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Computerized tomography and magnetic resonance imaging features with quantitative T2 mapping of a primary malignant müllerian mixed tumor of the ovary: A case report

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► ***Case report***

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ABSTRACT

Background: Ovarian Malignant Müllerian Mixed Tumor (MMMT), also named ovarian carcinosarcoma (OCS), is a rare and aggressive biphasic malignancy with malignant epithelial and mesenchymal components. Advanced magnetic resonance imaging (MRI) techniques like quantitative T2 mapping enable non-invasive tissue microstructural assessment, their diagnostic value for ovarian MMMT requires further elucidation with clinical case evidence. ***Case presentation:*** A 78-year-old female presented with chronic constipation and a pelvic mass. Imaging revealed a large, heterogeneous pelvic mass with peritoneal and omental involvement. Quantitative MRI analysis revealed a T2 mapping value of 148±18 ms and a low apparent diffusion coefficient (ADC) value of $0.98\pm0.08\times10^{-3}$ mm^2/s. Histopathological examination confirmed ovarian MMMT with heterologous chondrosarcoma components. ***Conclusion:*** This case demonstrates that quantitative MRI parameters, especially T2 mapping, can reflect the high-grade malignant microstructural features of ovarian MMMT. T2 mapping serves as a valuable non-invasive biomarker for characterizing this rare gynecological malignancy, potentially aiding in the differentiation of benign and malignant ovarian lesions and assessment of tumor aggressiveness.

INTRODUCTION

Ovarian malignant mixed Müllerian tumor (MMMT), also known as ovarian carcinosarcoma (OCS), is an exceptionally rare ovarian neoplasm [1] which accounts for less than 1-2% of all ovarian malignant lesions, a marked difference from its much more common uterine counterpart. This tumor is composed of both malignant epithelial components (mostly serous or endometrial-like) and malignant mesenchymal components (sarcomatous), showing significant histological heterogeneity [2]. The clinical manifestations are often insidious, and approximately 90% of the cases have already experienced ovarian metastasis at the time of diagnosis, resulting in a narrow treatment window [3]. Although its histological characteristics are well-defined, the pathogenesis remains controversial. The mainstream theories include the collision theory, the transformation theory, and the combination theory, suggesting that it may arise from the abnormal activation of epithelial-mesenchymal transition [2, 4]. The prognosis for this disease is very poor. The median overall survival is less than 2 years even when the lesion is localized to the ovary, the overall rate typically falls below 30% over a 5-year period [5]. Multiple studies have shown that major poor prognostic factors include advanced disease stage, older age, lymph node metastasis, residual tumor after surgery, histological heterogeneity, and overexpression of VEGF, p53, and WT1 [4].

It is important to note that the imaging characteristics of MMMT are complex, and conventional MRI is unable to accurately distinguish the biological activity of its epithelial and stromal components. Quantitative T2 mapping, an advanced MRI technique, measures transverse relaxation times to non-invasively quantify tissue properties, reflecting microstructural changes such as edema, fibrosis, necrosis, and vascularity - key features in high-grade malignancies [3]. This report underscores the diagnostic utility of these imaging modalities, supported by recent studies highlight the advantages T2 mapping in gynecological oncology [3, 6]. The primary novelty of this study is the first systematic report of precise quantitative T2 mapping values for ovarian MMMT with heterologous chondrosarcoma components, filling a critical gap in the existing imaging literature. Furthermore, this case establishes a direct correlation between quantitative MRI

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parameters (T2 mapping and ADC) and the aggressive pathological features of the tumor, validating their potential as non-invasive preoperative diagnostic biomarkers.

MATERIALS AND METHODS

Imaging equipment and parameters

Computed tomography (CT)

A contrast-enhanced abdominopelvic CT scan was performed on a 128-slice SOMATOM Definition AS+ CT scanner (Siemens Healthcare, Forchheim, Germany). The acquisition parameters of non-contrast and contrast-enhanced scans were tube voltage 120kV, tube current 250mA, slice thickness 5mm, reconstruction interval 1mm, field of view (FOV) 380mm×380mm and matrix of 512×512. In contrast, contrast-enhanced imaging was performed with bolus injection of the contrast agent via the antecubital vein using a high-pressure injector.

Magnetic Resonance Imaging (MRI)

Abdominopelvic MRI was conducted on a 3.0 T MAGNETOM Skyra MRI scanner (Siemens Healthineers, Erlangen, Germany) using an 18-channel phased-array body coil. All sequences were acquired in the axial plane with the patient in the supine position. The imaging protocol included conventional anatomical and quantitative functional sequences: T1-weighted imaging (T1WI), T2-weighted fat-suppressed imaging (T2 FS), diffusion-weighted imaging (DWI, b-values = 0 and 1000 s/mm^2), and quantitative T2 mapping. The T2 mapping sequence was acquired with a multi-echo spin-echo sequence (echo time range: 10–120 ms, 12 echoes, repetition time = 2000 ms, slice thickness = 4 mm, gap = 0.4 mm).

Contrast agent

The intravenous contrast agent used for contrast-enhanced abdominopelvic CT examinations was iohexol (350 mg I/mL; Omnipaque®, GE Healthcare, Chicago, IL, USA). A fixed volume of 80 mL was administered at a flow rate of 3.0 mL/s via a dual-head power injector, followed by a 40 mL saline flush.

The intravenous contrast agent used for the contrast-enhanced MRI examinations was gadopentetate dimeglumine (Magnevist®, Bayer HealthCare Pharmaceuticals, Berlin, Germany) at a concentration of 0.5 mmol/mL. A dose of 0.1 mmol/kg body weight was administered intravenously at a rate of 1.5 mL/s via a power injector, followed by a 20 mL saline flush.

Image post-processing and analysis software

All MRI images were post-processed and quantitatively analyzed using the Syngo.via VB30 software (Siemens Healthineers, Erlangen, Germany), which is the vendor-provided workstation compatible with the MAGNETOM Skyra scanner. In line T2 mapping and ADC maps were automatically generated. Two senior radiologists, each with over 10 years of experience in gynecological imaging, independently placed regions of interest (ROIs) in the solid tumor component, carefully avoiding cystic, necrotic, hemorrhagic, or non-viable areas, and manually verified the values. The final quantitative results, including mean T2 and ADC values, were calculated as the average of three independent ROIs per lesion to minimize measurement variability and observer bias.

Pathological detection reagents and kits

Pathological hematoxylin and eosin (H&E) staining was conducted using commercial H&E staining kits from Baso Diagnostics Inc. (Zhuhai, China), adhering to the manufacturer's standard protocol for deparaffinization, hydration, staining, differentiation, and mounting. Immunohistochemistry (IHC) was performed on formalin-fixed, paraffin-embedded tissue sections utilizing primary antibodies against S-100, p53, and Ki-67 (Cell Signaling Technology [CST], Boston, MA, USA). Antigen retrieval was achieved through heat-induced epitope retrieval (HIER) in a suitable buffer (e.g., citrate or EDTA, as recommended for specific antibodies), followed by endogenous peroxidase blocking, primary antibody incubation, and detection using the MaxVision™ HRP-Polymer IHC Kit (Fuzhou Maixin Biotech Co., Ltd., Fuzhou, China) as the secondary antibody/enzyme conjugate system. Visualization was accomplished using DAB chromogen, and sections were counterstained with hematoxylin. All procedures were carried out in strict accordance with the manufacturers' recommended protocols, including optimized incubation times, dilutions, and washing steps.

CASE PRESENTATION

Clinical history

A 78-year-old woman presented with a 10-year history of constipation, which had worsened over the past two weeks due to anal protrusion. Physical examination revealed significant tenderness in the lower abdomen and the presence of a palpable mass.

Laboratory tests

The level of human epididymis protein 4 (HE4) was measured at 618.33 pmol/L, while the levels of cancer antigen 125 (CA125) and cancer antigen 153 (CA153) were recorded at 533 U/ml and 46.4 U/ml, respectively. The postmenopausal woman had a high risk of ovarian malignancy, with a Risk of Ovarian Malignancy Algorithm (ROMA) index of 96.0%, which is strongly indicative of malignancy.

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Imaging findings

CT: A heterogeneous low-density mass measuring 89 × 85.6 mm (CT value 24 HU) was identified in the pelvic cavity. Contrast-enhanced imaging revealed moderate and uneven enhancement of the mass, with discernible internal vascular branches. Furthermore, thickening of the peritoneum and omentum was noted in both the pelvic and abdominal cavities.

MRI: The pelvic mass showed isointensity on T1WI and T2WI. Quantitative T2 mapping analysis indicated a mean value of 148 ± 18 ms for the solid component of the mass. DWI showed hyperintensity of the mass, with an ADC value of 0.98±0.08×10^{-3}mm^2/s on the corresponding ADC map. Additionally, pelvic effusion and peritoneal metastatic lesions in the right hepatorenal recess were identified on MRI scans (figure 1).

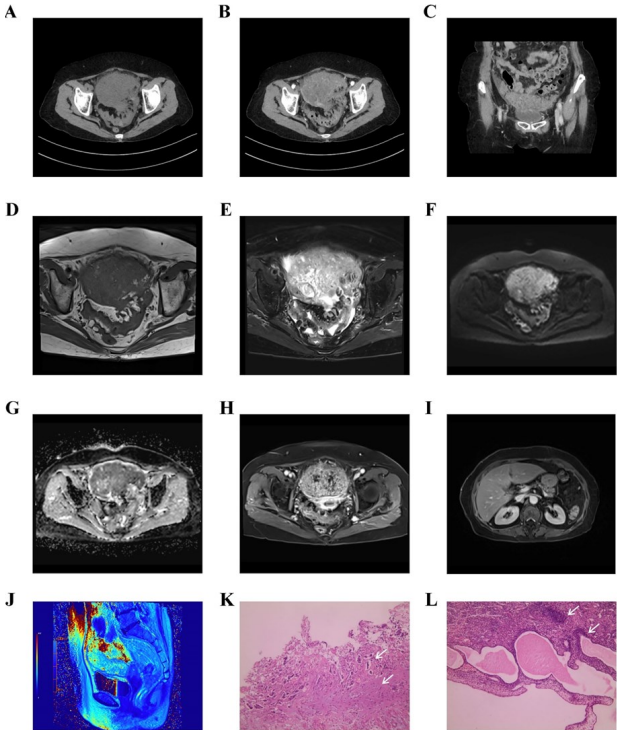

Figure 1. Right ovarian malignant mixed Müllerian tumor. **(A)** Axial non-contrast CT scan demonstrates a pelvic mass with patchy opacities in the greater omentum and fatty interspaces. **(B)** Axial contrast-enhanced CT shows moderate heterogeneous enhancement of the lesion with multiple visible internal vascular branches. **(C)** Enlarged lymph nodes and thickened peritoneum are indicated. **(D)** Axial T1-weighted imaging (T1WI) demonstrates multiple patchy hyperintense areas within the lesion (white arrows). **(E)** Axial T2-weighted fat-suppressed imaging (T2 FS) shows heterogeneous signal intensity of the lesion with associated pelvic effusion. **(F)** Diffusion-weighted imaging (DWI) reveals high signal intensity of the lesion. **(G)** Apparent diffusion coefficient (ADC) map demonstrates a low ADC value of (0.98 ± 0.08) × 10^{-3} mm^2/s within the lesion. **(H)** Contrast-enhanced scan shows heterogeneous enhancement of the mass. **(I)** Peritoneal metastatic deposit in the right hepatorenal recess. **(J)** T2 mapping pseudo color image demonstrates heterogeneous signal distribution within the lesion, with a quantitative T2 value of 148 ± 18 ms. **(K-L)** Histopathology (hematoxylin and eosin [HE] stain, ×400 magnification) shows biphasic tumor components consisting of high-grade malignant epithelial elements and sarcomatous stroma.

Management

The patient underwent a total abdominal hysterectomy, bilateral salpingo-oophorectomy, and extensive tumor debulking, which is standard for ovarian MMMT according to recent guidelines that emphasize the importance of cytoreductive surgery followed by platinum-based chemotherapy.

Pathology

The results confirmed the diagnosis of ovarian MMMT, characterized by high-grade serous carcinoma and heterologous chondrosarcoma. Immunohistochemical (IHC) markers included S-100 (positive in cartilage), p53 (mutant type) and Ki-67 (80% positive).

DISCUSSION

MMMT, also known as OCS, represent a biphasic malignancy that comprise high-grade malignant epithelial and mesenchymal components. These tumors are classified into homologous and heterologous subtypes based on the sarcomatous element. Homologous MMMTs feature mesenchymal tissue native to the Müllerian tract, such as fibrosarcoma or leiomyosarcoma-like elements, while heterologous MMMTs incorporate non-native tissues, including chondrosarcoma, rhabdomyosarcoma, osteosarcoma, or liposarcoma [7]. According to recent literature, heterologous elements are present in approximately 51.2% of ovarian MMMT, with chondrosarcoma being the most common (31.7%), followed by rhabdomyosarcoma (20.7%) and rarer types such as liposarcoma (2.4%). This finding updates earlier estimates of 20-30%, highlighting variability across different cohorts [8]. Chondrosarcoma is more frequently observed in MMMT with endometrioid carcinomatous components (52.9%) compared to high-grade serous (HGS) components (26.2%), while rhabdomyosarcoma is more common in HGS-type MMMT (24.6%) [8]. In our case, the presence of heterologous chondrosarcoma aligns with this subset, which is associated with more aggressive behavior, including extensive peritoneal seeding, omental involvement, and invasion of adjacent structures like the large intestine, as observed intraoperatively and on imaging [6]. Studies indicate that the presence of a heterologous component may be associated with worse overall survival (HR=1.81; 95% CI=1.15-2.85), though some analyses show no significant survival difference between homologous and heterologous subtypes (P=0.380) [7].

Conventional CT and MRI show overlapping features between MMMT and other high-grade ovarian malignancies, such as high-grade serous carcinoma. These features include cystic necrosis, heterogeneous contrast enhancement and peritoneal metastasis, leading to limited preoperative diagnostic

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specificity [9-11]. However, in recent years, quantitative functional MRI parameters have emerged as a powerful tool for characterizing tumor microstructural features and improving diagnostic accuracy [3, 6, 12, 13]. The ADC value, a crucial marker of water molecule diffusion in tissues, is closely correlated with tumor cellularity, nuclear-cytoplasmic ratio and extracellular matrix density [9, 12]. A recent study by Liu *et al.* [12] reported a mean ADC value of 1.105×10^{-3} mm^2/s in MMMT, compared to a mean value of $1.03\pm0.19\times10^{-3}$ mm^2/s for malignant ovarian tumors overall. The patient in this study exhibited an ADC value of $0.98 \pm 0.08 \times 10^{-3}$ mm^2/s, which is lower than the reported averages. This finding reflects the tumor's extremely high cellularity and dense stromal structure, characteristics indicative of high-grade malignancy [5, 9]. Jin *et al.* [5] also documented a significantly reduced ADC value of 0.740×10^{-3} mm^2/s in a case of MMMT that presented with extensive necrosis and invasion. This observation confirms that lower ADC values in MMMT correlate with more aggressive pathological features and higher malignancy grades. Additionally, for advanced epithelial ovarian cancers, a baseline ADC value below 0.92×10^{-3} mm^2/s has been associated with poor treatment response and reduced progression-free survival [12]. This further underscores the clinical significance of the low ADC value observed in our case.

Quantitative T2 mapping, an advanced MRI technique that non-invasively measures transverse relaxation times, has been increasingly applied in gynecological oncology for tissue characterization and malignancy stratification in recent years [3, 6]. Unlike qualitative T2WI, T2 mapping offers objective, reproducible quantitative metrics that reflect microstructural changes in tumors, including edema, fibrosis, necrosis, vascularity and cellularity [3, 6]. A recent study by Zhu *et al.* [3] demonstrated that T2 mapping achieves high diagnostic accuracy (area under the receiver operating characteristic curve [AUC] up to 0.94 at 3.0 T) in differentiating benign from malignant uterine lesions, with malignant tumors showing significantly lower T2 values than benign lesions due to higher cellular density and reduced extracellular water in malignant tumors. In ovarian malignancies, particularly those associated with endometriosis, T2 mapping values are generally lower in malignant regions (113.91±9.13 ms) than benign endometriotic lesions (122.85±7.03 ms). A cutoff value of 119.65 ms yields an AUC of 0.773 for predicting malignancy [6]. In contrast, the lesion of our patient's MMMT exhibited a significantly higher T2 value of 148 ± 18 ms, which can be attributed to the tumor's complex microenvironment, characterized by rich neovascularization, extensive necrosis, interstitial edema, and mixed epithelial/chondrosarcomatous components [5, 6]. This observation emphasizes the strength of T2 mapping in quantifying heterogeneity, surpassing qualitative T2WI [3, 6]. Furthermore, the combination of T2 mapping with intravoxel incoherent motion (IVIM) parameters enhances predictive accuracy, achieving a combined AUC of 0.874 for distinguishing benign endometriosis from malignant transformation [6]. This case underscores the role of T2 mapping as a quantitative, non-invasive biomarker for assessing the microstructure and aggressiveness of MMMTs.

The differential diagnosis of MMMT encompasses a wide range of aggressive ovarian neoplasms. Key considerations include high-grade serous carcinoma, which typically features more cystic components, papillary architecture, and minimal sarcomatous differentiation; pure sarcomas, which lack epithelial markers and keratin expression; immature teratomas, primarily affecting younger patients and characterized by immature neuroectodermal elements; endometrioid carcinoma with spindle cell features, exhibiting monophasic morphology with endometrioid glandular patterns, which shows diffuse keratin positivity without true sarcomatous elements; dedifferentiated carcinoma, arising in association with low-grade endometrioid carcinoma and often displaying rhabdoid morphology; Müllerian adenosarcoma, with or without sarcomatous overgrowth, distinguished by benign glandular elements with periglandular stromal condensation and absence of high-grade epithelial malignancy; metastatic tumors, such as Krukenberg tumor, characterized by signet-ring cells and desmoplastic stroma; and other multilineage tumors, including poorly differentiated Sertoli-Leydig cell tumor with heterologous elements, identified via sex cord–stromal or germ cell immunohistochemical markers [7, 14, 15]. Imaging modalities alone are insufficient for reliably distinguishing ovarian MMMT from other ovarian malignancies, as they often exhibit nonspecific and overlapping features, such as large heterogeneous masses, necrosis, hemorrhage, and ascites, which are present in more than 50% of advanced cases. However, quantitative parameters like low ADC and elevated T2 mapping values that reflect the tumor's complex microenvironment, can provide valuable preoperative insights. Ultimately, definitive differentiation relies on histopathological confirmation, which includes immunohistochemistry (IHC) for markers such as p53 (often mutated in epithelial components), cytokeratins (epithelial), and sarcomatous-specific markers (e.g., desmin, actin, or S-100 for heterologous elements). This multimodal approach enhances preoperative risk stratification and aids in narrowing the differential diagnosis from mimicking conditions [4].

This study acknowledges several limitations that warrant consideration. Firstly, it is a single-case report with a small sample size, which restricts the generalizability of the quantitative T2 mapping and ADC values observed in our patient to the broader

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MMMT population. To validate the diagnostic cutoff values for these quantitative MRI parameters in MMMT, larger prospective cohort studies are necessary. Secondly, we did not perform longitudinal follow-up on the patient to evaluate correlations between preoperative T2 mapping, ADC values and treatment response or long-term prognosis, highlighting an important avenue for future research on quantitative MRI biomarkers in MMMT. Thirdly, our analysis was limited to T2 mapping and DWI/ADC as quantitative MRI parameters; incorporating other advanced techniques, such as IVIM, could further enhance the diagnostic and prognostic value for OCS, which remains unexplored in this study [5, 16]. Lastly, the pathological analysis was confined to routine HE staining and basic IHC markers (S-100, p53, Ki-67); additional molecular and genetic testing (e.g., TP53 mutation, homologous recombination deficiency [HRD] status) [4, 7] could provide deeper insights into the biological characteristics of this rare tumor and its correlation with imaging features. Despite these limitations, this case report enriches the quantitative imaging database of MMMT with heterologous chondrosarcoma components and validates the clinical value of T2 mapping in characterizing this rare and aggressive ovarian malignancy.

Future studies on MMMT should prioritize the establishment of large-sample prospective cohorts to develop standardized quantitative MRI diagnostic criteria, including T2 mapping and ADC cutoff values. Furthermore, these studies should explore the correlations between these imaging parameters and molecular pathological features, such as TP53 mutations and heterologous component types. Longitudinal studies are also essential for evaluating the utility of T2 mapping and ADC in monitoring treatment responses and predicting prognoses in MMMT patients undergoing cytoreductive surgery and platinum-based chemotherapy [4, 15]. Additionally, the development of multi-parametric MRI models that integrate T2 mapping, DWI/ADC, IVIM, and dynamic contrast-enhanced MRI (DCE-MRI) is necessary to enhance preoperative diagnostic accuracy for MMMT and to better differentiate it from other high-grade ovarian malignancies [6, 16].

CONCLUSION

This case report describes the characteristic CT/MRI and quantitative T2 mapping features of ovarian MMMT with heterologous chondrosarcoma components in an elderly patient, confirming that a high T2 mapping value (148±18 ms) and low ADC value ($0.98\pm0.08\times10^{-3}$ mm^2/s) are distinctive quantitative imaging signatures of this rare, high-grade malignancy. Quantitative T2 mapping, as a non-invasive functional MRI technique, effectively reflects the complex microstructural features of ovarian MMMT and complements conventional imaging in characterizing tumor aggressiveness, providing valuable imaging evidence for clinical decision-making and treatment planning for this rare gynecological malignancy with poor prognosis.

***Authors' Contribution*:** X.W., G.S. and H.Z. contributed equally to this work. Conceptualization: X.W. and M.C.; Data curation: G.S. and H.Z.; Formal analysis: X.W. and G.S.; Imaging acquisition and interpretation: X.W. and G.S.; Pathological analysis: H.Z.; Writing-original draft: X.W.; Writing-review & editing: M.C.; Supervision: M.C. All authors have read and agreed to the published version of the manuscript.

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***Conflict of Interests*:** The authors declared no conflict of interest.

***Ethical statement*:** This study was approved by the ethics committee of Zhuhai Hospital of Integrated Traditional Chinese and Western Medicine (Approval no. 2026-03-053-E01). Signed written informed consents were obtained from the patients and/or guardians. This study was conducted in accordance with the Declaration of Helsinki.

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