Surface electroneurography of the tibial nerve in dogs

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Abstract

Electroneurography measures the speed of the action potential after nerve stimulation. The aim of this study was to evaluate the motor nerve conduction velocity in the tibial nerve after surface stimulation in healthy dogs, to correlate the obtained data by biological factors, and to compare these results with published findings utilizing needle electrodes. The study was performed in 11 clinically healthy dogs without anaesthesia. There were significant correlations among several indicators (age, limb length, conduction velocity, latency and duration of compound muscle action potentials). Age was found to have a significant effect on the duration of the compound muscle action potential from both stimulation sites (proximal/distal; $r = 0.68$, $r = 0.71$, $P < 0.05$), but there was no effect on the conduction velocity or amplitude of the compound muscle action potentials. Limb length was found to have a significant effect on the duration of the compound muscle action potential from the distal stimulation site ($r = 0.64$, $P < 0.05$), a significant effect on the conduction velocity ($r = -0.91$, $P < 0.01$), and a significant effect on the amplitude of the compound muscle action potential from both stimulation sites (proximal/distal; $r = -0.76$, $r = -0.63$, $P < 0.01$, $P < 0.05$ respectively). These results indicate that limb length should be considered as the most important biological factor in tibial nerve conduction studies and that electroneurography in dogs could be performed non-invasively, without a danger of infection, haematomas or complications related to anaesthesia.

Electrophysiology, neural conduction, electrodes, peripheral nerves, action potentials

Motor nerve conduction velocity (MNCV) testing is valuable in the detection of neuromuscular diseases: inherited and acquired polyneuropathies (Shelton et al. 2003; Gabriel et al. 2006; Vanhaesebrouck et al. 2008), general weakness (Jeffery et al. 2006), botulism (Uriarte et al. 2010), neuromuscular junction disorders (Meriggioli and Sanders 2005), polyradiculoneuritis (Hirschvogel et al. 2012), cauda equina syndrome (Sekiguchi et al. 2008), or peripheral nerve tumours (Le Chevoir 2012). Nerve conduction velocity (NCV) is defined as the speed at which an action potential propagates along a nerve. In humans, the velocity depends on many factors (age, limb temperature, etc.). Some similarities were described previously in dogs with utilizing needle electrodes (van Nes and van Den Brom 1986). Electroneurographic evaluation of the tibial nerve in healthy dogs was performed and reported by several authors; however, all of them used needle electrodes to stimulate the nerves directly which is more complicated and requires general anaesthesia (Lee and Bowen 1970; Swallow and Griffiths 1977; Takakura and Inada 1983). One recent study (Crespo et al. 2020) described electroneurographic evaluation of the tibial nerve in 25 dogs with orthopedic and neurological symptoms using recording surface electrodes but needle electrodes were used for stimulation.

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The purpose of our study was to evaluate the applicability of a new electroneurographic technique of performing nerve conduction velocity measurements with non-invasive surface stimulation and recording electrodes; to evaluate the obtained data by biological factors; and to compare the results with previously published findings recorded by different methods.

Materials and Methods

The tibial nerve was examined electroneurographically in 11 clinically healthy dogs. This experimental study was approved by the Animal Experimentation Ethics Committee of the University of Veterinary Sciences Brno (REFNO: ES_8-2021). Measurements of MNCV were performed by an electromyographic device (Keypoint® Portable, Medtronic, Denmark) with surface bipolar stimulating electrodes with soaked felt pads at the Small Animal Clinic of the University of Veterinary Sciences Brno by manually pressing the electrode to the skin analogically to human medicine with no influence of the animal's hair. The proximal stimulation site was distal to the stifle near the popliteal fossa and distal stimulation site lateral and proximal to the tuber calcanei just close to the anatomical pathway of the tibial nerve which was determined after studying canine anatomical models at the Department of Anatomy, Histology and Embryology. A surface recording electrode (argentchloride type of ten millimetre recording area covered with adhesive hydrogel) was placed on the plantar interossei muscles and fixed with a tape without clipping the hair. A grounding scalp electrode was placed subcutaneously above the tibia between the proximal stimulation site and recording electrode. A total of 11 dogs consisting of 9 males and 2 females, aged 4 months to 12 years, of 10 different breeds (including 1 mongrel dog) were examined. Rectal temperatures and limb lengths (measured as the distance between the two stimulation sites recorded by a tape measure) were recorded in all animals. We used supramaximal stimulation during the electroneurographic measurements in all dogs, no anaesthetic protocol or sedation were used. The mean values of age, body weight, rectal temperature, and limb length were 6.1 ± 4.4 years, 26.3 ± 13.4 kg, 38.3 ± 0.5 °C, and 109 ± 40 mm. Statistical analysis was done using the Statistica version 6.0 software (StatSoft, Inc., Tulsa, USA). All data are expressed as mean values ± SD. The Spearman rank R test was used for correlation studies. Level of significance was set at $P < 0.05$, unless specified otherwise.

Results

The mean values for stimulation, NCV, latency, duration, and amplitude of the compound muscle action potentials (CMAP, the *M-wave*) are summarized. The values from the right and left leg were not significantly different ($P > 0.05$), therefore they were combined. The mean value of stimulation at the proximal site was 30.7 ± 22 milliamperes (mA), at the distal site 34.0 ± 17 mA. The mean conduction velocity was 60.5 ± 19.1 metres per second (m/s). The mean latency of CMAP from stimulation at the proximal site was 6.5 ± 2.6 milliseconds (ms) and 4.5 ± 1.6 ms from stimulation at the distal site. The mean CMAP durations (negative phase of CMAP) were 2.6 ± 0.8 and 2.7 ± 1.0 ms (proximal and distal stimulation sites). The mean amplitude of CMAP (negative phase amplitude) from stimulation at the proximal site was 2.3 ± 1.3 millivolts (mV) and 2.8 ± 1.4 mV from stimulation at the distal site. All correlations among individual indicators are summarized in Table 1.

Table 1. Significant correlations between electrophysiological and biological indices.

	Age (years)	RT (°C)	LL (mm)	Velocity (m/s)	Latency 1 (ms)	Latency 2 (ms)	Duration 1 (ms)	Duration 2 (ms)
Mean	6.1 ± 4.4	38.3 ± 0.5	109 ± 40	60.5 ± 19.1	4.5 ± 1.6	6.5 ± 2.6	2.7 ± 1.0	2.6 ± 0.8
Correlation	Duration 1/2	Latency 1/2	Velocity	LL	Duration 1	Duration 1	Age Latency 1/2	Age

RT – rectal temperature; mm – millimetres; m/s – metres per second; ms – milliseconds; LL – limb length; Latency 1 – CMAP latency from stimulation at the distal site; Latency 2 – CMAP latency from stimulation at the proximal site; Duration 1 – CMAP duration from stimulation at the distal site; Duration 2 – CMAP duration from stimulation at the proximal site; CMAP – compound muscle action potential

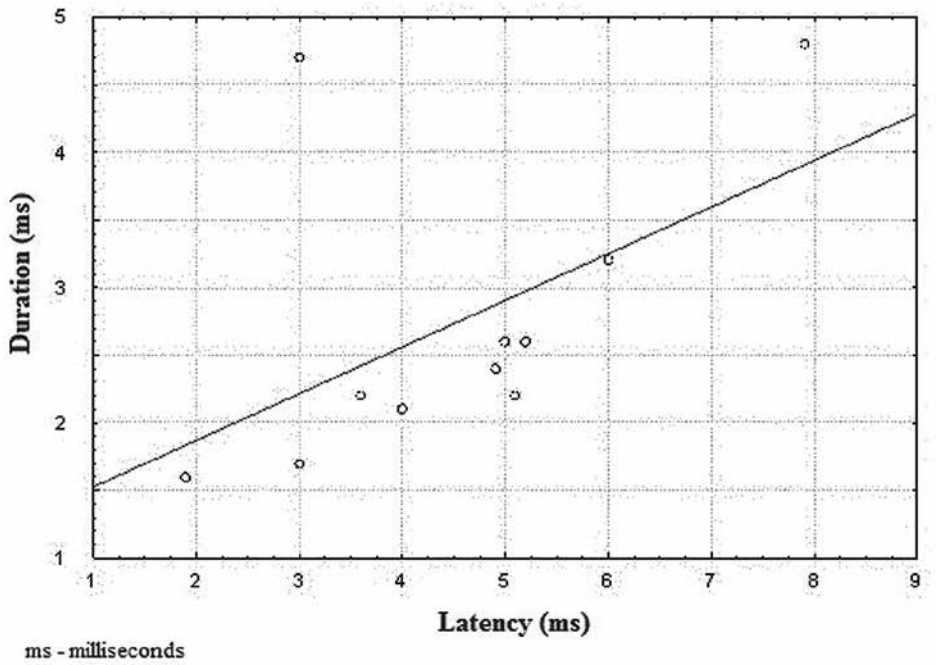

Fig. 1. The effect of limb length (latency) on the duration of the compound muscle action potential

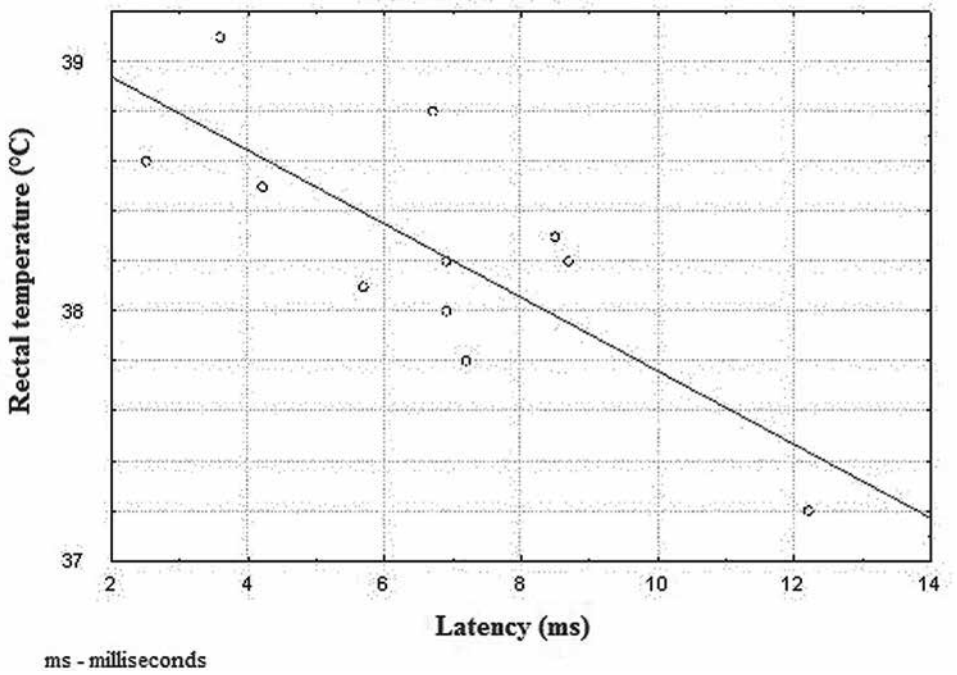

Fig. 2. The effect of rectal temperature on the latency of the compound muscle action potential

There was a significant negative correlation between rectal temperature and CMAP latencies from both stimulation sites (proximal/distal; r = −0.67, r = −0.64, $P < 0.05$). Age was found to have a significant effect on duration of CMAP from both stimulation sites (proximal/distal; r = 0.68, r = 0.71, $P < 0.05$). Limb length was found to have a significant effect on duration of CMAP from distal stimulation site (r = 0.64, $P < 0.05$), significant effect on conduction velocity (r = −0.91, $P < 0.01$) and significant effect on amplitude of CMAP from both stimulation sites (proximal/distal; r = −0.76, r = −0.63, $P < 0.01$, $P < 0.05$, respectively). Naturally, a significant correlation between limb length and body weight (r = 0.66, $P < 0.05$) was detected. A significant correlation between latency and duration of CMAP is shown in Fig. 1, significant correlation between rectal temperature and CMAP latency is shown in Fig. 2.

Discussion

Only a few studies focused on the methodology of MNCV and the associated indicators in dogs were published a long time ago; no recent studies are available because the needle stimulation technique is used without follow-up research in this area (Ichiyanagi et al. 1973; Lee and Bowen 1975; Walker et al. 1979). None of them used surface electrodes for stimulation (only needle electrodes). Conduction velocity recorded in our study in the tibial nerve between the right and left limbs is in agreement with results reported earlier (Lee and Bowen 1970; Swallow and Griffiths 1977). Our results showed that the conduction velocity measured in the canine tibial nerve with surface electrodes (60.5 ± 19.1 m/s) provided similar results to previous reports using needle electrodes (60 ± 1.7, 62.2 ± 2.1, 57.1 ± 5.5; Lee and Bowen 1970; Walker et al. 1979; Takakura and Inada 1983). Crespo et al. (2020) used recording surface electrodes for the evaluation of nerve conduction indicators but did not report the exact velocities in their study.

The high standard deviation in our results is due to the inclusion of one healthy dog with an exceptionally low value of NCV (m/s); most of the examined dogs' NCV was over 50 m/s, in some cases over 70 m/s. Van Nes and van Den Brom (1986) found significant differences in conduction velocity, amplitude, and duration of CMAP potentials between short-legged and long-legged dogs. In our study, limb length was found to have a significant effect on the conduction velocity ($P < 0.01$) and the CMAP amplitude from both stimulation sites. A significant correlation between CMAP latency (limb length) and the duration of CMAP from stimulation at the distal site was confirmed.

The CMAP amplitude depends on many factors and its range is very wide (1–56 mV) across the published studies (Lee and Bowen 1970; Chrisman et al. 1972; Takakura and Inada 1983; van Nes and van Den Brom 1986; Crespo et al. 2020). In our study, the CMAP amplitude values were in the lower spread which could be a consequence of surface versus subcutaneous recording (much better reproducibility of amplitude and CMAP duration is generally with surface recording electrodes). It is also important how the amplitude is measured, whether peak-to-peak or in the negative phase only, however, many authors do not describe their access precisely. In addition, we confirmed lower CMAP amplitudes from stimulation at the proximal site that had been previously described; we also observed a 30% decrease of amplitude from the proximal stimulation site compared to those from the distal stimulation site which corresponds with the 'physiological temporal dispersion' phenomenon (Cuddon 2002). Lower CMAP amplitudes obtained with surface versus needle recording were confirmed in a recent comparative study, as well. A possible explanation was that skin impedance interfered with recordings to a greater extent (14.97 ± 10.65 mV vs. 9.64 ± 5.13 mV; Crespo et al. 2020).

The CMAP duration values were a little lower than those published earlier. Walker et al. (1979) recorded CMAP duration for measuring MNCV in the distal tibial segment

4.0 ms, but whether it was for the negative phase of the action potential was not specified. Crespo et al. (2020) recorded a CMAP duration median value of 4.45 ms, but there was no difference in using the needle or surface recording electrodes. We did not find any influence of the rectal temperature (healthy dogs with values within the reference range) on NCV; however, temperature-related changes (decreased conduction in tissue hypothermia) were published in experimental studies (Ichiyanagi et al. 1973; Lee and Bowen 1975). We noticed an influence (negative correlation) of rectal temperature on CMAP latencies from both stimulation sites. This finding is not a consequence of the temperature's effect on peripheral nerves (because all dogs had a rectal temperature within 37.5–39.0 °C and we did not use any anaesthetic protocol) but it is directly related to the size of the individual animal. CMAP latency is a reflection of the limb length; bigger animals in our study had rectal temperatures closer to the lower limit and logically longer latencies because of their limb lengths, but no significant correlation was found between the rectal temperature and the body weight or the limb length. The correlation between age and NCV described previously was not statistically confirmed in this study, but most of the older dogs in our group had below-average values so it would be inaccurate to state that age has no effect on NCV in dogs (Swallow and Griffiths 1977). In our previous study focused on surface electroneurography of the ulnar nerve, the effect of age on NCV was recorded (Hajek et al. 2014). Nevertheless, NCV is not the only indicator that can be changed; a significant effect of age on the CMAP duration was recorded in this study. Swallow and Griffiths (1977) indicated that prolonged M-wave could be seen in older dogs. It is a question for further studies, how much importance we can attach to it.

We proved that nerve conduction measurements with surface stimulation and recording electrodes provide comparable results to needle electrodes. In fact, the most important indicator for clinical practice, conduction velocity, is identical. Beside conduction velocity, changes in the CMAP duration in long-legged dogs should be regarded. We found significant correlations between individual indicators in healthy dogs; some of them do not fully correspond to findings of studies done using other methods and different numbers of animals. Further studies are warranted to evaluate the potential changes of the obtained data in groups of dogs strictly divided according to age (especially young and old dogs). The first limitation of this study is a relatively small group of animals, but for comparison with similar studies it can be considered sufficient in veterinary medicine. The second limitation we see is in the nerve stimulation itself which can produce uncomfortable sensation or even pain without anaesthesia in both people and animals. Although the stimulation is very quick and the unpleasant feeling is very short (in some dogs we recognized signs of discomfort), electroneurography should always be indicated and performed by specialists in veterinary neurology.

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