Original Investigation / Özgün Araştırma

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Evaluation of Vertebral Bone Marrow with Diffusion Weighted MRI and ADC Measurements

Vertebral Kemik İliğinin Difüzyon Ağırlıklı MRG ve ADC Ölçümleri ile Değerlendirilmesi

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Abstract / Özet

Objective: The purpose was to determine the usefulness of diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) in the evaluation of vertebral bone marrow.

Methods: Patients were divided into; osteoporotic, traumatic, infectious spondylitis, hemangioma, malignancy and non-osteoporotic groups. Seventy-four patients (45 women and 29 men; mean age, 58 years; range 17-89) were investigated in this study. Conventional magnetic resonance imagining (MRI) sequences and SE-EPI sequence with b-value of 600 s/mm^2 were used. Qualitative and quantitative evaluation with DWI and ADC was carried out for each fractured vertebra and randomly chosen normal vertebrae. A p-value of <0.05 was considered significant.

Results: The mean DWI and ADC values of normal vertebrae was found to be 142.5±100 and 0.48±0.1x10^{-3} mm^2/s, respectively. A total of 103 fractures were encountered in 74 patients and L1 was the most commonly fractured vertebra (20 fractures, 19.4%). DWI and ADC qualitative assessment of fractures showed no significant difference between groups. The mean DWI and ADC values of fractured vertebrae was found to be 284.3±255.8 and 1.35±0.39x10^{-3} mm^2/s, respectively, which were significantly higher than that of normal vertebrae (p<0.05). The mean DWI value of normal vertebrae (76.2±37.3) and fractured vertebrae (124.5±87.6) in osteoporotic patients were significantly lower than that of non-osteoporotic patients (172.4±105.6 and 359.6±274.3) (p<0.05).

Conclusion: DWI and ADC quantitative evaluation can differentiate fractured vertebrae from normal vertebrae, but qualitative assessment of fractures cannot distinguish between groups. DWI with quantitative assessment is helpful in the differential diagnosis of osteoporotic fractures from malignant fractures and also osteoporotic normal vertebrae from non-osteoporotic normal vertebrae, but ADC values are unhelpful.

Key Words: ADC, DWI, fractured, normal, vertebrae

Amaç: Bu çalışmada vertebral kemik iliğinin değerlendirilmesinde difüzyon ağırlıklı görüntüleme (DAG) ve görünür difüzyon katsayısının (ADC) etkinliğini değerlendirmeyi amaçladık.

Yöntemler: Hastalar; osteoporotik, travmatik, enfeksiyoz spondilit, hemanjiom, malignite ve osteoporotik olmayanlar olarak gruplara ayrıldı. Yetmiş dört hasta (45 kadın ve 29 erkek; ortalama yaş, 58 yaş; aralık 17-89) çalışmaya dahil edildi. Konvansiyonel MRG sekanslarına ek olarak, SE-EPG sekansı ve b-değeri 600 sn/mm^2 kullanıldı. Kırık olan tüm vertebralardan ve rastgele seçilmiş normal vertebralardan görsel ve sayısal DAG ve ADC ölçümleri yapıldı. p-değeri <0,05 anlamlı kabul edildi.

Bulgular: Normal vertebralar için ortalama DAG ve ADC değerleri sırasıyla 142,5±100 ve 0,48±0,1x10^{-3} olarak bulundu. Yetmiş dört hastada toplam 103 kırık saptandı ve L1 vertebra en sık kırılan vertebraydı (20 kırık, %19,4). Kırıklar için DAG ve ADC görsel değerlendirmesinde gruplar arasında anlamlı farklılık saptanmadı. Kırık vertebralar için ortalama DAG ve ADC değerleri sırasıyla 284,3±255,8 ve 1,35±0,39x10^{-3} mm^2/s olarak bulundu ve normal vertebralara göre anlamlı olarak yüksekti (p<0,05). Osteoporotik hastalarda ortalama DAG değerleri normal vertebralarda (76,2±37,3) ve kırık vertebralarda (124,5±87,6) osteoporotik olmayan normal ve kırık vertebralara (sırasıyla; 172,4±105,6 ve 359,6±274,3) göre anlamlı olarak düşüktü (p<0,05).

Sonuç: DAG ve ADC sayısal değerlendirmesi kırık vertebraları normal olanlardan ayırt edebilir fakat görsel değerlendirme kırık gruplarını ayırt edemez. DAG sayısal değerlendirmesi osteoporotik kırık vertebraları malign olanlardan ve osteoporotik normal vertebraları osteoporotik olmayanlardan ayırmada yardımcıdır fakat ADC değerleri yararlı değildir.

Anahtar Kelimeler: ADC, DAG, kırık, normal, vertebra

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Introduction

Diffusion-weighted magnetic resonance imaging (DWI) and apparent diffusion coefficient (ADC) has become widely available in recent years. With this technique the mobility of tissue water can be measured in vivo on a microscopic level. DWI has proved to be especially useful in neuroradiology in the assessment of acute stroke, characterization of multiple sclerosis, tumors, abscesses of the brain (1) and cholesteatoma (2, 3). DWI and ADC can also be used in the detection of prostate cancer (4), differentiation of solid and cystic hepatic masses (5, 6), diagnosis of acute appendicitis (7) and differentiation of breast masses (8). In several studies, the DWI and ADC of normal and pathological vertebral bone marrow have been analysed (9-12).

In this study we investigated the usefulness of DWI and ADC in the evaluation of normal and fractured vertebrae.

Methods

Patient group

From September 2009 to April 2011, 74 patients (45 women and 29 men; mean age, 58 years; range 17-89) presenting with vertebral collapse in one or more vertebral body on conventional MR sequences were studied. The study was performed according to the World Medical Association Declaration of Helsinki. Informed consent was obtained from the research population. The patients were divided into five groups. These groups included; osteoporosis, trauma, infectious spondylitis, hemangioma and malignancy patients. A second classification was done as in osteoporotic and non-osteoporotic group. The non-osteoporotic group included trauma, spondylodiscitis, hemangioma and malignancy patients.

Twenty three patients with 33 fractures had a history of osteoporosis. Osteoporosis was diagnosed by bone densitometry with a T-score of <-2.5 and none of the osteoporotic patients had a history of serious trauma or malignancy. Thirty-seven patients with 54 fractures had a history of serious trauma like traffic accidents or falls from a height. None of the traumatic patients had a history of osteoporosis or malignancy. Three patients with 3 fractures had hemangiomas which were diagnosed earlier and followed-up by imaging modalities. Two patients with 3 fractures had a history of spondylodiscitis. These infections were diagnosed by imaging methods and confirmed by laboratory findings. Antibiotherapy was the treatment of choice for them.

The malignant group consisted of 9 patients with 10 metastatic vertebral fractures. The primary neoplasms included breast carcinoma (n=2), renal cell carcinoma (n=2), lung carcinoma (n=1), prostate carcinoma (n=1), plasmacytoma (n=1), langerhans cell histiocytosis (n=1) and multiple myeloma (n=1). The primary focus of all metastases were histopathologically proven with biopsies. In one case (plasmacytoma), the involvement of a vertebra was diagnosed with local puncture biopsy. In other cases with primary malignancies, diagnosis of metastases were suggested by vertebral involvement with accompanying soft tissue mass and/or spinal canal involvement.

Imaging protocol

All of the patients were scanned in a 1.5 Tesla (T) MRI scanner (Signa HDxt, GE Medical Systems, Milwaukee, Wisconcin, USA) using a 8-channel CTL spine coil. Imaging protocol included T1WI, T2WI and STIR sequences in all of the patients and postcontrast T1WI in the malignant group. The sequence parameters were TR/TE/NEX=500 ms/10ms/3 in T1WI, TR/TE/NEX=3500 ms/100 ms/4 in T2WI and TR/TE/NEX=3050 ms/50 ms/4 in STIR with a section thickness of 4 mm and interval of 1 mm and matrix size of 320x320.

DWI was performed according to these parameters; TR: 3000ms, TE: 85ms, section tickness: 5, interval: 1, matrix size: 160x160, NEX: 1 and b-value of 600 s/mm^2 with SE-EPI (spin echo echo planar imaging) sequence. ADC maps were created on a workstation (Advantage Workstation 4.4-GE Medical Systems, Milwaukee, Wisconcin, USA) using a software program (Functool-GE Medical Systems, Milwaukee, Wisconcin, USA).

Image interpretation

MRI scans were transferred to PACS workstations in DICOM 3.0 format, and retrospectively evaluated by using software programs (Fusion PACS and eFilm, Merge Healthcare, Chicago, Illinois, USA). All of the images were reviewed by three radiology specialists and any differences in opinions were resolved by consensus. For visual evaluation, DWI and ADC images of fractured vertebrae were classified as hypo, iso or hyperintense with guidance of conventional sequences. For quantitative evaluation, a region of interest (ROI) of 50-60 mm^2 was used to calculate DWI and ADC values of each fractured vertebrae and randomly chosen normal vertebrae.

Statistical analysis

All statistical calculations were performed using a software program (Epi Info version 3.5.1, CDC, Atlanta, USA). Normality tests were done for all measurable variables in the statistical analysis. All mean DWI and ADC values were compared and studied by one-way variance analysis for all subgroups. Comparisons for a difference in ADC values of lesion subgroups were conducted with the Tukey HSD and multiple difference tests. A p-value of <0.05 was considered statistically significant for all tests. The ROI measurements were compared by nonparametric Kruskall-Wallis analysis of variance, as they did not show a normal distribution. Paired comparison of the groups was carried out with the Mann–Whitney U test, using the Bonferroni correction. Spearman's rho coefficient was calculated to determine the relationship between DWI-ADC and patient ages. The optimal cutoff DWI value to separate the osteoporotic group from the non-osteoporotic group was determined by receiver operating characteristic (ROC) analysis. Sensitivity and specificity were calculated according to this threshold value.

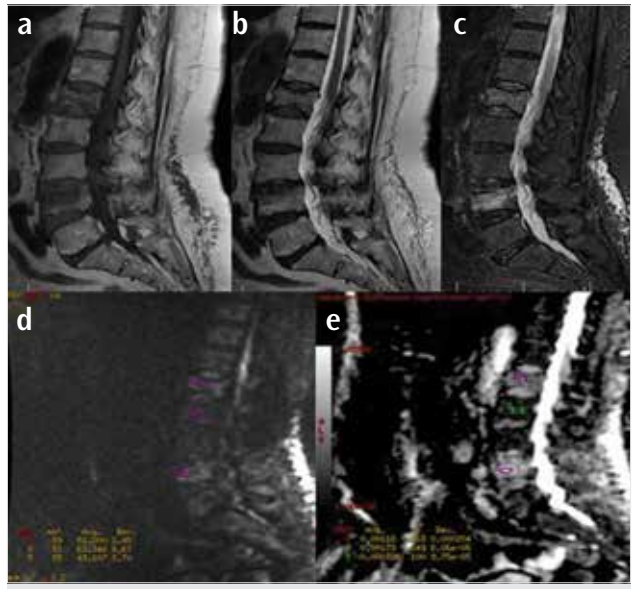

Figure 1. a-e. A 81 year-old osteoporotic patient presenting with L1 and L4 vertebra fracture: sagittal T1-weighted image shows hypointense, sagittal T2-weighted image (a) and sagittal STIR image (b) shows hyperintense signals of fractured vertebrae. Sagittal DWI (c) and sagittal ADC images shows hyperintense signals of fractured vertebrae. (d) ROI measurements were also performed from normal (L2) and fractured vertebrae. DWI values of L1, L2 and L4 vertebrae were 51, 43 and 63, respectively. ADC values of L1, L2 and L4 vertebrae were 1.18x10^{-3} mm^2/s, 0.32x10^{-3} mm^2/s and 1.79x10^{-3} mm^2/s, respectively (e)

DWI: diffusion-weighted imaging; ADC: apparent diffusion coefficient; ROI: return on investment; STIR: short T1 inversion recovery

Results

The mean DWI value of normal vertebrae was determined as 142.5±100.3, the highest value was in spondylodiscitis group (220±175.3) and the lowest was in osteoporotic group (76.2±37.3) (Figure 1). A statistically significant difference was found for the mean DWI value of normal vertebrae between groups ($p<0.05$). The mean DWI value of normal vertebrae in osteoporotic patients were significantly lower than that of non-osteoporotic patients (172.4±105.6) ($p<0.05$).

The mean ADC value of normal vertebrae was found as 0.48±0.1x10^{-3} mm^2/s, the lowest value was in the spondylodiscitis group (0.40±0.2x10^{-3} mm^2/s) and the highest was in the malignant group (0.61±0.2x10^{-3} mm^2/s). No statistically significant difference was found for the mean ADC value of normal vertebrae between groups ($p>0.05$). There was no statistically significant difference between the mean ADC value of osteoporotic patients (0.48±0.1x10^{-3} mm^2/s) and the value of non-osteoporotic patients (0.49±0.2x10^{-3} mm^2/sn) ($p>0.05$) (Table 1).

Table 1. Mean patient age and mean fracture number of each groups, DWI and ADC values of normal and fractured vertebrae

		Normal Vertebrae		Fractured Vertebrae		
	Mean Patient Age	DWI	ADC (x10^{-3} mm^2/s)	DWI	ADC (x10^{-3} mm^2/s)	Mean Fracture Number
Malignity	53.11±15.95	192.11±155.76	0.61±0.29	417.9±436.22	1.24±0.31	1.11±0.33
Trauma	53.62±18.50	167.35±92.3	0.46±0.19	334.28±232.33	1.41±0.37	1.46±0.9
Osteoporosis	66.3±12.77	76.26±37.32	0.48±0.13	124.52±87.65	1.35±0.41	1.43±0.73
Hemangioma	56±22.07	144.33±86.43	0.46±0.29	431±458.79	1.03±0.67	1
Spondylodiscitis	72.5±16.26	220.±175.36	0.40±0.28	550.67±43.59	1.09±0.06	1.5±0.71
P	0.051	0.001	0.757	0.001	0.157	0.533
Mean	58.11±17.41	142.54±100.35	0.48±0.19	284.31±255.86	1.35±0.39	1.39±0.77
Non-osteoporotic	58.5±18.1	172.4±105.6	0.49±0.2	359.6±274.3	1.36±0.38	1.26±0.48

DWI: diffusion weighted imaging; ADC: apparent diffusion coefficent

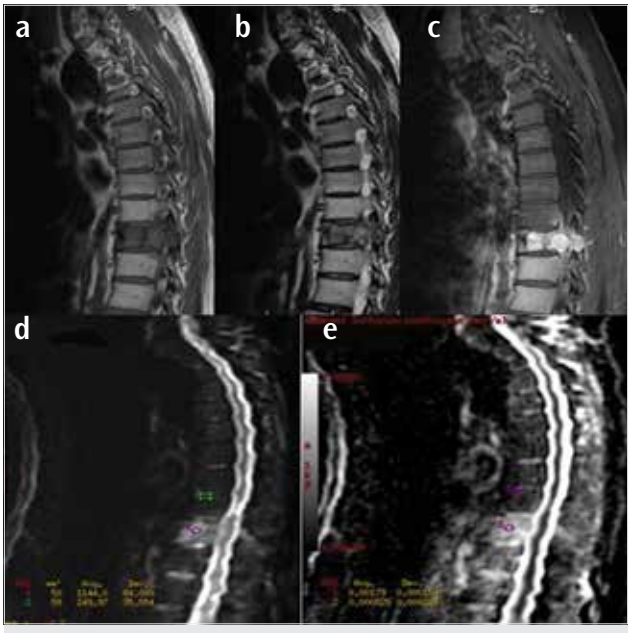

Figure 2. a-e. A 61 year-old renal RCC patient presenting with T10 vertebra metastatic fracture, sagittal T1-weighted image shows hypointense, sagittal T2-weighted image (a) shows hyperintense signals of fractured vertebrae. Sagittal fat-saturated contrast-enhanced T1-weighted image (b) shows marked contrast enhancement of vertebra. Sagittal DWI (c) and sagittal ADC images shows hyperintense signals of fractured vertebrae (d) ROI measurements were also performed from normal (T9) and fractured vertebrae. DWI values of T9 and T10 vertebrae were 2 and 1144, respectively. ADC values of T9 and T10 vertebrae were 0.52x10^{-3} mm^2/s and 1.79x10^{-3} mm^2/s, respectively (e)

DWI: diffusion-weighted imaging; ADC: apparent diffusion coefficient; ROI: return on investment; RCC: renal cell carcinoma

In the data of all the groups, there was no correlation between patient age and the mean DWI values (r=0.221, p=0.059) and the mean ADC values (r=-0.232, p=0.46) of normal vertebrae. In the osteoporotic group, no correlation was determined between patient age and the mean DWI values (r=0.164, p=0.45) and the mean ADC values (r=-0.207, p=0.34) of normal vertebrae. In the non-osteoporotic group, no correlation was observed between patient age and the mean DWI values of normal vertebrae (r=-0.028, p=0.84), although there was a moderate negative correlation between patient age and the mean ADC values of normal vertebrae (r=-0.338, p=0.015).

A total of 103 fractures were encountered in 74 patients. Fractures of lumbar, thoracic and cervical regions were encountered in 55 (%53), 44 (%43), 4 (%4) of patients, respectively. L1 was the most commonly fractured vertebra (20 fractures, %19.4) and the second most commonly fractured vertebra was T12 (19 fractures, %18.4).

In the DWI sequence qualitative assessment; of all fractures, 84 (81.6%) were hyperintense, 8 (7.8%) hypointense and 11 (10.7%) were isointense. Hyperintense signal was observed in all spondylodiscitis fractures, in 8 (80%) of malignant and 26 (78.8%) of osteoporotic fractures. In the ADC sequence qualitative assessment; of all fractures, 96 (93.2%) were hyperintense, 2 (1.9%) hypointense and 5 (4.9%) isointense. A hyperintense signal was observed in all spondylodiscitis fractures, in 7 (70%) of malignant and 31 (93.9%) of osteoporotic fractures (Table 2).

The mean DWI value of fractured vertebrae was found as 284.3±255.8, which was significantly higher than the mean value of normal vertebrae ($p<0.05$). The highest value was in the spondylodiscitis group (550.6±43.5) and the lowest was in the osteoporotic group (124.5±87.6). A statistically significant difference was found for the mean DWI value of fractured vertebrae between groups ($p<0.05$).

The mean DWI value of osteoporotic fractures was significantly lower than the mean value of malignant (417.9±436.2) (Figure 2), traumatic (334.2±232.3) and non-osteoporotic (359.6±274.3) fractures ($p<0.05$). The mean DWI value of malignant fractures was higher than traumatic ones, however there was no statistically significant difference between the two groups ($p>0.05$) (Table 1). The mean ADC value of fractured vertebrae was found as 1.35±0.39x10^{-3} mm^2/s, which was significantly higher than the mean value of normal vertebrae ($p<0.05$). The highest value was in the traumatic group (1.41±0.37x10^{-3} mm^2/s) (Figure 3) and the lowest was in the hemangioma group (1.03±0.67x10^{-3} mm^2/s). No statistically significant difference was observed for the mean ADC value of fractured vertebrae between groups ($p>0.05$).

The mean ADC value of malignant fractures (1.24±0.31x10^{-3} mm^2/s) was lower than traumatic (1.41±0.37x10^{-3} mm^2/s) and osteoporotic (1.35±0.41x10^{-3} mm^2/s) fractures, however there was no statistically significant difference between these groups ($p>0.05$). The mean ADC value of osteoporotic fractures was lower than the non-osteoporotic

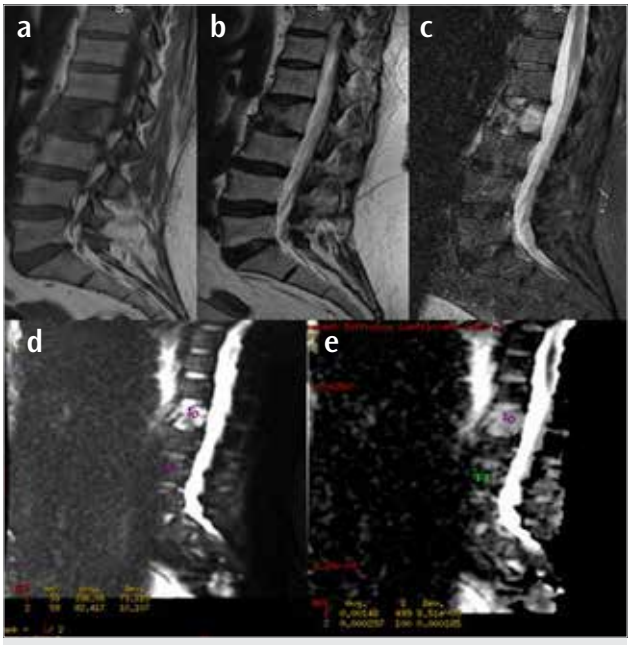

Figure 3. a-e. A 58 year-old trauma patient presenting with L2 vertebra fracture, sagittal T1-weighted image: shows hypointense, sagittal T2-weighted image (a) and sagittal STIR i mage (b) shows hyperintense signals of fractured vertebrae. Sagittal DWI (c) and sagittal ADC images shows hyperintense signals of fractured vertebrae (d). ROI measurements were also performed from normal (L4) and fractured vertebrae. DWI values of L2 and L4 vertebrae were 336 and 82, respectively. ADC values of L2 and L4 vertebrae were $1.48x10^{-3}$ mm^2/s and $0.29x10^{-3}$ mm^2/s, respectively (e)

DWI: diffusion-weighted imaging; ADC: apparent diffusion coefficient; ROI: return on investment; STIR: short T1 inversion recovery

fractures ($1.36\pm0.38x10^{-3}$ mm^2/s), however there was no statistically significant difference between the two groups ($p>0.05$).

Sensitivity and specificity were calculated and receiver operating characteristics (ROC) curves were obtained for the mean DWI value of normal and fractured vertebrae of osteoporotic and non-osteoporotic groups at different cut-off values. The area under the curve (AUC) for normal osteoporotic vertebrae was calculated as 0.82 (Confidence interval [CI] 95%, 0.72-0.91) (Table 3). If the cut-off value of the mean DWI value of normal vertebrae is taken as 88, the estimation of osteoporotic normal vertebrae test sensitivity is 80.4% and specificity is 78.2%. AUC for osteoporotic fractured vertebrae was calculated as 0.76 (CI 95%, 0.68-0.85). If the cut-off value of the mean DWI value of fractured vertebrae is taken as 149.5, the estimation of osteoporotic fractured vertebrae test sensitivity is 72.8% and specificity is 75.7% (Table 4).

Discussion

Conventional MR techniques cannot always be used to differentiate benign from malignant lesions because of their similar appearences (13). The first publication about the differentiation of benign and malignant vertebral fractures by DWI was reported by Baur et al. (14).

In a study by Castillo et al. (15), most of the fractures (53%) showed hypointensity on DWI evaluation. The metastases which showed hyperintense signals on DWI, also showed a hyperintense signal on T2 WI, and they stated that this was due to the T2 shine through effect.

Table 2. Visual evaluation of fractured vertebrae with DWI and ADC

	DWI/ADC			
	Hyperintense	Hypointense	Isointense	Total
Malignity	8/7	2/2	0/1	10/10
	80/70%	20/20%	0/10%	
Trauma	45/53	4/0	5/1	54/54
	83.3/98.1%	7.4/0%	9.3/1.9%	
Osteoporosis	26/31	1/0	6/2	33/33
	78.8/93.9%	3/0%	18.2/6.1%	
Hemangioma	2/2	1/0	0/1	3/3
	66.7/66.7%	33.3/0%	0/33.3%	
Spondylodiscitis	3/3	0/0	0/0	3/3
	100/100%	0/0%	0/0%	
Total	84/96	8/2	11/5	103/103
	81.6/93.2%	7.8/1.9%	10.7/4.9%	

DWI: diffusion weighted imaging; ADC: apparent diffusion coefficent

Table 3. ROC curve analysis for the mean DWI value of normal and fractured vertebrae in the estimation of osteoporosis

	AUC	Std. Dev.	p	CI 95%	
Normal DWI	0.82	0.049	<0.001	0.724	0.917
Fractured DWI	0.769	0.045	<0.001	0.681	0.858

ROC: receiver operating characteristics; DWI: diffusion weighted imaging; AUC: area under curve, Std. Dev.: standard Deviation, CI 95%: confidence interval 95%

Table 4. Cut-off values, sensitivity and specificity for the mean DWI value of normal and fractured vertebrae in the estimation of osteoporosis

	Cut-off value	Sensitivity	Specificity
	81	82.3	73.9
Normal DWI	88	80.3	78.2
	121.5	60.7	82.6
	123.5	75.7	69.6
	133	74.2	72.7
Fractured DWI	149.5	72.8	75.7
	177.5	70	81.8
	189.5	68.5	81.8

DWI: diffusion weighted imaging

In our study, most of the benign and malignant fractures showed a hyperintense signal in both of the DWI and ADC qualitative evaluations. We consider that qualitative assessment of DWI and ADC images of benign and malignant fractures cannot differentiate these pathologies. Our different results compared with other studies might be due to application of the lower b-values with different sequences by other authors.

Biffar et al. (16) found a statistically significant difference between the normal and fractured vertebrae for the osteoporotic and malignant group on both sequences. In our study we found similar results, the ADC values of fractured vertebrae were significantly higher than the normal vertebrae in all of the groups. We consider that the increase of DWI and ADC values of fractured vertebrae might be due to intercellular hypermobility of water molecules in osteoporotic and trauma patients relative to the edema or hemorrhage and might be due to the increase of malignant cells and intercellular water amount in the malignant group.

In our study we found a statistically significant difference for mean DWI value of normal vertebrae between groups. The mean DWI value of osteoporotic patients was statistically significant lower than the mean value of non-osteoporotic patients, but a statistically significant difference was not found for the mean ADC value of normal vertebrae between all groups. The mean ADC value of osteoporotic patients was lower than the value of non-osteoporotic patients but there was no statistically significant difference between the two groups. We consider that the lower DWI and ADC values of the osteoporotic vertebrae might be due to the displacement of bone marrow by fat cells and restriction of water diffusion.

Bone mineral density (BMD) loss is well recognized in osteoporosis. It has been speculated that the unfilled portions of the vertebrae with decreased BMD are filled with fatty bone marrow. Histologic studies found similar results. With aging, the composition of bone marrow shifts to favor the presence of adipocytes, osteoclast activity increases and osteoblast function declines, resulting in osteoporosis. MR perfusion studies showed a substantial decrease in vertebral marrow perfusion in osteoporotic and osteopenic subjects compared with normal groups in both genders. This might indicate the vascular component in the pathogenesis of osteoporosis. The atherosclerosis of small vessels was hypothesized as a major factor in the reduced perfusion of vertebrae of patients with osteoporosis. The reduced perfusion might be a contributing factor in the diffusion restriction of osteoporotic vertebrae (17).

Hatipoglu et al. (17) found statistically lower DWI and ADC values in osteoporotic vertebrae than osteopenic and normal ones. Yeung et al. (18) stated that osteoporotic subjects had statistically significant lower ADC values than normal subjects. Griffith et al. (19) reported that a statistically significant difference was not found for mean ADC value of vertebrae between osteoporotic, osteopenic and normal groups in their study.

In our study, we found the mean ADC value of normal vertebrae as $0.48\pm0.19x10^{-3}$ s/mm^2. Our results were consistent with other studies. In the literature, authors reported the ADC values of normal vertebrae as $0.2\text{-}0.5x10^{-3}$ mm^2/s. The varying values were attributed to different sequences and b-values.

Balliu et al. (20) found that osteoporotic fractured vertebrae had statistically significant higher ADC values than malignant and spondylitic ones. Öner et al. (21) found that the ADC values of metastases were lower than benign fractures.

In our study; the mean DWI values of osteoporotic and traumatic fractured vertebrae were statistically lower than that of malignant ones. We consider that these results might be due to changing diffusion dynamics of bone marrow by edema in trauma or tumor cells in malignancy, and in the case of osteoporosis, the increase of fat cells in bone marrow may be the reason. The mean ADC values of malignant fractured vertebrae were lower than the osteoporotic and traumatic ones, but there was no statistically significant difference between the groups, we consider that these results might be due to the number of patients and inhomogeneity between the groups.

There were some limitations in our study. Since the number of malignant, spondylodiscitis and hemangioma cases were lower than the number of osteoporotic and traumatic ones, there was inhomogeneity between the groups. In all the osteoporotic patients, osteoporosis was diagnosed with bone densitometry, but in some non-osteoporotic patients bone densitometry could not be applied, so clinical classification could be made for these patients. In the malignant group, the involvement of vertebra was diagnosed with local puncture biopsy in only one case, however the primary foci of all other metastases had been histopathologically proven earlier. DWI was applied with only one sequence (SE-EPI) and one b-value (600 s/mm^2), so comparison with other sequences and b-values could not bemade.

Conclusion

Qualitative assessment of DWI and ADC images of vertebral fractures cannot distinguish between etiological groups. DWI and ADC quantitative evaluation can differentiate fractured vertebrae from normal vertebrae. DWI with quantitative assessment is helpful in the differential diagnosis of osteoporotic fractures from malignant fractures and also osteoporotic normal vertebrae from non-osteoporotic normal vertebrae, but ADC values were found to be unhelpful. DWI and ADC can help conventional MRI sequences in final decision making, but the results were different according to some studies, more accurate results can be achieved with an expanded series including larger numbers of patients and a wider spectrum of b-values and sequences.

Ethics Committe Approval: Ethics Committee Approval: Ethics committee approval was not received for this study due to the retrospective nature of the study.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - Ö.T., M.D.A.; Design - G.T, Y.K.; Supervision - Ö.T.; Funding - M.D.A.; Materials - Y.K.; Data Collection and/or Processing - Ö.K.; Analysis and/or Interpretation - Ö.K, I.F.T.; Literature Review - Ö.T, M.D.A.; Writing - Ö.T, I.F.T.; Critical Review - Y.K.; Other - G.T.

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