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Current Research in MRI

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Editor in Chief: Mecit Kantarcı
Address: Department of Radiology, Erzincan Binali Yıldırım University School of Medicine, Erzincan, Turkey
E-mail: akkanrad@hotmail.com

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Original Article

Do We Need Breast Magnetic Resonance Imaging or Biopsy for Breast Imaging and Reporting Data System Category 3 Lesions on Ultrasound?

Muhsin Özgün Öztürk[1], Esra Bilici[1], Taner Kösetürk[2], Türkhun Çetin[1]

[1]Department of Radiology, Erzincan Binali Yıldırım University, Faculty of Medicine, Erzincan, Turkey
[2]Department of Anatomy, Erzincan Binali Yıldırım University, Faculty of Medicine, Erzincan, Turkey

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Corresponding author: Esra Bilici, e-mail: esra.bilici@hotmail.com

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Abstract

Objective: Breast Imaging and Reporting Data System category 3 was established for lesions that were thought to be probably benign, and its aim was to limit the number of biopsies performed. Breast Imaging and Reporting Data System category 3 lesions are common, but they remain controversial due to high interobserver variability. Our aim is to examine how many cases with a sonographically identified Breast Imaging and Reporting Data System category 3 lesion were performed on breast magnetic resonance imaging and/or biopsy and whether the Breast Imaging and Reporting Data System category changes with the breast magnetic resonance imaging.

Methods: This retrospective study included 498 patients who underwent breast ultrasonography between November 1, 2022, and June 30, 2023, and who had Breast Imaging and Reporting Data System category 3 lesion(s). Among these patients, those who underwent breast magnetic resonance imaging and/or biopsy within 3 months were found. Magnetic resonance images were evaluated for sonographically identified Breast Imaging and Reporting Data System category 3 lesion(s). Tru-cut biopsy results were also evaluated.

Results: Of 498 patients who had Breast Imaging and Reporting Data System category 3 lesion(s) on ultrasonography, 66 (13.3%) underwent breast magnetic resonance imaging subsequently. With the magnetic resonance imaging, there were 17 patients (25.7%) whose Breast Imaging and Reporting Data System category downgraded, 12 (18.1%) whose category upgraded, and 37 (56.1%) whose category remained unchanged. The mean age of those who had a biopsy was found to be lower than those who did not have a biopsy ($P = .028$).

Conclusion: The aim of Breast Imaging and Reporting Data System category 3 was to limit the number of breast biopsies performed. Magnetic resonance imaging can be used as a problem solver for Breast Imaging and Reporting Data System category 3 lesions and can also update the Breast Imaging and Reporting Data System category. Biopsy of Breast Imaging and Reporting Data System category 3 lesions may not be cost effective due to the low probability of malignancy.

Keywords: BIRADS 3, breast US, breast MRI

INTRODUCTION

Breast cancer is the most common solid-organ malignancy in women in developed countries.[1] Since the introduction of breast screening modalities, both malignant and benign lesions have been more easily identified.[2] The most commonly used screening modalities of breast are mammography and ultrasonography (US). Magnetic resonance imaging (MRI) is most commonly used as a problem solver. It is known that the sensitivity of mammography decreases with increasing breast density.[3]

The Breast Imaging and Reporting Data System (BIRADS) has been published by the American College of Radiology in order to provide a standardized categorization of breast lesions on mammography, ultrasound, and MRI.[4] Breast Imaging and Reporting Data System category 3 was initially established for mammographic lesions that were thought to be probably benign and to carry an estimated cancer risk of 2% or less. The aim was to limit the number of breast biopsies performed for findings that cannot be definitively characterized as benign on mammograms but ultimately have benign pathologic results.[5]

Ultrasonography is a commonly used screening modality for breast and especially indicated for young, lactating, or pregnant women. It is also used as a supplement to mammography screening in women with heterogeneous or dense breasts.[6] It has a high dependence on the operator; therefore, the sensitivity and specificity of US vary between studies. Previous studies reported 81%-98% sensitivity, 33%-89% specificity, 13%-68% positive predictive value, and 92%-100% negative predictive value (NPV) for US.[7]

Findings in ultrasound for BIRADS 3 lesions are as follows: oval circumscribed solid mass, probable isolated complicated cyst, probable clustered microcysts, hyperechoic mass with a central hypoechoic or anechoic component suggestive of fat necrosis, posterior shadowing without the presence of a mass, and architectural distortion thought to be a postsurgical scar.[8] According to the recent studies, the vast majority of clustered microcysts can now be assessed as benign findings from BIRADS 2.[9]

The current recommended management for BIRADS 3 lesions is imaging surveillance with diagnostic mammography or diagnostic ultrasound at 6, 12, and 24 months.[10] Once 2 years of stability has been obtained, the lesion has decreased in size or has been biopsied with benign results. The lesion can then be recategorized as benign.[8] Growth in diameter >20% in 6 months should prompt a biopsy.[9]

Breast Imaging and Reporting Data System category 3 lesions are common, but they remain controversial due to high interobserver variability and low compliance with the standard imaging surveillance protocol. In their study, Nam et al reviewed and reclassified lesions seen on US and identified BIRADS 3 lesions in 41.5% of women. In their study, 745 BIRADS 3 lesions were found, and 124 (16.6%) underwent US-guided biopsy due to patient preference and/or risk factors. Benign pathology results were found in 119 lesions, and 5 of them were found to be malignant.[9] Also recently, Berg et al (2020) assessed the malignancy rate of BIRADS 3 lesions to be 1.86%.[8-10]

Breast MRI is the most sensitive imaging modality for detecting breast cancer.[11] The American Cancer Society and American College of Radiology recommend MRI as an adjunct to mammography for women with a high hereditary risk for breast cancer.[5] For the detection of breast lesions, the sensitivity and specificity of dynamic contrast enhanced MRI are reported as 94%-100% and as 37%-97%, respectively. The NPV of MRI is higher than any imaging modality (over 90%), and a negative breast MRI rules out malignancy.[11] Some studies have suggested that MRI may help the clinician manage BIRADS 3 and 4A lesions and limit unnecessary biopsies.[6]

Lesions are classified as BIRADS 3 in MRI when they have an oval or round shape with a circumscribed margin, homogeneous internal enhancement, and type 1 or type 2 kinetic enhancement curve.[12]

MAIN POINTS

- Breast Imaging and Reporting Data System category 3 (BIRADS 3) lesions are common, but they are controversial due to high interobserver variability and low compliance with the standard imaging surveillance protocol.
- With magnetic resonance imaging (MRI), 17 patients' (25.7%) BIRADS category downgraded, 12 patients' (18.1%) category upgraded, and 37 patients' (56.1%) category remained BIRADS 3.
- The rate of biopsy was found to be significantly higher in patients who had breast MRI.
- There was a tendency for younger people to have more biopsies irrespective of whether there is an upgrade in the BIRADS category on MRI or not.
- Magnetic resonance imaging can be used as a problem solver for lesions that are probably benign but difficult to manage, such as BIRADS category 3 lesions, and can update the BIRADS category of lesions.

In this study, our aim is to examine how many of the cases, which were reported as BIRADS 3 on US of the breast, underwent breast MRI for any reason and to investigate whether the BIRADS category changes with the breast MRI performed. In addition, our aim is to investigate the results of biopsies performed after MRI or without MRI in cases with BIRADS 3 lesion(s) on US.

METHODS

The study was carried out at Erzincan Binali Yıldırım University Mengucek Gazi Hospital. Our institutional review board approved this retrospective study (Date: February 23, 2022-KAEK-2023-4/21) with waiver of the requirement for informed consent.

Patient Selection and Radiological Evaluation

Patients who underwent breast US for any reason (including palpable mass) between dates 01/11/2022 and 30/06/2023 and who had at least 1 BIRADS 3 lesion according to sonographic criteria were included in our study (n=513). Care was taken to ensure that mammography was not performed within 3 months before or after sonography in the included patients. Among the patients who had BIRADS 3 lesion(s) sonographically, those who underwent breast MRI and/or biopsy within 3 months of sonography were found in the hospital database. Magnetic resonance imaging images in Picture archiving communication systems (PACS) and reports in the hospital database were evaluated for BIRADS 3 lesion(s) previously identified by sonography. In addition, biopsy results for BIRADS 3 lesions with or without prior MRI were evaluated. Those with poor MR image quality (due to artifacts and inadequate patient cooperation) and those who underwent surgical biopsy or Fine needle aspiration biopsy (FNAB) were excluded from the study. Also among the patients who underwent Tru-cut biopsy, those whose histopathological results showed insufficient material were excluded from the study. The final analysis included 498 patients.

The ultrasound examination was performed with the Samsung RS85 Prestige ultrasound system (Samsung Medison Co. Ltd., Hongcheon, Korea) and a high-resolution linear LM4-15B (15 MHz) transducer. Magnetic resonance images were obtained in the axial plane with a slice thickness of 2 mm at 1.5 T with a dedicated breast coil. The protocol involved an unenhanced nonfat-suppressed T1-weighted sequence and an unenhanced, fat-suppressed T2-weighted sequence. Also, an unenhanced fat-suppressed gradient-echo T1-weighted sequence was performed, followed by 2 to 4 dynamic contrast-enhanced T1-weighted gradient-echo series with fat suppression after IV administration of a gadolinium-based contrast agent. Post processing included sagittal and coronal reconstructions, subtracted contrast-enhanced images, and maximum-intensity projection images. Examinations were interpreted by an experienced breast radiologist using the terminology of the BIRADS atlas.

Tru-cut biopsies were performed by the Interventional Radiologist of our clinic with 16-Gauge tru-cut biopsy needles without any complications. Histopathological evaluations were made by the pathologists of our institution.

It was not investigated why mammography was not performed before or after US in these patients. In addition, the reason for the biopsy or MRI was not investigated in our study.

Statistical Analysis

Data were analyzed using the Statistical Package for Social Sciences version 27.0 for Windows 20 software (IBM SPSS Corp., Armonk,

NY, USA). The normal distribution of the data was evaluated using the Kolmogorov-Smirnov test. Numerical variables with a normal distribution are shown as minimum-maximum values. Categorical variables are shown as percentages. Differences in normally distributed variables between groups were evaluated using the Student's *t*-test and 1-way analysis of variance. Categorical variables were evaluated by the chi-square test between groups. A 2-tailed *P*-value <.05 was considered statistically significant.

RESULTS

The mean age of 498 patients included in the final analysis was 40.2 (maximum: 96, minimum: 13). In the study, 66 (13.3%) of 498 patients who had BIRADS 3 lesions sonographically underwent dynamic contrast-enhanced breast MRI within 3 months.

The mean age of those who had breast MRI was 40.56 and that of those who did not have it was 40.23, and there was no statistically significant difference in age between these groups.

According to the MRI results, there were 17 patients (25.7%) whose BIRADS category decreased, 12 patients (18.1%) whose BIRADS category increased, and 37 patients (56.1%) whose BIRADS category remained BIRADS 3. Representative MR images of one of the patients who had participated in the study are shown in Figures 1 and 2.

The mean age of the patients whose BIRADS category increased with breast MRI was 36.92 years, those whose BIRADS category did not change was 42.19 years, and those whose BIRADS category decreased was 39.59 years, and there was no statistically significant age difference between these groups (*P* = .297).

The BIRADS category of 37 out of 66 patients who underwent MRI remained unchanged (BIRADS 3). Magnetic resonance imaging of the patients with the unchanged category costs $682.46.

Of those who underwent MRI, biopsy was performed in 12 patients (18.2%); histopathological examination was not performed in 54 patients (81.8%). Among those who did not have an MRI, biopsy was performed in 19 patients (4.4%) and histopathological examination was not performed in 413 patients (95.6%). The rate of biopsy was found to be significantly higher in patients who had breast MRI (*P* = .001).

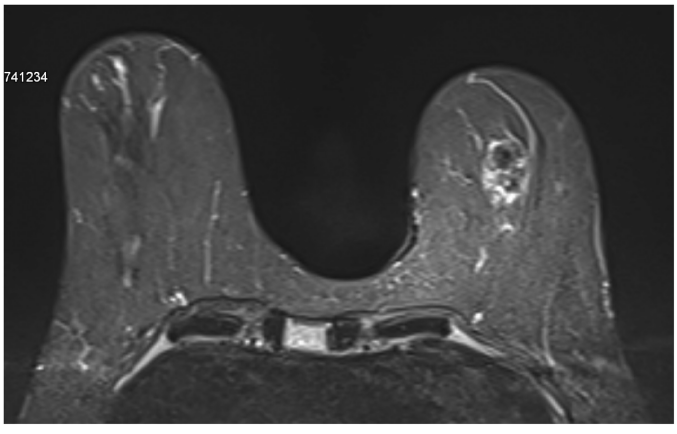

Figure 1. A patient who had a BIRADS 3 solid lesion sonographically underwent MRI, and on postcontrast dynamic fat-saturated images, there is an oval-shaped solid lesion with circumscribed margins. BIRADS, Breast Imaging and Reporting Data System; MRI, magnetic resonance imaging.

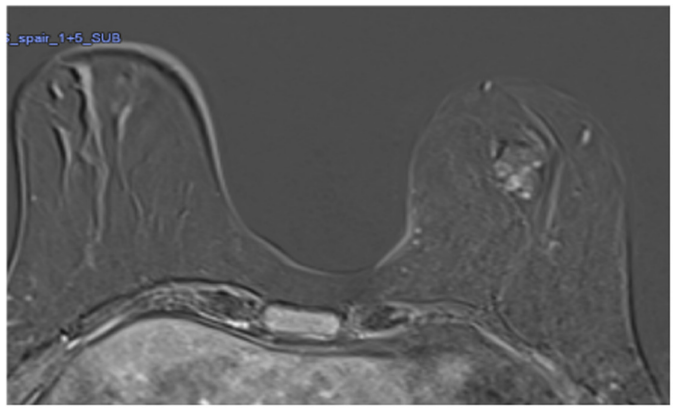

Figure 2. A dynamic kinetic curve was obtained in the same patient. The lesion demonstrated type 1 kinetic enhancement curve. This lesion was reported as BIRADS 3 on MRI. BIRADS, Breast Imaging and Reporting Data System; MRI, magnetic resonance imaging.

Histopathological examination was performed in 31 (6.2%) of the 498 patients in the study. Malignant histopathological results were found in only 1 patient out of a total of 31 biopsied patients (poorly differentiated malignant epithelial tumor). This patient was 33 years old, and biopsy was performed without prior breast MRI. A representative US image of the BIRADS 3 lesion and the image of the US-guided tru-cut biopsy procedure of one of the patients who had participated in the study are shown in Figures 3 and 4, respectively. Histopathologic results of the patients' who underwent biopsy are shown in Table 1.

The mean age of those who had a biopsy was 35.77; the mean age of those who did not have a biopsy was 40.57 years old. The mean age of those who had a biopsy was found to be lower than that of those who did not (*P* = .028).

Biopsy was performed in 1 patient (5.4%) in the group whose BIRADS category decreased as a result of MRI, in 5 patients (13.5%) in the group with an unchanged BIRADS category, and in 6 patients (50%) in the group with an increased BIRADS category. The reason

Figure 3. A representative US image of the BIRADS 3 lesion of one of the patients who had participated in the study. BIRADS, Breast Imaging and Reporting Data System; US, ultrasonography.

Figure 4. Image of the US-guided tru-cut biopsy procedure of one of the patients who had participated in the study. US, ultrasonography.

Table 1. Histopathologic Results of the Patients Who Underwent Biopsy are Shown with Numbers and Percentages

Histopathology	N	%
Benign	30	96.7
Fibrosis	6	19.3
Mesenchymal tissue	1	3.2
Nonneoplastic ductal and glandular structures	2	6.4
Fibroadenoma	15	48.3
Fibrocystic disease	2	6.4
Usual ductal hyperplasia	1	3.2
Adenosis	1	3.2
Fibroadenolipoma	1	3.2
Malignant	1	3.2
Poorly differentiated malignant epithelial tumor	1	3.2

why the rest of the patients whose BIRADS category increased after MRI (BIRADS 4) were not biopsied was that either these patients did not accept the biopsy or the patients were not followed up at our center. Biopsy rates were found to be higher in the group with increased BIRADS category than in the groups with unchanged and decreased BIRADS categories. The lowest biopsy rate was found in the decreased BIRADS category group ($P = .005$). There was a tendency for younger people to have more biopsies with or without an increase in BIRADS on MRI.

DISCUSSION

The aim of the BIRADS 3 category was to limit the number of breast biopsies performed. Magnetic resonance imaging can be used as a problem solver for BIRADS 3 lesions and can also update the BIRADS category. Biopsy of BIRADS 3 lesions may not be cost effective due to the low probability of malignancy. In this study, with MRI, 17 patients' (25.7%) BIRADS category downgraded, 12 patients' (18.1%) category upgraded, and 37 patients' (56.1%) category remained BIRADS 3.

Breast cancer is the most common solid-organ malignancy in women in developed countries.[1] The imaging modalities of breast are US, mammography(MG), and MRI.[3] The BIRADS is a widely accepted lexicon that has been published in order to provide a standardized categorization of breast lesions on modalities.[4] Breast Imaging and Reporting Data System category 3 was initially established for lesions that were likely to be benign. The aim of this category was to limit the number of breast biopsies performed.

Ultrasonography is a commonly used screening method for breast, especially in young women who have dense breasts.[6] The recommended management for BIRADS 3 lesions is imaging surveillance with MG or US at 6, 12, and 24 months.[10]

Magnetic resonance imaging is the most sensitive imaging modality for breast lesions.[11] It is most commonly used as a problem solver in equivocal lesions and is also used for women with a high hereditary risk for breast cancer.[5] Due to the high NPV, a negative breast MRI rules out the malignancy.[11] Some studies have suggested that MRI may help the clinician manage BIRADS 3 and 4A lesions and limit unnecessary biopsies.[6] However, it is not uncommon for lesions identified as BIRADS 3 sonographically to form a type 2 kinetic curve on dynamic contrast-enhanced MRI. Especially in lesions such as sclerosing adenosis, a type 2 kinetic curve can be seen on MRI, and subsequently biopsy may be performed.[13]

In their study which investigate the outcomes of imaging and biopsy of BIRADS 3 lesions, Polat et al found that patients younger than 40 years were more likely to undergo biopsy compared with patients older than 40 years. In their study, the mean age of the biopsied patients was 38.2 years compared with 47 years for patients that were not biopsied.[8] Similarly, in our study, the mean age of those who had a biopsy was found to be lower than that of those who did not have a biopsy. In our study, the mean age of those who had a biopsy was 35.77; the mean age of those who did not have a biopsy was 40.57 years old. In their study, 5 out of 173 biopsied lesions were found to be malignant (2.9%). However, in their study, there were also biopsies performed due to size increase and morphology changes during imaging follow-ups. In our study, there were no other imaging or histopathological results related to the breast before and after. In our study, only 1 of 31 people who underwent biopsy had a malignant result (3.2%). In our series, the rate of biopsy for sonographic BIRADS category 3 lesions was 6.2%. Polat et al found this rate to be 7.5% in their study.[8] In another study, Turk et al[2] found that 9 out of 84 (10.9%) biopsied lesions which were identified by MG and/or US were found out to be malignant. Pistolese et al[14] found a malignancy rate of 4.9% in sonographically detected BIRADS 3 lesions.

In our study, the reason for the biopsy decision was not investigated. However, the difficulties in compliance with the 2-year follow-up, patient anxiety, or the clinician's thought of needing a biopsy in the breast examination may be among the reasons.

In this study, 66 of these patients who had BIRADS 3 lesion(s) sonographically underwent MRI, and there were 17 patients (25.7%) whose BIRADS category downgraded, 12 patients (18.1%) whose BIRADS category upgraded, and 37 patients (56.1%) whose BIRADS category remained the same. However, these findings contradict the findings of Arian et al's study, which investigated the contribution of MR in sonographically detected BIRADS 3 lesions. In their study, they found that BIRADS remained the same in 87%, BIRADS downgraded in 9.8%, and BIRADS upgraded in 3.3% after MRI.[12] Also in their study, which investigated sonographically BIRADS 4 lesions on MRI, Ertekin et al found that 61.2% of the lesions were downgraded and 10.7% of the lesions were upgraded. Their BIRADS category upgrade ratios were

also lower when compared to our study.[7] Additionally, Hernandez et al's study which investigated the use of MRI in indeterminate lesions found a 90% downgrade ratio in sonographically identified BIRADS 3 lesions.[6] As seen in these studies, downgrading and upgrading with MRI differ substantially. In our study, biopsy rates were higher in the group that had upgraded the BIRADS category after MRI.

Also in their study, Hernández et al found that breast MRI avoided 22 unnecessary biopsies and 64 short-term follow-ups, allowing the exclusion of malignancy in 81.9% of the patients.[6] This reflects the potential of breast MRI to avoid unnecessary biopsies and short-term follow-ups for indeterminate lesions.

In our study, 37 of 66 patients from the BIRADS category with MRI remained unchanged; The cost of the MR is $682.46. The use of MRI is forestalled by the high cost of the examination. There are some literature data which show that for patients at high risk for breast cancer, MRI screening is cost effective. However, for women at lower risks, most studies show that breast MRI is likely not cost effective.[15]

Our study has some limitations. First of all, this is a retrospective study; therefore, extensive data review and a detailed history were not possible. Second, our relatively small sample size limits the statistical analysis and decreases the power of our results. Thirdly, the reason why the biopsies were performed could not be investigated.

In conclusion, MRI can be used as a problem solver for lesions that are probably benign but difficult to manage and require patient compliance, such as BIRADS category 3, and can update the BIRADS category of lesions. Biopsy of BIRADS 3 lesions may not be cost effective due to the low probability of malignancy, according to our results and also the results in the literature. Therefore, in BIRADS 3 lesions, it may be useful to re-evaluate the lesion(s) with MRI. However, in the literature, the results differ in terms of recategorization in MRI examinations for BIRADS category 3 lesions. This may be due to the fact that US and MRI evaluations are made by different radiologists or may be due to subjectivity of the interpretations. Our study provides direction for future research on the appropriate usage of MRI for the sonographically detected BIRADS 3 lesions.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Erzincan Binali Yıldırım University (Date: February 23, 2022, Number: EBYU -KAEK-2023-4/21).

Informed Consent: Due to the retrospective design of the study, informed consent was waived.

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Declaration of Interests: The authors declare that they have no competing interest.

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Current Research in MRI

Original Article

Evaluation of Imaging Findings in Hepatic Hydatid Cyst Patients with Intrabiliary Rupture: A Retrospective Magnetic Resonance Imaging Study

Bünyamin Ece[1], Mustafa Koyun[2]

[1]Department of Radiology, Kastamonu University, Faculty of Medicine, Kastamonu, Turkey
[2]Department of Radiology, Kastamonu Training and Research Hospital, Kastamonu, Turkey

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Corresponding author: Bünyamin Ece, e-mail: bunyaminece@hotmail.com

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Abstract

Background: Liver hydatid cyst ruptures entering the biliary tree can lead to life-threatening conditions. This study investigates the frequency of biliary rupture and the most common magnetic resonance imaging findings.

Methods: Patients with hydatid cyst within the last 5 years were screened. Demographic data, the hepatic segment location, number of lesions, lesion size, and type of cyst were recorded, and biliary communication was evaluated. In patients with biliary rupture, the presence of dilation bile ducts, the presence of structures consistent with cyst contents in the bile ducts, the presence of fistulous connections, and the frequency rates of these findings were evaluated.

Results: Fifty-five cyst hydatid lesions from 50 patients (30 male and 20 female) were included. 4 (8%) patients had biliary rupture. Among them 4 (100%) patients had dilation in the intrahepatic and common bile ducts, 3 (75%) had deformation of cyst, 2 (50%) had structures consistent with cyst contents in the even ducts, and 1 (25%) had a fistulous connection shown by magnetic resonance imaging. Age and gender did not differ between patients with and without biliary rupture ($P > .05$). Patients with biliary rupture had larger cysts than those without ($P < .05$), and type 3 hydatid cysts were the most common.

Conclusion: In conclusion, the frequency of intrabiliary rupture in our study was found to be 8%, and significant imaging findings can be obtained with magnetic resonance imaging in the evaluation of intrabiliary rupture. Bile duct dilation, cyst deformation, cyst contents in the bile ducts, and fistulous connection are the most common magnetic resonance imaging findings in patients with intrabiliary rupture.

Keywords: Cyst hydatid, Echinococcosis granulosus, rupture, cystobiliary fistula, cystobiliary communication, intrabiliary rupture, magnetic resonance imaging

INTRODUCTION

Hydatid cysts are parasitic infections caused by *Echinococcus* larvae. Hydatid cyst disease affects various regions of the world. There are 2 primary types of hydatid cysts, namely *Echinococcus granulosus* and *Echinococcus multilocularis*. Humans are fortuitous intermediary hosts and typically contract the illness through indirect exposure. The cyst can grow in any organ of the body,[1] but it is most commonly found in the liver (60%-70%) and lungs (20%-30%). The infection is acquired by the ingestion of tapeworm eggs, which are shed in the feces of canines and other carnivores. The eggs undergo hatching inside the limits of the small intestine and subsequently migrate to other organs in the body. Upon reaching their ultimate location, the larvae form cysts.[2-5]

Patients with symptomatic hydatid liver cysts typically present with upper abdominal pain and a loss of appetite; bile duct compression may result in jaundice. Palpation may reveal a tumor-like mass, hepatomegaly, or distension in the abdomen. Cysts in the lung can cause pain in the chest, coughing, or hemoptysis, and cyst rupture into the bronchi can result in the evacuation of hydatid materials. Cyst rupture in any organ can cause fever, urticaria, eosinophilia, and anaphylactic shock. Any puncture of a hydatid cyst lesion is contraindicated due to the possibility of potentially lethal allergic reactions resulting from cyst rupture.[5,6]

Cyst hydatid is diagnosed based on clinical signs, imaging studies, and serology tests. The utilization of routine imaging or population-based ultrasound (US) screening of the liver has the potential to detect asymptomatic cysts, making it a crucial practice for the early identification of patients in regions with a high prevalence of this condition.[6-8] Imaging modalities play a crucial role in the diagnostic process, wherein the cost-effective and easily transportable US is commonly employed for the detection of cyst hydatid liver lesions. On the other hand, x-ray imaging is utilized for the diagnosis of lung cysts. Both procedures are employed for the purposes of diagnosis, population screening, and subsequent monitoring. Abdominal US, computed tomography (CT), and magnetic resonance imaging (MRI) are employed for the purpose of diagnosing complications. Recently, the use of dual-energy CT has been reported.[9] In contemporary medical practice, the utilization of endoscopic retrograde cholangiopancreatography (ERCP) has become widespread for both the identification and the management of biliary complications associated

Table 1. Magnetic Resonance Imaging Sequence Parameters

	Non-Contrast Scans					Contrast-Enhanced Scans
MRI Sequences Type of Scan	**Ax T2 SSFSE BH**	**Ax T2 SSFSE ASPIR BH**	**Cor T2 SSFSE BH**	**Ax Dual Echo BH**	**Ax DWI b0-b800 Rtr**	**+C Ax LAVA Dyn BH**
TR (ms)	1000	1000	1200	200	4500 6000	6.4
TE (ms)	85	85	85	2.3 4.6	80 120	2.1
NEX	1	1	1	1	1	1
FOV (mm^2)	340 × 340	340 × 340	360 × 360	320 × 320	340 × 340	340 × 340
Slice thickness (mm)	6	6	6	4	6	4

Ax, axial; Cor, coronal; DWI, diffusion weighted imaging; FOV, field of view; MRI, magnetic resonance imaging; TE, echo time; TR, repetition time; T2, T2-weighted image.

with hepatic hydatid cysts.[3] The diagnostic value of MRI looks to be better compared to that of CT scan in cases of cyst hydatid. Both imaging techniques, however, are complementary in the diagnosis of cyst hydatid and should be employed in order to obtain adequate information for making therapeutic decisions. Nevertheless, it is worth noting that T2-weighted MRI microcystic images are considered to be pathognomonic indicators of cyst hydatid lesions.[10-13]

Although there is a link between the biliary system and the cyst in around 80%-90% of individuals with hepatic hydatid cysts, the occurrence of clinical biliary rupture is rather low, ranging from 13% to 37%. Due to the high mortality and morbidity of biliary rupture, its management becomes crucial. However, the diagnosis of occult intrabiliary rupture, which accounts for 10%-37% of cases, is challenging due to the lack of notable symptoms and preoperative radiological findings.[4] Biliary rupture represents the prevailing complication associated with hepatic hydatid cysts, manifesting in around 14%-25% of individuals who experience postoperative bile leakage.[14] The most prevalent complications associated with anaphylactic shock include cyst infection of the biliary tract and rupture into the peritoneal space. The occurrence of intrabiliary rupture has been documented to range from 6.1% to 17%.[4,15] In a research conducted during a period when the US and CT were not accessible, the reported rate was found to be 41%.[16]

The aim of this study was to investigate the frequency of intrabiliary rupture in patients with hepatic hydatid cysts and evaluate the most common MRI findings in patients with biliary rupture.

METHODS

Ethical approval was obtained from the Kastamonu University Hospital's Ethics Committee for this retrospective study (Date: July 5, 2023, Number: 2023-KAEK-78).

MAIN POINTS

- Due to the high mortality and morbidity of biliary rupture, its management becomes crucial.
- The frequency of cystobiliary fistula in our study was found to be approximately 8%.
- The most commonly observed magnetic resonance imaging finding in cystobiliary fistula is bile duct dilation, along with other important findings such as cyst deformation, structures consistent with cyst contents in the bile ducts, and fistulous connection.

The reports of patients who underwent upper abdominal and liver MRI within the last 5 years were screened using the hospital's information management system with the keyword "hydatid cyst."

The inclusion criteria were defined as follows: positive diagnosis of hepatic hydatid cyst, images obtained using a protocol specific to the liver, images free of artifacts suitable for evaluation, and being 18 years of age or older.

The exclusion criteria were defined as follows: being under 18 years of age, having additional liver pathologies that could affect the study results such as diffuse liver parenchymal disease or malignancy, having undergone surgical intervention involving the gallbladder or bile ducts, images with artifacts, MRI performed without the use of contrast agent, and images obtained without an appropriate protocol specific to the liver.

All examinations were performed using a 1.5 Tesla MR device (Signa Explorer, GE Medical Systems, Milwaukee, Wis, USA). The sequence parameters are shown in Table 1.

In addition to demographic data such as age and gender of the scanned patients, information regarding the hepatic segment location of the hydatid cyst lesion, number of lesions, lesion size, and type of cyst according to the Gharbi classification was recorded. Furthermore, the presence or absence of biliary communication was evaluated, and the clinical and laboratory findings of these patients were checked from the hospital information system.

In patients with biliary communication, the presence of dilation in the intrahepatic bile ducts and common bile duct, the presence of structures consistent with cyst contents in the bile ducts, the presence of fistulous connections, and the frequency rates of these findings were evaluated. Additionally, the ERCP findings of patients with biliary communication were retrospectively evaluated from the hospital information management system.

Statistical Analysis

The statistical program used for all analyses was IBM Statistical Package for the Social Sciences 26.0 (IBM SPSS Corp., Armonk, New York, USA). Descriptive statistics are presented as mean ± SD for numerical data as well as counts and percentages for categorical data. The normality of the data was evaluated through the utilization of the Kolmogorov–Smirnov test, which revealed that none of the variables exhibited adherence to a normal distribution. Therefore, in order to compare groups, nonparametric tests such as the Mann–Whitney *U*- test are employed. A *P*-value <.05 was considered to be statistically significant.

RESULTS

As a result of the screening conducted through the hospital information system, the study included a total of 50 patients who met the predetermined criteria for inclusion.

Among the 50 patients, 3 of them had 2 lesions each and 1 patient had 3 lesions. In total, there were 55 lesions. The mean age of the patients was 44.7 ± 10.4 years. Of the 50 patients, 30 (60%) were male and 20 (40%) were female. Age and gender values are shown in Table 2.

Table 2. Patients' Gender, Age, and Lesion Number Values and Comparison of These Values by Gender

	Male (n = 30)	Female (n = 20)	Total (n = 50)	*P*
Age (years)	46.7 ± 11.3	42.9 ± 9.1	44.7 ± 10.4	.547
Number of lesions	31	24	55	.354

Thirty-two (58.2%) of 55 hydatid cyst lesions were located in the right lobe and 23 (41.8%) were located in the left lobe. The mean lesion diameter was 45.8 ± 29.6 mm. There was no significant difference between the lesions in the right and left lobes in terms of lesion sizes

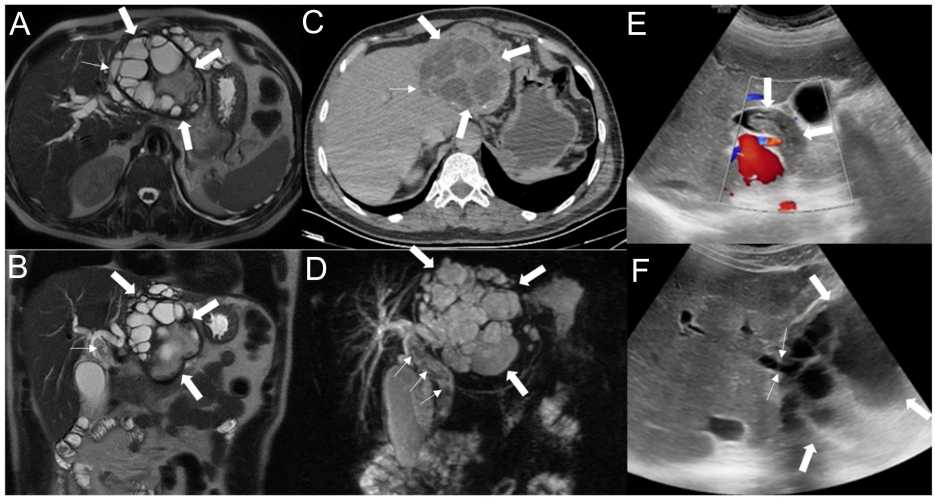

Figure 1. Fifty-four-year-old male with Gharbi type 3 hydatid cyst lesion in the left lobe of the liver with 6-day epigastric stomach pain and dyspeptic symptoms. (A, B) Axial/coronal T2-weighted fast spin echo magnetic resonance images demonstrate a type 3 hydatid cyst lesion (thick arrows). The common and main hepatic bile ducts contain hypointense membranous structures connected to hydatid cysts and are dilated. (C) Axial abdominal contrast-enhanced computed tomography scan shows a type 3 hydatid cyst (thick arrows) and a fistulous connection between it and one of the intrahepatic bile ducts (thin arrow). (D) Coronal magnetic resonance cholangiopancreatography image shows a type 3 hydatid cyst lesion (thick arrows). There is also bile duct dilatation and hypointense membranous structures caused by hydatid cysts in the common and main hepatic bile ducts (thin arrows). (E, F) Grayscale ultrasound (US) and color Doppler US images show semi-solid structures with uneven heterogeneous supply and no blood supply in the main hepatic bile duct in (thick arrows).

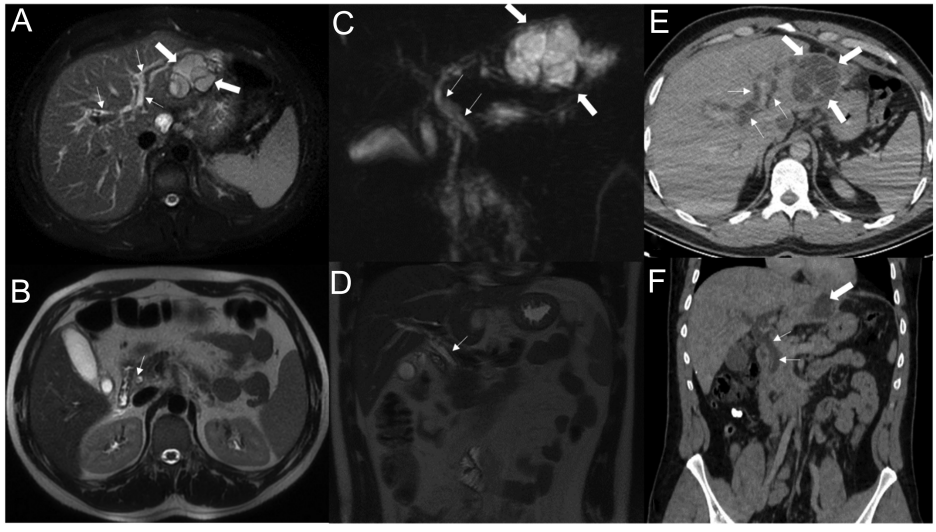

Figure 2. Twenty-six-year-old male patient with epigastric abdominal pain that had been ongoing for 5 days and had a Gharbi type 3 hydatid cyst lesion in liver segment 2**.** (A, B) Axial T2-weighted fast spin-echo magnetic resonance images show a hydatid cyst lesion (thick arrows) and dilatation of the bile ducts (thin arrows). (C, D) Coronal magnetic resonance cholangiopancreatography images and coronal T2-weighted fast spin-echo magnetic resonance images show a hypointense membranous structure related to the hydatid cyst in the lumen of the common bile duct (thin arrows) and show hydatid cyst lesion (thick arrows). **(**E, F**)** The axial and coronal abdominal contrast-enhanced computed tomography images of the patient show a hydatid cyst lesion (thick arrows) and dilatation of the bile ducts (thin arrows).

Table 3. Magnetic Resonance Imaging Findings in Patients with Intrabiliary Rupture

Findings	N	%
Dilation in the intrahepatic bile ducts and common bile duct	4	100
Deformation of cyst	3	75
Structures consistent with cyst contents in the bile ducts	2	50
A fistulous connection	1	25

($P > .05$). Out of the 55 lesions, 10 (18.2%) were classified as type 1 according to the Gharbi classification, 4 (7.3%) were type 2, 6 (10.9%) were type 3, 15 (27.3%) were type 4, and 20 (36.4%) were type 5, consistent with hydatid cysts.

Out of the 50 patients, 4 (8%) had biliary communication. In addition to the MRI findings of all patients, the ERCP results were also consistent with biliary communication. All patients with biliary communication had a single lesion. Among the 4 patients with biliary communication, 4 (100%) had dilation in the intrahepatic bile ducts and common bile duct, 3 (75%) had deformation of cyst, 2 (50%) had structures consistent with cyst contents in the bile ducts, and 1 (25%) had a fistulous connection shown by MRI (Figures 1 and 2). The data of patients with biliary communication are shown in Table 3.

No significant differences were found in terms of age and gender between patients with biliary communication and those without ($P > .05$). However, the cyst size was significantly larger in patients with biliary communication compared to those without ($P < .05$). In terms of the cyst type, the most common type of hydatid cyst in patients with biliary communication was type 3.

DISCUSSION

In our study, we retrospectively evaluated the frequency of intrabiliary rupture in patients with hydatid cyst, the factors influencing rupture, and the most common MRI findings in cases with rupture. According to our study, the most common MRI finding in hydatid cyst with biliary communication is biliary dilation. Following that, the presence of cystic material within the bile ducts and direct demonstration of fistulous connections are observed in descending order of frequency.

Rupture of cysts into the bile ducts is a common complication of hepatic hydatid disease. Communication between the biliary tree and the hydatid cyst can be either evident or occult. If an occult cystobiliary communication remains undetected and is not properly repaired during surgery, it can result in postoperative biliary fistulas. Imaging plays a crucial role in the detection of hydatid cysts and accurate localization of intrabiliary ruptures, which is essential for early surgical intervention.[16,17]

Prior to the utilization of US and CT, preoperative identification of hepatic hydatid cyst complications was challenging and relied on clinical symptoms and laboratory results. Ultrasound or CT can often indicate the presence of overt intrabiliary rupture, while MRI offers the advantage of additional multiplanar images. Magnetic resonance cholangiopancreatography (MRCP) reveals distinct features such as a daughter cyst, dilated biliary tree containing hydatid materials, prominent border, and membrane separation.[18,19]

Rupture of hydatid cysts can occur due to increased pressure inside the cyst triggered by trauma, exertion, or forceful coughing. The rupture can be categorized into 3 types: contained rupture, communicating rupture, and direct rupture. In a contained rupture, the endocyst ruptures, but the contents of the cyst are still confined within the pericyst. Communicating rupture involves the rupture of the endocyst, resulting in the leakage of cyst contents through smaller biliary ducts. Direct rupture occurs when the 2 layers of endocyst and pericyst rupture, causing the cyst contents to leak into the peritoneal or pleural spaces.[3,4]

The radiological findings of intrabiliary rupture encompass both direct and indirect signs.[20] The sole direct sign of rupture is evident communication between the cyst and the biliary tree. In our study, this finding was positive in only 25% of cases with ruptured cysts. Similarly, Erden et al[17] reported a relatively low rate of 33% in their study, which assessed MRCP for cystobiliary communication in a population of 54 hydatid cyst patients and 12 cystobiliary communication patients. Although the presence of this finding indicates a high probability of cystobiliary rupture, it can be relatively low in detection by MRI and MRCP, as demonstrated in our study and literature.

The cyst deformation, which is one of the indirect signs of intrabiliary rupture and considered as a result of decreased intracystic pressure, was found positive in 75% of cases with cystobiliary communication in our study. Our findings are consistent with the study conducted by Erden et al,[17] which reported the same rate of 75%. This finding may also be secondary to decreased cyst pressure in patients who have undergone treatment.[21] However, none of the patients in our study had a history of treatment. Although this sign does not definitively indicate rupture, it can be considered as a highly indicative indirect finding of cystobiliary connection based on our study and the literature. The identification of collapse or deformation in a known hydatid cyst during follow-up and comparison with previous images can be considered as a significant indirect finding of cystobiliary fistula.

The pericyst layer, consisting of thick avascular and fibrous tissue, is located on the outermost part of the hydatid cyst lesion.[22] Loss of integrity in this pericyst layer and demonstration of communication with the bile ducts are direct signs of biliary rupture. Discontinuity in the pericyst layer was relatively low in our cases and found in only about 25% of cases. In the literature, it has been reported that this finding was present in approximately 66.7% of cases in the study conducted by Erden et al.[17] The relatively lower percentage in our study could be attributed to a lower number of positive cases for cystobiliary fistula. Nevertheless, the detection of defects in the pericyst, especially in T2-weighted series, and loss of integrity in the cyst wall should be emphasized as significant findings of rupture.

It has been stated that the inner layer of a hydatid cyst, known as the endocyst, can detach not only due to aging or ischemia but also in cases of rupture.[23] In the study by Erden et al,[17] it was reported that endocyst detachment was observed in 50% of cases. However, we did not observe this finding in any of our cases. Additionally, the presence of cyst fragments within the bile ducts due to biliary communication is another finding, and we observed this in 50% of our cases. In the study by Erden et al,[17] they reported a 25% incidence of this finding. Variations in the visibility of cystic contents in the bile ducts on MRI may arise depending on the size and location of the cyst and the degree of rupture.

In our study, all cases with intrabiliary rupture showed dilation in the intrahepatic bile ducts and common bile duct. In the literature, Wani et al[24] reported findings from a study evaluating CT findings in 6 patients

with intrabiliary rupture, stating that, similar to our study, all patients showed dilation in the bile ducts. Additionally, dilation in the intrahepatic bile ducts can sometimes be observed in pericystic areas due to an increase in the cyst size. Focal dilation and localized pericystic areas can sometimes be falsely interpreted as intrabiliary rupture, as reported in the literature.[17] However, in our study, the dilation of the bile ducts in the cases was not localized but rather generalized, and the intrabiliary rupture was confirmed by ERCP without any false-positive results.

Our study had some limitations. The most important limitation was its retrospective design and the relatively small population of patients with hepatic hydatid cysts who underwent abdominal MRI. Additionally, the relatively low number of cases with cystobiliary fistula was also a significant limitation of the study. Furthermore, due to the retrospective design, sufficient data regarding the clinical symptoms of the patients could not be obtained, which was another limitation of the study. However, a strong aspect of the study was that all 4 cases with cystobiliary fistula were confirmed by ERCP.

In conclusion, the frequency of cystobiliary fistula in our study was found to be approximately 8%, and significant imaging findings can be obtained with MRI in the evaluation of cystobiliary fistula. The most commonly observed MRI finding in cystobiliary fistula is bile duct dilation, along with other important findings such as cyst deformation, structures consistent with cyst contents in the bile ducts, and fistulous connection. Longitudinal prospective studies with a larger patient population could provide additional benefits in this regard.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Kastamonu University (Date: July 5, 2023, Number: 2023-KAEK-78).

Informed Consent: Due to the retrospective design of the study, patient consent was not obtained for this study.

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Current Research in MRI

Original Article

Normal Achilles Tendon Morphology: A Radioanatomical Study

Taner Kösetürk[1], Mukadder Sunar[1], Ömer Kazcı[2], Özlem Çelik Aydın[3]

[1]Department of Anatomy, Erzincan Binali Yıldırım University, Mengücek Gazi Training and Research Hospital, Erzincan, Turkey
[2]Department of Radiology, Ankara Training and Research Hospital, Ankara, Turkey
[3]Department of Medical Pharmacology, Erzincan Binali Yıldırım University, Mengücek Gazi Training and Research Hospital, Erzincan, Turkey

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Corresponding author: Taner Kösetürk, e-mail: tanerkoseturk@gmail.com

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Abstract

Objective: The evaluation of the morphometric features of the Achilles tendon with magnetic resonance imaging is an essential aspect of musculoskeletal imaging, with significant implications for the diagnosis and management of Achilles tendon injuries. The aim of this study is to investigate the morphology of the Achilles tendon in normal and healthy individuals and establish a standard value using specific measurement techniques.

Methods: The sagittal images were used to compute the free Achilles tendon length between the most distal portion of the soleus muscle fibers and the proximal-superior calcaneal insertion of the Achilles tendon. On the axial images, the most distal portion of the soleus muscle fibers was identified, and the free Achilles tendon length was measured between this location and the Achilles tendon's most distal calcaneal insertion.In the axial section, the thickest portion of the unrestricted portion of the Achilles tendon in the anteroposterior plane was measured.The distance between the point at which the Achilles tendon attained its maximum thickness and its proximal insertion into the calcaneus was measured.

Results: The thickest portion of the unconstrained portion of the Achilles tendon, known as the APM distance, was measured to be 5 ± 0.2 mm in the anteroposterior plane.The MKPM distance, which is the distance from the point where the Achilles tendon reaches its maximal thickness to the proximal insertion of the calcaneus, was measured to be 18.4 ± 4.7 mm.

Conclusion: Future research should aim to expand our understanding of the factors influencing Achilles tendon morphology and their impact on tendon health and injury risk. Such knowledge can inform the development of personalized strategies for the prevention, diagnosis, and treatment of Achilles tendon disorders.

Keywords: Tendons, radiology, muscles

INTRODUCTION

The Achilles tendon, the most substantial tendon in the human body, is critical to mobility due to its role in enabling walking, running, and jumping.[1] However, it is also one of the most frequently injured tendons, with approximately 5%-12% of all athletes experiencing Achilles tendon injuries in their lifetimes.[2] These injuries not only disrupt an individual's daily life and athletic performance but may also necessitate lengthy recovery periods or surgical intervention in severe cases.[3]

Magnetic resonance imaging (MRI) has become a pivotal tool for the clinical assessment of Achilles tendon pathology. It provides a comprehensive assessment of the tendon's structural and morphological features, identifying injuries or pathological changes that may not be discernible with physical examination alone.[4] Nevertheless, the utilization of MRI in this context is predicated on a nuanced understanding of the normal morphology and variations within the general population. This understanding can aid clinicians in differentiating normal anatomical variations from pathological deviations, which is essential for accurate diagnosis and effective therapeutic intervention.

Several studies have elucidated the normal morphological characteristics of the Achilles tendon. The Achilles tendon, a fibrous structure formed from the confluence of the gastrocnemius and soleus muscles, has an average length of 15 cm in adults, with a broadest cross-sectional area at about 4 cm from the tendon's insertion onto the calcaneus.[5] However, the Achilles tendon demonstrates substantial inter-individual variability in its morphometric features, including length, width, and thickness. The reasons behind these variations are multifactorial and likely include age, gender, physical activity level, and genetic predisposition.[6]

In order to interpret MRI images of the Achilles tendon accurately, it is crucial to appreciate not only its typical morphometric features but also the normal variations that may occur. For instance, recent research using MRI revealed that the cross-sectional area of the Achilles tendon tends to decrease with age, suggesting age-specific reference values may be beneficial for optimal interpretation. Similarly, gender-specific differences in Achilles tendon morphology have been reported, with men generally having larger and longer tendons than women.[7] These findings underscore the importance of taking individual patient characteristics into account when evaluating Achilles tendon images.

Assessment of the morphometric features of the Achilles tendon via MRI has significant implications for the management of Achilles tendon injuries. Understanding the normal Achilles tendon morphology can aid in identifying pathological changes that may contribute to the risk of injury, such as tendon thickening, which is commonly observed in tendinopathy.[8] Moreover, it can inform the design and application of surgical procedures for Achilles tendon repair, potentially improving patient outcomes.[9]

The evaluation of the morphometric features of the Achilles tendon with MRI is an essential aspect of musculoskeletal imaging, with significant implications for the diagnosis and management of Achilles tendon injuries. The aim of this study is to investigate the morphology of the Achilles tendon in normal and healthy individuals and establish a standard value using specific measurement techniques.

METHODS

The Clinical Research Ethics Committee of Erzincan Binali Yildirim University approved this study (Date: February 21, 2022, Number: 15/19) and the patients gave their written consent. Examining ankle MRI scans from the years 2019 to 2023, data relevant to 342 patients were retrospectively collected from the Department of Radiology, Erzincan Binali Yildirim University Faculty of Medicine. Excluded from the study were patients with Achilles tendon rupture, diseases affecting the anatomy and physiology of the musculoskeletal system (such as cancer and soft tissue infections), patients who underwent ankle surgery, patients with calcaneal fractures, and patients unable to obtain suitable images due to orthopedic equipment or movement-related artifacts. Only patients with high-quality anatomical and pathophysiological images of the musculoskeletal system were included in the study.

This manuscript adheres to the applicable STROBE guidelines.

Using 18-channel coils on a 1.5T power 32-channel MRI device (Siemens magnetom aera, Erlangen, Germany), ankle imaging was performed. Using the Siemens Somatom Sensation-Syngo.via software (Siemens Healthineers, Erlangen, Germany), images from the Picture Archiving Communication System archive were analyzed.

The T1-weighted sequences in the coronal and sagittal planes, T2-weighted sequences in the axial and sagittal planes, and Proton density (PD)-weighted fat-suppressed sequences in the axial and coronal planes were performed on all patients. The PD-weighted turbo spin echo (TSE) with echo time (TE) of 21 ms and repetition time (TR) of 2400 ms, T2-weighted (TSE) with TE of 56 ms and TR of 3920 ms, and T1-weighted with TE of 10 ms and TR of 797 ms were the most frequently used protocols. The field of view was 200 mm and voxel size was 0.80 × 0.83.5 mm. Section thickness was 4 mm.

MAIN POINTS

- The morphometric characteristics of the Achilles tendon, such as length, thickness, and cross-sectional area, are critical to its functionality and can be precisely assessed by magnetic resonance imaging.
- The morphometric properties of the Achilles tendon vary significantly in the general population, underscoring the significance of personalized examinations in clinical practice.
- The morphological properties of the Achilles tendon are influenced by age, gender, and physical activity level, and understanding these aspects can aid in the prevention, diagnosis, and treatment of Achilles tendon problems.

The sagittal images were used to compute the free Achilles tendon length between the most distal portion of the soleus muscle fibers and the proximal-superior calcaneal insertion of the Achilles tendon (SPM) (Figure 1). On the axial images, the most distal portion of the soleus muscle fibers was identified, and the free Achilles tendon length was measured between this location and the Achilles tendon's most distal calcaneal insertion.

In the axial section, the thickest portion of the unrestricted portion of the Achilles tendon in the anteroposterior plane was measured. Figure 2 depicts sagittal sections used to confirm this measurement (APM).

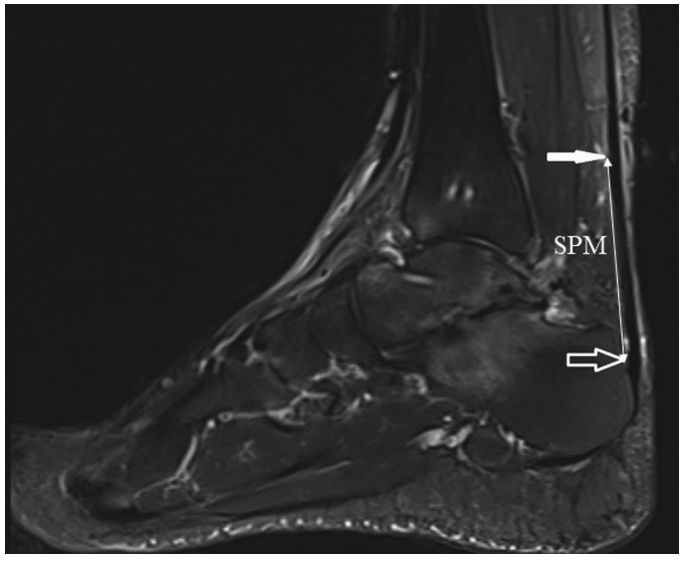

Figure 1. T2 fat-suppressed sequence showing the Achilles tendon, showing the most distal part of the soleus muscle (solid white arrow) and the most proximal anterior calcaneal insertion of the Achilles tendon (hollow white arrow). The distance between the 2 arrows is defined as the SPM distance.

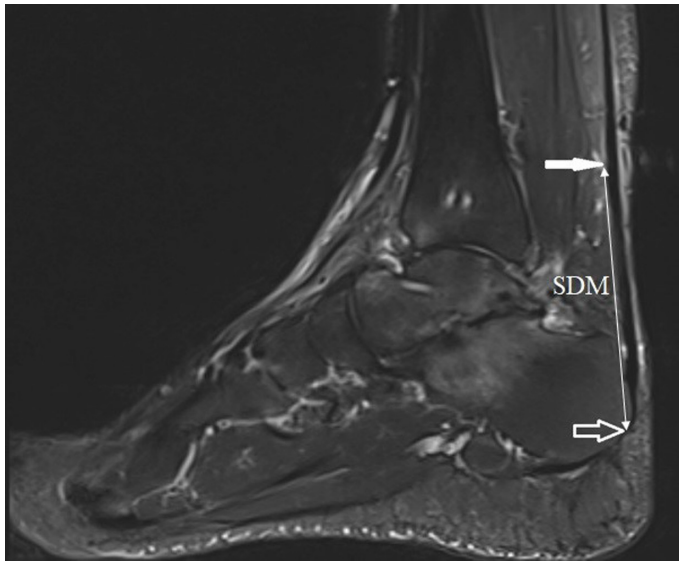

Figure 2. T2 fat-suppressed sequence showing the Achilles tendon, showing the most distal part of the soleus muscle (solid white arrow) and the most distal calcaneal insertion of the Achilles tendon (hollow white arrow). The distance between the 2 arrows is defined as the SDM distance.

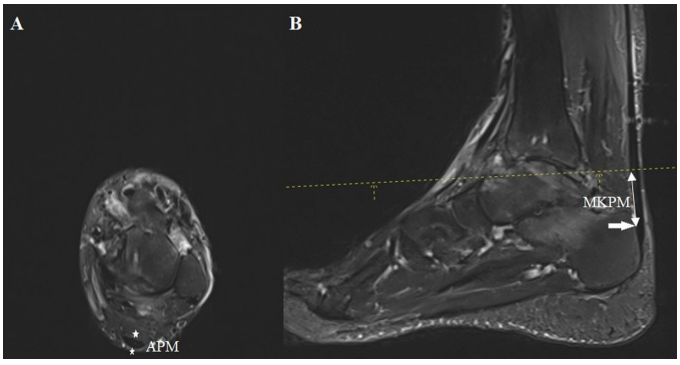

Figure 3. Axial (A) and sagittal (B) sections of the Achilles tendon in T2 fat-suppressed sequence. The thickest part of the Achilles tendon in the axial sections (the distance between the 2wo white stars) was determined, and the anteroposterior thickness of the tendon at this level was defined as the APM distance. In addition, this level was determined in sagittal sections (dashed yellow line), and the distance from the point determined in sagittal sections to the calcaneus antero-proximal insertion of the Achilles tendon (solid white arrow) was defined as the MKPM distance.

The distance between the point at which the Achilles tendon attained its maximum thickness and its proximal insertion into the calcaneus was measured (MKPM) (Figure 3).

You can find STROBE Statement in the Appendix.

Statistical Analysis

Data were analyzed using the IBM Statistical Package for Social Sciences v25 for Windows (IBM SPSS Inc., Chicago, Ill, USA). The normal distribution of the data was evaluated with the Kolmogorov–Smirnov test. Numerical variables with normal distribution were shown as mean ± SD. Categorical variables were shown as numbers and percentages. For the comparison of numerical variables between the 2 groups, Student's *t*-test was used.

A 2-tailed value of $P < .05$ was considered statistically significant.

RESULTS

In our investigation, we retrospectively examined 342 MRI images devoid of Achilles tendon pathology. There were 174 males and 168 females in the examined images, with a mean age of 36.6 ± 13.2 (18-75) years. The distance between the most distal portion of the soleus muscle fibers and the proximal-superior calcaneal insertion of the Achilles tendon, known as the SPM distance (value range 6.7-69.3 mm), was measured to be 38.9±13.8 mm in the healthy population. The length of the free Achilles tendon between the most distal segment of the soleus muscle fibers and the distal calcaneal insertion of the Achilles tendon was measured to be 59.3 ± 11.4 mm (value range: 27-91.9 mm).

The thickest portion of the unconstrained portion of the Achilles tendon, known as the APM distance, was measured to be 5±0.2 mm (value range: 3.8-5.9 mm) in the anteroposterior plane.

The MKPM distance, which is the distance from the point where the Achilles tendon reaches its maximal thickness to the proximal insertion of the calcaneus, was measured to be 18.4 ± 4.7 mm (value range: 3.8-21.9 mm).

The ratio of the maximal tendon thickness to the proximal calcaneal insertion, termed MKPM/SPM, was 49.6 ± 17.2% (value range: 15.9-0.98 mm) (Table 1). Men had a greater APM distance and MKPM distance to the calcaneal insertion than women (Table 1). There was no other difference between the sexes in the measurements.

Table 1. Patient Values Measured by Age and Gender and Their Comparison

Distances	Mean (mm)	Male (mm)	Female (mm)	*P* (*t*-Tests)
SPM	38.9 ± 13.8	41.6 ± 13.6	36.3 ± 12.6	>.05
SDM	59.3 ± 11.4	63.8 ± 11.9	53 ± 12.6	>.05
APM	5 ± 0.2	5.1 ± 0.1	4.3 ± 0.7	.002
MKPM	18.4 ± 4.7	19.1 ± 3.4	16.5 ± 4.0	.005
MKPM/SPM (percent)	49.6 ± 19.5	48.1 ± 18.7	48.6 ± 15.2	>.05

DISCUSSION

The morphometric features of the Achilles tendon have become a focal point of research given their fundamental role in diagnosing and managing tendon disorders. In this discussion, we will review these features in the context of recent studies and their implications for our understanding of Achilles tendon health and disease.

The Achilles tendon's morphological characteristics, including length, thickness, and cross-sectional area, play a vital role in its functionality.[10] These features, which can be accurately measured via MRI, reflect the tendon's mechanical properties and its ability to transmit forces from the calf muscles to the foot. As such, deviations from the normal morphology can adversely affect these functions and potentially increase the risk of injury.

Recent MRI studies have shed light on the variability of Achilles tendon morphometric features within the general population. For instance, Szaro et al[5] found a substantial range in the cross-sectional area and thickness of the Achilles tendon in their cohort of healthy adults, highlighting the importance of individualized assessments in clinical practice. These findings echo earlier studies that demonstrated significant variations in Achilles tendon morphology and suggested that these differences might be related to factors such as age, sex, and physical activity level.[11]

Age-related changes in Achilles tendon morphology are particularly noteworthy. As the cross-sectional area is a determinant of tendon strength, age-related decreases could potentially contribute to the higher incidence of Achilles tendon injuries observed in older adults. Consequently, the application of age-specific reference values in clinical practice may facilitate earlier identification of individuals at risk and promote preventive measures.

Similarly, gender differences in Achilles tendon morphometry have been reported, with men generally having larger tendons than women.[11] These findings could partly explain the higher incidence of Achilles tendon injuries in men compared to women and emphasize the need for gender-specific reference values in the clinical interpretation of Achilles tendon MRI images.

The morphometric features of the Achilles tendon are also thought to be influenced by physical activity level. Several studies have shown that regular physical activity can lead to adaptations in the Achilles tendon, such as increased thickness and cross-sectional area, which may enhance the tendon's ability to withstand mechanical loads.[12] However, excessive or inappropriate loading, as often seen in high-level sports, can induce pathological changes in the tendon, including thickening

and disorganized collagen structure.[8] Therefore, in athletes and highly active individuals, careful interpretation of MRI images is necessary to differentiate normal adaptations from pathological changes.

Our study differs from other studies in the literature in several ways. First, we had a larger reservoir of data than those in the literature. On the analyzed images, measurements of the normal tendon were recorded using a variety of techniques, and a standard value was sought. By reference to these values, the values above and below the defined values may support pathology.

Our work is subject to certain restrictions. One health facility has been utilized. Unfortunately, diversity is lacking. It is a limitation that the quantity of data is not greater.

In conclusion, the evaluation of the morphometric features of the Achilles tendon with MRI offers valuable insights into the health and function of this critical structure. Future research should aim to expand our understanding of the factors influencing Achilles tendon morphology and their impact on tendon health and injury risk. Such knowledge can inform the development of personalized strategies for the prevention, diagnosis, and treatment of Achilles tendon disorders.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Erzincan Binali Yıldırım University (Date: February 21, 2022, Number: 15/19).

Informed Consent: Informed consent is waived as a result of retrospective nature.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – T.K., M.S.; Design – T.K.; Supervision – T.K.; Resources – M.S.; Materials – Ö.K.; Data Collection and/or Processing – Ö.K.; Analysis and/or Interpretation – T.K.; Literature Search – Ö.A.; Writing Manuscript – T.K.; Critical Review – Ö.A.

Declaration of Interests: The authors declare that they have no competing interest.

Funding: The authors declared that this study has received no financial support.

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APPENDIX. STROBE STATEMENT—CHECKLIST OF ITEMS THAT SHOULD BE INCLUDED IN REPORTS OF OBSERVATIONAL STUDIES

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case–control study*—Give the eligibility criteria and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case–control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe the comparability of assessment methods if there is more than 1 group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case–control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking into account of sampling strategy
		(*e*) Describe any sensitivity analyses
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—for example, numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyzed
		(b) Give reasons for non-participation at each stage
		(c) Consider the use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (e.g., demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate the number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarize follow-up time (e.g., average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case–control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% CI). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—for example, analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarize key results with reference to study objectives
Limitations	19	Discuss the limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalizability	21	Discuss the generalizability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case–control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of *PLoS Medicine* at http://www.plosmedicine.org/, *Annals of Internal Medicine* at http://www.annals.org/, and *Epidemiology* at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Current Research in MRI

Case Report

Pseudostenosis Artifact in the Subclavian Artery

Ramazan Orkun Önder, Cemre Akdeniz, Alptekin Tosun

Department of Radiology, Giresun University, Faculty of Medicine, Giresun, Turkey

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Corresponding author: Ramazan Orkun Önder, e-mail: orkunonder535@gmail.com

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Abstract

Pseudostenosis is a magnetic resonance angiography artifact that mimics arterial stenosis. In early arterial phase magnetic resonance angiography, pseudostenosis artifact of the subclavian artery can be seen due to susceptibility effects caused by residual gadolinium in the subclavian vein. Delayed phase-specific magnetic resonance imaging subclavian scanning shows that suspected pseudostenosis seen in the early arterial phase magnetic resonance angiography is no longer present during the venous phase.

We present our case of a 21-year-old female with complaints of pain, fatigue, and numbness in the left arm that showed severe stenosis of the left subclavian artery in her upper extremity magnetic resonance angiography, but there was not any finding compatible with stenosis in her delayed phase dynamic magnetic resonance imaging with contrast.

Clinicians and radiologists should consider repeating the imaging with contrast injection to the contralateral extremity or using a more special high-resolution delayed dynamic magnetic resonance imaging to confirm suspected true stenosis and avoid misdiagnosis.

Keywords: Magnetic resonance angiography, pseudostenosis artifact, subclavian artery

INTRODUCTION

Pseudostenosis is a magnetic resonance angiography (MRA) artifact that mimics arterial stenosis. Arterial pseudostenosis is a magnetic artifact that is present only during early arterial phase magnetic resonance imaging (MRI) when there is persistent gadolinium in the ipsilateral venous system of the contrast injection site.[1-3] Delayed phase-specific MRI subclavian scanning shows that suspected pseudostenosis seen in the early arterial phase MRA is no longer present during the venous phase. In this case report, we aimed to present the findings of a pseudostenosis artifact in the subclavian artery in a 21-year-old female patient.

CASE PRESENTATION

A 21-year-old female patient with no additional disease was admitted with complaints of pain, fatigue, and numbness in the left arm. In her physical examination, the only finding was hypotension. The patient was scheduled for an upper extremity arterial system Color Doppler Ultrasonography (CDUS). Her CDUS examination showed no significant signs of stenosis or impaired flow hemodynamics. Since the patient's complaints persisted, MRI of the subclavian region and dynamic MRI after intravenous injection of contrast material in the left arm was performed. In her upper extremity early arterial phase MRA, severe stenosis was observed in the middle part of the left subclavian artery and there was no significant contrast transition at this level (Figure 1A and B). There was a decrease in artery calibrations in the axillary and brachial arteries at the distal of the stenosis region, more evident in the brachial artery. In delayed phase-specific MRI for the left subclavian region—conventional T1-weighted imaging (T1WI) and fat-suppressed T1WIs—left subclavian vein and subclavian artery calibrations were completely normal. After not seeing any pathological appearance causing compression in the left subclavian artery and vein, it came clear that the stenosis that was detected in the MRA was pseudostenosis artifact (Figure 1C and D).

DISCUSSION

In MRI, susceptibility artifacts may be seen due to metallic objects implanted in the body (e.g., iatrogenic stents and metallic stents).[4,5] Gadolinium, a typical component of MR contrast agent, has metallurgical features. Gadolinium can cause susceptibility artifacts due to these features. If images are captured in MRA immediately after injection of gadolinium-based contrast into an upper extremity, it is found that high concentrations of gadolinium in the ipsilateral subclavian vein can cause susceptibility artifacts in the subclavian artery nearby. This artifact, which appears in the subclavian artery, can mimic a stenosis, and this false appearance is called pseudostenosis. Pseudostenosis artifact of the arteries of the upper extremities, which always occurs on the same side as the injection site, is focal and typically located in the most distal segment of the subclavian artery just before the axillary artery.[6-9] Compared to the right upper extremity, pseudostenosis artifact occurs in the left upper extremity more often possibly due to the longer duration of venous return.[10] Marinelli et al[1] conducted a total of 189 MRA studies in 2019. In this study, the largest of its kind to assess prevalence of pseudostenosis in a cohort of patients using a standardized imaging protocol, an equal prevalence of pseudostenosis was found in the right and left upper extremities. In the carotid and vertebral arteries, pseudostenosis

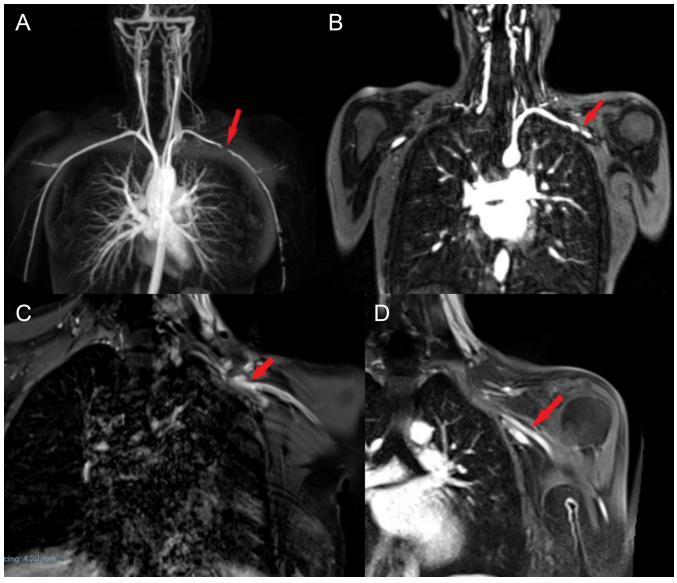

Figure 1. (A) Coronal section, maximum intensity projection reconstruction of an early arterial phase MRA shows a pseudostenosis in the left subclavian artery in a healthy subject (red arrow). (B) In early arterial-phase MRA, severe stenosis was observed in the middle section of the left subclavian artery (red arrow). (C) In the delayed-phase magnetic resonance imaging–fat suppressed T1WI, left subclavian vein and subclavian artery calibrations were normal. There was no pathological appearance that caused the compression of the subclavian artery or the subclavian vein. (D) A delayed-phase magnetic resonance imaging–dedicated subclavian scan shows that the suspected pseudostenosis seen during the early arterial phase magnetic resonance imaging is no longer visualized when imaging the same subject during the venous phase magnetic resonance imaging (red arrow).

has rarely been reported. In early arterial-phase MRA, pseudostenosis artifact of the subclavian artery can be seen due to susceptibility effects caused by residual gadolinium in the subclavian vein. Delayed phase-specific MRI subclavian scanning shows that suspected pseudostenosis seen in the early arterial phase is no longer present during the venous phase.[12-14] Therefore, clinicians and radiologists should consider repeating the imaging with contrast injection to the contralateral extremity or using more special high-resolution delayed dynamic imaging to confirm a suspected true stenosis and avoid the misdiagnosis.

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

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – R.O.Ö., C.A., A.T.; Design – R.O.Ö., C.A., A.T.; Supervision – A.T.; Resources – R.O.Ö., C.A., A.T.; Materials – R.O.Ö., C.A., A.T.; Data Collection and/or Processing – R.O.Ö., C.A.; Analysis and/or Interpretation – R.O.Ö., C.A., A.T.; Literature Search – R.O.Ö., C.A., A.T.; Writing Manuscript – R.O.Ö., C.A., A.T.; Critical Review – A.T.

Declaration of Interests: The authors declare that they have no competing interest.

Funding: The authors declared that this study has received no financial support.

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Current Research in MRI

Case Report

Mild Encephalitis/Encephalopathy with Reversible Splenial Lesion: Two Case Reports

Esat Kaba, Mehmet Beyazal, Muhammed Kaya, Fatma Beyazal Çeliker

Department of Radiology, Recep Tayyip Erdoğan University, Faculty of Medicine, Rize, Turkey

Cite this article as: Kaba E, Beyazal M, Kaya M, Beyazal Çeliker F. Mild encephalitis/encephalopathy with reversible splenial lesion: Two case reports. *Current Research in MRI*, 2023;2(2):38-40.

One of the cases was sent for evaluation to be presented as a poster in the congress of the Turkish Neuroradiology Society.

Corresponding author: Fatma Beyazal Çeliker, e-mail: fabeceliker@gmail.com

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Abstract

Mild encephalitis/encephalopathy with reversible splenial lesion is a clinical and radiological diagnosis and is defined as reversible diffusion restriction in the corpus callosum splenium. It is generally reported to be related with viral infections. We present 2 adult patients with reversible diffusion restriction in the corpus splenium and mild encephalitis. Mild encephalitis/encephalopathy with reversible splenial lesion has a good prognosis, but the differential diagnosis should be made from ischemia, posterior reversible encephalopathy syndrome, lymphoma, diffuse axonal damage, and extrapontine myelinolysis.

Keywords: Diffusion restriction, MRI, reversible, splenium

INTRODUCTION

Mild encephalitis/encephalopathy with reversible splenial lesion (MERS) is a clinic–radiologic diagnosis with a good prognosis, presenting with encephalitis findings characterized by reversible lesion of the splenium of the carpus callosum.[1] Although it is generally reported to be related with viral infections, it may also be related with metabolic conditions and drug use.[2] Reversible magnetic resonance imaging (MRI) findings including diffusion restriction and T2-weighted-Fluid-Attenuated Inversion Recovery (FLAIR) hyperintensity are observed in the splenium of the corpus callosum. Although this entity is reported to be more common in children, many adult patients have been reported in recent years.[3]

We aimed to present 2 adult patients with a clinical and radiological diagnosis of MERS.

CASE PRESENTATIONS

Case 1

A 40-year-old female patient who had been suffering from malaise and fever for a week was admitted to our hospital with slurred speech and confusion. The patient with no comorbidities was started to be investigated with a prediagnosis of encephalitis. Cranial MRI obtained from the patient showed diffusion restriction in the splenium of the corpus callosum. In the same localization, T2 was hyperintense and T1 was isointense and did not show contrast enhancement. C-reactive protein was 338 mg/L, and cerebrospinal fluid values were normal after the lumbar puncture. The clinical and radiological images were evaluated together, and the patient was diagnosed with MERS. After 3 days, the patient's complaints decreased, and regression was observed in the findings of the same localization on the control MRI. After 14 days, the lesion completely disappeared (Figure 1). The patient was discharged with complete recovery after a total of 15 days.

Case 2

A 35-year-old male patient presented to the emergency department with complaints of confusion, nausea, vomiting, and urinary incontinence. He had no known disease other than asthma. The patient's complaints increased and delirium was added. In the cerebrospinal fluid (CSF) examination performed with the preliminary diagnosis of encephalitis, protein and glucose were high and 170 erythrocyte cells were detected. Meanwhile, brain MRI revealed a lesion in the splenium of the corpus callosum, slightly hyperintense in the T2-weighted sequence and slightly hyperintense in the FLAIR sequence, isointense in the T1-weighted sequence, without contrast enhancement, and restricted in the diffusion-weighted image (Figure 2). No hemorrhage was observed in the susceptibility weighted imaging sequence, and the magnetic resonance venography was completely normal. The patient's clinical and radiological images were evaluated together, and MERS was diagnosed and treatment was started. After 4 days, the patient's complaints decreased, and diffusion restriction in splenium almost completely regressed in the control imaging. The patient was discharged with complete recovery after a total of 14 days.

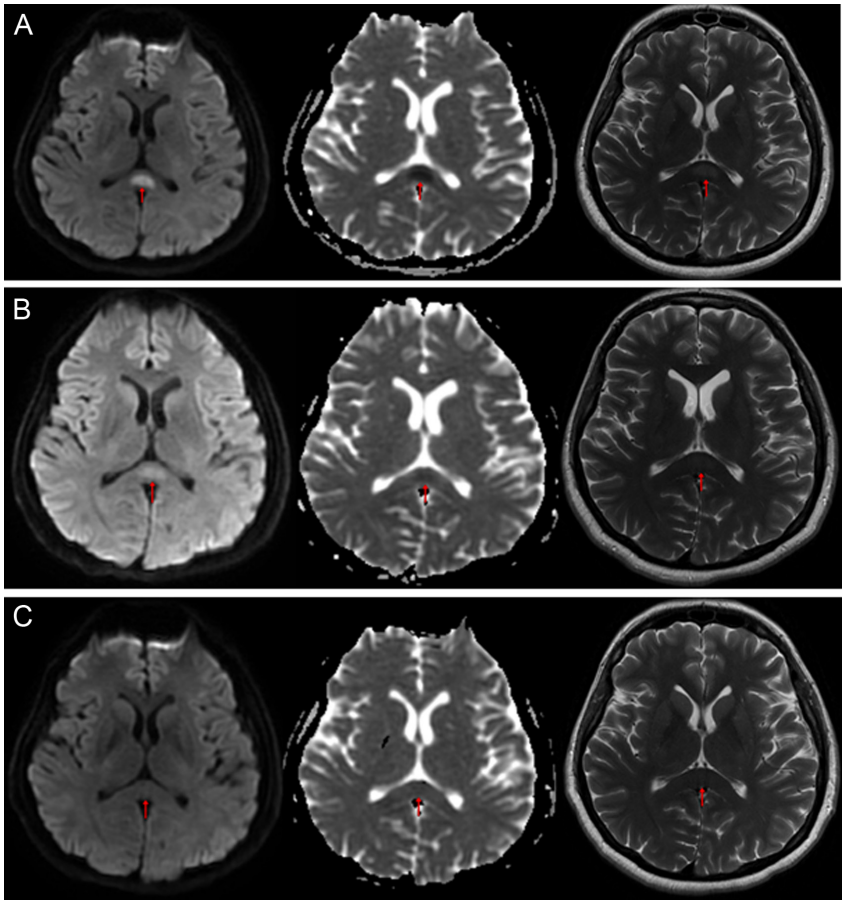

Figure 1. (A) Diffusion-weighted image hyperintense, apparent diffusion coefficient hypointense, and T2 mild hyperintense area in the splenium of the corpus callosum. (B) Decrease in findings in the same localization after 3 days. (C) Complete regression of findings in the same localization after 14 days.

DISCUSSION

This entity, which has been called cytotoxic lesion of the corpus callosum or reversible splenial lesion syndrome or MERS in recent years, may be secondary to many conditions such as infections, epileptic drug use, metabolic disorders, malignancies, cerebrovascular disease, and trauma.[4] The pathogenesis is still unclear but thought to be due to excitotoxicity caused by an increase in extracellular glutamate with water accumulation in cells due to cell–cytokine interaction.[5] It is discussed that hyponatremia detected in some patients may also play a role in the pathogenesis.[7] Corpus callosum involvement has been defined in 3 patterns—a small round lesion in the center of the splenium, a lesion centered in the splenium but extending to the adjacent white matter, and lesion centered posteriorly and extending anteriorly to the corpus callosum.[5]

MAIN POINTS

- Mild encephalitis/encephalopathy with reversible splenial lesion presents with transient diffusion restriction in the splenium of the corpus callosum.
- It is a clinical and radiological diagnosis.
- It usually occurs after viral infections.
- Differential diagnoses include ischemia, posterior reversible encephalopathy syndrome, human immunodeficiency virus-associated encephalopathy, diffuse axonal damage, multiple sclerosis, lymphoma, and epilepsy.
- Prognosis is good.

Mild encephalitis/encephalopathy with reversible splenial lesion is a clinical–radiologic entity characterized by mild signs of encephalopathy in addition to the involvement of the splenium of the corpus callosum.[6] Clinically, it progresses with confusion, headache, seizures, nausea, vomiting, urinary incontinence, and delirium.[6,7] Nakajima et al[8] also reported that it presented cerebellar ataxia. The cause is frequently viruses such as influenza, rotavirus, mumps, herpes, and varicella, but it is rarely seen after bacterial infections.[8] In addition, several cases developing after coronavirus disease (COVID) have been reported in the literature in recent years.[9,10] Kubo et al[9] reported that 11 of the 30 related to COVID cases published were from Turkey.

Typical MRI findings are T2-weighted and FLAIR hyperintense, diffusion-restricted and decreased ADC, and isointense on T1-weighted sequence without contrast enhancement.[11] The lesions in our cases were also T2-FLAIR hyperintense, T1-weighted isointense, and diffusion-restricted with low apparent diffusion coefficient (ADC) values and no contrast enhancement.

It is divided into 2 types: type 1, which is characterized by diffusion restriction only in the splenium of the corpus callosum, and type 2, which has lesions in the periventricular–supraventricular white matter in addition to the splenium.[12] Type 1 MERS is the most common

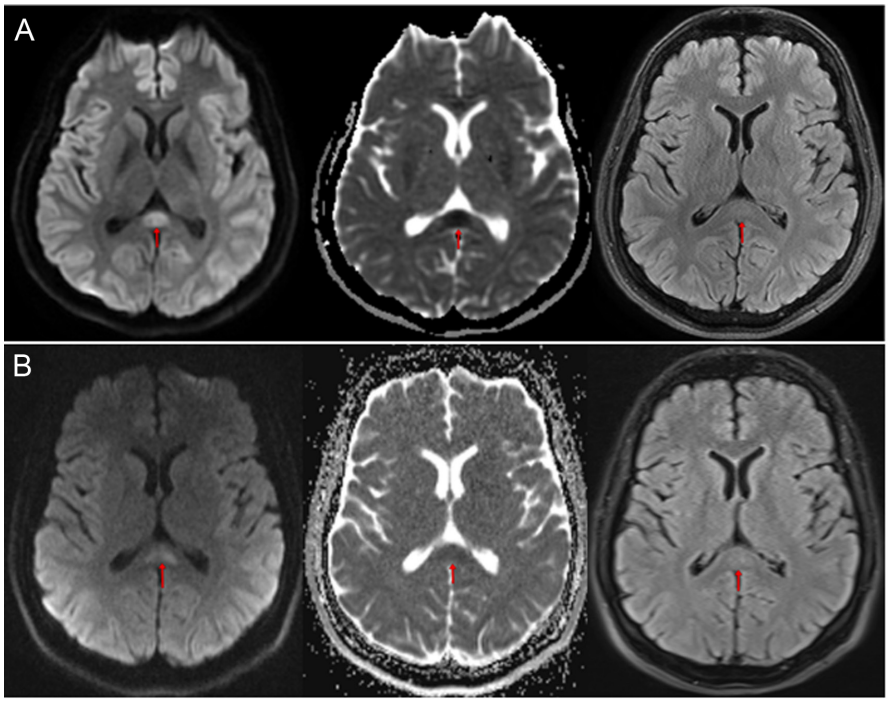

Figure 2. (A) Diffusion-weighted image hyperintense, apparent diffusion coefficient hypointense, and FLAIR mild hyperintense area in the splenium of the corpus callosum. (B) Decrease in findings in the same localization after 4 days.

type, and our patients had only splenium lesions and both were considered type 1. Differential diagnosis should be made with many diseases such as ischemia, posterior reversible encephalopathy syndrome, human immunodeficiency virus-associated encephalopathy, diffuse axonal injury, multiple sclerosis, lymphoma, epilepsy, and extrapontine myelinolysis.[10] Grosset et al[13] suggested lower ADC values in differentiation by ischemia.

Although it is still debated whether treatment is needed and what to use in treatment, the prognosis of both types of MERS is quite good. Most of the cases in the literature were discharged with full recovery.[1,3] Our 2 patients were discharged with complete recovery after 15 and 14 days, respectively.

Informed Consent: Written informed consent was obtained from patient and their relatives who participated in this study.

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