doi: 10.21860/medflum2024_319216

Assessment of Tubo-Ovarian Abscess Using Diffusion-Weighted Magnetic Resonance Imaging – a Literature Review

Difuzijsko oslikavanje tuboovarijskog apscesa magnetskom rezonancijom – literaturni pregled

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Abstract. ***Aim*:** To evaluate systematically the magnetic resonance imaging (MRI) features of tubo-ovarian abscess (TOA), the efficacy of diffusion-weighted imaging (DWI) in the assessment of TOA, and the differentiation of TOA from ovarian masses. ***Material and methods*:** PubMed/MEDLINE, Web of Science, and ResearchGate were searched with keywords: Tubo-ovarian abscess and Diffusion-weighted magnetic resonance imaging. No restrictions regarding the language or publication year were applied. Inclusion criteria regarded research papers evaluating the role of MRI and DWI in the assessment of TOA, and the differentiation of TOA from ovarian tumours. Studies appearing to meet inclusion criteria were reviewed in full. ***Results*:** A total of 14 studies were included. TOA is usually presented as a multilocular, cystic, pelvic mass with a heterogeneously high signal on T2-weighted (T2W) and low signal on T1-weighted (T1W) images with the "penumbra sign" on T1W images. Following contrast administration, septal and thick wall rim enhancement could be visualized. TOA usually demonstrated hyperintensity on DWI and hypointensity on ADC maps with lower ADC values of cystic, and higher ADC values of solid components compared to ovarian malignancy. TOA was smaller in size, and invasion into adjacent organs and tubal dilatation were more frequent in TOA than in ovarian neoplasms. In comparison to other methods, DWI possessed the highest sensitivity, specificity, positive predictive value, negative predictive value, and accuracy in differentiating TOA from adnexal tumours. ***Conclusions*:** The addition of DWI with ADC values improves the detection, characterization, and overall diagnostic accuracy of TOA and its distinction from ovarian malignancy. The combination of DWI with MRI in the assessment of TOA is obligatory.

Keywords: abscess; diffusion magnetic resonance imaging; ovarian neoplasms; pelvic inflammatory disease

Sažetak. ***Cilj*:** Sustavno interpretirati obilježja tuboovarijskog apscesa (engl. *tubo-ovarian abscess*; TOA) na snimkama magnetske rezonancije (engl. *magnetic resonance*; MR), procijeniti učinkovitost difuzijskih sekvencija (engl. *diffusion-weighted imaging*; DWI) u oslikavanju tuboovarijskog apscesa i njegovu razlikovanju od tumorskih masa jajnika. ***Materijali i metode*:** Pregled *PubMed/MEDLINE*, *Web of Science* i *ResearchGate* proveden je korištenjem ključnih riječi: *Tubo-ovarian abscess* i *Diffusion-weighted magnetic resonance imaging*. Prilikom pretrage nisu primijenjena jezična ograničenja ili ograničenja glede godine publikacije. Uključni kriteriji odnosili su se na radove koji su vrednovali ulogu MR-a i DWI-ja u analizi tuboovarijskog apscesa, kao i u razlikovanju TOA-e od tumorskih masa jajnika. Studije koje su odgovarale uključnim kriterijima, recenzirane su u cijelosti. ***Rezultati*:** Odabrano je 14 studija. Tuboovarijski apsces obično se prezentirao kao multilokularna, cistična, zdjelična masa s heterogeno visokim intenzitetom signala na mjerenim snimkama T2 te niskim intenzitetom signala na mjerenim snimkama T1 s karakterističnim „znakom penumbre" na mjerenim snimkama T1. Nakon primjene kontrastnog sredstva mogla se uočiti rubna imbibicija debele stijenke, kao i imbibicija septa. Tuboovarijski apsces tipično je pokazivao hiperintenzitet na DWI sekvencijama te hipointenzitet na mapi pojavnih

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difuzijskih koeficijenata (engl. *apparent diffusion coefficient*; ADC) s nižim ADC vrijednostima cistične i višim ADC vrijednostima solidne komponente u usporedbi s malignim tvorbama jajnika. Tuboovarijski apsces je u odnosu na novotvorine jajnika veličinom bio manji i češće je pokazivao invaziju u okolne zdjelične organe i dilataciju jajovoda. U usporedbi s drugim slikovnim metodama, DWI je imao najveću osjetljivost, specifičnost, pozitivnu prediktivnu vrijednost i točnost u razlikovanju TOA-e od tumora adneksa. ***Zaključak*:** Dodatak DWI sekvencija s ADC vrijednostima unaprjeđuje detekciju, karakterizaciju i ukupnu dijagnostičku točnost tuboovarijskog apscesa i njegovu distinkciju od malignih novotvorina jajnika. Korištenje DWI-ja u kombinaciji s konvencionalnim MR sekvencijama obavezno je za procjenu tuboovarijskog apscesa.

Ključne riječi: apsces; difuzijsko oslikavanje magnetskom rezonancijom; novotvorine jajnika; zdjelična upalna bolest

The addition of DWI with ADC values improves the detection, characterization, and overall diagnostic accuracy of TOA and its distinction from ovarian malignancy. The combination of DWI with conventional MRI in the evaluation of TOA is obligatory.

INTRODUCTION

Diffusion-weighted magnetic resonance imaging (DWI) is a functional imaging technique that acquires image contrast based on the water-diffusion attributes of the tissues and provides data on cell density and organization, microstructure, and microcirculation[1]. The apparent diffusion coefficient (ADC) values are a quantitative measurement of differences in tissue diffusivity between two different *b*-values displayed as a parametric map[2, 3]. High cellular tissues with preserved cell membranes (e.g., inflammation zones, neoplastic tissues) demonstrate decreased water diffusion, a hyperintense signal on DWI, and a hypointense signal on the ADC map. Tissues with low cellularity and/or impaired cell membranes enable water molecules to diffuse more increasingly leading to a hypointense signal on DWI and a hyperintense signal on ADC[2, 3]. According to the review by Bonde et al.[2], standard DWI of the pelvis is performed in the axial plane using at least one lower *b*-value (0-50 s/mm²) and one higher *b*-value (≥600 s/mm²). At lower *b*-values, intravascularly allocated water molecules will display a signal loss, while at higher b-values the hypercellular tissues (e.g., neoplasms) will demonstrate restricted water diffusion. A tubo-ovarian abscess (TOA) is the most severe form of acute pelvic inflammatory disease (PID) and around a third of women with PID develop TOA[4, 5]. TOA may also develop during appendicitis or diverticulitis[6]. Patients are usually sexually active women of reproductive age who present with a triad of symptoms such as fever (≥38°C), leukocytosis (>10x10^9/L), and diarrhea[5]. The aim of this literature review was to systematically evaluate the characteristic TOA features on conventional magnetic resonance imaging (MRI) sequences, the efficacy of DWI in the assessment of TOA, and the differentiation of TOA from ovarian masses.

MATERIAL AND METHODS

A literature search was conducted in PubMed/MEDLINE, Web of Science, and ResearchGate. The search terms included: Tubo-ovarian abscess and Diffusion-weighted magnetic resonance imaging. No restrictions regarding the language or the year of publication were applied. Any research paper (original article, review article, and case report) evaluating the MRI features of TOA, the role of DWI in the assessment of TOA, and the differentiation of TOA from ovarian tumours was included in the review process. The exclusion criteria were duplicated articles, title-unrelated and abstract-only papers, thesis, chapters, and books. Titles and abstracts of the retrieved papers were screened and any studies appearing to meet inclusion criteria were reviewed in full. Additional studies were included after reviewing the reference lists of retrieved articles. Studies published until 07 September 2023 were included in the review.

RESULTS

A total of 14 studies were included in the study (Figure 1). Characteristic MRI and DWI features of TOA are displayed in Table 1 and in Figures 2 and 3. According to the retrieved studies, TOA is usually presented as multilocular, cystic, pelvic mass with heterogeneously high signal on T2-weighted (T2W) and low signal on T1-weighted (T1W) images with the hypertensive thin rim en-

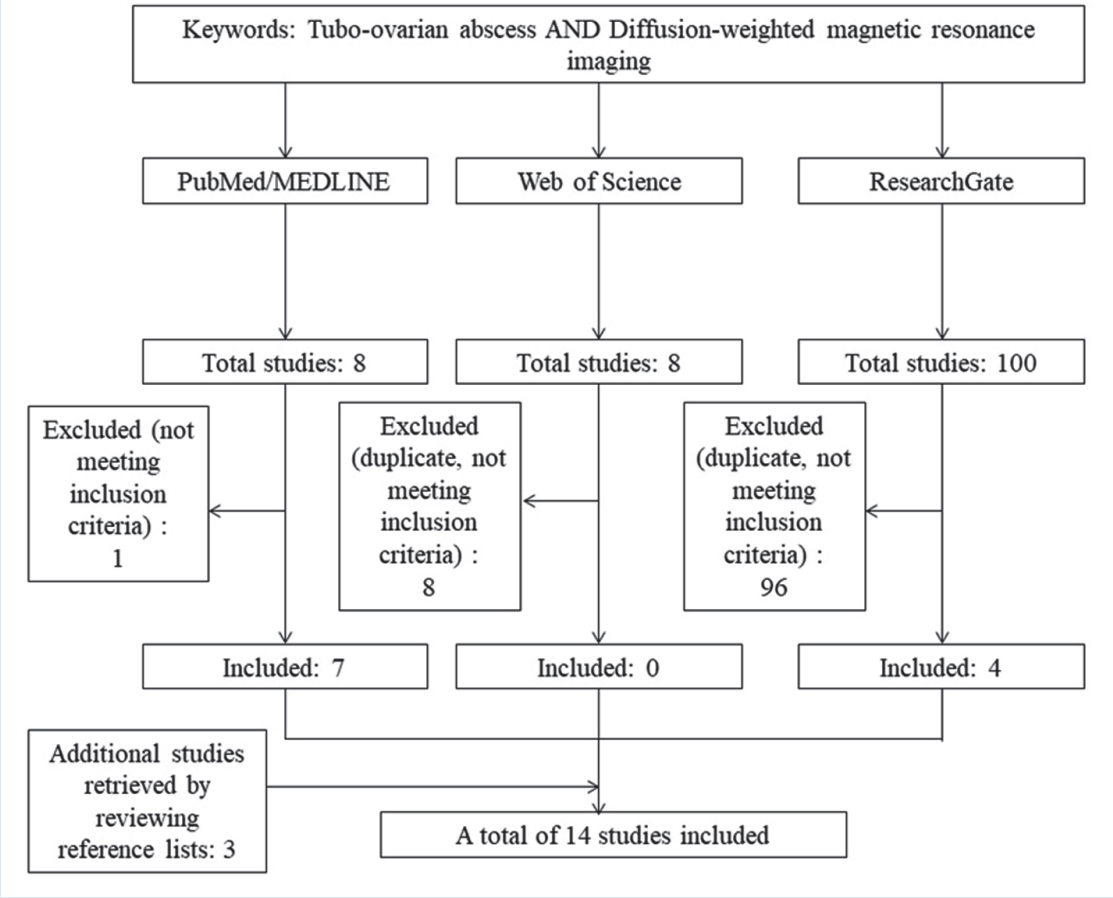

Figure 1. Flow diagram of literature search.

Table 1. Summarized characteristic MRI features of TOA.

	Morphology	T1WI	T2WI	DCE	DWI/ADC	Additional features	Ref.
TOA	Ill-defined, multilocular, cystic mass with solid components	Low signal intensity (hemorrhagic, proteinous content – high signal intensity)	Intermediate to high signal intensity	Septal and thick wall enhancement, cystic areas no enhancement	Cystic areas – restricted diffusion; Solid areas – no diffusion restriction	Fat stranding, parametrial fat edema, pelvic adhesions, broad uterine ligament displacement, invasion into adjacent organs, tubal dilatation	[3, 4, 6, 7, 10, 11, 13]

T1WI – T1-weighted images; T2WI – T2-weighted images; DCE – dynamic contrast-enhanced images; DWI/ADC – diffusion-weighted imaging/ apparent diffusion coefficient; Ref. – reference

hancement ("penumbra sign") on T1W images due to the granulation tissue with microscopic haemorrhage (Figure 2A). Fat stranding, parametrial fat oedema, and pelvic adhesions were frequently found. After contrast administration, septal and thick wall rim enhancement could be visualized (Figure 2B). As an additional sign, TOA often displaced the broad uterine ligament. TOA features on DWI were the high signal intensity of the wall and septa with the detectable restriction in water diffusion of the purulent content, wall, and septa on ADC maps (Figure 3).

Compared to ovarian tumours, TOA was usually smaller and more frequently associated with invasion into adjacent organs and tubal dilatation (Figure 4). Cystic components of TOA usually demonstrated high signal on DWI and low signal intensity on ADC maps (restricted diffusion)

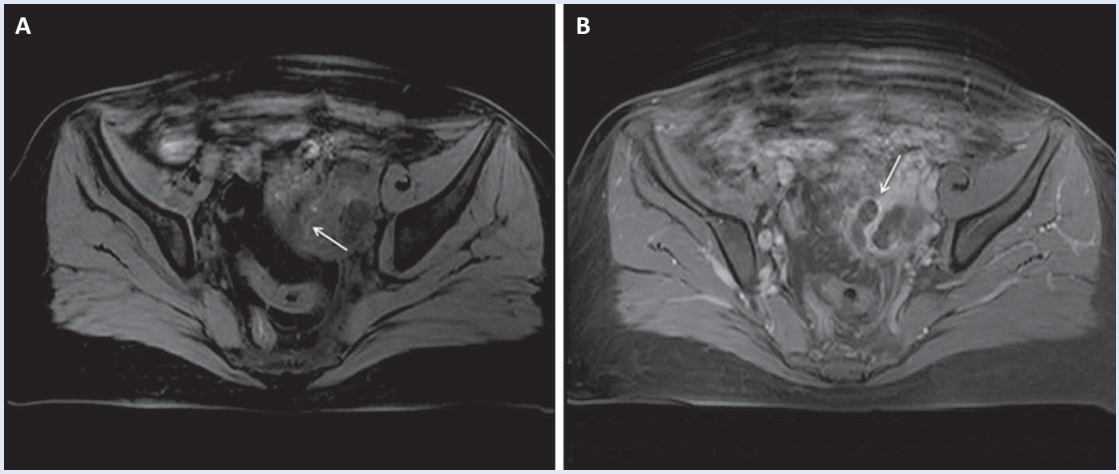

Figure 2. MRI images of a tubo-ovarian abscess (A – axial plane, T1 weighted image, "penumbra sign"; B – axial plane, T1-weighted contrast-enhanced image, multilocular, cystic, pelvic mass with solid component).

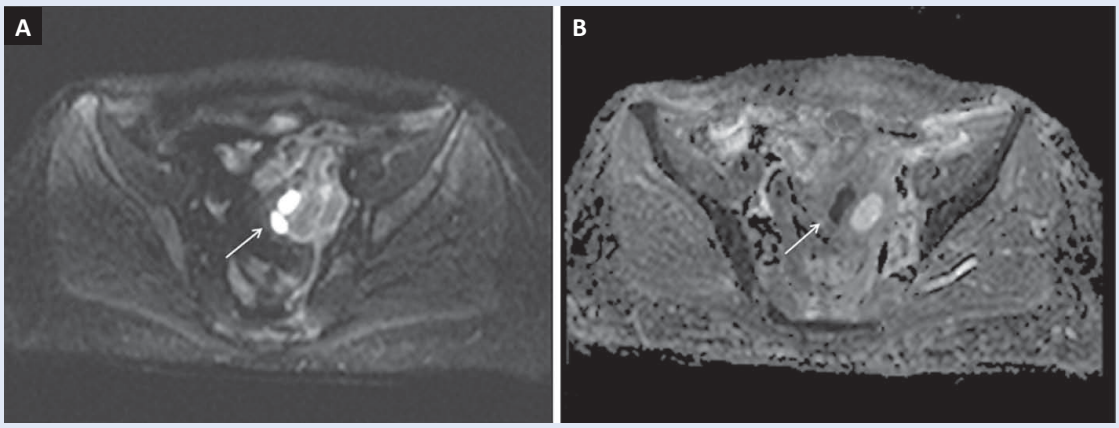

Figure 3. Tubo-ovarian abscess with a diffusion restriction in cystic and no diffusion restriction in solid areas on DWI (A) and ADC map (B).

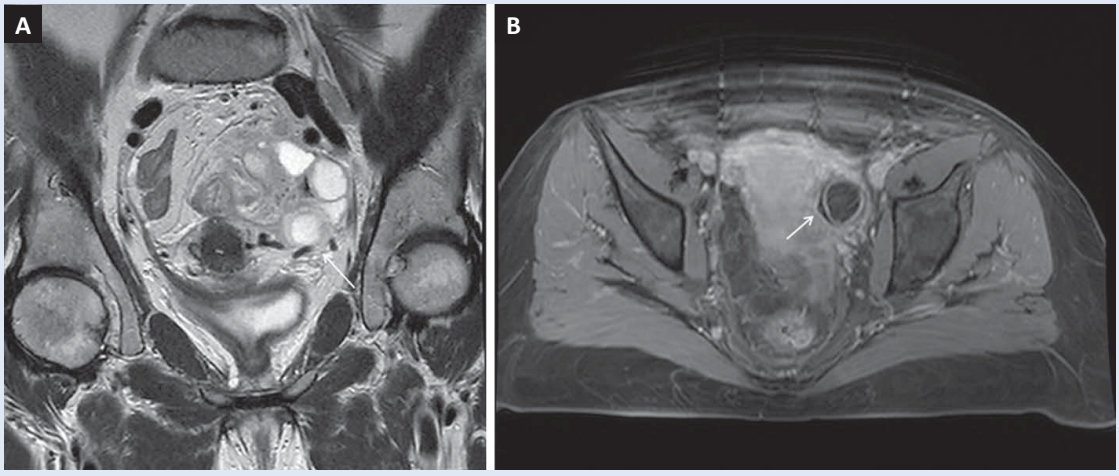

Figure 4. MRI images of a dilated fallopian tube (A – coronal plane, T2-weighted image; B – axial plane, T1-weighted contrast-enhanced image).

Table 2. ADC values in the differentiation of TOA and ovarian tumors.

Study	ADC values of TOA ($x10^{-3}$ mm^2/s)	ADC values of ovarian neoplasms ($x10^{-3}$ mm^2/s)	Proposed cut-off value ($x10^{-3}$ mm^2/s)	Reference
Takeshita et al. (2009)[a]	0.663	N/A	N/A	[6]
Chou et al. (2012)[b]	c 0.73 ± 0.15	c 2.27 ± 0.45	1	[7]
Nguyen et al. (2013)[a, c]	0.79 ± 0.23	0.84 ± 0.19	N/A	[8]
Wang et al. (2016)[d]	c 1.04 ± 0.41 s 1.43 ± 0.16	c 2.42 ± 0.38 s 1.18 ± 0.36	N/A	[4]
Fan et al. (2018)[e]	c 0.85 ± 0.31	c 2.57 ± 0.25	N/A	[1]
Patel et al. (2021)[f]	c 0.779 ± 0.317 s 1.041 ± 0.192	c 2.368 ± 0.698 s 0.760 ± 0.129	c 1.31 s 0.869	[13]
Gao et al. (2022)[a, g]	1.05 ± 0.45	N/A	N/A	[14]

N/A – unknown; c – cystic component ; s – solid component

[a] Solid or cystic component was not specified; [b] Study population of 38 patients was divided into "pelvic abscess" and "pelvic tumor" with 6 cases of TOA and 12 cases of cystic ovarian tumor; [c] Study group was categorized as "pelvic abscess" with 3 abscesses of gynecological origin; a control group of patients with non-ovarian tumors; [d] 45 cases of TOA and 37 ovarian malignant tumors; [e] 19 cases of TOA and 24 non-inflammatory adnexal lesions (except one case were ovarian tumors); [f] 24 cases of TOA and 26 ovarian malignancy; [g] 72 patients with pelvic inflammatory disease, 19 cases of TOA

Table 3. Diagnostic performance of DWI in the assessment of TOA in comparison to conventional MRI and other imaging methods.

	DWI	cMRI	ceCT	PET/CT	Reference
Sens. (%)	100.0	47.1	N/A	N/A	Wang et al.[4] (2016)[a]
Spec. (%)	97.1	91.4			
PPV (%)	97.1	84.2			
NPV (%)	100.0	64.0			
Acc. (%)	98.6	69.6			
Sens. (%)	95.0	87.5	78.6	86.7	Fan et al.[1] (2018)[b]
Spec. (%)	100.0	81.5	72.4	78.5	
PPV (%)	100.0	73.7	57.9	68.4	
NPV (%)	95.8	91.7	87.5	91.7	
Acc. (%)	97.7	83.7	74.4	81.4	

N/A – unknown; DWI – diffusion-weighted imaging; cMRI – conventional magnetic resonance imaging; ceCT – contrast-enhanced computed tomography; PET/CT – positron emission tomography/computed tomography; sen. – sensitivity; spec. – specificity; PPV – positive predictive value; NPV – negative predictive value; acc. – accuracy

[a] 45 cases of TOA and 37 ovarian malignant tumors; [b] 19 cases of TOA and 24 non-inflammatory adnexal lesions (except one case were ovarian tumors)

whereas cystic components of malignant ovarian lesions displayed low signal on DWI and high signal intensity on ADC maps (facilitated diffusion). Mean ADC values of cystic collections in TOA were lower in comparison to malignant tumours. In most patients, solid components of TOA exhibited low or intermediate signal intensity on DWI whereas solid areas in malignant lesions mainly demonstrated high signal intensity on DWI. Mean ADC values of solid TOA areas were higher in comparison to the ovarian neoplasms. A list of studies with reported ADC values of TOA and ovarian masses is displayed in Table 2. In comparison to conventional MRI and other imaging methods, DWI demonstrated the highest sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy in distinguishing TOA from adnexal tumours (Table 3).

DISCUSSION

Earlier studies have shown that DWI with derived ADC values is a useful modality for the assessment of cerebral, orbital, abdominal, musculoskeletal, and soft tissue abscesses, and components such as pus, blood, serous, and mucinous fluid[1, 4, 7, 8]. However, to this date, only several reports are available on the efficacy of DWI

in the evaluation of patients with TOA and the differentiation between TOA and ovarian malignancy. In 2009, Takeshita et al.[6] published a case report of a 41-year-old woman who had been experiencing fever and abdominal pain in the right lower quadrant. Conventional MRI images displayed a complex cystic lesion in the right adnexal area with multiple internal septa, a thick wall, fat stranding around the mass, and fluid in the recto-uterine pouch. The innermost layer of the wall had a thin rim of high signal intensity on T1W images while the internal content of the lesion presented with a low signal on T1W and high signal intensity on T2W images. After contrast administration, the enhancement of internal septa and a thick wall was visible, as well as the ill-defined margins of the mass. DWI was performed using a free-breathing single-shot echo-planar imaging sequence. The hyperintense signal of the lesion was detected on DWI with an ADC map demonstrating low signal intensity and a value of 0.663 x 10^{-3} mm^2/s. These findings were compatible with TOA. Similar features were also reported in the review by Foti et al.[3] where authors described that TOA usually presents on MRI as a multilocular, cystic, pelvic mass with heterogeneously high signal on T2W and low signal on T1W images. The hypertensive thin rim enhancement on T1W images represents the layer of granulation tissue with microscopic haemorrhage. With the administration of gadolinium, septal and thick wall rim enhancement of the lesion can also be seen. TOA features on DWI are the high signal intensity of the wall and septa with the restriction in the diffusion of the purulent content, wall, and septa on ADC maps. Additionally, TOA often presents with stranding of the pelvic fat, parametrial fat oedema, pelvic adhesions and frequently causes displacement of the broad uterine ligament[3].

Imaging findings that are distinctive of TOA are positive "penumbra sign", restricted diffusion, lower ADC values of cystic, and higher ADC values of solid components and dilated fallopian tube.

A study by Tukeva et al.[9] demonstrated that MRI in comparison to transvaginal ultrasound possesses superior sensitivity and specificity for the detection of TOA (100%, and 90%, respectively, vs. 56%, and 86%, respectively). In one French study from 2013[8], authors have shown that there is no inferiority in the diagnostic performance of combined MRI and DWI compared to the MRI with gadolinium administration for the detection of pelvic abscesses (only 3 cases of gynaecological aetiology). Furthermore, all three readers improved their detection when using DWI, especially the less experienced reader. These results suggest that DWI is an equal alternative to contrast-enhanced MRI when there is a high clinical suspicion of pelvic abscess.

On several occasions, it has been reported how TOA can mimic benign and malignant masses in the pelvis[10]. One of the first reports to evaluate pelvic abscesses on the MRI and to highlight the diagnostic pitfalls of pelvic masses was by Hawnaur et al.[11]. The authors presented a 41-year-old female patient with the intrauterine device, right iliac thrombosis, right hydronephrosis, and the ill-defined, soft tissue mass on the right side of the pelvis. MRI showed a solid pelvic mass (7 cm in diameter) near the right ovary with intermediate T1W and T2W signals, including several T2W hyperintense peripheral cystic zones. Ovarian malignancy was suspected; however, only after pathological analysis was TOA secondary to actinomycosis confirmed.

Inflammatory and neoplastic lesions may display similar MRI features and findings such as thick walls or septa (>3 mm), solid components, and free fluid in the Douglas pouch can raise suspicion of ovarian malignancy[4]. Several studies evaluated DWI's role with corresponding ADC values in distinguishing pelvic abscesses from pelvic tumours and TOA from ovarian tumours. A study by Chou et al.[7] was conducted on 38 participants (68% females) with various inflammatory and malignant pelvic pathology, among which were patients with TOA (16%). Pelvic abscesses were present in 23 individuals and displayed a homogeneously high signal on DWI in 21 cases (91%). Out of the 21 participants, all displayed a hypointense signal on derived ADC maps with a mean ADC value of 0.73 ± 0.15x10^{-3} mm^2/s. Cystic areas of cystic pelvic tumors demonstrated low signal

intensity, while solid parts demonstrated high signal intensity on DWI. The respective mean ADC values were 2.27 ± 0.45x10^{-3} mm^2/s and 4 patients with cystadenoma demonstrated ADC of 2.5 ± 0.36x10^{-3} mm^2/s. The authors suggested using an ADC cut-off value of 1 x 10^{-3} mm^2/s with 100% accuracy in the distinction between pelvic abscess and pelvic tumour. One study compared two groups of patients: TOA not associated with endometriosis and TOA associated with endometriosis[12]. Authors found statistical significance in several situations: a) peritoneal ascites were hyperintense on T1W images in all patients with ruptured endometrial cyst (6/6) compared to none with TOA (0/15), b) strong peritoneal enhancement after contrast administration was observed in all women with ruptured endometrial cyst (3/3) in contrast to only 7 out 13 women with TOA, c) 80% of patients with TOA demonstrated T1-hyperintense rim signal intensity, all of the TOA not associated with endometriosis showed pronounced wall enhancement and such enhancement pattern was not observed in any of the women with non-infected endometrial cysts. Therefore, hyperintense ascites on T1W images and pronounced wall enhancement of cystic lesions in the pelvis may be useful radiological signs for the differentiation between ruptured ovarian endometrial cysts and TOA. A study by Nguyen et al.[8] (2013) evaluated patients with pelvic abscesses, cysts, and tumours with mean ADC values being 0.79 x 10^{-3} mm^2/s, 1.98 x 10^{-3} mm^2/s, and 0.84 x 10^{-3} mm^2/s, respectively. A quinquennial retrospective study from Wang et al.[4] evaluated 69 patients (mean age 47.4 years; 62% of women were post-menopausal) admitted to the hospital with the suspicion of TOA or ovarian neoplasms. All participants underwent an MRI examination, with and without DWI. The authors found that the size of malignant lesions, in comparison to TOA, was significantly larger (mean 10.7 ± 6.3 cm vs. 6.8 ± 2.5 cm). Furthermore, TOA was more frequently associated with invasion into adjacent organs and tubal dilatation. In all patients, cystic collections of TOA presented with hyperintensity on DWI while the same components of all malignant lesions displayed DWI hypointensity. Mean ADC values of cystic areas in TOA were significantly lower compared to those of malignant tumours. On the other hand, most patients with TOA exhibited low or intermediate signal intensity of the solid components on DWI and higher corresponding ADC values in comparison to the ovarian neoplasms. Moreover, a multivariate regression model analysis showed that statistically significant variables for the detection of TOA were a combination of ADC values and tubal structure. In distinguishing TOA from ovarian malignancy, DWI demonstrated 100% sensitivity, 97.1% specificity, 97.1% positive predictive value (PPV), 100% negative predictive value (NPV), and 98.6% accuracy. A recent retrospective study from Fan et al.[1] evaluated 43 patients (mean age 49.5 years; 56% of women were post-menopausal) with the diagnosis of TOA and adnexal tumours. All of them underwent contrast-enhanced computed tomography (CT), positron emission tomography and computed tomography (PET/CT), and conventional MRI (with and without DWI). The authors evaluated the sensitivity, specificity, PPV, NPV, and accuracy of the above-mentioned imaging techniques. Out of the selected cohort, 19 patients had proven TOA, and 24 of them presented with various adnexal lesions. On DWI, all TOAs demonstrated high signal intensity with low ADC values of cystic components (0.85 ± 0.31 x 10^{-3} mm^2/s). The authors postulated that a combination of these parameters with the high or intermediate signal intensity of the same cystic area on native T2W images may serve as a possible recognition pattern in predicting TOA. In comparison to other methods, authors concluded that DWI possesses the highest sensitivity, specificity, PPV, NPV, and accuracy in differentiating TOA from adnexal tumours (95%, 100%, 100%, 95.8%, 97.7%, respectively). A recent study from an Indian group of authors compared patients with TOA and ovarian neoplasms[13]. They reported findings such as a) ovarian tumours are larger in size compared to TOA, b) the more frequent presence of free ascites was found in the ovarian malignancy group, c) lower ADC values of cystic components were detected in TOA, and lower ADC values of solid components were found in the ovarian neoplasms with the cut-off values set

at 1.31 x 10^{-3} mm^2/s (95.8% sensitivity; 89.5% specificity) for cystic and 0.869 x 10^{-3} mm^2/s (80.8% sensitivity; 79.2% specificity), for solid components for the distinction between TOA and ovarian malignancy. On MRI, a higher rate of dilated fallopian tubes was detected among patients with TOA. This study also put emphasis on the hyperintense rim signal ("penumbra sign") on T1W images which was displayed in 21/24 patients with TOA and 2/26 patients with ovarian neoplasm. This sign alone possessed sensitivity, specificity, PPV, and NPV of 87.5%, 89.5%, 91.3%, and 85%, respectively in distinguishing TOA from ovarian tumours. Research by Gao et al.[14] demonstrated that average ADC values of a chronic inflammatory process in the pelvis were significantly higher compared to acute inflammation (2.86 ± 0.20 x 10^{-3} mm^2/s vs. 1.07 ± 0.38 x10^{-3} mm^2/s) with reported ADC values for pyosalpinx, TOA, and pelvic abscess of 1.13±0.26, 1.05±0.45, and 1.09±0.36 x10^{-3} mm^2/s, respectively.

According to Bonde et al.[2], DWI has several diagnostic pitfalls. The T2 shine-through effect can be seen when the lesion demonstrates high signal intensity on both DWI and ADC maps, and the T2 blackout effect is when the lesion demonstrates low signal intensity on both DWI and ADC maps. Moreover, highly differentiated tumours may present with a lack of restricted diffusion; however, secretory endometrium, haemorrhage zones, proteinaceous content, and lymph nodes may display restriction in water diffusion.

CONCLUSIONS

The addition of DWI, with corresponding ADC values, to conventional MRI sequences, improved the detection, characterization, and overall diagnostic accuracy of TOA and its differentiation from ovarian malignancy. Radiological findings that are distinctive of TOA are positive "penumbra sign", restricted diffusion, lower ADC values of cystic, and higher ADC values of solid components and signs of the dilated fallopian tube. Since DWI may present with several diagnostic pitfalls, radiologists should be careful with the interpretation of high signal intensity which is not always a pathognomonic feature of TOA.

Conflicts of Interest: Authors declare no conflicts of interest.

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