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The Usefulness of the HASTE Sequence in the Diagnosis of Spinal Diseases in Dogs and Cats

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Abstract: Single-shot turbo spin-echo sequences are dense T2-weighted sequences that are well suited for evaluating the subarachnoid space. In T2-weighted fast spin-echo sequences routinely used in spinal magnetic resonance (MR) imaging, the subarachnoid space is poorly distinguished from the surrounding epidural fat, which may lead to the under detection of neurological disorders. We aimed to determine the utility of the Half-ourier single-shot turbo spin-echo (HASTE) sequence in the diagnosis of neurological disorders in dogs and cats and the agreement between the HASTE sequence and T2 sequences. The study included 17 patients (cats and dogs) with suspected neurological disorders and an indication for magnetic resonance imaging. One observer was initially asked to interpret T2-weighted images only and then T2-weighted and HASTE sequences together. The MR images were anonymized and no signal, history, or clinical information was provided. Without the HASTE sequence, the observer recognized 71% of the neurological disorders. With the addition of the HASTE sequence, the observer recognized 100% of the neurological disorders. After the addition of the HASTE sequence, the observer was able to make a more accurate diagnosis with a difference of 29%. In addition, according to the results obtained, a moderate to good diagnostic agreement was found between T2-weighted and T2-weighted + HASTE sequences. Without the HASTE sequence, the observer was able to localize 89% of the lesions. With the addition of the HASTE sequence, the observer was able to localize 100% of the lesions, the difference of 11% was not statistically significant (P=0.15). In conclusion, our study has shown that the acquisition of single-shot fast spin-echo sequences in addition to standard T2-weighted fast spin-echo sequences provides more accurate detection of neurological disorders and provides advantages in terms of localization of neurological disorders.
Keywords: Cat, dog, HASTE sequence, magnetic resonance imaging, neurological disorders

Kedi ve Köpeklerde Spinal Hastalıklarının Teşhisinde HASTE Sekansının Kullanılabilirliği

Öz: Tek atışlı turbo spin-eko dizileri, subaraknoid boşluğu değerlendirmek için oldukça uygun olan yoğun T2 ağırlıklı sekanslardır. Spinal manyetik rezonans (MR) görüntülemede rutin olarak kullanılan T2 ağırlıklı hızlı spin-eko sekanslarında, subaraknoid boşluk çevredeki epidural yağdan yeterince ayırt edilemez ve bu durum nörolojik bozuklukların yeterince tespit edilememesine yol açabilir. Amacımız, köpeklerde ve kedilerde nörolojik bozuklukların tanısında yarım fourier tek atışlı turbo spin-eko (HASTE) sekansının kullanışlılığını ve HASTE sekansı ile T2 ağırlıklı sekans arasındaki uyumu belirlemekti. Çalışmaya nörolojik bozukluk şüphesi olan ve manyetik rezonans görüntüleme endikasyonu olan 17 hasta (kediler ve köpekler) dahil edildi. Bir gözlemciden başlangıçta yalnızca T2 ağırlıklı görüntüleri, sonrasında ise T2 ağırlıklı ve HASTE sekansı görüntülerini birlikte yorumlaması istenmiştir. MR görüntüleri anonimleştirildi ve hiçbir sinyal, geçmiş veya klinik bilgi sağlanmadı. HASTE sekansı olmadan gözlemci nörolojik bozuklukların %71'ini tanıdı. HASTE sekansının eklenmesiyle gözlemci nörolojik bozuklukların %100'ünü tanıdı. HASTE sekansının eklenmesinden sonra gözlemci %29'luk bir farkla daha doğru tanı koyabilmiştir. Ayrıca elde edilen sonuçlara göre, T2 ağırlıklı ve T2 ağırlıklı + HASTE sekanslar arasında orta ve iyi düzeyde bir tanısal uyum tespit edildi. HASTE sekansı olmadan gözlemci lezyonların %89'unu lokalize edebildi. HASTE sekansının eklenmesiyle gözlemci lezyonların %100'ünü lokalize edebildi, %11'lik fark istatistiksel olarak anlamlı değildi (P=0.15). Sonuç olarak çalışmamız, standart T2 ağırlıklı hızlı spin-eko dizilerine ek olarak tek atımlı hızlı spin-eko dizilerinin elde edilmesinin spinal lezyonların daha doğru tespitini sağladığını ve spinal lezyonların lokalizasyonu açısından avantajlar sağladığını göstermiştir.
Anahtar Kelimeler: HASTE sekansı, kedi, köpek, manyetik rezonans görüntüleme, nörolojik bozukluklar

Introduction

Magnetic resonance imaging (MRI) is regarded as the "gold standard" for spinal imaging in both humans and veterinary patients due to the detailed tissue information it provides, and its greater safety compared to radiography, computed tomography, or myelography (Dennis, 2011). T2-weighted spin-echo sequences are commonly utilized for imaging the brain, spinal cord, and subarachnoid space (Pease et al.,

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2006). Ultra-fast heavily T2-weighted sequences, such as the HASTE sequence, were initially developed for cardiac and abdominal imaging (Burke et al., 2021). HASTE is a proprietary term used by Siemens Medical Solutions (Malvern®, PA, USA) (Seiler et al., 2012). This sequence is advantageous for neurological imaging in both humans and animals due to the high signal obtained from cerebrospinal fluid (CSF) in the subarachnoid space and ventricular system (Mankin et al., 2012; Pease et al., 2006). The HASTE sequence provides a high signal from the CSF without capturing signals from fat (Khan and Freeman, 2023), allowing the vertebral canal to be scanned for compressive lesions and enabling the identification of structural changes caused by cerebrospinal fluid (Pease et al., 2006).

This study aimed to investigate the usability of the HASTE sequence in the diagnosis of various neurological disorders in cats and dogs and to evaluate the agreement between the HASTE sequence and the T2 sequence.

Material and Methods

The experimental protocol was approved by the Animal Experiments Ethics Committee of Burdur Mehmet Akif Ersoy University, Faculty of Veterinary Medicine (protocol number: 1276/2024). The study involved 17 cats and dogs with suspected neurological disorders, for which magnetic resonance imaging (MRI) was warranted. Each patient underwent a thorough clinical and neurological evaluation, and lesion localization was determined following the neurological assessment. Recorded data included patient history, time to examination, trauma type, and neurological grade. Neurological grading was performed using the Modified Frankel Scale, which categorizes cases as follows: 0= paraplegia without deep pain sensation, 1= paraplegia without superficial pain sensation, 2= paraplegia with deep pain sensation intact, 3b= non-ambulatory paraparesis unable to bear weight on hind limbs without support, 3a= non-ambulatory paraparesis capable of bearing weight on hind limbs without support, 4= ambulatory paraparesis, 5= normal gait with paraspinal paresthesia (Griffin et al., 2009). Additionally, cases were classified based on onset as peracute (<1 hour), acute (1-24 hours), and chronic (>24 hours) according to Scott and McKee (1999).

All MRI examinations were conducted under general anesthesia. The patients were placed under general anesthesia with a combination of medetomidine (respectively, 0.08 ml/kg and 0.1 ml/kg, intramuscular (IM), Tomidin, Provet, Turkey) and ketamine (5 mg/kg, IM, Alfamin, Erse, Turkey). The effect of medetomidine was then reversed with atipamezole (100 µg/kg IM, Reversal, Provet, Turkey) at the end of MRI. Imaging was performed with a 1.5 T MRI scanner (MAGNETOM-Avanto, Siemens) with patients positioned prone. Based on neurological examination findings, lesion areas were localized, and T2-weighted sagittal and transverse, as well as dorsal and sagittal HASTE sequences, were acquired from the specified regions. Imaging parameters varied according to patient size (T2-weighted sequence: TR= 900-3970 ms, TE= 76-130 ms, slice thickness= 2.5-3.5 mm; HASTE sequence: TR= 8000 ms, TE= 341-346 ms, slice thickness=0.8-1.0 mm). An experienced veterinary surgeon reviewed all MRIs using a standard DICOM viewer (MicroDicom viewer).

The MR images were anonymized, and the observer was blinded to the animal's signalment, history, clinical findings, final diagnosis, and study objective. However, the observer was informed that a spinal lesion was anticipated. They were instructed to analyse the images, identify any important lesions, and make a diagnosis based on the findings. Initially, the observer was shown only transverse and sagittal images from the T2-weighted sequence. Afterward, T2-weighted and HASTE images were provided together for re-evaluation. The observer was also asked to rate their diagnostic confidence on a scale of 1-3 (1= sure, 2= somewhat sure, 3= not sure) (Seiler et al., 2012).

Statistical Analysis

The statistical analyses were conducted using the IBM SPSS Statistics 27 software package. A significance threshold of $P<0.05$ was applied. Categorical variables were represented as "n, %n." Agreement between sequences used in magnetic resonance imaging was evaluated using Cohen's Kappa test. Wilcoxon Signed Rank test was used to determine whether the difference between the two sequences was significant in terms of lesion localization.

Results

The study included a total of 8 dogs and 9 cats. The dog breeds were as follows: French Bulldog (n=1), Pincher (n=1), Terrier (n=2), and, Mixed breed (n=4). The cat breeds were Mixed (n=7) and Scottish Fold (n=2). Among the dogs, there were 4 males (50%) and 4 females (50%), while the cats consisted of 4 males (45%) and 5 females (55%). The median age of the dogs was 5.7 years, with a range from 2 to 13 years, and for cats, it was 5.3 years, ranging from 2 to 10 years.

The clinical severity scores for dogs were: grade 0 (n=2), grade 1 (n=1), grade 2 (n=4), and grade 4 (n=1). For cats, the scores were: grade 0 (n=4), grade 1 (n=1), grade 2 (n=3), and grade 4 (n=1). Time to examination was classified as acute (n=2) and chronic (n=6) for dogs, and acute (n=3) and chronic (n=6) for cats (Table 1).

Table 1. Signalement, examination, and neurological findings

Case	Breed, gender, age	Patient history	Duration	Neurological examination findings	Neurological grading	Diagnosis
1	Dog, mixed, male, 4 y	Non-ambulation	Acute	Paraplegia, deep pain sensation present, UMN findings present	2	IVDH
2	Dog, pincher, female, 2 y	Seizures	Chronic	Tetraparasia, generalized pain, decreased corneal reflex, phantom scratching	4	Chiari-like malformation
3	Dog, mixed, male, 2 y	Non-ambulation	Acute	Paraplegia, deep pain sensation present, UMN findings present	2	IVDH
4	Dog, french bulldog, male, 5.5 y	Non-ambulation	Chronic	Paraplegia, deep pain sensation is not present, LMN findings present	0	IVDH
5	Dog, mixed, female, 6 y	Non-ambulation	Chronic	Paraplegia, deep pain sensation present, LMN findings present	1	IVDH
6	Dog, Terrier, female, 10 y	Weakness in walking	Chronic	Tetraparasia, generalized pain, phantom scratching	2	Syringomyelia
7	Dog, Terrier, male, 13 y	Non-ambulation	Chronic	Paraplegia, deep pain sensation present, LMN findings present	2	Arachnoid cyst
8	Dog, mixed, female, 3 y	Non-ambulation	Chronic	Paraplegia, deep pain sensation is not present, LMN findings present	0	IVDH
9	Cat, mixed, female, 2 y	Non-ambulation	Acute	Paraplegia, deep pain sensation present, UMN findings present	2	Vertebral fracture
10	Cat, Scottish fold, male, 2 y	Non-ambulation	Chronic	Tetraparasia, deep pain sensation present	4	IVDH
11	Cat, mixed, female, 3 y	Non- ambulation	Acute	Paraplegia, deep pain sensation present, LMN findings present	2	Vertebral fracture
12	Cat, Scottish fold, female, 4 y	Non-ambulation	Acute	Paraplegia, deep pain sensation is not present, UMN findings present	0	Vertebral fracture
13	Cat, mixed, male, 5.7 y	Non-ambulation	Chronic	Paraplegia, deep pain sensation is not present, UMN findings present	0	Vertebral fracture
14	Cat, mixed, female, 6 y	Non-ambulation	Chronic	Paraplegia, deep pain sensation present, LMN findings present	2	IVDH
15	Cat, mixed, male, 7 y	Non-ambulation	Chronic	Paraplegia, deep pain sensation is not present, LMN findings present	0	Vertebral Fracture
16	Cat, mixed, male, 8 y	Non-ambulation	Chronic	Paraplegia, deep pain sensation is not present, UMN findings present	0	Vertebral Fracture
17	Cat, mixed, female,10 y	Non-ambulation	Chronic	Paraplegia, deep pain sensation present, UMN findings present	1	Vertebral Fracture

y year, UMN Upper motor neuron, LMN Lower motor neuron, IVDH Intervertebral disc herniation

Table 2. Diagnostic percentages of T2-weighted sequences and T2-weighted + HASTE sequences

Method	Diagnosis			Total number of cases	Accuracy (%)
	Sure	Somewhat sure	Not sure		
T2-weighted	12	2	3	17	71%
T2 weighted+HASTE	17	0	0	17	100%

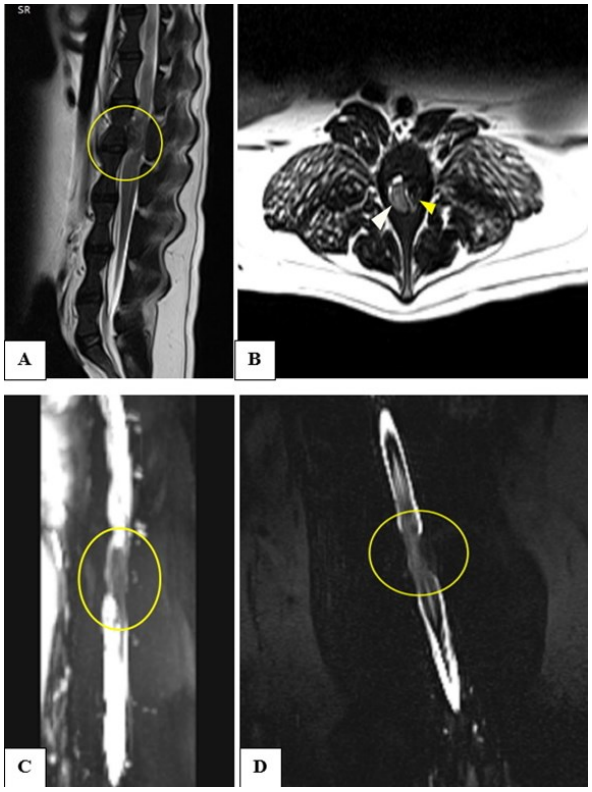

Figure 1. Sagittal and transverse T2-weighted, sagittal, and dorsal HASTE sequence images obtained in a dog. A) Extruded disc material on sagittal T2-weighted image at the lumbar 3-4 vertebrae level (yellow circle). B) Extruded disc material (yellow arrowhead) and spinal cord (white arrowhead) on transverse T2-weighted image. C) Attenuated cerebrospinal cord image on sagittal HASTE sequence imaging (yellow circle). D) Attenuated cerebrospinal cord image on dorsal HASTE sequence imaging (yellow circle).c

In the initial review of sagittal and transverse T2-weighted images, the observer was sure (score: 1) of the diagnosis in 12 cases (71%), somewhat sure (score: 2) in 2 cases (12%), and not sure (score: 3) in 3 cases (17%). After reviewing both T2-weighted images along with dorsal and sagittal HASTE images, the observer was sure of the diagnosis across all cases (100%) (Table 2). In three cases out of 17, the initial diagnosis (edema) was revised to another diagnosis (intervertebral disc herniation (IVDH), fracture, or combined fracture) upon review of the combined sequences. In two initially ambiguous cases (arachnoid cyst/syringomyelia and IVDH/fracture), a definitive diagnosis (syringomyelia and fracture) was

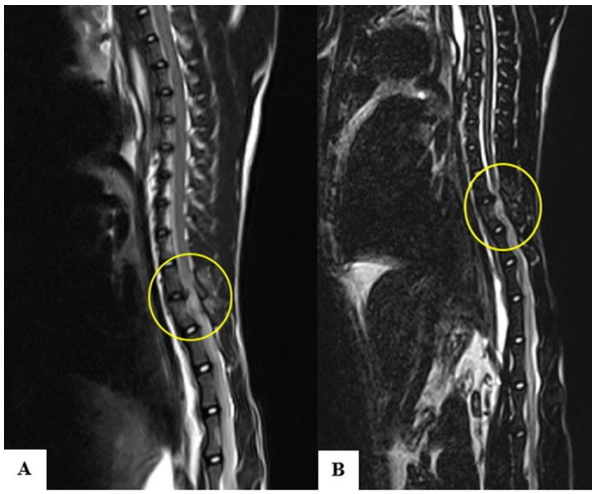

Figure 2. Sagittal T2-weighted and sagittal HASTE sequence images obtained in a cat. A) Fracture and spinal cord compression at thoracic 10-11 vertebral level on sagittal T2-weighted imaging (yellow circle). B) Fracture and spinal cord compression at thoracic 10-11 vertebral level on sagittal HASTE sequence imaging (yellow circle).

established. After the addition of the HASTE sequence, the observer was able to make a more accurate diagnosis with a difference of 29%. In addition, according to the results obtained, Cohen's Kappa coefficient for the diagnostic agreement of T2 weighted and T2 weighted+HASTE sequences was calculated as 0.61. According to the classification accepted in the literature, a Kappa value of 0.61 indicates moderate to good agreement. In the end, the diagnoses included IVDH (n=7), fracture (n=7), Chiari -like malformation (n=1), syringomyelia (n=1), and arachnoid cyst (n=1), all later confirmed surgically. (Figure 1) (Figure 2).

In the initial examination of T2-weighted sagittal and transverse images, the observer successfully identified the lesion location in 15 cases (89%), with 2 cases (11%) where localization was unsuccessful. The two cases with non-localized lesions involved multiple IVDH (lumbar 5-6/thoracic 13-1 in one case and cervical 2-3/cervical 5-6 in the other). Upon evaluating T2-weighted and dorsal and sagittal HASTE images together, the observer was able to pinpoint the lesions with maximum CSF compression (thoracic 13-1 and cervical 5-6) in both cases. The resulting 11% difference after adding the HASTE sequence was statistically non-significant (P=0.15).

Discussion and Conclusion

In studies on HASTE sequence in dogs, it was found that there was CSF attenuation due to compressive lesions in disc herniations (Mankin et al., 2012; Pease et al., 2006), and in a study on arachnoid diverticulum, it was found that there was enlargement of the subarachnoid region (Seiler et al., 2012). In our study, CSF attenuation was detected similar to the studies conducted in disc herniations. In addition, unlike other studies, Chiari-like malformation, syringomyelia, and arachnoid cyst cases were diagnosed with enlargement of the subarachnoid region and increased CSF hyperintensity, similar to the study on arachnoid diverticulum. In vertebral fracture cases, swelling in the subarachnoid region and increased CSF hyperintensity were present after CSF attenuation in the compressed area.

In a study assessing the role of HASTE sequences in detecting arachnoid diverticula in dogs, only 25% of these diverticula were identified without using HASTE sequences. However, the inclusion of the HASTE sequence raised the detection rate of arachnoid diverticula to 52.8%. The 27.8% improvement in detection with the addition of HASTE was statistically significant (Seiler et al., 2012). In the current study, the HASTE sequence was combined with the T2-weighted sequence for identifying spinal lesions, resulting in a 29% increase in accurate diagnoses. Integration of the HASTE sequence with other imaging protocols for diagnostic evaluation improved diagnostic accuracy and suggests that the use of this sequence is a useful improvement to MRI protocols for the diagnosis of neurological disorders in cats and dogs.

When multiple disc herniations with varying levels of spinal cord compression are present, identifying the most clinically relevant lesion can be challenging. In the HASTE sequence, a compressive (surgical) lesion is recognized based on the extent of subarachnoid space narrowing, similar to the diagnostic approach used for extradural lesions in myelography. Given that the HASTE sequence enhances visualization of subarachnoid space alterations more effectively than conventional T2-weighted sequences, our findings suggest it may be more effective for detecting clinically important compressive lesions indicated by focal narrowing of the subarachnoid space when included in a standard spinal MR imaging protocol (Mankin et al., 2012). In our study, we examined the degree of subarachnoid space compression in multifocal disc herniation cases and the spinal region with the highest CSF attenuation was the region with the most compressive disc herniation. Accordingly, we believe that the addition of HASTE sequence to the imaging protocol in cases of indeterminate disc herniation will be very important in guiding clinical decisions.

To accurately identify the anatomical location of a compressive lesion, the HASTE sequence should be compared with another sequence that enables precise vertebral body numbering (Mankin et al., 2012; Pease et al., 2006). The HASTE sequence alone does not allow for detailed identification of anatomical structures and primarily excels at visualizing the subarachnoid space. Therefore, in studies assessing the effectiveness of the HASTE sequence for accurate localization, it has been evaluated alongside T2-weighted images, and it is recommended that it be used in conjunction with other imaging protocols to determine the lesion's anatomical position.

Canine patients undergoing MRI are under general anesthesia, which eliminates any issues with movement or claustrophobia. However, a complete MRI evaluation of the spine can be lengthy and can take from 45 minutes to an hour, depending on the magnet strength and sequences obtained. As the strength of the magnet decreases, the time required to acquire a single sequence can double, further increasing the time required to complete an entire study (Pease et al., 2006). There are additional benefits to routinely using the HASTE sequence for spinal imaging when combined with other sequences, such as T2-weighted images, that provide greater morphologic detail. The HASTE sequence is acquired in approximately 5 seconds; therefore, the addition of this sequence does not compromise patient safety or efficiency by increasing the duration of anesthesia. Other imaging techniques, such as T2-weighted imaging with fat suppression, that focus on the CSF and provide higher resolution take significantly longer to acquire. While fat suppression techniques may enhance the detection of subarachnoid space lesions (Seiler et al., 2012), the HASTE sequence can be completed in seconds and is helpful in rapidly identifying compressive or spinal regions (Gallach et al., 2011). At our institution, we first obtain the HASTE sequence to localize the lesion in patients with poor general conditions who cannot remain under anesthesia for long periods. This reduces the duration of anesthesia and provides additional benefits to the neurologic examination by aiding in lesion localization.

In conclusion, our study demonstrates that the use of single-shot fast spin-echo sequences in combination with standard T2-weighted fast spin-echo sequences increases the accuracy of detecting neurological disorders and provides advantages for precise lesion localization. Therefore, we recommend routine inclusion of this sequence in spinal MRI protocols when applicable.

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Conflict of Interest

There is no conflict of interest to be declared by the authors.

Author Contributions

MNÇ, YSŞ, and BN took part in the study planning and sample collection. The writing of the study and final checks were carried out with the contributions of all authors.

Ethical Statement

The experimental protocol was approved by the Animal Experiments Ethics Committee of Burdur Mehmet Akif Ersoy University, Faculty of Veterinary Medicine (protocol number: 1276/2024).

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