

# Comparison of 3 and 7 Tesla Magnetic Resonance Imaging of Obstructive Hydrocephalus Caused by Tectal Glioma

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Obstructive hydrocephalus caused by tectal glioma, which relived by neuroendoscopy, have been described using 3.0 Tesla magnetic resonance imaging (3T MRI) so far, we present the results obtained from 3T and 7T MRI in this patient. A 21-year-old woman presented at our hospital with gait disturbance, hormonal insufficiency, and urinary incontinence that began prior to 6 years of age. 3.0T MRI revealed a non-enhancing tectal mass along with obstructive hydrocephalus. The mass measured approximately 1.1×1.0×1.2 cm. An endoscopic third ventriculostomy was performed to relieve the hydrocephalus. We compared hydrocephalus and cerebrospinal fluid (CSF) flow findings from 3T and 7T MRI, both preoperative and postoperative at 1, 6 months. Intraventricular CSF voiding on T2-weighted images obtained with 7T MRI showed greater fluid inversion than those obtained with 3T MRI. This study shows that 7T brain MRI can provide detailed information on hydrocephalus caused by tectal glioma. Further studies are needed to develop refined 7T MRI protocols for better images of hydrocephalus.

**Key Words** Magnetic resonance imaging; Brain neoplasms; Hydrocephalus; Glioma.

## INTRODUCTION

Tectal gliomas are a distinct form of pediatric brainstem tumor. Patients typically present with symptoms related to increased intracranial pressure, which results from obstructive hydrocephalus [1]. We report 7.0 Tesla magnetic resonance imaging (7T MRI) results in a case of obstructive hydrocephalus caused by tectal glioma.

The recent developments in 7T MRI have been fueled by the promise of increased signal-to-noise ratio (SNR) compared with that of 1.5T and 3T MRI. Several pilot studies have used 7T MRI to image brain tumors [2-6]. Phase-contrast cine MRI provides important information on the hemodynamics of cerebrospinal fluid (CSF) circulation [7]. CSF flow physiology and pathology have been investigated with the phase-contrast cine MRI method over the last 15 years [8-10]. 7T brain MRI can potentially improve our understanding of CSF flow in cas-

es of hydrocephalus by providing detailed anatomical and pathophysiological data.

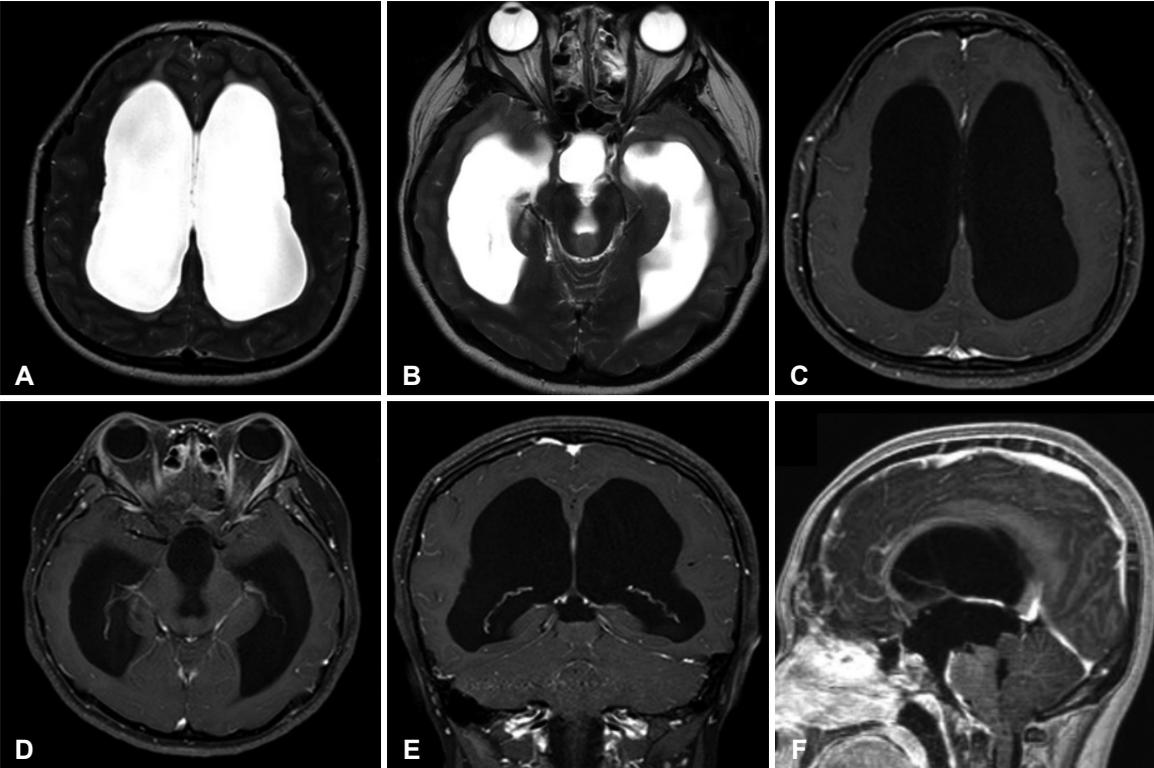
In this study, we report the results of 7T brain MRI in a patient with obstructive hydrocephalus caused by tectal glioma to document the safety and highlight the potential benefits of 7T MRI for the clinical diagnosis of hydrocephalus. We also report the results of a comparison between 3T and 7T MRI in this patient.

## CASE REPORT

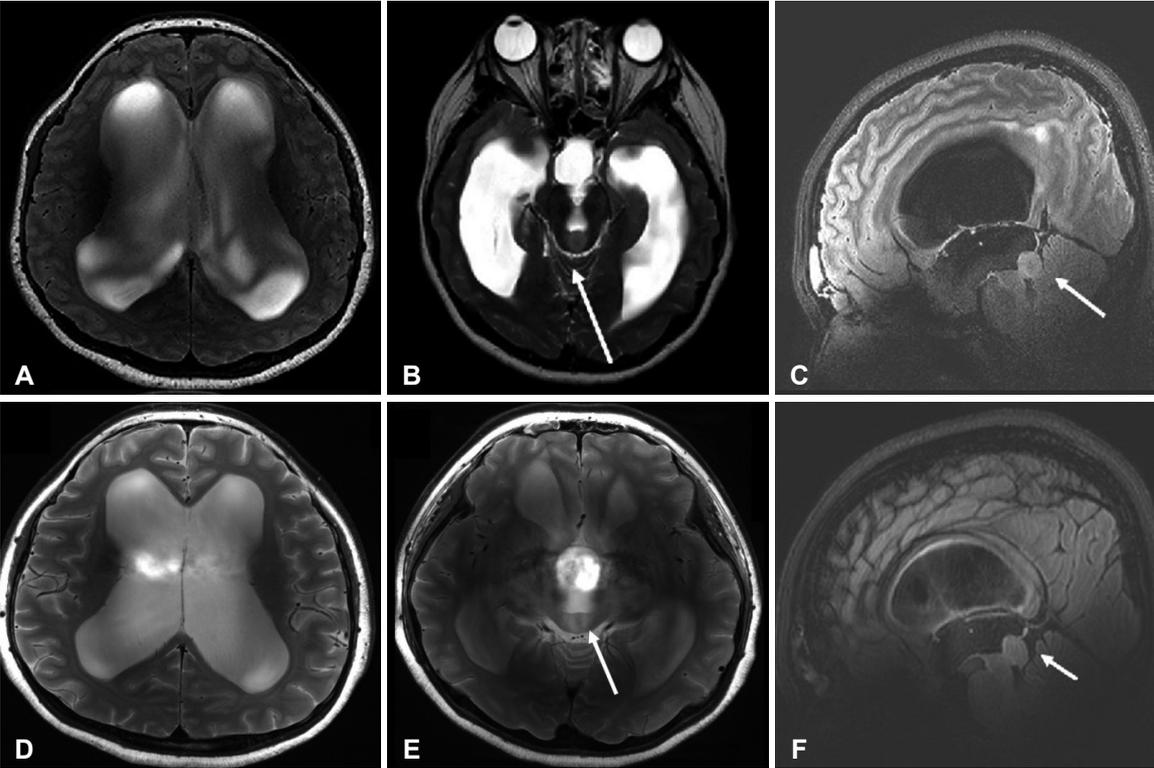
A 21-year-old woman presented at our hospital with gait disturbance and urinary incontinence persisting since before the age of 6. We observed exophthalmos and papilledema, and the patient complained of diplopia, primary amenorrhea, and cognitive decline over several years. A computed tomography scan showed obstructive hydrocephalus with transependymal edema. MRI revealed a non-enhancing mass of tectum with obstructive hydrocephalus. The mass measured approximately 1.1×1.0×1.2 cm (Fig. 1). We performed an endoscopic third ventriculostomy (ETV) and fenestration at the floor of the third ventricle into the prepontine cistern, but

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**Fig. 1.** Preoperative 3T MRI imaging. A: Axial T2-weighted 3T MR image confirming the presence of significant hydrocephalus. B: Axial T2-weighted 3T MR imaging confirming the tumor in the tectal plate. C: Axial T1-weighted gadolinium enhance 3T MR imaging confirming the presence of significant hydrocephalus. D: Axial T1-weighted gadolinium enhance 3T MR imaging confirming the the tumor in the tectal plate. E: Coronal T1-weighted gadolinium enhance 3T MR imaging. F: Sagittal T1-weighted 3T MR imaging hydrocephalus with non enhancing mass.

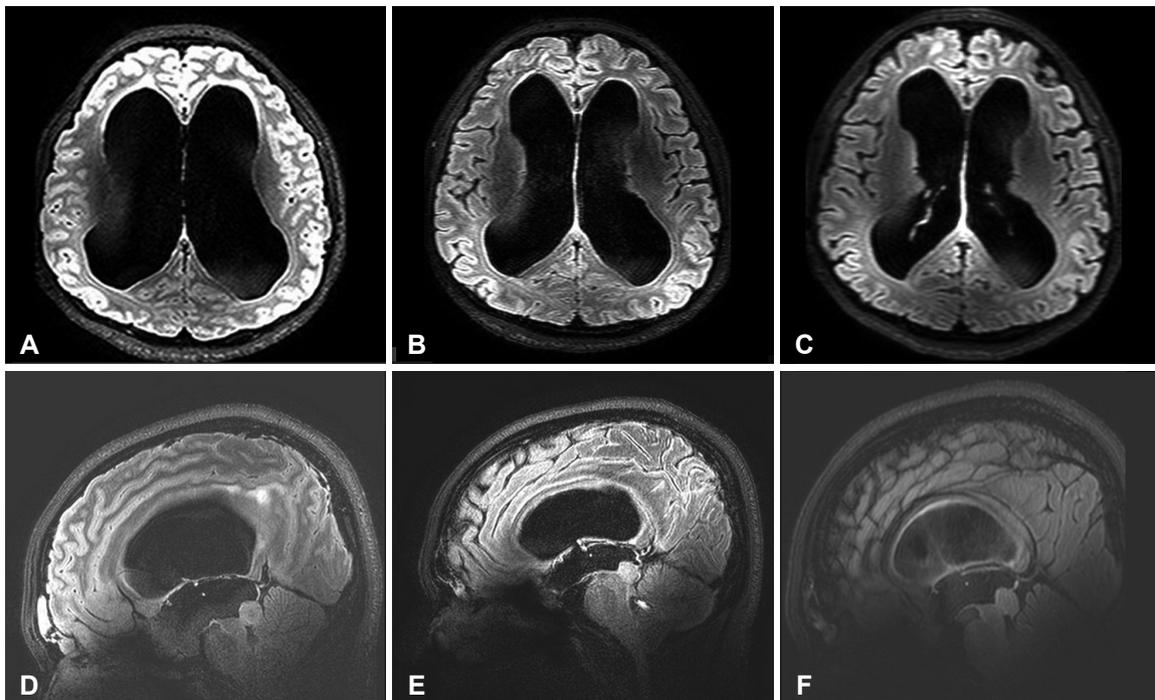


**Fig. 2.** Preoperative 7T MR axial T2-weighted image with hydrocephalus (A), axial T2-weighted image showing tectal glioma (B), and sagittal T1-weighted image (C). Postoperative 6 month MRI imaging (D-F). The arrow showing tectal glioma.

we did not obtain biopsy samples from the tectal glioma. These procedures were successful in ameliorating the patient's neurological symptoms and hydrocephalus. We performed 3T and 7T brain MRI, both preoperatively and postoperatively at 1, 6 months (Fig. 1, 2, 3). At the postoperative follow-up, the patient reported that she had begun menstruating for the first time, and also reported a dramatic improvement of her diplopia.

We tested whether CSF flow dynamic parameters were different in 3T and 7T phase-contrast cine MRI, and whether ETV had an effect on MRI findings. 3T phase-contrast cine MRI was performed on a 3T Philips MR system (Philips Healthcare, Cleveland, OH, USA). The standard scanning protocol included a fluid attenuation inversion recovery image (repetition time 8,000 ms; nominal echo time 388 ms; inversion time 2,200 ms; matrix size 344×342; voxel size

0.7×0.7×0.7 mm<sup>3</sup>; scan duration 8 min) and a T2-weighted image (repetition time 3,000 ms; echo time 56 ms; matrix size 488×396; voxel size 0.5×0.5×0.5 mm<sup>2</sup>; scan duration 6 min 48 s), which were used to assess small vessel pathology (Fig. 2, 3, Table 1). The floor of third ventricle, this membrane better delineated in 7T MRI image, also tectal glioma showing more prominent in 7T MRI (Fig. 4). We measured the mean and peak velocity of CSF flow in the prepontine cistern postoperatively. Postoperative 3T phase-contrast cine MRI showed increased CSF flow in the prepontine area (Table 2). This confirms flow of CSF through endoscopic fenestration site using both 3T and 7T MRI. 7T scans were acquired using a whole-body 7T MR system (Philips Healthcare, Cleveland, OH, USA) with a volume transmit and 16- or 32-channel receive head coil (Nova Medical, Wilmington, MA, USA).



**Fig. 3.** Preoperative imaging (A and D) and postoperative 1 month (B and E), postop 6 month 7T (C and F) fluid attenuation inversion recovery (FLAIR) MR studies showing parenchymal change and ventricle size. Preoperative (D) and postoperative (E and F) sagittal FLAIR MR image demonstrating a decrease in the ventricle scalloping and stable appearance of the tectal glioma.

**Table 1.** Imaging protocol for 7T MRI

Parameters	T2	T1	FLAIR
TR	3,000	4.6	8,000/2,200 (TI)
TE	56	2.3	388
FA	110	8	40
FOV	240×240×200	240×240×160	240×240×168
Voxel size	0.5×0.5×0.5	0.5×0.5×0.5	0.7×0.7×0.7
Matrix size	488×396	480×480	344×342
Acquisition time	6:48 min	5:53 min	8:00 min

TR, repetition time; TE, echo time; FA, flip angle; FOV, field of view; FLAIR, fluid attenuation inversion recovery; TI, the inversion time

## DISCUSSION

We have shown that obstructive hydrocephalus caused by tectal glioma induces changes in brain parenchyma and CSF pathways, and that the resulting cerebral expansion and volume changes can be detected using 7T MRI. We also compared 3T and 7T MRI for evaluating this condition. Tectal glioma often present in patients with late-onset obstructive hydrocephalus, which can be confused with benign aqueductal stenosis [1]. These lesions tend to grow slower than other tumor types [1,11,12]. Because the tumors grow slowly, initial surgical therapies are primarily directed at treating hydrocephalus using shunt placement or neuroendoscopy [1].

Older phase-contrast cine MRI (1.5T or 3T) methods provide only a qualitative description of CSF flow in the stenotic aqueduct and ventricles through the CSF flow-void sign [12,13]. However, recent surgical technology can provide both quantitative and qualitative information [14,15]. Furthermore, phase-contrast 7T MRI improves the detail in which anatomical changes in the periventricular region and hemodynamic changes can be visualized. This improved detail and the capability to measure quantitative CSF flow parameters makes phase-contrast 7T a more useful tool for the diagnosis of hydrocephalus than conventional 1.5T or 3T MRI. At 7T, the enhanced susceptibility effects around blood vessels means that relatively short echo times can be used to generate suffi-

cient  $T_2$  contrast whereas maintaining clinically acceptable acquisition times and a high SNR. In principle, at 3T a longer echo time might yield equivalent contrast between vessels and surrounding tissue, however, extending the echo time was found to lower the SNR, an effect which is likely to account for the slightly lower detection rate of lesions at 3T [16].

The higher SNR at 7T can be used to increase image resolution and improve the visualization of both tectal tumors and obstructive hydrocephalus. Other advantages of 7T MRI include faster scans [17] and increased sensitivity for susceptibility contrast, compared with 1.5T or 3T brain MRI [6]. Because of the higher susceptibility sensitivity of 7T MRI, the image quality of gradient-echo sequences may be reduced compared with that of 1.5T MRI, resulting from local magnetic field inhomogeneities near the skull base and the aerated paranasal sinuses [6]. The diagnostic gain provided by 7T imaging is a prerequisite for the clinical acceptance of ultra-high-field anatomical data, but until now, 7T MRI examinations have been confined to the research environment [13]. High-field MRI systems, such as 7T scanners, can deliver data with higher spatial resolution, which is often demanded by users in clinical and neuroscientific imaging fields [18]. The effective resolution of *in vivo* MRI can be increased substantially using prospective motion correction; however, long scan times and high fields are needed to generate sufficient signal [18].

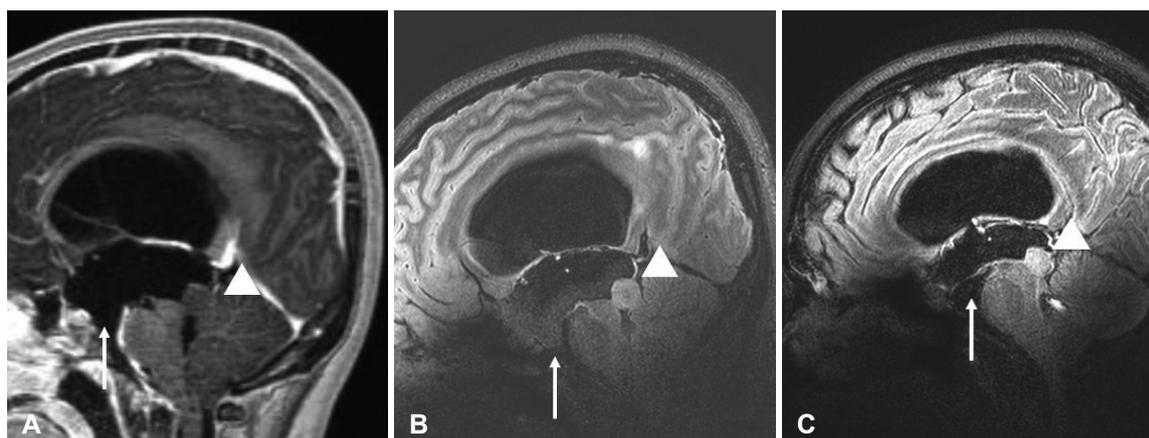
From a clinical point of view, the diagnostic accuracy of CSF velocity measurements is not perfect. Unfortunately, hydrocephalus MR imaging at 3T is less effective than at 7T for identifying periventricular edema and evaluating CSF flow. The main advantage of 7T MRI over 1.5T or 3T MRI in cases of hydrocephalus is that it can provide more accurate parenchymal changes due to higher SNR.

This study has several important limitations. First, the MRI results in this single case are not necessarily representative of

**Table 2.** The mean and peak velocity of CSF flow in the prepontine cistern, measured using 3T and 7T MRI postoperatively

Parameters	3T MRI	7T MRI
Prepontine area (cm <sup>2</sup> )	0.110	0.050
Peak velocity (cm/sec)	4.23	2.74
Mean velocity (cm/sec)	1.67	1.02
Back flow volume (mL)	0.033	0.072

CSF, cerebrospinal fluid; MRI, magnetic resonance image



**Fig. 4.** Preoperative sagittal T1-weighted gadolinium enhanced 3T MR (A), 7T MR (B), and postoperative 7T fluid attenuation inversion recovery MRI image (C). The arrow show floor of third ventricle, this membrane better delineated in 7T MRI image, also tectal glioma showing more prominent in 7T MRI (arrowhead).

those for hydrocephalus resulting from other medical conditions. Second, we did not perform cine MRI at 7T. Further technological advances are necessary to measure CSF velocity at 7T. Third, we did not perform any contrast-enhanced studies at 7T, and further research is necessary to determine whether 7T MRI can be useful for diagnosis of obstructive hydrocephalus with tectal glioma. Fourth, we lacked MR hardware, such as more efficient Radiofrequency coils and stronger or faster gradient coils, that are necessary for effective 7T MRI, according to Feinberg and Mark [18] and Stucht et al. [19].

We have shown that 7T brain MRI can be performed safely in a patient with hydrocephalus and intra-axial brain tumors. 7T brain MRI offers a more detailed view of brain parenchyma compressed by hydrocephalus than 3T MRI. We also report the first use of phase-contrast 7T cine MRI. 7T MRI and phase-contrast cine 7T MRI are feasible and valuable tools in the diagnosis and treatment of hydrocephalus with tectal glioma. The benefits of 7T MRI over conventional 1.5T or 3T MRI for hydrocephalus include the quantitative measurement of CSF flow parameters and enhanced anatomical detail. However, further study is needed to develop refined MRI protocols for better imaging of hydrocephalus.

#### Conflicts of Interest

The authors have no financial conflicts of interest.

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