J Vet Intern Med 2007;21:1299–1306

Electroencephalography Findings in Healthy and Finnish Spitz Dogs with Epilepsy: Visual and Background Quantitative Analysis

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Background: Qualitative and quantitative electroencephalography (EEG) parameters of healthy and Finnish Spitz dogs with epilepsy have not been determined.

Objective: To determine if EEG can provide specific characteristics to distinguish between healthy dogs and dogs with epilepsy.

Animals: Sixteen healthy and 15 Finnish Spitz dogs with epilepsy.

Methods: A prospective clinical EEG study performed under medetomidine sedation. Blinded visual and quantitative EEG analyses were performed and results were compared between study groups.

Results: Benign epileptiform transients of sleep and sleep spindles were a frequent finding in a majority of animals from both groups. The EEG analysis detected epileptiform activity in 3 Finnish Spitz dogs with epilepsy and in 1 healthy Finnish Spitz dog. Epileptiform activity was characterized by spikes, polyspikes, and spike slow wave complexes in posterior-occipital derivation in dogs with epilepsy and with midline spikes in control dog. The healthy dogs showed significantly less theta and beta activity than did the dogs with epilepsy ($P < .01$), but the only significant difference between healthy dogs and dogs with untreated epilepsy was in the alpha band ($P < .001$). Phenobarbital treatment increased alpha, beta ($P < .001$), and theta ($P < .01$), and decreased delta ($P < .001$) frequency bands compared with dogs with untreated epilepsy.

Conclusions and Clinical Importance: Benign epileptiform transients of sleep could be easily misinterpreted as epileptiform activity. Epileptiform activity in Finnish Spitz dogs with epilepsy seems to originate from a posterior-occipital location. The EEG of dogs with epilepsy exhibited a significant difference in background frequency bands compared with the control dogs. Phenobarbital treatment markedly influenced all background activity bands. Quantitative EEG analysis, in addition to visual analysis, seems to be a useful tool in the examination of patients with epilepsy.

Key words: Benign transients of sleep; Canine; Focal idiopathic epilepsy; Medetomidine; Quantitative electroencephalography.

Electroencephalography (EEG) is an important, sensitive, noninvasive diagnostic tool for human patients with a history of seizures.[1] In veterinary medicine, EEG is seldom used. Previous reports focused mainly on qualitative visual EEG changes in dogs with epilepsy.[2–8] Few reports of the quantitative analysis of EEG (qEEG) in normal or dogs with epilepsy have been published.[9–12] One important limitation has been the relative scarcity (<500 patients) in the number of reported EEG findings in dogs suffering from idiopathic epilepsy. This lack of information makes drawing conclusions difficult. Another weakness is the heterogeneity of study groups. To the authors' knowledge, only 1 report compares the EEG of dogs with epilepsy and normal dogs of the same breed but offers no qEEG analysis.[4] The lack of information about variations in normal findings among different dog breeds complicates the interpretation of pathologic EEG changes. Some of first reports of EEG examinations in dogs attempted to emulate human medicine and were performed in awake animals.[13] Soon, however, investigators realized that, in veterinary medicine, sedation or anesthesia should be used during EEG examinations because of the uncooperative nature of the patients. The use of different sedative agents was previously published.[4,5,8,10]

Use of digital EEG equipment facilitates analysis of EEG data. Quantitative EEG analysis was used to calculate the prevalence of variance frequency bands of EEG records in dogs.[9] However, the practical value of such quantitative data should be to determine specific background activity characteristics typical of normal individuals and individuals with epilepsy. Such information is lacking in veterinary medicine. Our study sought to describe EEG parameters under medetomidine[a] sedation in healthy Finnish Spitz dogs and to compare findings with those obtained from the same breed of dog with idiopathic epilepsy. We compared the qualitative EEG and qEEG parameters of the study groups. We hypothesized that EEG would provide specific qualitative and quantitative analysis characteristics to distinguish between healthy dogs and dogs with epilepsy.

Materials and Methods

This study was performed at the Small Animal Clinic of Helsinki University in collaboration with the Finnish Spitz Breeder Club in Finland and with the permission of the Ethics Committee on Animal Trials. Study groups consisted of 16 healthy Finnish Spitz dogs (FSC) and 15 Finnish Spitz dogs with epilepsy (FSE) (1 dog was excluded from the epileptic group because of concurrent diabetes mellitus). The FSE group comprised 4 females and 11 males, and the FSC group had 7 females and 9 males. The mean

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Submitted November 28, 2006; Revised April 24, 2007; Accepted June 20, 2007.

0891-6640/07/2106-0020/$3.00/0

age of FSE was 74 months (range, 30–120 months) and in FSC, 70 months (range, 16–144 months).

Some of the examination results from 11 FSE and 3 FSC included in this study appeared in previous reports.[14] The inclusion criteria for this study on dogs with epilepsy were a history of at least 2 epileptic seizures. Seizures were classified as having either a focal or generalized onset (described previously).[14,15] A normal general physical and neurologic examination, normal blood biochemistry analysis, and normal CBC count were the minimal inclusion criteria for all dogs. In addition, 11 FSE and 3 FSC had urinalyses performed (specific gravity, chemistry, and sediment examination), a cerebrospinal fluid (CSF) examination (cell count, protein concentration), and magnetic resonance imaging (MRI) with 1.5 T equipment.[b,c]

We used portable EBNeuro EEG equipment[d] for the recordings. An EEG was performed in all animals under medetomidine sedation in a quiet, darkened room. A dosage of 40–60 μg/kg medetomidine was administered IM. An additional 10–20 μg/kg was administered IM if the dog was not ready for manipulations by 20–30 minutes after the initial injection. No additional medications were used. No other electronic monitoring of patients was used during recording to avoid possible artifacts from additional electrical devices. The ECG and respiratory rate (RR) were recorded via the polygraphic electrodes of the ECG (for ECG: sensitivity, 70 μV/mm; time constant, 0.3 seconds; Hf, 70 Hz; and for RR: sensitivity, 20 μV/mm; time constant, 0.3 seconds; Hf, 70 Hz); the polygraphic electrodes[e] were connected to alligator clips, and a volumetric transducer[f] was applied to the chest. In addition, the electroencephalographer examined both the pulse rate and its quality (femoral artery) during EEG recording, as well as the deepness of sedation (palpebral reflex). The electroencephalographer marked possible sources of EEG artifacts, such as external noise or animal movements (eg, eye, ear, or nose movements) on the EEG during recording.

Patients were positioned in a sternal recumbency. We used a method of standardized placement of EEG electrodes that resembled the 10 to 20 international system for humans. A 14-channel reference montage, modified from a 17-channel montage, described previously[9,12] (F7, F3, F4, F8, T3, C3, Cz, C4, T4, P3, Pz, P4, O1, O2; sensitivity, 10 μV/mm; time constant, 0.3 seconds; Hf, 70 Hz; notch filter inserted; reference: on the ridge of the nose between the eyes; ground: caudally to the external occipital protuberance) was used to record EEGs. Sixteen EEG needles[g] were inserted as subdermal active, reference, and ground electrodes. Impedances did not exceed 5 kΩ. EEG recording lasted 20 minutes, after which EEG data were stored in the acquisition station[h] for subsequent analysis. The EEG records of all dogs were visually examined in a blinded manner (in bipolar montage). The reviewer (SK) was asked to describe the sleep stage, possible normal variants, or epileptiform findings, without knowing the clinical status of the dogs. Additional review of EEG records was performed on referential montage to eliminate all epileptiform patterns and artifacts from further background analysis, because they can strongly affect the frequency analysis of the EEG (qEEG). Cardiovascular, muscular activity and physiologic rhythmic movements were marked at the time of visual analysis.

For all dogs, 60 replications of 2-second artifact-free epochs were randomly selected from the entire EEG to analyze 2 minutes of recording. For dogs with epilepsy, we analyzed unsuppressed epochs without epileptic activity. We analyzed the background activity with the same acquisition station, where one of authors (LB) used an integrated software program called Fast Fourier Transform (FFT). We calculated and averaged FFT for each channel. The spectral bands of delta (0.5–4.0 Hz), theta (4.5–8.0 Hz), alpha (8.5–12.0 Hz), and beta (12.5–30.0 Hz) were calculated and expressed as relative power (%).

For statistical analysis, we used the relative power of background analysis to minimize errors created by differences in amplifier gain among channels and the effects of amplitude differences of noncerebral origin, such as those caused by varying skull thickness or asymmetrical interelectrode distance. By definition, the relative band value refers to 1 absolute band divided by another and multiplied 100 times to yield the final relative percentage of the selected frequency band. In our study, the relative power of each of the 4 frequency bands corresponded to the ratio between a given band and the sum of the power of the entire spectrum (which includes all of the frequency bands) multiplied 100 times to yield the final relative percentage of the selected frequency band.

The Kolmogorov-Smirnov technique for normality was used to check for Gaussian distribution of the study groups, and the Wilk-Shapiro technique was used to check that of the qEEG data. Ordinary analysis of variance (ANOVA), in combination with the pairwise *t*-test for multiple comparisons with Bonferroni p correction, was applied first to evaluate the significance of differences. Bartlett's test was used to evaluate the differences among the standard deviations. Thereafter, the Kruskal-Wallis test (nonparametric ANOVA) and Dunn's Multiple Comparison test were used for reevaluating the significance of differences among the groups for delta, theta, and beta bands. Multivariate analyses were performed by using the multiple logistic regression technique with EEG activity type as the dependent variable, and age, sex, weight, heart rate, medetomidine dosage, number of drug administrations, and time from initial injection to the beginning of recording as the independent variables. All of the analyses were performed with the software R v. 2.2.1.[i] All data were expressed as mean ± standard deviation, and the probability value was set at $P < .05$.

For all electrodes of a single animal, the relative power mean value was calculated. The values of each derivation were averaged for every study group (14 derivations) and used later to calculate single values for every dog group.

Results

Five of 15 dogs with epilepsy were receiving phenobarbital[j] monotherapy. General physical and neurologic examinations were normal in all dogs, serum biochemistry, and CBC counts were within the reference range in all dogs, and urinalysis and CSF revealed no abnormalities (protein < 25 mg/dL, cells < 5/μL). MRIs were unremarkable in all examined dogs. At the visual examination of the EEG recordings, all dogs exhibited a high-voltage low-frequency background activity. Background activity was superimposed with spindles or focal beta bursts in 8 control dogs and 5 dogs with epilepsy (Fig 1A) and with benign epileptiform transients of sleep (BETS) in 13 FSC and 8 FSE dogs with epilepsy (Fig 1B).

Paroxysmal epileptiform activity was observed in 3 dogs with epilepsy, and it was characterized by spikes, polyspikes, and spike and slow wave complexes in posterior-occipital derivation in all of them (Fig 2A, B). In addition, 1 dog with epilepsy exhibited periodic delta activity at right temporal localization, and, in 2 dogs, delta rhythms were diffuse. One of the control dogs exhibited midline spikes (Fig 3), and one had occipital theta rhythms.

For statistical analysis, the epileptic group was divided into 2 subgroups: dogs with epilepsy without treatment (FSENT) and dogs with epilepsy under

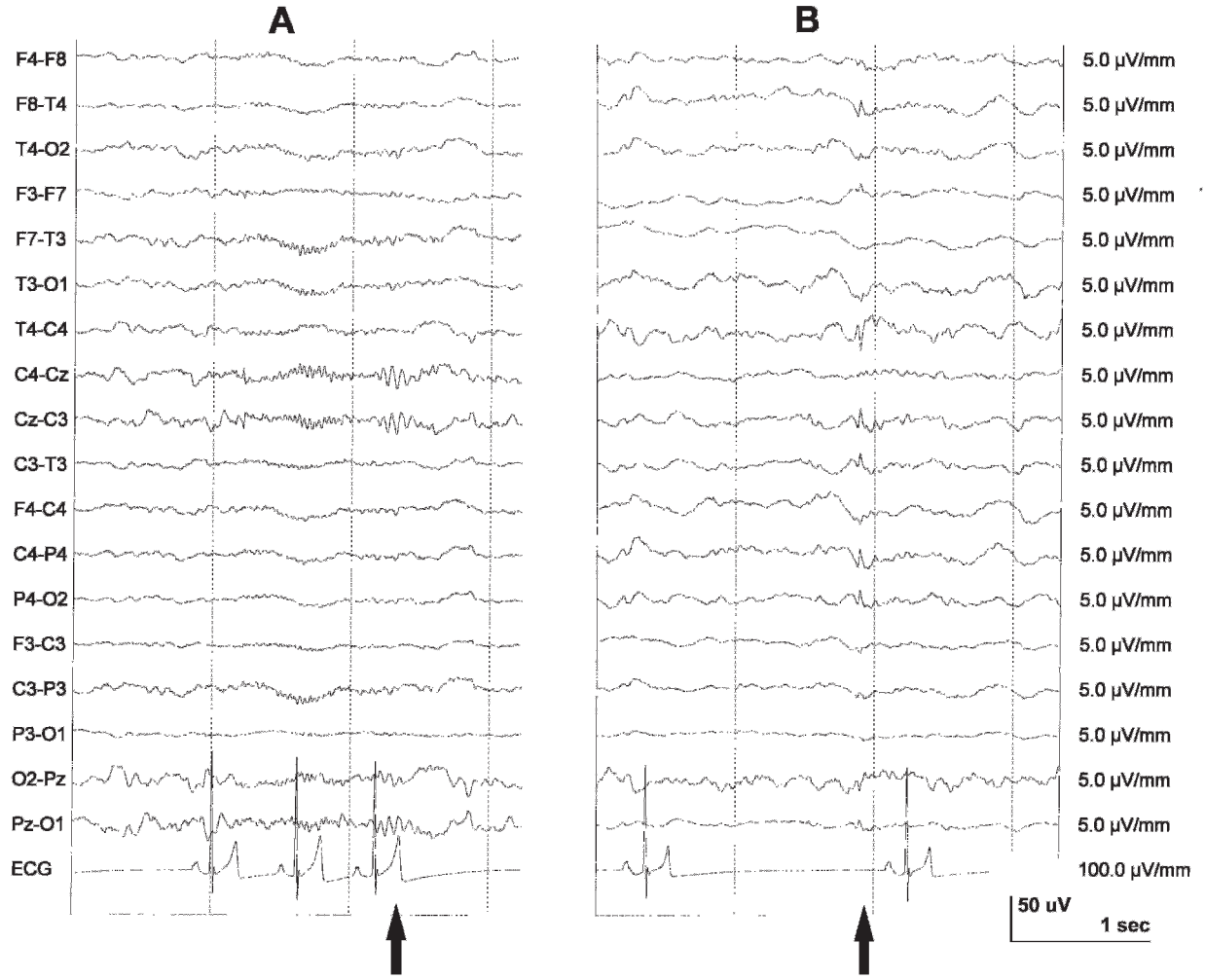

Fig 1. Electroencephalographic traces of a control Finnish Spitz dog. **(A)** The 12-Hz sleep spindles follow beta activity in the midline region. **(B)** Benign transients of sleep in bipolar montages (arrows). Recording is in bipolar montage, time constant 0.3 second, and high-frequency filter 70 Hz; notch filter inserted.

phenobarbital treatment (FSEPh). We found no significant correlations by multivariate analyses between EEG activity type and age, sex, weight, heart rate, nervousness of the patient, medetomidine dosage, number of drug administrations, and time from initial injection to the beginning of recording. The results of the qEEG showed a prevalence of slow rhythms (delta and theta) in all groups, whereas fast rhythms (alpha and beta) were poorly represented. All data but theta band relative power for FSENT were sampled after Gaussian distribution and passed a normality test. Differences among standard deviations for delta and alpha bands were significant. The results of the mean relative power are presented in Table 1. A summary of these data appears in Figure 4, with significance levels for the compared results of different groups in Table 2.

The control dogs showed significantly less theta and beta activity ($P < .01$) on their EEG than did the common group of dogs with epilepsy (FSE), although the only significant difference between healthy dogs and dogs with untreated epilepsy was in the alpha band ($P < .001$). Phenobarbital treatment increased alpha, beta ($P < .001$), and theta ($P < .01$), and decreased delta ($P < .001$) bands compared with dogs who have untreated epilepsy. All dog groups had similar characteristic relationships for theta and beta frequency bands.

Discussion

In our study, we compared the visual and background characteristics of EEG in healthy dogs and dogs with epilepsy of the same breed. Such a selection for an EEG study population is seldom described in the veterinary literature.[4] Such a study population should add homogeneity to results, because it would be logical to suppose that different breeds would exhibit different normal EEG patterns because of their different sizes, temperaments, and other characteristics. This phenomenon is described in human medicine.[16] Future EEG studies in dogs should be designed to address this question.

Another advantage of our study is the blinded visual EEG evaluation, which contained records from the control dogs and the dogs with epilepsy. This approach has not been previously reported in the veterinary

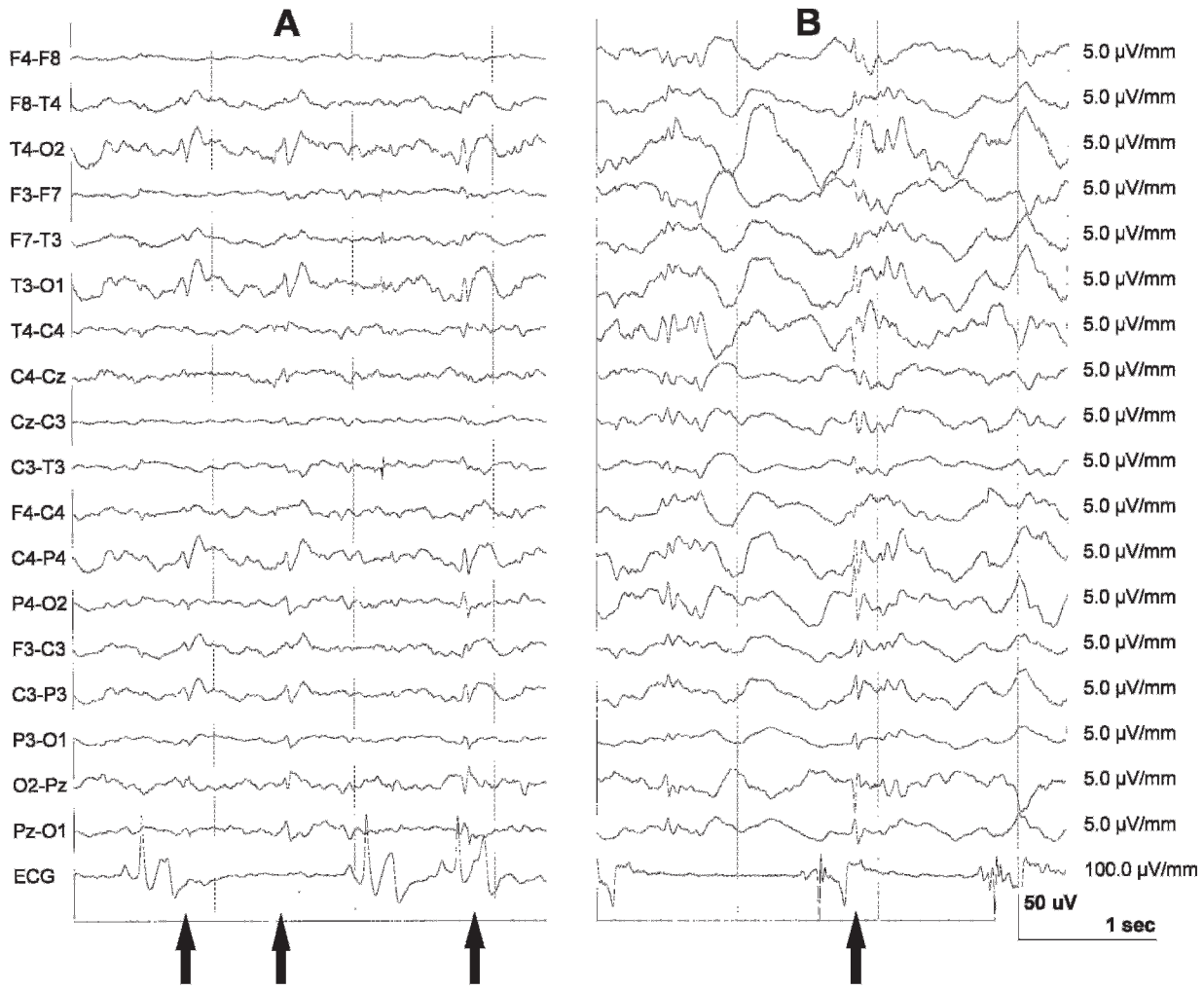

Fig 2. Electroencephalographic traces of an epileptic Finnish Spitz dog. **(A)** Repeated spike and slow wave complexes in bilateral occipital and parietal derivations. **(B)** Slow background activity superimposed with spike in bilateral occipital and parietal derivations (arrows). Recording is in bipolar montage, time constant 0.3 second, and high frequency filter 70 Hz; notch filter inserted.

literature. An homogenous study population and blinded descriptive review of EEG records should allow us to draw more realistic estimations about the presence of normal patterns and epileptiform findings in dogs, without introducing bias. We described BETS and sleep spindles in 68% of dogs in our study. These findings are well recognized in healthy humans and in ones with epilepsy.[16–19] Sleep spindles occur mainly in the II stage of sleep. They begin and end abruptly with frequencies up to 15 Hz and amplitudes of 30–50 µV. The duration of discharges usually is from 0.5 to 1 second.[17,20] Beta bursts are very similar paroxysms. They differ in having higher frequency (up to 30 Hz), longer duration, and do not begin and end abruptly.[21] Both of these transients occur in the frontal, central, and parietal derivations. BETS, also described as small sharp spikes, are recognized as epileptiform normal variants.[17,18,22] They have a low amplitude and are sharply contoured transients that occur in the I–II sleep stage. They have average amplitudes of 60 µV and 60 msec duration and are found in the central and temporal areas.[17,22] One study in humans reported 93% of sharp transients in the sleep EEG of healthy volunteers, with an incidence of 13% for true epileptiform discharges.[19] These changes could be misinterpreted as true epileptic discharges, especially if the clinical status of the patient is known and the interpreter has little experience in detection of this phenomenon. We adapted standard descriptions used in the neurophysiology of humans to describe all EEG patterns in FS dogs.[23] Larger studies should be designed in the future in a variety of dog breeds to describe in detail specific characteristics of different EEG patterns in dogs and to compare results with those of humans.

Epileptiform activity in healthy dogs has not been studied in the veterinary literature. In our study, we detected midline spikes in 1 control dog. In addition, we observed a similar finding in other healthy FS dogs not included in this study. In humans, this finding is thought to represent epileptiform activity of uncertain clinical relevance.[24,25] In the healthy human population, interictal epileptic discharges are present in up to 2.6% of individuals.[25] We found epileptiform paroxysms in 1 of the 16 healthy dogs (6%). The seizure frequency in FS

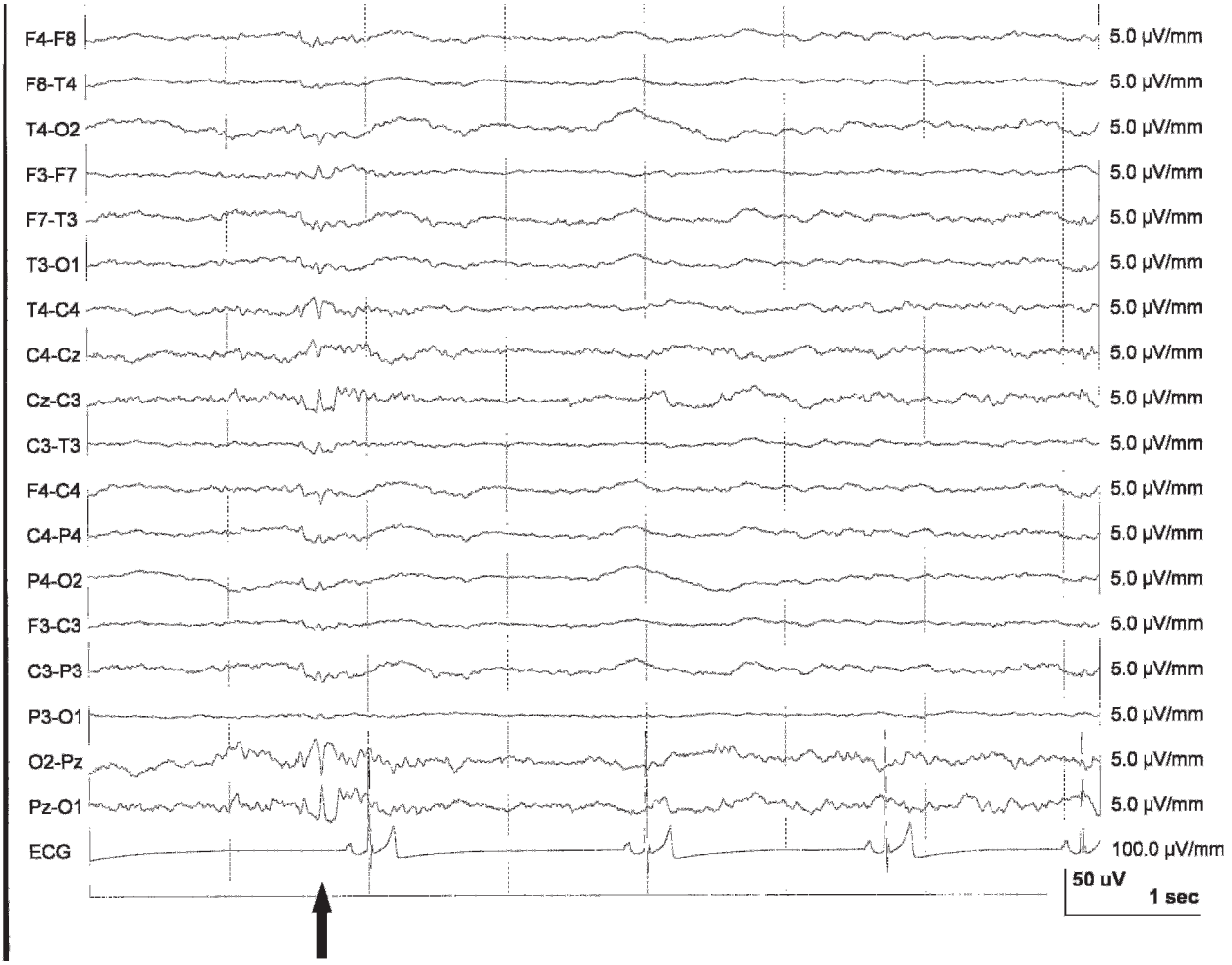

Fig 3. Electroencephalographic traces of a control Finnish Spitz dog. Spikes in midline derivations (arrow). Recording is in bipolar montage, time constant 0.3 second, and high-frequency filter 70 Hz; notch filter inserted.

dogs often is as low as 1–2 episodes per year. As described in our previous study, these dogs are kept outdoors and are under the direct observation of their owners 25 to 50% of the time.[14] Therefore, some mild ictal events could be missed by their owners, and subclinical epilepsy cannot be excluded. The control dogs with epileptiform paroxysmal activity showed no closer relationship to the dogs with epilepsy than to the control groups on average. The majority of control dogs had relatives with epilepsy in their pedigrees at least in the 2nd or 3rd generations. The literature on humans clearly defines the higher prevalence of epileptic discharges (up to 50%) on the EEG recordings of the siblings of persons with epilepsy.[26] At present, we are unable to answer whether epileptiform activity in healthy individuals has some predictive value for the future development of epilepsy or indicate genetic carrier status in the FS dogs.

All of the dogs with epilepsy included in this study, according to information obtained from their owners,

Table 1. Results of mean relative power of electroencephalography background activity bands for different groups of Finnish Spitz dogs.

	Delta Band	Theta Band	Alpha Band	Beta Band
Group	Mean (±SD)	Mean (±SD)	Mean (±SD)	Mean (±SD)
FSE	82.33 (1.10)	10.46 (0.70)	3.79 (0.34)	2.92 (0.20)
FSENT	83.37 (0.90)	9.97 (0.65)	3.46 (0.27)	2.73 (0.17)
FSEPh	80.24 (1.74)	11.46 (1.00)	4.44 (0.55)	3.30 (0.29)
FSC	82.79 (0.61)	9.64 (0.27)	4.08 (0.18)	2.66 (0.14)

FSE, Finnish Spitz dogs with epilepsy; FSENT, subgroup of Finnish Spitz dogs with epilepsy without treatment; FSEPh, subgroup of Finnish Spitz dogs with epilepsy on phenobarbital monotherapy; FSC, group of all control Finnish Spitz dogs; SD, standard deviation.

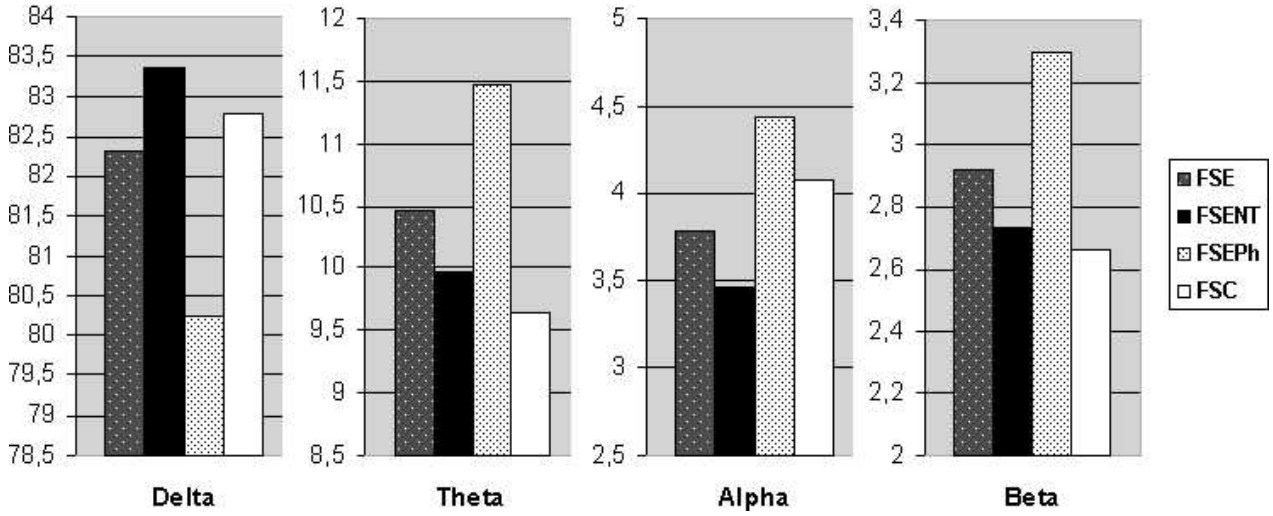

Fig 4. Results of mean relative power of electroencephalography background activity bands for different groups of Finnish Spitz dogs. FSE, Finnish Spitz dogs with epilepsy; FSENT, subgroup of Finnish Spitz dogs with epilepsy without treatment; FSEPh, subgroup of Finnish Spitz dogs with epilepsy on phenobarbital monotherapy; FSC, group of all control Finnish Spitz dogs.

suffered from focal seizures, and some with generalization. In 3 FSE dogs, focal epileptic activity was noted upon visual examination of the EEG records. Spike, polyspikes, and spike slow wave complexes were located in the posterior and occipital areas in all of them. Spikes and spike slow wave patterns are recognized as specific findings in many epileptic syndromes in human medicine.[25,27] These findings on EEG were the only abnormal findings detected in the dogs with epilepsy. Interictal EEG showed focal paroxysmal changes in 20% of the dogs with epilepsy. The results of other diagnostic tools (eg, blood tests, CSF, MRI, urinalysis) all were negative. All of the dogs with epilepsy with positive EEG findings were examined with 1.5 T MRI, and structural brain lesions were not observed. Therefore, the diagnosis for the dogs was idiopathic epilepsy. In a previous EEG study of dogs with epilepsy, focal epileptic activity occurred in 64%, but not all of the dogs were diagnosed with either idiopathic epilepsy or focal seizures.[6] In humans, epileptiform activity is found in 29 to 55% of patients with epilepsy at first EEG examination. The percentage can be increased up to 90% after repeated examination with sleep deprivation, hyperventilation, or photic stimulation.[24,27] Use of similar methods in veterinary medicine to increase the sensitivity of EEG findings is clearly restricted. Epileptiform activity in dogs with focal idiopathic epilepsy recorded interictally seems to be a less frequent finding as described until now.

Epileptic discharges in the occipital lobe are a relatively common finding in human patients, especially in children, but, as a separate epilepsy syndrome, they have been recognized only during the last 15 to 20 years.[28] FS dogs may experience focal idiopathic epilepsy originating from occipital or other posterior areas.

Quantitative EEG was used to analyze the frequencies of background activity. Two-second epochs from the recorded EEG were selected for qEEG. As mentioned in a previous study, this approach helps to maximally eliminate the negative influence of artifacts.[9] Suppression of the fast alpha and beta bands of the EEG by using medetomidine sedation was described previously in experimental dogs.[10] Similar reports involve the use of other sedative or anesthetic drugs used for

Table 2. Significance in electroencephalography background activity bands between different groups of Finnish Spitz dogs.

	DELTA Relative Power (%)	THETA Relative Power (%)	ALPHA Relative Power (%)	BETA Relative Power (%)
FSE versus FSC	NS	**	NS	**
FSENT versus FSEPh	***	**	***	***
FSENT versus FSC	NS	NS	***	NS
FSEPh versus FSC	**	***	NS	***

FSE, Finnish Spitz dogs with epilepsy; FSENT, subgroup of Finnish Spitz dogs with epilepsy without treatment; FSEPh, subgroup of Finnish Spitz dogs with epilepsy on phenobarbital monotherapy; FSC, group of control Finnish Spitz dogs; NS, not significant with significance level $P > .05$.

*, significant difference between compared study groups in the level of $P < .05$.

**, significant difference between compared study groups in the level of $P < .01$.

***, significant difference between compared study groups in the level of $P < .001$. Significance levels for delta, alpha, and beta bands were examined with nonparametric tests. Significance level for theta band was evaluated with parametric test.

EEG recordings.[4,8,12] The results of this study support this approach, because low delta and theta activity was the dominant background activity in all of the FS dogs, but alpha and beta bands were poorly represented. Slow theta and fast beta frequency bands appeared more frequently in dogs with epilepsy than in FSC, but only alpha activity showed a statistical difference between FSENT and FSC. An increase in the beta band was observed in a previous EEG study of healthy human volunteers after PO administration of phenobarbital and in a study of patients with epilepsy, but the results failed to reach statistical significance.[29,30] A dose-dependent increase in beta and theta bands after phenobarbital administration also is reported in rats.[31] Theta rhythm is associated with the use of sedatives (such as barbiturates or neuroleptics) in humans.[32] We observed highly significant differences in all background bands between untreated and treated dogs with epilepsy. The phenobarbital influence described here is in agreement with previous publications. Phenobarbital seems to increase the theta, alpha, and beta bands, and to decrease the delta band. The number of treated dogs in our study, however, was too small to draw conclusions about the clinical relevance of the described findings.

An EEG recording is an important part of the diagnostic evaluation in patients with epilepsy. Performing EEG in conscious dogs is very difficult because of the uncooperative or even aggressive behavior of some patients and the frequent muscle movement artifact. To eliminate these factors, sedation or anesthesia is necessary. A study by Viitmaa et al[14] reported the use of medetomidine as a single agent for the sedation of dogs with epilepsy during EEG recording. Sedation with medetomidine, an alpha-2 adrenergic agonist, is easily accomplished by IM injection. We used a dosage of 40–60 μg/kg and observed a good level of sedation within 20–30 minutes after injection in the majority of patients. Medetomidine is a highly selective apha-2 adrenoreceptor agonist with neuroprotective properties.[33] Conflicting reports discuss both alpha-2 agonist pro- and anticonvulsive properties. Some investigators found medetomidine to be a proconvulsive agent.[34,35] Nevertheless, the inability of medetomidine alone to induce seizures argues against direct pro-epileptic action. Therefore, by taking into account its ease of use and the availability of an antidote, we consider medetomidine the drug of choice for sedation during EEG recording in veterinary medicine. Moreover, a report on humans demonstrates an increase in the detection of paroxysmal epileptic activity in patients during sleep or drowsiness.[1]

An EEG is recommended as a routine examination in humans for the evaluation of patients with seizures.[1] However, limitations in the use of EEG in veterinary medicine include the interictal nature of the recordings, the need for sedatives or anesthesia, extensive muscles over the calvarium in dogs, expensive equipment available only in large referral institutions, and limited knowledge in the interpretation of EEG findings in veterinary medicine. Nevertheless, an EEG seems to be a sensitive examination for detecting abnormal brain activity even in sedated dogs. Certainly, an EEG has the potential to become more important in diagnosing epileptic conditions in veterinary neurology, especially in the referral setting. Both visual epileptic discharges and interictal background rhythms can provide information that may complement the patient's history and neurologic examination, and aid in diagnosis. The interictal EEG also can be normal in patients with epilepsy. Quantitative EEG analysis may increase the yield of diagnostic information in such patients.

Footnotes

[a] Medetomidine hydrochloride, Domitor 1 mg/mL, Orion Pharma, Espoo, Finland
[b] Siemens Magneton Symphony 1.5 T, Siemens AG, Medizinische Technik, Erlangen, Germany
[c] Picker Edge 1.5 T, Cleveland, OH
[d] Galileo Be Light Peripheral Configuration, EBNeuro, Firenze, Italy
[e] Polygraphic electrodes, BIONEN S.a.s., Firenze, Italy
[f] Thoracic respiratory transducer, BIONEN S.a.s., Firenze, Italy
[g] EEG needles, 30-gauge 15-mm monopolar stainless-steel needle electrodes, BIONEN S.a.s., Firenze, Italy
[h] Acquisition station RST Galileo System, EBNeuro, Firenze, Italy
[i] R Development Core Team (2005). R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing; 2005
[j] Phenobarbital, Barbivet vet 30 mg tab, Vetcare, Salo, Finland

Acknowledgments

This work was supported by the Archimedes Foundation (Estonia) and the Helvi Knuuttila Foundation (Finland). The authors thank the Finnish Spitz Breeder Club for its fruitful collaboration. We also thank the Central Laboratory, Department of Clinical Veterinary Sciences, University of Helsinki (Finland), for support with laboratory examinations and the Veterinary Clinic of the Estonian University of Life Sciences for its supply of EEG equipment and technical assistance.

References

1. Flink R, Pedrsen B, Guekht AB, et al. Guidelines for the use of EEG methodology in the diagnosis of epilepsy. Acta Neurol Scand 2002;106:1–7.

2. Klemm WR. Electroencephalography in the diagnosis of epilepsy. Probl Vet Med 1989;1:535–557.

3. Jaggy A, Heynold Y. Die idiopatische epilepsie des Hundes. Schweiz Arch Tierheilk 1996;138:523–531.

4. Srenk P, Jaggy A. Interictal EEG findings in a Golden Retrievers with idiopathic epilepsy. J Small Anim Pract 1996;37:317–321.

5. Jaggy A, Bernardini M. Idiopatic epilepsy in 125 dogs: A long-term study. Clinical and electroencephalographic findings. J Small Anim Pract 1998;39:23–29.

6. Holliday TA, Williams DC. Interictal paroxysmal discharges in the EEG of epileptic dogs. Clin Tech Small Anim Pract 1998;13:132–143.

7. Berendt M, Høgenhaven H, Flagstad A, et al. Electroencephalography in dogs with epilepsy: Similarities between human and canine findings. Acta Neurol Scand 1999;99:276–283.

8. Pellegrino FC, Sica REP. Canine EEG recording technique: findings in normal and epileptic dogs. Clin Neurophysiol 2004;115: 477–487.

9. Moore MP, Greene SA, Keegan RD, et al. Quantitative EEG in dogs anesthetized with 2.0% end-tidal concentration of isoflurane anesthesia. Am J Vet Res 1991;52:551–560.

10. Itamoto K, Taura Y, Wada N, et al. Effect of medetomidine on EEG and use of a q-EEG for evaluating sedation levels in dogs. J Vet Med A Physiol Pathol Clin Med 2001;48:525–535.

11. Itamoto K, Taura Y, Wada N, et al. Quantitative EEG of medetomidine, medetomidine-midazolam and medetomidine-midazolam-butorphanol in dogs. J Vet Med A 2002;49:169–172.

12. Bergamasco L, Accatino A, Priano L, et al. Quantitative EEG findings in beagles anaesthetized with propofol. Vet J 2003;166:58–66.

13. Croft PG. The EEG as an aid to diagnosis of nervous diseases in the dog and cat. J Small Anim Pract 1962;3:205–213.

14. Viitmaa R, Cizinauskas S, Bergamasco L, et al. Magnetic resonance imaging findings in Finnish Spitz dogs with focal epilepsy. J Vet Intern Med 2006;20:305–310.

15. Licht BG, Licht MH, Harper KM, et al. Clinical presentations of naturally occurring canine seizures: Similarities to human seizures. Epilepsy Behav 2002;3:460–470.

16. Radhakrishnan K, Santoshkumar B, Venugopal A. Prevalence of benign epileptiform variants observed in an EEG laboratory from South India. Clin Neurophysiol 1999;110:280–285.

17. Westmoreland BF. Epileptiform electroencephalographic patterns. Mayo Clin Proc 1996;71:501–511.

18. Zumsteg D, Andrade DM, Wennberg RA. Source localization of small sharp spikes: Low resolution electromagnetic tomography (LORETA) reveals two distinct cortical sources. Clin Neurophysiol 2006;117:1380–1387.

19. Beun AM, Boas W van Emde, Dekker E. Sharp transients in the sleep EEG of healthy adults: A possible pitfall in the diagnostic assessment of seizure disorders. Electroencephalogr Clin Neurophysiol 1998;106:44–51.

20. Stern JM, Engel J. Spindles. Atlas of EEG patterns. Philadelphia, PA: Lippincott Williams & Wilkins; 2005;255–256.

21. Stern JM, Engel J. Beta activity. In: Atlas of EEG patterns. Philadelphia, PA: Lippincott Williams & Wilkins; 2005;93–94.

22. Stern JM, Engel J. Benign epileptiform transients of sleep In: Atlas of EEG patterns. Philadelphia, PA: Lippincott Williams & Wilkins; 2005;87–88.

23. Noachtar S, Binnie C, Ebersole J, et al. A glossary of terms most commonly used by clinical electroencephalographers and proposal for the report form for the EEG findings. Electroencephalogr Clin Neurophysiol 1999(Suppl);52:21–41.

24. Jabbari B, Russo MB, Russo ML. Electroencephalogram of asymptomatic adult subjects. Clin Neurophysiol 2000;111:102–105.

25. Stern JM, Engel J. Interictal epileptiform discharges. In: Atlas of EEG patterns. Philadelphia, PA: Lippincott Williams & Wilkins; 2005;161–165.

26. Degen R, Degen HE, Hans K. A contribution to the genetics of febrile seizures: Waking and sleep EEG in siblings. Epilepsia 1991;32:515–522.

27. Pillai J, Sperling MR. Interictal EEG and the diagnosis of epilepsy. Epilepsia 2006;47(Suppl 1):14–22.

28. Taylor I, Scheffer IE, Berkovic SF. Occipital epilepsies: Identification of specific and newly recognized syndromes. Brain 2003;126:753–769.

29. Sannita WG, Rapallino MW, Rodriguez G, et al. EEG effects and plasma concentrations of phenobarbital in volunteers. Neuropharmacology 1980;19:927–930.

30. Herkes GK, Lagerlund TD, Sharbrough FW, et al. Effects of antiepileptic drug treatment on the background frequency of EEGs in epileptic patients. J Clin Neurophysiol 1993;10:210–216.

31. Sato H. Relationship between serum levels and fast EEG activities in rats by a single administration of phenobarbital. Electroencephalogr Clin Neurophysiol 1980;50:509–514.

32. Stern JM, Engel J. Theta activity. In: Atlas of EEG patterns. Philadelphia, PA: Lippincott Williams & Wilkins; 2005;273.

33. Jolkkonen J, Puurunen K, Koistinaho J, et al. Neuroprotection by the α2-adrenoceptor agonist, dexmedetomidine, in rat focal cerebral ischemia. Eur J Pharmacol 1999;372:31–36.

34. Mirski MAZ, Rossell LA, McPherson RW, et al. Dexmedetomidine decreases seizure threshold in a rat model of experimental generalized epilepsy. Anesthesiology 1994;81: 1422–1428.

35. Miyazaki Y, Adachi T, Kurata J, et al. Dexmedotomidine reduces seizure threshold during enflurane anaesthesia in cats. Br J Anaesth 1999;82:935–937.