

# Clinical and Electrophysiological Mapping of Nerve Root Injury Following Trauma of Brachial Plexus: A Retrospective Study in 23 Dogs and 42 Cats

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## Abstract

Objective of this study is to report mapping of nerve root injury with clinical and electrophysiological examination in cats and dogs following trauma of brachial plexus (TBP). Medical record of 65 patients (23 dogs and 42 cats) with brachial plexus injury without any fracture between July 2009 and January 2014 were reviewed. Needle electromyography, motor nerve conduction and/or sensory nerve conduction and somatosensory evoked potentials (SEP) of the forelimb were studied. Injured area was examined at necropsy in 3 cases (1 dog, 2 cats), and in 11 cases (4 dogs, 7 cats) during surgery. Assessment of cutaneous zone innervation revealed caudal brachial plexus lesion in 40 cases (29 cat and 11 dogs) and complete brachial plexus lesions in 25 cases (13 cats, 12 dogs). Nociception was also absent at the denervated cutaneous zone in all cases. Complete avulsion of isolated radial nerve roots was diagnosed in 11 cats and 5 dogs, and injury of isolated radial nerve roots was diagnosed in 4 dogs and 11 cats. Rest of the cases had complete avulsion (17 cats, 14 dogs) or injury (3 cats) of radial nerve roots in addition to other nerves' of the brachial plexus. In conclusion, Radial nerve roots prone to TBP, but other nerve roots of brachial plexus can also be affected. Electrophysiological assessment of TBP should be carried out as an ancillary diagnostic tool for determining affected nerves and type of lesion for radial nerve.

**Keywords:** Brachial plexus injury, Trauma, Electrophysiology, Dog, Cat

## Travmatik Brakial Pleksus Yaralanmalarının Klinik ve Elektrofizyolojik Olarak Değerlendirilmesi: 23 Köpek ve 42 Kedide Retrospektiv Bir Çalışma

### Özet

Bu çalışmanın amacı kedi ve köpeklerde brakial pleksus travmasını takiben oluşan sinir kökü hasarının klinik ve elektrofizyolojik muayene ile haritalanmasını bildirmektir. Çalışmada herhangi bir kırığa bağlı olmaksızın gelişen brakial pleksus yaralanması ile Haziran 2009 ve Ocak 2014 arasında kliniğimize başvuran 65 hastanın (23 köpek, 42 kedi) medikal kayıtları incelendi. Elektrofizyolojik olarak iğne elektromyografi, motor sinir iletimi ve/veya sensorik sinir iletimi ve somatosensörük uyandırılmış potansiyeller çalışıldı. Hasarlı bölge üç hastada (1 köpek, 2 kedi) nekropside, 11 hastada ise (4 köpek, 7 kedi) cerrahi girişim sırasında incelendi. Kutanöz innervasyon alanlarının değerlendirilmesi sonucunda 40 olguda (29 kedi, 11 köpek) kaudal ve 26 olguda (14 kedi, 12 köpek) total brakial pleksus yaralanması belirlendi. Ayrıca bütün olgularda denerve kutanöz alanlarda nosisepsiyon yoktu. On bir kedi ve 5 köpekte izole radial sinir köklerinin total avulzasyonu belirlendi. Dört köpek ve 11 kedide izole radial sinir kökü hasarı tespit edildi. Geriye kalan vakalarda radial sinir ile birlikte diğer brakial pleksus sinirlerinin total avulzasyonu (18 kedi, 14 köpek) ya da hasarı (3 kedi) belirlendi. Sonuç olarak, brakial pleksusu oluşturan sinirlerden radial sinir travmatik olarak en çok yaralanan olsa da diğer sinirlerin de yaralanması söz konusudur. Travmatik brakial pleksus lezyonlarının değerlendirilmesinde elektrofizyolojik muayene, lezyonun tipinin ve etkilenen sinirin belirlenmesi açısından yararlı bir tanı aracı olarak göz önünde bulundurulmalıdır.

**Anahtar sözcükler:** Brakial pleksus hasarı, Elektrofizyoloji, Travma, Köpek, Kedi

## INTRODUCTION

Traumatic brachial plexus injuries are explained as traction injury, which occurs while the limb is abducted

severely from the body, and the entire shoulder mechanism is driven away from its normal position <sup>[1,2]</sup>. Brachial plexus



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injuries are the most common neurological disorder of the forelimb in small animals [1,3]. They can occur separately, or can be accompanied by fractures of the humerus or Horner's syndrome [4].

The dorsal and ventral rootlets of the C6-T2 spinal cord segments form the spinal nerves from which the ventral branches arise and interweaving of them lead to the formation of the brachial plexus. Individual peripheral nerves coming from brachial plexus descend distally to innervate the muscles of the forelimb. The dorsal branches that arise from spinal nerves innervate paraspinal muscles and skin [2,5]. Following trauma different nerves of the brachial plexus can be affected in different degrees, and the combination of these multiple injuries causes varying degree of deficits effecting forelimb muscles [3]. The prognosis for most brachial plexus injuries is poor for functional return of the limb [6].

Recent development in imaging technology provide to diagnosis brachial plexus nerve roots lesion in human, but limited number of study published in dogs [7]. Ultrasonography is another valuable diagnostic tool in the setting of suspected brachial plexus lesion especially a mass or traumatic lesion in humans [8]. However, the functional integrity of brachial plexus injury can be evaluated through neurological and electrophysiological examination. Cutaneous sensation can be used as a clinical tool in localizing peripheral nerve lesions. Autonomous zones are those sensory areas of the skin supplied only by particular nerve lesions. The clinician should be familiar with these autonomous zones. With brachial plexus injuries, there may be inconsistency in patterns of sensory versus motor deficits as the ventral nerve roots appear to be more susceptible to damage than the dorsal roots [6]. Reports for electrophysiological examinations of dogs and cats are limited in number [9]. The objective of this study was to report mapping of nerve root injury with clinical and electrophysiological examination of traumatic brachial plexus injury in dogs and cats.

## MATERIAL and METHODS

Medical records of Ankara University Faculty of Veterinary Medicine Department of Surgery were searched between July 2009 and January 2014 for the cases presented with the clinical signs of brachial plexus injury without any fracture and had electrophysiological examination. Breed, age, sex, aetiology and the time passed since trauma were recorded.

Neurological examination findings were retrospectively analysed to record clinical signs of injury to radial, median-ulnar, musculocutaneous and suprascapular nerves. Each nerve involved was diagnosed by its characteristic clinical findings. Radiological examination was also carried out to diagnose fracture and/or luxation of the forelimb. The

distribution of sensory loss in an affected limb has great localizing value because lesions can be pinpointed to a particular nerve or within two to three spinal cord segments. The total area innervated by a particular cutaneous nerve is termed "cutaneous area". The cutaneous area includes a peripheral overlap zone innervated by other cutaneous nerves and a central autonomous zone innervated solely by that nerve. These zones can be detected clinically using a method termed the "two-step pinch technique" [6]. The motor deficits associated with brachial plexus injury were accepted as the major clinical signs for determining affected nerve. According to the cutaneous sensation and affected nerves, brachial plexus injury was further classified as cranial (C6-C7 nerve roots - loss of shoulder movement and elbow flexion), caudal (C8-T2 nerve roots - elbow flexion are spared) or complete (C6-T2 nerve roots - loss of extension and flexion in all joints) lesion [1].

Electrophysiological assessment was carried out under general anesthesia. This was achieved using xylazine hydrochloride (2 mg/kg IM, Alfazyne®, Izmir, Turkey) and ketamine hydrochloride (15 mg/kg, IM, Alfamine®, Izmir, Turkey). All of the electrophysiological assessments were performed after the 5<sup>th</sup> day from the injury.

Stainless steel disposable monopolar needle electrodes (diameter: 0.3 mm and length: 12 mm) were used for all recordings and stimulations. The recording electrodes were attached to a 5-channel electromyography - evoked potentials (EMG/EP) system (Medelec, Oxford).

*Electromyography:* In all cases digital extensor muscles, triceps brachii muscles, biceps brachii muscles, superficial and/or deep digital flexor muscles, supraspinatus muscle, infraspinatus muscle, deltoid muscle and paraspinal muscles were assessed for presence of denervation potentials (fibrillation potentials, positive sharp waves and complex repetitive discharges).

*Motor nerve conduction studies:* This was carried out for radial and ulnar nerves. Frequency limits for recording were 10 Hz-2 KHz, sweep duration was 10 msec. A rectangular 0.1 ms duration stimulus at supramaximal intensity was used and at least 3 consecutive, repeatable compound muscle action potentials (CMAP) were recorded. The distal stimulation point of the radial nerve was at the flexor angle of the elbow. A cathode electrode was inserted near the radial nerve, just lateral to the cephalic vein and an anode was inserted subcutaneously about 1 cm laterally. The proximal stimulation point of the radial nerve was at the mid-portion of the humerus. Active electrode was inserted sub facially over the common extensor digitalis muscle, and the reference electrode was inserted subcutaneously 1-2 cm laterally to the cathode electrode. The distal stimulation point of the ulnar nerve was at the medial aspect of the elbow joint and just caudally to the epicondylar crest of the humerus. The cathode electrode was inserted subcutaneously over the olecranon. The

proximal stimulation point of the ulnar nerve was at the medial aspect of proximal third of humerus and just cranial to brachial arteries. Recording was carried out from the digital flexor muscles. Ground electrode was inserted between stimulating and recording electrodes.

*Sensory nerve conduction studies:* This was carried out for radial and ulnar nerves. The stimulation point for the radial nerve was from its superficial branch over the carpal joint. Recording was from the radial nerve over the cranio-lateral elbow joint and the reference electrode 1-2 cm laterally to the radial nerve. The stimulation point for the ulnar nerve was from its dorsal branch over the metacarpal bones and recording was from the same point as for distal ulnar nerve stimulation point for motor nerve conduction study. The ground electrode was inserted between stimulating and recording electrodes. Presence of sensory nerve action potentials (SNAP) with profound denervation in related muscles was accepted as an indicator of dorsal root avulsion.

*Somatosensory Evoked Potential (SEP):* SEP was performed in radial nerve SNAP recorded cases. The radial nerve was stimulated as described before for motor nerve conduction studies, and SEP was recorded from the scalp and 250 responses were averaged. Presence of the potential was accepted as an indicator of dorsal root integrity, and absence was accepted as preganglionic loss of integrity.

Results of the neurological examination and electrophysiological assessment were compared.

## RESULTS

Twenty-three dogs and 42 cats matched the inclusion criteria. All animals had forelimb paresis or paralysis without fracture or luxation of the forelimb. Dog breeds presented were mainly medium to large size breeds. (Anatolian Sheep dog (n=5), Doberman (n=1), Rottweiler (n=1), German Shepherd dog (n=1), Golden Retriever (n=2), Afghan Hound (n=1) and mixed breed (n=12, minimum 15 kg). Cat breeds were mainly domestic short haired except two Angora cat and three Van cat. The mean age was 2.68 years (5 months–9 years) for dogs and 1.78 years (1 months–8 years) for cats. The sex dispersion was 14 male, 9 female for dogs, and 24 male, 18 female for cats. The etiology of the brachial plexus injury was traffic accidents (n=13 dogs, n=8 cats), falling from heights (n=2 cat), fighting (n=1 dog), and unknown causes (n=9 dog, n=32 cats). All the cases were outdoor pets.

The mean time between trauma and presentation was 12 days (5-60 days). The left fore limb was involved in 17 dogs (73.9%) and the right fore limb in 6 dogs, and the left fore limb in 31 cats (73.8%) and the right fore limb in 11 cats. Two cats were presenting Horner's syndrome in addition to brachial plexus injury.

Cutaneous sensation mapping were suggestive of

complete brachial plexus trauma in 13 cats and 12 dogs (38.46%), and caudal brachial plexus trauma in 29 cats and 11 dogs (61.54%). Nociception was also absent at the area without cutaneous twitches. Cranial brachial plexus trauma was no seen in any case.

The affected nerves based on needle EMG in dogs were; isolated radial nerve (n=10, 43.47%), radial, ulnar - median, suprascapular and musculocutaneous nerves (n=8) and radial, ulnar - median nerves (n=2), and radial, ulnar - median, musculocutaneous nerves (n=3) (Fig. 1a-1b). The radial nerve was unexcitable after stimulating from the distal point in 17 dogs, while in the remaining 6 cases, the motor nerve conduction velocity was lower than 40 m/s.

The affected nerves in cats were; isolated radial nerve (n=22, 52.38%), and radial, ulnar - median nerves (n=7, 16.66%), and radial, ulnar - median, suprascapular nerves (n=2), and radial, musculocutaneous (n=2), and radial, ulnar-median, suprascapular, musculocutaneous nerves (n=9). The deltoid muscle was not evaluated in cats because of its small size. The radial nerve was unexcitable after stimulating the distal point in 25 cats (62.5%), while means motor nerve conduction velocity were under the reference values in the rest. Radial SNAP was recorded in six dogs and 15 cats, while SEP was reliable and repeatable in 3 of dogs and 12 of cats.

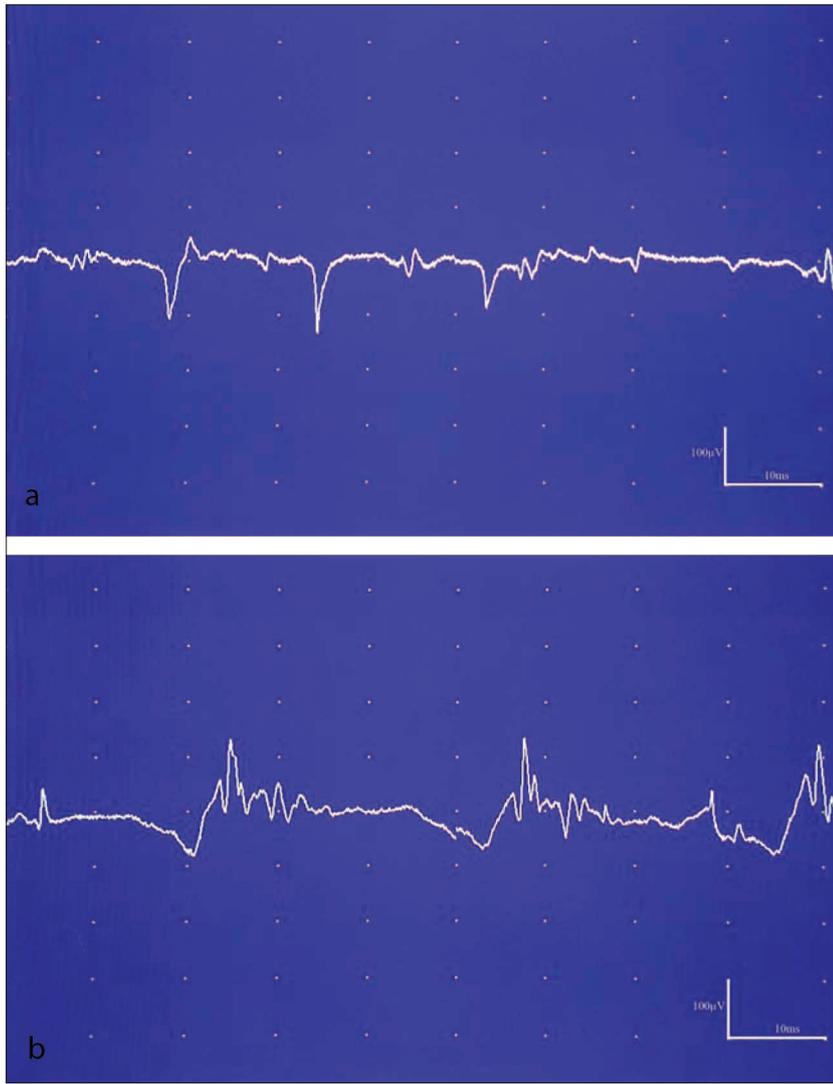
The type of lesion for radial nerve, identified by electrophysiological examination was avulsion of the isolated radial nerve roots in 11 cats and 5 dogs (Fig. 2). Isolated radial nerve injury or avulsion of some of its roots was diagnosed in 11 cats and 4 dogs (Fig. 3). Rest of the cases had avulsion (17 cats, 14 dogs) or injury (3 cats) of radial nerve concomitant to other nerves of the forelimb.

The C6-8 and T1 nerve roots found to be avulsed in the post mortem examination of 2 euthanized cats. However just C7 and C8 nerve roots were avulsed in one cat. Post mortem examination of one of the dogs revealed that all the nerve roots of brachial plexus were avulsed (Fig. 4). The lower part of the brachial plexus was exposed surgically in 11 cases (4 dogs, 7 cats). Among these cases, avulsed stump of probably C7 and C8 nerve roots was seen in 2 dogs and 4 cats. There was no abnormality in the exposed area in the rest of cases.

When the clinical signs were compared to the affected nerve which was diagnosed by the needle EMG, cranial brachial plexus trauma was not seen individually in both methods and the results was at the same line.

## DISCUSSION

In this study, the involved nerves and preganglionic or postganglionic injury for radial nerve roots was depicted by electrophysiological evaluation. Most of the cases had

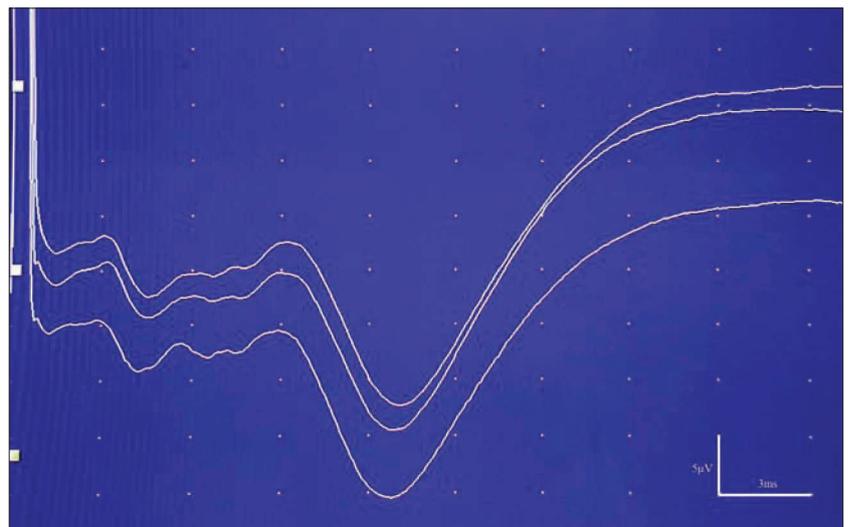


**Fig 1.** a- Abnormal spontaneous activity, in the form of positive sharp waves in extensor digitorum communis muscle in a dog; b- Abnormal spontaneous activity in the form of mainly fibrillation potentials in triceps brachii muscle in a dog

**Şekil 1.** a- Bir köpekte ekstensor digitorum communis kasında ağırlıklı olarak pozitif keskin dalgalardan oluşan anormal spontan aktivite, b- Bir köpekte triceps brachii kasında ağırlıklı olarak fibrilasyon potansiyellerinden oluşan anormal spontan aktivite

**Fig 2.** In SEP study, triphasic reproducible potentials following stimulation of radial nerve and recording from scalp in cats with radial nerve injury

**Şekil 2.** Radial sinir hasarı olan bir kedide yapılan SEP çalışmasında, radial sinirin uyarılmasıyla oluşan ve kafadan kaydedilen trifazik tekrarlanabilir potansiyeller



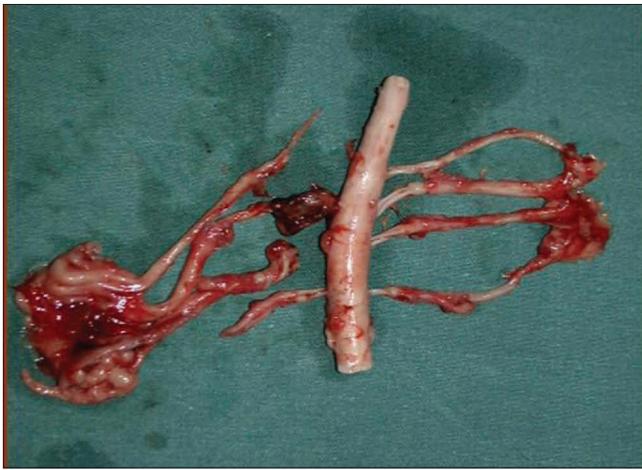
avulsion-type (preganglionic) injuries of the radial nerve in both dogs and cats, and there was no other case with isolated nerve injury of forelimbs except for the radial nerve based on clinical and needle EMG results of this study.

Traumatic brachial plexus injury is a traction injury, which usually results from traffic accidents [10]. Although unknown causes and traffic accidents were cited in equal numbers in the present study. The cases presented as



**Fig 3.** Sensory nerve action potential following stimulation from superficial branch of radial nerve over the carpal joint and recording from the nerve over the cranio-lateral elbow joint in a dog

**Şekil 3.** Bir köpekte karpal eklem üzerinden geçen radial sinirin süperfişyal dalının uyarımı sonucu oluşan ve kraniyolateral dirsek eklemi üzerindeki sinirden kaydedilen sensorik sinir aksiyon potansiyeli



**Fig 4.** Macroscopic appearance of root avulsions in dog.

**Şekil 4.** Köpekte sinir kökü avulzasyonunun makroskopik görünümü

unknown causes were identified as their forelimbs could not support their body weight and all of them were kept outdoors. It is not wrong to assume some sort of trauma (traffic accidents or falling from height) could be cause behind the initial trauma. All of the dog cases in this retrospective study were medium to large sized dogs. This indicates a relationship between body weight and traumatic injury to brachial plexus. We speculate that the force responsible for injury is greater in larger dogs. The body side involved in TBP was predominantly (73.84%) the left in both dogs and cats. However, this interesting finding is likely being coincidental; the authors think it should be investigated in more detail.

Spinal nerve roots are more susceptible to traction injury. This is likely because they contain less connective tissue than the extra-vertebral neural structures. This is possibly why the nerve roots are often avulsed from the spinal cord intradurally rather than the more peripheral portions of the nerves [1,11]. Caudal and complete avulsions are more common than cranial avulsions and cause more severe clinical signs [12]. They both cause paralysis of the

triceps brachii muscle, so the animal cannot extend the elbow or bear weight on the affected limb. In this case series the incidence of caudal brachial plexus injuries was higher (69.04%) than complete brachial injury in cats, however caudal brachial plexus injury was 47.82% in dogs. Cranial avulsion was not diagnosed in the current retrospective cases. These differences between both species should be followed in more detail. The absence of cranial lesions can be explained by the concentrated force in this area is weaker than the caudal area, or the differences between roots of two area (eg. Amount of fibrose tissue around the roots).

The affected radial nerve was seen as isolated or associated with other nerves in both dogs and cats in the current study. There was no other isolated nerve involvement of the forelimb in any case. These findings indicate that radial nerve which innervates the main weight bearing muscles of the fore limb is dominant clinically and electro physiologically. However multiple nerve injuries are common because they share some of the nerve root. When the associated nerve was evaluated, the ulnar median and musculocutaneous nerve was affected most commonly. These findings are important for prognosis and also to justify the treatment procedure like tendon transposition for restoration of phalangeal extension.

Electrophysiological assessment of traumatic injury of the brachial plexus is the most reliable method in human and veterinary medicine [13,14]. Electrophysiological findings are found to be more characteristic for the axonal degeneration that occurs after the 5<sup>th</sup> day, and most authors prefer to evaluate 5-10 days after trauma. The ventral nerve roots are most often involved in humans [15]. Electrophysiological examination was performed after 5 days in all cases in the current study. The radial nerve was found to be unexcitable during standard nerve conduction studies in 40 cases. This finding represents axonal degeneration. Sensory nerve conduction studies are

the first choice to determine whether the injury site is preganglionic or post-ganglionic [13,15,16]. When the damage to the sensory fibers is proximal to the dorsal root ganglia, the distal sensory fibers are viable, thus producing normal sensory nerve action potentials in the forelimb. In contrast, if the injury is to the nerve forming the plexus, Wallerian degeneration of axons distal to the injury occurs and no sensory nerve action potential would be detectable. Somatosensory evoked potentials can also be used to estimate pre-ganglionic or postganglionic involvement of brachial plexus roots in humans [17,18]. However, in an excitable nerve SEP cannot be recorded reliably. In this study, the type of injury was elucidated by standard sensory nerve conduction studies, but in cases where there was doubt; SEP was studied to clarify root avulsion or brachial plexus lesion. The presence or absence of SNAP and/or SEP was found to be valuable as an indicator of the type of lesion. Decrease in nerve conduction velocity relative to the previously reported reference values was interpreted as partial involvement of the nerve [16,19,20].

EMG may be helpful in assessing the functional integrity of brachial plexus in determining the extent and severity of brachial plexus lesion and in distinguishing such a lesion from nerve root or peripheral nerve pathology [13]. In the current study, paralysis of involved nerves of the extremity was diagnosed with needle EMG. Identification of denervation activity in a muscle was accepted as an indicator of paralysis of its nerve. Spontaneous denervation activity was found in all animals that underwent needle EMG examination. The results were in agreement with the clinical examination results.

Management methods and prognosis differ for brachial plexus injury depending on the nerve involved and the type and the level of the lesions present (pre-postganglionic) [21]. One of the most important roles of electromyography in traumatic brachial plexus injury is to clarify whether nerve root avulsion or brachial plexus injury is present [15]. However anatomical confirmation is the best way to make clear conclusions. In this case series avulsed roots were seen in 8/11 cases that were surgically explored. Even though in 3 cases there was no abnormality at the brachial plexus after exposing surgically, in both clinically and electrophysiologically diagnosed complete brachial plexus injury.

In conclusion, large size dogs have a predisposition for traumatic brachial plexus injury and the nerve roots of the radial nerve are affected predominantly in both dogs and cats. Before planning treatment for traumatic brachial plexus injury, the possibility of involvement of associated nerves in addition to the radial nerve and also the fact that avulsion-type injuries are dominant in dogs and cats should be kept in mind. In electrophysiological evaluation

(EMG, sensory and motor nerve conduction studies and SEP) can be suggested to identify the nerves involved and the type of injury.

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