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Ultrahigh-field imaging (7 Tesla) in DNET: Unmasking microstructural imaging characteristics – A case report

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ABSTRACT

Commercial ultrahigh-field 7 Tesla (T) MRI has been approved for clinical brain imaging, including applications in epilepsy and brain tumors. Increasing magnetic field strength offers significant advantages over lower-field MRI due to improved spatial resolution, signal-to-noise ratio, and contrast-to-noise ratio. These improvements provide better anatomical delineation and gray-white matter tissue-contrast differentiation.

We present a case of a presumed dysembryoplastic neuroepithelial tumor (DNET) imaged at 7 T MRI of the second generation, which revealed an unprecedented level of detail of the complex and intricate tumor architecture. Insights of its different components correlate closely with its known histopathological features. These tumors are unique among low-grade neoplasms due to their distinct clinical presentation, imaging features, and histopathological architecture. DNETs are rare, typically occurring in young patients with refractory epilepsy, and are classified by their well-defined histological subtypes. We review the various MRI patterns of DNET, which have been shown to correlate with histological subtypes and the extent of the epileptogenic zone.

Complete tumor resection is essential for long-term control and recurrence prevention, emphasizing the importance of precise preoperative visualization of the tumor and its surrounding tissue. In this case, 7 T images demonstrated superior lesion conspicuity and clearer boundaries, highlighting the advantages of ultrahigh-field MRI in defining the full extent of the lesion. Although 7 T MRI is not yet widely available, it has started to gain an important role in the management of epilepsy, particularly for cases requiring detailed structural analysis.

1. Introduction

Resulting from numerous technical advances in the last years, MRI scanners operating at 7 Tesla (T) or higher, reaching up to 11.7 T, have become available. These ultrahigh-field MRI scanners, defined as those with magnetic field strengths ≥7 T [1], offer the potential to achieve neuroimaging with unprecedented detail. This capability facilitates better characterization of normal tissue and pathological lesions, while also improving treatment planning and monitoring of therapeutic response [1,2].

Commercial ultrahigh-field 7 T MRI received FDA approval for clinical brain imaging in October 2017 (Magnetom Terra, Siemens Healthcare, Erlangen, Germany). Increasing magnetic field strength improves signal-to-noise ratio (SNR), spatial resolution and contrast-to-noise ratio, resulting in greater resolution and better differentiation of fine anatomical structures, better tissue detail (particularly in gray-white matter differentiation) and improved lesion conspicuity, also allowing better visualization of smaller lesions [3]. Additionally, the higher spatial resolution reduces partial volume effects due to the improved in-plane resolution and thinner slice thickness [4]. The advantages of high-field imaging are further exemplified in the second-generation 7 T MRI scanner, the Siemens Magnetom MAGNETOM Terra.X (Siemens Healthcare, Forchheim, Germany), which received FDA approval in March 2024, leveraging the higher field strength to achieve even better SNR and spatial resolution.

We present a case of a presumed dysembryoplastic neuroepithelial

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tumor (DNET) imaged at a second generation 7 T MRI scanner, which revealed unprecedented level of detail of the complex and intricate tumor architecture.

2. Case presentation

A 22-year-old male patient is known for a frontoinsular tumoral lesion, responsible for a 10-year history of drug-resistant epilepsy. The patient's seizure semiology included an auditory aura (buzzing sound lateralized to the left), followed by an inability to speak and sensory deficits in the right hemibody. Seizures frequently progressed to generalized tonic-clonic episodes. Postictally, the patient experienced aphasia with phonological jargon and semantic paraphasias lasting up to 30 min. EEG evaluation found no interictal abnormalities. However, two seizures were recorded, both occurring as the patient was falling asleep. The electroencephalogram showed flattening of baseline activity, followed by rhythmic slow discharges at 5 Hz in the left frontotemporal region, with propagation to the frontocentral area. Generalized delta slowing at 3 Hz, predominantly on the left side, was observed in the postictal phase. The semiology was consistent with his usual episodes and suggested a left hemispheric origin. EEG showed the emergence of rapid rhythms near the left parietal region.

Informed consent was provided, and the patient underwent ultrahigh-resolution second-generation 7 T MRI (Siemens Magnetom MAGNETOM Terra.X, Siemens Healthcare, Forchheim, Germany), certified for clinical use, with a dedicated standard epilepsy protocol (**Supplementary Table S1**) as part of the presurgical planning for optimal definition of the tumoral extent.

We used a 8Tx-dipoles/32Rx-loops coil array with parallel transmit capabilities (NovaMedical, Wilmington, MA, USA; CE-certified in 2023). Used acceleration methods are indicated in **Supplementary Table S1**, tailored pulse profiles were used for the T1 MP2RAGE and the T2 FLAIR SPACE sequence, based on dynamic pTx pulses. The other sequences used universal pulse profiles. Gradient distortion correction was applied in all the sequences.

Diffusion tensor imaging (DTI) was added to visualize the arcuate fasciculus. Images were postprocessed at a workstation equipped with a commercially available postprocessing software (Syngo.via® VB30A, Siemens Healthcare).

MRI demonstrated enlarged left posterior frontoinsular gyri due to an intracortical, well-demarcated, multinodular mass (Fig. 1), markedly hypointense on T1-weighted images, hyperintense on T2-weighted and T2 FLAIR-weighted images, without contrast enhancement, highly suggestive of dysembryoplastic neuroepithelial tumor (DNET), which has been stable for 10 years. No satellite lesions or areas of distant focal dysplasia were detected. DTI revealed displacement of the white matter fibers due to tumoral mass effect, with no evidence of fiber infiltration. However, the proximity of the tumor to the arcuate fasciculus, Wernicke's area, and deep motor pathways presents a significant challenge with a high risk of subsequent neurological deficits, particularly in language, sensory, or visual domains, in a patient whose evaluations suggest left-lateralized language function. The preferred strategy was, therefore, to watch and wait, while clinically monitoring patient symptomatology and radiologically monitoring tumor growth.

At closer look, the increased in-plane resolution at 7 T up to 0.15 x 0.15 mm^2 provided excellent detail of the «soap-bubble-like» appearance with inframillimeter resolution and very precise delineation of the tumoral extent in a way which, to the best of our knowledge, has not been reported to date on a DNET (Fig. 2). The radiological architectural appearance, somewhat columnar, highly resembles the classic components histopathologically defined by Dupont-Daumas in 1988 (Fig. 2D) [5]. The imaging features encountered in our case align with the DNET

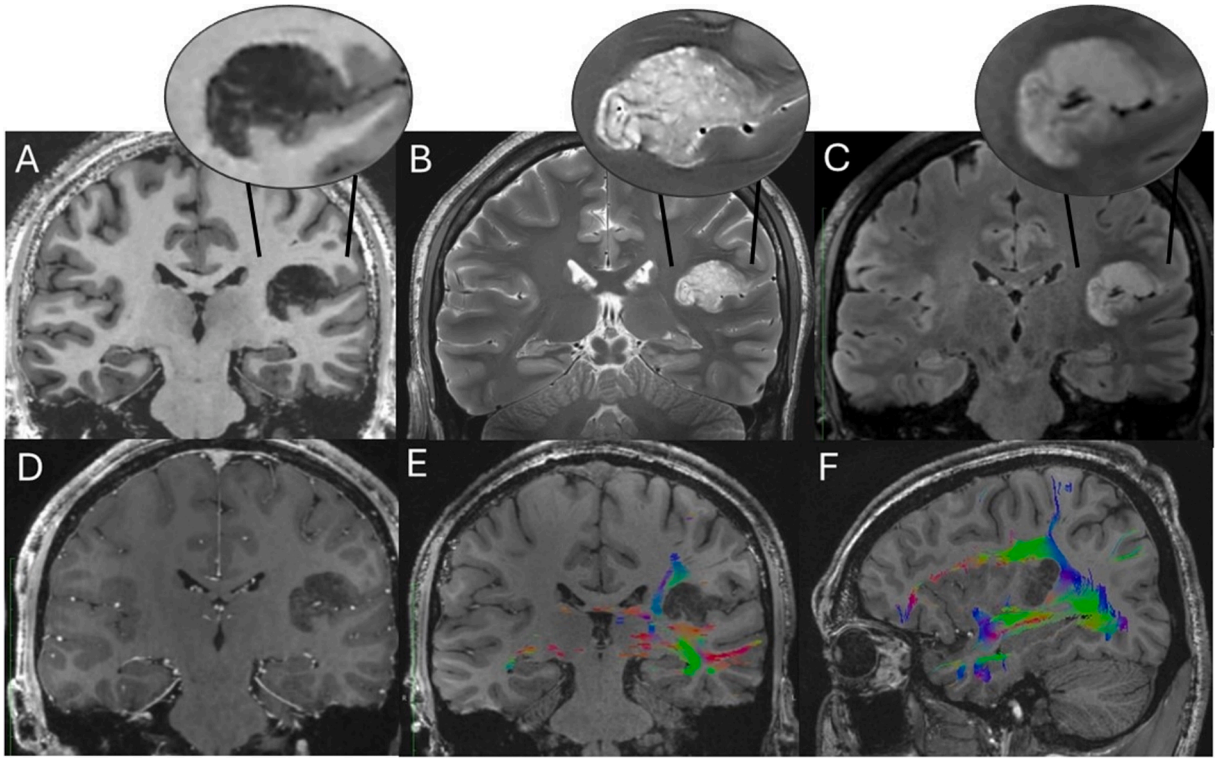

Fig. 1. Brain MRI at 7 T shows enlarged left posterior frontoinsular gyri containing a well-demarcated, multinodular mass. **A**, coronal T1-weighted image reveals a markedly hypointense intracortical mass (zoomed box). **B**, coronal high-resolution T2-weighted image (2 mm slice thickness) and **C**, T2 FLAIR-weighted image confirm the pseudocystic nature of the mass, showing hyperintense signal of the left mass (zoomed boxes). **D**, post-Gadolinium T1-weighted image shows no contrast enhancement. **E, F**, diffusion tensor imaging (DTI) tractography of the arcuate fasciculus shows displacement of the white matter fibers due to the mass effect of the tumor, with no evidence of fiber infiltration. The lesion's distinct intracortical, pseudocystic appearance, along with the clinical context, strongly suggests a diagnosis of dysembryoplastic neuroepithelial tumor (DNET).

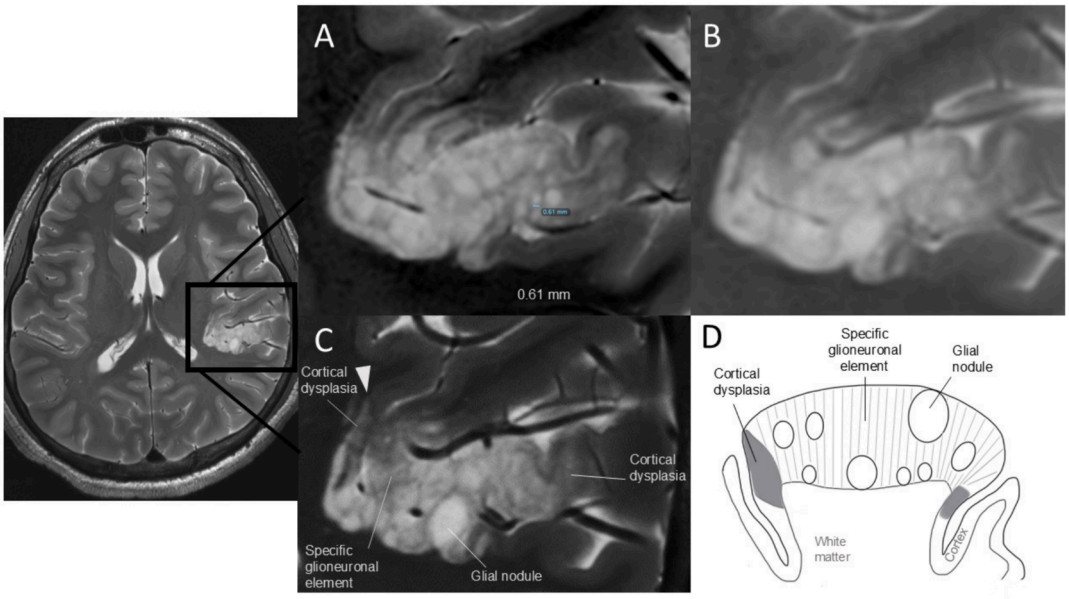

Fig. 2. Insights into the microarchitecture of DNET from an axial zoomed view. Comparison of ultrahigh-resolution 7 T (in-plane resolution up to 0.15 x 0.15 mm^2) vs 3 T MRI (in-plane resolution of 0.43 x 0.43 mm^2). **A and C**, axial T2-weighted images at 7 T (contiguous slices); **B**, axial T2-weighted image at 3 T at the same slice as A. The improved spatial resolution at 7 T, with a precision down to micrometers, provided an unprecedented level of detail of the "bubble-like" septa and allowed for precise delineation of the tumor's extent at a submillimetric scale. **C**, noted microarchitecture in an axial T2-weighted image at 7 T; **D**, graphical representation of the classic histopathological components a DNET as described by Dupont-Daumas in 1988 [5], showcasing the complex form of DNET (multinodular architecture and adjacent dysplastic cortex). The tumor's radiological microarchitecture closely mirrors the histopathological components, where we can also see a columnar pattern, and clear visualization of cystic nodules and well delimitation of the cortical dysplastic rim from normal cortex (arrowhead).

type 1-MRI classification proposed by Chassoux and colleagues in 2012 [6]. They created an MRI-based scheme for surgery, correlating imaging features with histologic subtypes and the extent of epileptogenic zone with neurophysiological tests. Accurate presurgical definition of the tumor extent is essential to achieve its complete resection and thus optimize patient outcomes, not only in terms of long-term tumor control but also to avoid seizure recurrence [7].

3. Discussion

In our patient, a 7 T MRI with optimal image quality was successfully performed. In this particular case no new lesions were observed compared to previous 3 T studies. However, in terms of visual identification of the tumor, a better definition of the lesion boundaries was achieved, including a better visualization of its internal microstructure (e.g., the extension of the dysplastic component into the cortical edges of the lesion (Fig. 2C)) which is of great importance. This detailed delineation of the different tumor components may improve surgical resection, whenever possible, thus increasing the likelihood of a seizure-free postoperative outcome.

3.1. 7 T in brain tumors and epilepsy

The advantages of high-field imaging make 7 T particularly suitable for epilepsy and brain tumors cases, where lesions are often subtle and difficult to detect, and precise delineation is essential for surgical planning [4]. Recently, the 7 T Epilepsy Task Force published consensus recommendations on the use of 7 T MRI in clinical patients [8]. Previous studies have demonstrated its clinical utility in patients with pharmacoresistant focal epilepsy [4,9]. Compared with 3 T MRI, 7 T is superior at visualizing conditions such as focal cortical dysplasia, hippocampal sclerosis, periventricular nodular heterotopia or vascular malformations, and assessing the extent of polymicrogyria or multifocal abnormalities [10]. The increased sensitivity of 7 T MRI for detecting previously missed lesions on 1.5 T or 3 T MRI in patients with focal epilepsy varies across studies. A systematic review by Van Lanen et al. reported an added diagnostic gain of 7 T MRI in such cases, ranging from 18 % to 67 % across different patient cohorts, with a pooled gain of 31 %. This indicates that nearly one-third of patients with negative findings on 1.5 and/or 3 T MRI benefited from 7 T imaging, identifying clinically relevant lesions that directly influenced treatment strategies [11]).

Currently, the availability of sequences at 7 T is almost comparable with those at 1.5 or 3 T.

However, challenges remain related to increased sensitivity to peripheral artifacts, motion, pulsation, and field inhomogeneity, particularly in the antero-basal temporal lobes [4]. Exclusion criteria for 7 T MRI are more stringent compared to lower-field MRIs due to the higher magnetic field strength and associated safety considerations. Safety concerns persist for patients with implants or metallic devices, for whom 7 T MRI remains contraindicated [3].

3.2. Dysembryoplastic neuroepithelial tumors (DNET)

In 1988 Dumas-Duport and colleagues first described DNET, a slow-growing, low-grade glioneuronal tumor commonly associated with pharmacoresistant epilepsy in young children and adolescents [5]. Classified as a grade 1 tumor by the World Health Organization, DNETs are typically located in the cortex or deep gray matter, involving a whole gyrus or a wedge-shaped part of the cerebral parenchyma [7,12]. They frequently involve the temporal lobe, followed by the frontal lobe, caudate nucleus and cerebellum, and are frequently associated with adjacent cortical dysplasia [5]. The intracortical location, together with the dysplastic associated nature, explain the strong epileptogenic disposition of this tumor [7].

3.3. DNET histopathology

The unique architecture of DNETs that led to its first description, consists of a «specific glioneuronal element» (SGE) at the tumor core, often accompanied by a rim of cortical dysplasia with small nodular foci

on the inner side of the mass (Fig. 2D). DNETs are classified into three histological subtypes: simple, complex, and diffuse/nonspecific [5]. The simple form contains only the SGE, while complex DNET includes multinodular architecture and adjacent dysplastic cortex. Nonspecific DNET lacks the SGE but shares clinical and neuroimaging characteristics with the complex form [7].

3.4. MR imaging of DNETs

Later, MRI studies observed additional small nodules located in the proximity of the tumor mass, separated by a thin layer of white matter, in half of the patients [13]. These lesions, referred as satellite lesions, share the same histological features and oncogenic mutations as the main tumor mass [12].

MRI plays a crucial role in the diagnosis, characterization and surgical planning of DNETs [7]. These tumors typically appear as well-demarcated intracortical masses, often lacking surrounding edema or significant mass effect. In some cases, they can extend into the adjacent white matter, with less defined borders and triangular shape (best appreciated on coronal images) [12,14]. MRI must assess the presence of associated focal cortical dysplasia or satellite lesions [13], as they can influence treatment planning and impact seizure recurrence.

On T1-weighted images, DNETs usually appear as hypointense intracortical masses, with T2-weighted hyperintense «soap-bubble» appearance, indicative of their multicystic architecture. Ultrahigh-field 7 T MRI enhances the visualization of these inframillimetric septa-like structures (Fig. 2**)**. T2-FLAIR may reveal a bright rim sign and partial suppression of the "bubbles" (not present in our case). DTI often shows displacement of adjacent fiber tracts, consistent with a non-infiltrative mass (Fig. 2D) [14]. Contrast enhancement is generally absent [7]. Satellite lesions typically exhibit a nodular, ovoid morphology, and are usually hyperintense on T2-weighted images, without contrast enhancement. DNETs may resemble other tumors, such as gangliogliomas, which may also involve the cerebral cortex and subcortical white matter. Differentiating non-enhancing gangliogliomas from DNETs and even from focal cortical dysplasia can be challenging [7].

3.5. Chassoux's classification and treatment

Chassoux and colleagues classified DNETs into three MRI types, based on the extent of signal abnormalities and gray-white matter demarcation. Type 1 MRI (cystic − 1a; or polycystic − 1b) shows clear gray-white matter demarcation and well-defined borders. Type 2 MRI (nodular/multinodular) presents with less defined T1 signal intensities (iso-, hypo-, or hyperintense), T2/FLAIR hyperintensity and generally well-defined gray-white matter demarcation. Type 3 MRI (dysplastic) exhibits poor delineation with diffuse gray-white matter boundaries and variable signal across sequences [6].

MRI types have been found to correlate with histological subtypes (simple, complex, and nonspecific), and the extent of the epileptogenic zone. Type 1 MRI, often associated with simple and complex DNET forms, has more favourable surgical outcomes due to better-defined tumor margins, and co-localization of the epileptogenic zone within the tumor itself (simple form) or involving the surrounding dysplastic cortex (complex form) [7]. In such cases, resection is proposed to be restricted to the visible tumor on MRI. In contrast, Type 2 and 3 MRI subtypes, associated with nonspecific histology, have broader epileptogenic zones, less defined borders and a strong predilection for the temporo-mesial areas, often requiring more extensive resections (partial lobectomy and/or amigdalectomy) potentially affecting surgical outcomes [6,7]. Even in incomplete resections, seizures frequently cease. Nevertheless, it is important to include satellite lesions in the resection area, when possible, as they are associated with increased rate of tumor or seizure recurrence [12,15].

4. Conclusion

Recognition of the imaging features of DNETs is important as surgical resection can be curative with excellent prognosis. Ultrahigh-field MRI at 7 T provides unprecedented detail in tumor characterization, offering insights that may significantly impact surgery planning. Its ability to accurately characterize and delineate tumor margins is essential for achieving maximal safe resection, particularly for long-term control and seizure freedom. This technology, even though it is not widely available, has the potential to significantly impact diagnosis, surgical planning, and long-term outcomes in patients with epilepsy.

Ethical statement

The research was conducted in accordance with the principles embodied in the Declaration of Helsinki and in accordance with local statutory requirements.

The patient gave written informed consent.

CRediT authorship contribution statement

Marta Calvo-Imirizaldu: Writing – original draft, Methodology, Formal analysis. **Daniele Botta:** Writing – review & editing, Methodology. **Margitta Seeck:** Writing – review & editing, Investigation. **Jan Novy:** Writing – review & editing, Investigation. **Aikaterini Fitsiori:** Writing – review & editing. **Corrado Santarosa:** Writing – review & editing. **Kevin Battistini:** Writing – review & editing. **Karl-Olof Lövblad:** Writing – review & editing. **Felix T. Kurz:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ebr.2025.100749.

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