b] SPS involves preserved consciousness and CPS involves impaired consciousness. Three levels of consciousness are defined.
1. Lost consciousness: Owner's answer to a standard "responsiveness" question indicates that he/she cannot get dog's attention by any method *and* dog is not navigating environment in any way (e.g., dog not walking, running, or jumping).
2. Impaired consciousness: Dog does *not* meet *both* criteria for "lost" consciousness *and* does meet one or more of the following criteria:
(a) Owner's answer to "responsiveness" question indicates altered attention (i.e., either that he/she cannot get dog's attention or that he/she can get, but not keep, dog's attention).
(b) Dog's behavior is judged by coder to be "out of context" (e.g., running frantically as if being chased, cowering or hiding for no reason, aggression in otherwise nonaggressive dog).
(c) Owner explicitly says dog was disoriented.
(d) Automatisms are reported.
(e) Postictal disorientation is reported.
3. Preserved consciousness: Owner's answer to "responsiveness" question indicates normal attention *and* dog does not meet criterion for impaired consciousness.
(C) Signs that can accompany SPS or CPS. Unless noted otherwise, signs are defined largely the same as in ILAE system.[c]
1. Motor.
2. Autonomic.
3. Psychic signs are limited to aggressive behaviors, biting or snapping at imaginary flies, and fearful/anxious behaviors.

II. *Generalized seizures*
(A) General criteria. First clinical signs suggest involvement of both cerebral hemispheres. Movements are bilateral and largely symmetrical. If seizure lasts 30 s or longer, consciousness must be "lost" at some point during the seizure to be classified as generalized.
(B) Specific types.[d] Unless noted otherwise, clinical signs of each type are defined largely the same as in the ILAE system.
1. Tonic.
2. Clonic.
3. Tonic–clonic: includes generalized seizures involving both tonic and clonic components, regardless of the ordering of components (e.g., clonic–tonic–clonic) or whether the tonic and clonic components occur simultaneously.
4. Myoclonic.
5. Typical absence.
6. Atonic.

III. *Other terms and classification rules*
(A) Automatisms. Seizure-related behaviors coded as automatisms include chewing or swallowing movements, lip smacking, licking mouth, licking (grooming) or scratching body, rubbing face or body part, coordinated paddling of four legs. Changing positions or circling is coded as automatism if done more than twice.
(B) Cluster. Two seizures that occur less than 24 h apart.
(C) Prodrome. When seizure is preceded by 1 h or more of attention seeking, irritability, or anxious behavior without impairment of consciousness and without motor signs. If this lasts less than one hour, it is classified as a simple partial onset.
(D) Progression of a seizure. When a partial seizure progresses to a generalized seizure, it is coded as a partial seizure (SPS or CPS) that *secondarily generalized*. The progression of an SPS to CPS was difficult to identify reliably. Thus, if this kind of episode occurred, it was coded as CPS.

[a] This is a *brief summary* of our modification of the International League Against Epilepsy (ILAE) Seizure Classification System [19] for use with dogs. The detailed 11-page coding manual is available from the senior author. Definitions in this table focus on classifications that are different for dogs than for humans and on additional modifications that were made to increase reliability among coders.
[b] SPS, simple partial seizure(s); CPS, complex partial seizure(s).
[c] Somatosensory or special sensory symptoms (e.g., tingling or numbness of a limb) were not included in the system because it is not possible to reliably identify these symptoms in dogs.
[d] Atypical absence was not included due to the difficulty of differentiating it from CPS.

classified as having "mixed" onsets were reclassified as always having partial onsets because only their generalized onset episodes were eliminated, and one Dalmatian initially classified as having "mixed" onsets was reclassified as always having generalized onsets. Although the exact numbers and percentages of dogs in each category are different than in the prior analysis, the conclusion remains the same: for 80% or more of both breeds, at least some of their seizures had a partial onset. That is, they were classified either as having partial onsets only or as having "mixed" onsets. Finally, we conducted the same analysis a third time after omitting all dogs entirely whose owner missed *any* of the seizure onsets. Although this greatly reduced the number of dogs in the analysis, the conclusion remained the same.

Although it was uncommon for the dogs to have primary generalized seizures, it was common for their partial seizures to *secondarily* generalize. Eighty-one

Table 2
Seizure onsets: number and percentage of dogs with each type of onset

Breed	Always generalized	Always partial	Mixed[a]
All seizures			
Standard Poodle	7 (17.1%)	28 (68.3%)	6 (14.6%)
Dalmatian	2 (18.2%)	4 (36.4%)	5 (45.5%)
Only seizures for which owner was confident that the first signs were observed[b]			
Standard Poodle	4 (12.1%)	27 (81.8%)	2 (6.1%)
Dalmatian	2 (20.0%)	8 (80.0%)	0 (0.0%)

[a] Mixed, some seizures had partial onset and some had generalized onset.
[b] Eight Poodles and one Dalmatian were eliminated from this analysis because owners were never highly confident that they saw the first clinical signs.

percent of the Poodles (33 dogs) and 90.9% of the Dalmatians (10 dogs) had at least some generalized seizures (either primary or secondarily generalized). The top half of Table 3 presents the distribution of generalized seizure types. By far, the most common kind of generalized seizure was a generalized tonic–clonic seizure (GTCS). Of the 33 Poodles and the 10 Dalmatians with some generalized seizures, at least 80% had GTCS. However, only about one-third of all GTCS would fit the classic description of having an initial tonic phase that gives way to a clonic phase. In some cases, the tonic and clonic phases alternated more than once, and in other cases, owners described the dog's limbs as being rigidly extended and jerking at the same time. Besides GTCS, the only other kinds of generalized seizures were tonic seizures and clonic seizures.

The bottom half of Table 3 presents the number and percentage of dogs with generalized seizures that showed autonomic signs and/or automatisms. The most commonly reported autonomic signs during and/or immediately after a generalized seizure were salivation (often foamy) and loss of bladder control. Others included brief respiratory arrest, panting, loss of bowel control and/or release of anal glands, increased pulse, and pupil dilation. By far the most common automatism to occur during or right after a generalized seizure was a coordinated paddling motion (while lying on side), as if swimming or running. Also common were chewing motions and, to a lesser extent, licking the mouth and face.

Video clips 1 and 2 provide two examples of canine GTCS. Although the dogs are a Shepherd mix and Standard Schnauzer, respectively, the clips illustrate the kinds of GTCS seen in many of our Poodle and Dalmatian subjects. (Note that clips 1 and 3 are the only videos in this paper that include sound.)

With respect to partial onset seizures (with or without secondary generalization), complex partial seizures (CPS, with impaired consciousness) were reported more frequently than were simple partial seizures (SPS, with unimpaired consciousness). Table 4 presents the distribution of partial seizure types. For both breeds, roughly two-thirds of the dogs that had some partial onset seizures had exclusively CPS.

Motor signs were commonly seen during both CPS and SPS. The top quarter of Table 5 presents the numbers and percentages of dogs that showed motor signs during CPS and SPS. Commonly reported motor

Table 3
Types and other characteristics of generalized seizures:[a] number and percentage[b] of dogs with each characteristic

Breed	Seizure types		
	Tonic–clonic	Tonic	Clonic[c,d]
Standard Poodle	27 (81.8%)	2 (6.1%)	4 (12.1%)
Dalmatian	8 (80.0%)	0 (0%)	2 (20.0%)
	Other characteristics		
	Autonomic signs	Automatisms	
Standard Poodle	29 (87.9%)	18 (54.5%)	
Dalmatian	8 (80.0%)	5 (50.0%)	

[a] Table includes both primary and secondarily generalized seizures.
[b] Percentages are based on total number of dogs with any primary or secondarily generalized seizures. $N_{Poodles} = 33$, $N_{Dalmatians} = 10$. A dog was classified into one, and only one, seizure type (thus, adding across seizure types equals 100%). However, a dog could show both autonomic signs and automatisms in the same seizure (thus, adding across these characteristics exceeds 100%).
[c] One Poodle and one Dalmatian with clonic seizures also had tonic–clonic seizures.
[d] For dogs with clonic seizures, owners of one Poodle and both Dalmatians did not observe seizure onsets. Thus, they may have missed an early tonic phase.

Table 4
Partial seizure types:[a] number and percentage[b] of dogs with each type

Breed	Seizure type[c]		
	CPS only	SPS only	Both CPS and SPS
Standard Poodle	23 (67.6%)	3 (8.8%)	7 (20.6%)
Dalmatian	6 (66.7%)	3 (33.3%)	0 (0%)

[a] Table includes partial seizures whether or not they secondarily generalized.
[b] Percentages are based on number of dogs that had at least some partial onset seizures. $N_{Poodles} = 34$; $N_{Dalmatians} = 9$. One Poodle had partial seizures for which consciousness could not be assessed.
[c] CPS, complex partial seizures; SPS, simple partial seizures.

Table 5
Characteristics of partial seizures:[a] number and percentage of dogs with each characteristic

Breed	During CPS[b]	During SPS[c]
Motor signs		
Standard Poodle	23 (76.6%)	7 (70.0%)
Dalmatian	6 (100%)	3 (100%)
Autonomic signs		
Standard Poodle	15 (50.0%)	3 (30.0%)
Dalmatian	4 (66.7%)	0 (0%)
Psychic signs		
Standard Poodle	14 (46.7%)	1 (10.0%)
Dalmatian	3 (50.0%)	2 (66.7%)
Automatisms		
Standard Poodle	6 (20.0%)	—
Dalmatian	3 (50.0%)	—

[a] Table includes partial seizures whether or not they secondarily generalized.
[b] Percentages for all characteristics during complex partial seizures (CPS) were based on total number of dogs that had at least some CPS. $N_{Poodles} = 30$, $N_{Dalmatians} = 6$.
[c] Percentages for all characteristics during simple partial seizures (SPS) were based on total number of dogs that had at least some SPS. $N_{Poodles} = 10$; $N_{Dalmatians} = 3$.

signs included tonic contractions and/or clonic movements (often only mild trembling) of certain body parts or regions (e.g., head, one leg, or hind end). When dogs tried to come to their owners, which was very common, the dogs' walk often would be described as "staggering back and forth" or as a "stiff, stilted" walk, sometimes veering to one side. Also reported were rocking back and forth. Video clips 3 (Whippet), 4 (Jack Russell Terrier mix), and 5 (Standard Poodle) provide examples of motor signs that were reported during partial seizures. Motor signs in the Whippet are restricted to the head, and these episodes involve no impairment of consciousness. For the Jack Russell mix, motor signs involve both front and rear end, though not always simultaneously, and consciousness typically is impaired during these episodes. In video clip 5, the Standard Poodle in the front shows subtle head shaking and an unnatural sharp upward movement of the front leg. Although not seen in this clip, consciousness was impaired, as evidenced by unresponsiveness to the owner.

Autonomic signs occurred during partial seizures, but they were less frequent than during generalized seizures, and they were less frequent during SPS than during CPS. The second quarter of Table 5 presents the numbers and percentages of dogs that showed autonomic signs. Common autonomic signs during partial seizures included salivation, pupil dilation, and vomiting. Also reported were panting, brief respiratory arrest, and losing bladder and/or bowel control.

Psychic signs also were reported during partial seizures. The third quarter of Table 5 presents the numbers and percentages of dogs that showed psychic signs. With one exception, the only psychic signs reported were behavioral (hiding or cowering) or facial expressions of fear. "Hallucinatory fly biting" was the only other psychic sign reported, and it was seen in one Dalmatian. During fly biting episodes, the dog bites upward as if trying to catch a fly, but there is no fly. Although no one can verify whether a dog is hallucinating, fly biting in dogs traditionally has been assumed to reflect a visual hallucination [6,23].

Automatisms were reported with a number of CPS (see bottom fourth of Table 5). The most commonly reported automatisms were oroalimentary, including chewing motions, licking the mouth and face, and swallowing. Others included repetitive licking or rubbing/scratching other body part(s), repeated circling as if getting ready to lie down, and a coordinated paddling motion as if swimming or running. In video clip 6, the Poodle (on the right) shows repetitive licking of the face and swallowing during a CPS.

For some Poodles, their CPS involved aimless wandering, behavioral arrest, and/or staring. Video clips 7 and 8 show two such Poodles that are littermates. The Poodle in clip 7, a male, is shown panting and staring, while wedging himself in a corner of the bathroom. During other episodes, he is reported to climb up on the toilet seat, tables, and other precarious places. The Poodle in clip 8, a female, begins this episode by wandering through the kitchen without any apparent goal. In the video, she stops wandering, turns her head in both directions, and stares. (Note also her leg lifting—her left front later followed by right rear.)

The owners' estimates of seizure durations are presented in Table 6. Owners often found it difficult to provide duration estimates. In part, this was because it was difficult to know when the seizure ended and the postictal period began. Also, it was infrequent that owners actually timed the episodes because when the episodes began, owners were more concerned with trying to comfort and/or protect the dog from injury. Thus, owners were much more tentative when providing estimates of seizure duration than when providing seizure descriptions.

Table 6
Duration (in min) of seizures and postictal periods

	N	Mean	Median	SD	Range
Standard Poodles					
Generalized seizures[a]	33	5.0	3.2	5.3	0.6–22.5
Partial seizures that did not generalize	19	10.8	3.0	22.1	0.3–90.0
Partial onset (seizures did generalize)[b]	19	2.3	0.6	3.8	0.1–12.5
Postictal for generalized seizures[a]	31	182.4	15.0	284.5	0.5–720.0
Postictal for partial seizures[c]	17	33.9	7.5	60.4	0.0–240
Dalmatians					
Generalized seizures[a]	10	3.3	3.5	1.4	1.1–5.0
Partial seizures that did not generalize	6	4.7	4.1	4.1	0.5–9.63
Partial onset (seizures did generalize)[b]	4	5.6	1.3	9.6	0.1–20.0
Postictal for generalized seizures[a]	8	16.0	4.0	19.8	1.0–50.8
Postictal for partial seizures[c]	5	0.9	0.0	1.2	0.0–2.5

[a] Includes both primary and secondarily generalized seizures.
[b] Includes only duration of the partial onset phase.
[c] Includes only postictal for partial seizures that did not generalize.

Table 6 also presents the owners' estimates for the duration of the postictal periods. As expected, postictal periods were longer after generalized seizures than after partial seizures that did not generalize. Following generalized seizures, owners most commonly reported that their dogs were disoriented and did not seem to know where they were, staggered or had wobbly legs (at least initially), and/or were very tired and sleepy. Also common were nervous pacing, bumping into things, drooling, atypical attention seeking, and carefully smelling each room in the house. Although less common, some reported that the dog growled when the owner approached, vomited, panted, hid, and/or sought out food or water. Owners reported similar behaviors after partial seizures (primarily after CPS), although they most frequently reported that the dogs were tired and sleepy. Interestingly, owners rarely reported that the dogs were disoriented after CPS, perhaps because any disorientation was viewed as part of the seizure itself. Video clip 9 shows the ending of a GTCS and the initial postictal period for the Standard Schnauzer seen earlier (clip 2). She shows fairly severe postictal behaviors.

A relatively small proportion of owners reported that their dogs had prodromes. Of the 37 Poodles that had primary generalized seizures and/or CPS, 10.8% (4 dogs) were reported to have prodromes; of the 9 Dalmatians that had primary generalized seizures and/or CPS, 33.3% (3 dogs) were reported to have prodromes.

3.2. Other clinical characteristics

Fifty-one percent of the Poodles and 36.4% of the Dalmatians were male. Clinical characteristics of the dogs in this study are presented in Table 7. (When interpreting ages, note that 1 canine year is roughly the equivalent of 7 human years.) As seen in the table,

Table 7
Clinical characteristics of dogs

	N[a]	Mean	Median	SD	Range	Percent
Standard Poodles						
Age of onset (years)	39	2.8	2.4	1.6	0.5–6.4	—
Disorder duration (years)[b]	39	3.3	2.4	2.7	0.1–11.4	—
Seizures per year	39	7.4	2.8	12.3	<1–69	—
Experienced clusters	41	—	—	—	—	34.1
Taking anticonvulsants	41	—	—	—	—	46.3
Dalmatians						
Age of onset (years)	11	3.2	2.9	1.3	1.3–5.8	—
Disorder duration (years)[b]	10	4.9	4.1	2.0	2.8–8.4	—
Seizures per year	10	9.7	5.7	10.7	<1–32	—
Experienced clusters	11	—	—	—	—	63.6
Taking anticonvulsants	11	—	—	—	—	72.7

[a] Total number of Standard Poodles was 41 and that of Dalmatians was 11. Smaller *N*'s occurred due to missing data.
[b] Disorder duration is the number of years from the dog's first seizure to the start of this study, or to the death of the dog if that preceded the study.

the mean age of onset is 2.8 years for Poodles and 3.2 years for Dalmatians. Although age of onset can neither confirm nor rule out any diagnosis [16], the ages of onset seen in this study are within the range of what is most commonly reported for canine idiopathic epilepsy (1–5 years) [12].

With respect to the dogs that experienced cluster seizures (see Table 7), it should be noted that the majority of their episodes did not involve clusters. Specifically, for dogs that experienced clusters, the mean percentage of total episodes that were clusters was 23.0% for Poodles and 17.8% for Dalmatians. With the exception of one Poodle, cluster episodes always involved generalized seizures (either primary or secondarily generalized).

Regarding the dogs that were taking anticonvulsants (see Table 7), all dogs were taking phenobarbital and/or potassium bromide, which are the most common anticonvulsants used to treat dogs [12]. Of the 19 Poodles taking anticonvulsants, 15 provided enough "baseline" data (i.e., seizure frequency prior to treatment) to evaluate the efficacy of treatment. Of these, 80.0% responded favorably. More specifically, 7 (46.7%) became seizure-free, and 5 (33.3%) showed a reduction in seizure frequency, but did not become seizure-free. Of the 8 Dalmatians taking anticonvulsants, only 3 provided enough "baseline" data, making it impossible to evaluate their overall response to treatment. For dogs not taking medication, most owners reported that they and/or their veterinarians felt the dog's seizures were not frequent enough to warrant the risks and inconvenience of medication. Many owners expressed concerns that medication might alter the dog's personality.

4. Discussion

This study examined the clinical presentations of 119 canine seizures (from 41 Poodles and 11 Dalmatians) that were classified according to a modified version of the ILAE system. We found that for more than 80% of the dogs in both breeds, at least some of their seizures had a partial onset (i.e., they were classified as having either partial onsets only or "mixed" onsets). We also found that it was common for partial seizures to secondarily generalize. Thus, the large majority of Standard Poodles (81%) and Dalmatians (91%) experienced at least some generalized seizures—either primary or secondarily generalized. Among partial seizures (with or without secondary generalization), CPS were more frequent than SPS. For both breeds, two-thirds of those with partial onset seizures had exclusively CPS. Among dogs with generalized seizures (primary or secondarily generalized), at least 80% of both breeds had GTCS, with the remaining dogs having either clonic or tonic seizures. Finally, as illustrated throughout the Results, the clinical manifestations of both generalized and partial onset canine seizures shared many similarities with comparable types of human seizures.

Our finding that partial onset seizures were more common than generalized onset seizures is contrary to what frequently is reported in the veterinary literature, which is that generalized seizures are the most prevalent [1,5,11,15]. However, our findings are consistent with the studies that gave careful attention to the first clinical signs of the dogs' episodes [8,16,17], including one prior study that used the ILAE classification system [18]. Thus, it is likely that much of the prior research on dogs underestimated the number of partial onset seizures because the classification rules employed did not give sufficient emphasis to the first clinical signs of an episode.

Although our general findings of more frequent partial onset seizures are consistent with some other studies, the specific rates and types of partial onset seizures varied among these studies. Several factors might account for these differences. First, there was variation across these studies in the breeds and variety of dogs studied. While some studies included many different breeds [16,18], others, including ours, focused on specific breeds [8,17]. Second, while some studies, including ours, recruited participants largely through breed clubs [8], others examined dogs that were referred to teaching colleges or institutes of neurology [16,18]. A broader range of severity is expected with dogs recruited from breed clubs, whereas teaching colleges and neurology institutes are expected to be more heavily weighted with severe cases. Third, the clinical diagnoses of the dogs varied across studies. The one prior study employing the ILAE system [18] included dogs with symptomatic, idiopathic, as well as cryptogenic diagnoses. In contrast, the Swiss studies [8,16,17] included only dogs diagnosed with idiopathic epilepsy. As indicated earlier, the present study included dogs with a "probable," but not confirmed, diagnosis of idiopathic epilepsy.

The fourth, and most important, reason that it is difficult to compare specific findings across these (or other) studies is that it is not possible to determine the ways in which the procedures used for classifying seizures might have differed across studies. This was because none of these prior studies provided clear operational definitions for either seizure types or other seizure-related behaviors (e.g., automatisms). Although one of these studies [18] used the seizure classification system of the ILAE, there was insufficient information to determine the similarity of their definitions to the operational definitions in our classification manual.

Although these differences across studies make it difficult to determine why the *specific* findings differed, it is particularly noteworthy that the same *general* conclusion emerged from each of the studies that gave careful attention to the first clinical signs of the dogs'

seizures. In other words, our general conclusion that partial onset seizures are considerably more common than generalized onset seizures does not appear to be limited to our specific methods of data collection or seizure classification, the specific breeds that we chose to study, our recruiting and selection procedures, or the tentative diagnoses of our dogs. However, to understand differences across studies in their specific findings and whether seizure types vary as a function of breeds, referral procedures, whether the dogs have symptomatic versus idiopathic epilepsy, or specific syndromes, it is necessary to establish a standardized system for seizure classification.

Any seizure classification scheme is going to have some problems and will need to evolve as more is learned about the nature of canine seizures. This certainly has been the case with the use of the ILAE system for classifying human seizures [24]. Nonetheless, the universal use of a classification system that employs standardized terminology and operational definitions for canine seizures, like the system used in the current study, will promote future advances by facilitating comparisons across studies and communication among researchers and clinicians. The current study, together with that of Berendt and Gram [18], demonstrates that a modified version of the ILAE system can be used to classify canine seizures. Further, the use of the ILAE system should facilitate appropriate comparisons of canine and human seizures. Not only will this allow canine epilepsy researchers to glean potentially relevant information from studies on human seizures, but there also is the potential for canine research to advance our knowledge of human seizures. The fact that many of the clinical manifestations of canine seizures (e.g., automatisms with CPS and with generalized seizures; motor, autonomic, and psychic signs with partial seizures; postictal disorientation after generalized seizures) are similar to those found with comparable types of human seizures suggests that some canine seizure types might be naturally occurring models of some human seizure types.

Before the potential for canine models of human seizures can be fully realized, additional kinds of data must be collected. First, more research is needed on the EEG patterns that are associated with different types of canine seizures. And, as suggested by Sarkisian's [25] criteria for a good animal model of human seizures (or epilepsy syndromes), researchers will need to show that the EEG correlates of specific seizure types seen in dogs correspond to the EEG correlates of the human seizure types being modeled. As indicated earlier, EEGs are conducted only infrequently on dogs. However, a few recent EEG studies on dogs with seizures indicate that, at least on a general level, certain interictal (and possibly ictal) EEG abnormalities seen with some human seizures also are seen in some dogs with seizures [13,14,16]. Of course, emphasizing the necessity of EEG data should not be taken to minimize the importance of proper classification of the clinical presentations of seizures. EEG findings need to be interpreted in conjunction with the clinical presentations of seizures as well as patients' complete medical histories [26].

As Sarkisian [25] suggests, a good animal model also should show etiology similar to that of the human epilepsy condition being modeled. Although, to date, no epilepsy genes have been identified in dogs, there is considerable evidence for the heritability of idiopathic epilepsy in numerous breeds [3,8,9]. Thus, the idiopathic epilepsy syndromes found in some affected breeds may eventually prove to be models for some human idiopathic epilepsies. The fact that breeders may breed the same dogs multiple times to each other and/or to other dogs before they realize that seizures run in their dogs' bloodlines, combined with multiple births, can produce large numbers of affected relatives. This has the potential to provide informative data for gene mapping studies. In a similar vein, as indicated in Section 1, a variety of other conditions (e.g., congenital anomalies, infectious and inflammatory diseases, progressive neurological disorders) can cause symptomatic seizures in dogs, and some of these conditions also might prove to be models for human symptomatic seizures [27].

Clearly, more data need to be collected before one can determine how well any canine seizure types can model human seizures or whether any canine epilepsy syndromes correspond to human epilepsy syndromes. However, our findings and those of other studies that carefully examined the first clinical signs of canine seizures [16–18] suggest that partial onset seizures are among the most likely to be modeled by dogs. Although fewer dogs in these studies had primary generalized seizures, there still may be sufficient numbers with primary generalized major motor seizures—particularly GTCS—to suggest the possibility of a canine model for this seizure type as well. However, with respect to generalized seizure models, we should caution that none of these studies found any episodes for which the clinical signs were consistent with those of absence, myoclonic, or atonic seizures. These seizure types in dogs have been only infrequently reported elsewhere [11,15].

While we are hopeful that what is learned from dogs will have implications for understanding some human seizures and epilepsies, it should be noted that canine seizures and epilepsy syndromes are worthy of attention in their own right. Seizures, and the medications needed to control them, often impair the quality of life for dogs and their owners. Our research suggests that a modified version of the ILAE seizure classification system can be applied to the study of canine seizures. The use of a standardized seizure classification system with clearly documented operational definitions should promote advances by facilitating comparisons across studies and communication among professionals.

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