

Predictors of Pneumocephalus after Deep Brain Stimulation in Parkinson's Disease: The Role of Intracranial Volume, Procedure.

WSSFN 2025 Interim Meeting. Abstract 0083.

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How to Cite: Calado Godoy AV, De Favi Bocca L, Rodrigues Renato RB, Pereira Rodrigues T, Candeias Silva C, Ricardo Silva Centeno R. Predictors of Pneumocephalus after Deep Brain Stimulation in Parkinson's Disease: The Role of Intracranial Volume, Procedure: WSSFN 2025 Interim Meeting. Abstract 0083. NeuroTarget. 2025;19(2):56-7.

Abstract

Introduction: Parkinson's disease (PD) is a neurodegenerative disorder characterized by the progressive loss of dopaminergic neurons, especially in the substantia nigra, leading to motor symptoms such as bradykinesia, tremor, and rigidity. Treatment involves dopaminergic medications and, in advanced stages, surgical options such as deep brain stimulation (DBS), typically targeting the subthalamic nucleus (STN) or internal globus pallidus (GPi). Stereotactic guidance is used to implant electrodes; however, factors such as pneumocephalus and cerebrospinal fluid (CSF) leakage may impair electrode positioning accuracy. Brain shift caused by these factors can affect the electrode placement and clinical outcomes. Thus, assessing the relationship between brain shift, atrophy, and pneumocephalus is key to optimizing DBS implantations. We aimed to analyze the potential correlations between pneumocephalus, brain atrophy, and brain shift in patients with PD undergoing DBS.

Method: This retrospective study included patients diagnosed with PD who underwent DBS. Clinical and surgical data were collected from medical records. Surgical approach was classified as unilateral or bilateral lead implantation on the same day. Pneumocephalus and total intracranial volume (TIV) were manually segmented from postoperative CT images using 3D Slicer, whereas brain volume was obtained using CAT12. The brain index was defined as the ratio of the brain volume to TIV. Associations among the variables were assessed using multiple linear regression, and statistical significance was set at $p < 0.05$.

Results: Thirty-eight patients (44 surgeries) with a mean disease duration of 12.9 years ($SD = 3.54$) were included. Most patients were male (70%), with 86% of the electrodes placed in the STN and 14% in the GPi. The regression model, which included TIV, brain index, sex, procedure duration, and DBS

target, was significant ($F(5,38) = 5.255$; $p < .001$), explaining 40.9% of the variance ($R^2 = 0.409$; adjusted $R^2 = 0.331$). The Durbin-Watson statistic (1.786; $p = 0.426$) indicated no autocorrelation of residuals. TIV ($\beta = -0.456$; $p = 0.024$) and procedure duration ($\beta = 0.328$; $p = 0.022$) were significant predictors of pneumocephalus. Female sex was also associated with a lower PV ($p = 0.003$). Brain index ($p = 0.602$) and DBS target ($p = 0.307$) were not statistically significant. Multicollinearity was not detected ($VIF < 3.2$; Tolerance > 0.3).

Discussion: Pneumocephalus after DBS in PD patients was influenced by TIV, surgical duration, and sex. Larger cranial volumes are associated with reduced pneumocephalus, whereas longer procedures lead to greater air accumulation. Female patients showed a trend toward lower pneumocephalus volumes. Brain atrophy, as reflected by the brain index, was not a significant factor, suggesting that brain shift may occur independently of preoperative brain volume shrinkage.

Conclusions: The findings underscore the relevance of anatomical and procedural factors in DBS planning and highlight the need for strategies to minimize pneumocephalus and its impact on electrode accuracy. Although TIV influenced pneumocephalus, a relatively larger CSF space, indirectly measured as brain atrophy, did not influence postoperative intracranial air in head CT imaging.

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