Diffusion tensor imaging for Brainstem cavernous malformation

- The role of DTI in surgical management of brainstem cavernous malformations: A meta-analysis of 4159 cases
- Surgical resection of A giant ventral pontine cavernous malformation: Two-dimensional video
- Automated White Matter Fiber Tract Segmentation for the Brainstem
- Implementation of high-definition fiber tractography for preoperative evaluation and surgical planning of brainstem cavernous malformation: long-term outcomes
- Improving tractography in brainstem cavernoma patients by distortion correction
- The Brainstem Cavernoma Case Series: A Formula for Surgery and Surgical Technique
- Safety and efficacy of the endoscopic transsphenoidal transclival approach performed using direct cortical stimulation for pontine cavernous malformations
- The Guillain-Mollaret triangle: a key player in motor coordination and control with implications for neurological disorders

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The utilization of preoperative diffusion tensor imaging significantly increased the proportion of improved patients and decreased the proportion of worsened patients. However, further controlled research is needed to draw a definite conclusion about the usefulness of its role [1)].

A study aimed to systematically review the literature to determine the clinical utility and perspectives of diffusion tensor imaging (DTI) in the management of patients with brainstem cavernous malformations (BSCMs). PubMed, Embase, and Cochrane were searched for English-language articles published until May 10, 2021. Clinical studies and case series describing DTI-based evaluation of patients with BSCMs were included. Fourteen articles were included. Preoperative DTI enabled to adjustment of the surgical approach and choose a brainstem safe entry zone in deep-seated BSCMs. Preoperatively lower fractional anisotropy (FA) of the corticospinal tract (CST) correlated with the severity of CST injury and motor deficits. Postoperatively increased FA and decreased apparent diffusion coefficient (ADC) corresponded with the normalization of the perilesional CST, indicating motor improvement. The positive (PPV) and negative predictive value (NPV) of qualitative DTI ranged from 20 to 75% and from 66.6 to 100%, respectively. The presence of preoperative and postoperative motor deficits was associated with a higher preoperative resting motor threshold (RMT) and lower FA. A higher preoperative corticospinal tract score was indicative of a lower preoperative and follow-up Medical Research Council (MRC) grade. DTI facilitated the determination of a surgical trajectory with minimized risk of WMTs damage. Preoperative FA and RMT might indicate the severity of preoperative and postoperative motor deficits. Preoperative CST score can reliably reflect patients' preoperative and follow-up motor status. Due to high NPV, normal CST morphology might predict intact neurological outcomes. Contrarily, sparse and relatively low PPV limits the reliable prediction of neurological deficits [2)].

In 2016 Januszewski et al. compared with the standard magnetic resonance imaging, DTI provided

improved visualization of cavernous malformation involvement in eloquent fiber tracts of the brainstem. This additional information might help in selecting a more appropriate surgical trajectory in selected lesions. Larger patient cohorts are needed to assess the effect of this modality in patients' outcome [3].

Positive findings on DTT such as fiber tract deviation, deformation, disruption or interruption should be taken cautiously before drawing conclusions of clinically relevant damage of white matter tracts [4].

Preoperative diffusion tensor imaging may influence the selection of surgical approach or brainstem entry zones, especially in deep-seated lesions without pial or ependymal presentation. DTI/DTT findings may allow for more aggressive management of lesions previously considered surgically inaccessible. Preoperative DTI/DTT changes do not appear to correlate with functional postoperative outcome in long-term follow-up [5]

Intact corticospinal tract (CST) morphology in diffusion tensor imaging DTI predicts a favorable postoperative outcome in patients with BSC. Interrupted CSTs and decreased Fractional anisotropy (FA)-values correlate well within lesion level, nevertheless morphologic characteristics and diffusion parameter changes cannot predict poor prognosis. Caudal and rostral diffusion parameters can provide more information of the integrity of CSTs compared with morphological study alone [6].

Hemorrhagic brainstem CMs can disrupt and displace perilesional white matter tracts with the latter occurring in unpredictable directions. This requires the use of tractography to accurately define their orientation to optimize surgical entry point, minimize morbidity, and enhance neurological outcomes. Observed anisotropy decreases in the perilesional segments are consistent with neural injury following hemorrhagic insults. A model using these values in different CST segments can be used to longitudinally monitor its craniocaudal integrity. Diffusion connectometry is a complementary approach providing longitudinal information on the rostrocaudal involvement of the CST [7].

In 2007 compared with the information provided by conventional MR imaging, DTI and WMT provided superior quantification and visualization of lesion involvement in eloquent fiber tracts of the brainstem. Moreover, DTI and WMT were found to be beneficial for white matter recognition in the neurosurgical planning and postoperative assessment of brainstem lesions [8].

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Al-Salihi MM, Al-Jebur MS, Al-Salihi Y, Saha R, Daie MM, Rahman MM, Ayyad A. Diffusion Tensor Imaging with Tractography in Surgical Resection of Brainstem Cavernous Malformations: A Systematic Review and Meta-analysis. Int J Neurosci. 2023 May 16:1-30. doi: 10.1080/00207454.2023.2214696. Epub ahead of print. PMID: 37194114.
2)
Rogalska M, Antkowiak L, Mandera M. Clinical application of diffusion tensor imaging and fiber tractography in the management of brainstem cavernous malformations: a systematic review. Neurosurg Rev. 2022 Feb 25. doi: 10.1007/s10143-022-01759-7. Epub ahead of print. PMID: 35211879.
3)
Januszewski J, Albert L, Black K, Dehdashti AR. The Usefulness of Diffusion Tensor Imaging and Tractography in Surgery of Brainstem Cavernous Malformations. World Neurosurg. 2016 Sep;93:377-88. doi: 10.1016/j.wneu.2016.06.019. Epub 2016 Jun 14. PMID: 27312394.

4)

Topcuoglu OM, Yaltirik K, Firat Z, Sarsilmaz A, Harput V, Sarikaya B, Ture U. Limited Positive Predictive Value of Diffusion Tensor Tractography in Determining Clinically Relevant White Matter Damage in Brainstem Cavernous Malformations: A Retrospective Study in a Single Center Surgical Cohort. J Neuroradiol. 2019 Sep 17. pii: S0150-9861(19)30438-9. doi: 10.1016/j.neurad.2019.07.005. [Epub ahead of print] PubMed PMID: 31539583.

5)

Flores BC, Whittemore AR, Samson DS, Barnett SL. The utility of preoperative diffusion tensor imaging in the surgical management of brainstem cavernous malformations. J Neurosurg. 2015 Mar;122(3):653-62. doi: 10.3171/2014.11.JNS13680. Epub 2015 Jan 9. PubMed PMID: 25574568.

6)

Yao Y, Ulrich NH, Guggenberger R, Alzarhani YA, Bertalanffy H, Kollias SS. Quantification of corticospinal tracts with diffusion tensor imaging in brainstem surgery: Prognostic value in 14 consecutive cases at 3T-MRI. World Neurosurg. 2015 Mar 5. pii: S1878-8750(15)00067-4. doi: 10.1016/j.wneu.2015.01.045. [Epub ahead of print] Review. PubMed PMID: 25749578.

7)

Faraji AH, Abhinav K, Jarbo K, Yeh FC, Shin SS, Pathak S, Hirsch BE, Schneider W, Fernandez-Miranda JC, Friedlander RM. Longitudinal evaluation of corticospinal tract in patients with resected brainstem cavernous malformations using high-definition fiber tractography and diffusion connectometry analysis: preliminary experience. J Neurosurg. 2015 Jun 5:1-12. [Epub ahead of print] PubMed PMID: 26047420.

8)

Chen X, Weigel D, Ganslandt O, Buchfelder M, Nimsky C. Diffusion tensor imaging and white matter tractography in patients with brainstem lesions. Acta Neurochir (Wien). 2007 Nov;149(11):1117-31; discussion 1131. doi: 10.1007/s00701-007-1282-2. Epub 2007 Aug 23. PMID: 17712509.