

# Force pyramid

[Virtual reality simulators](#) allow development of novel methods to analyze neurosurgical performance. The concept of a force pyramid is introduced as a Tier 3 metric with the ability to provide visual and spatial analysis of 3D force application by any instrument used during simulated tumor resection.

A study was designed to answer 3 questions: 1) Do study groups have distinct force pyramids? 2) Do handedness and ergonomics influence force pyramid structure? 3) Are force pyramids dependent on the visual and haptic characteristics of simulated tumors?

Using a virtual reality simulator, [NeuroVR](#) (formerly NeuroTouch), ultrasonic aspirator force application was continually assessed during resection of simulated brain tumors by neurosurgeons, residents, and medical students. The participants performed simulated resections of 18 simulated brain tumors with different visual and haptic characteristics. The raw data, namely, coordinates of the instrument tip as well as contact force values, were collected by the simulator. To provide a visual and qualitative spatial analysis of forces, the authors created a graph, called a force pyramid, representing force sum along the z-coordinate for different xy coordinates of the tool tip. **RESULTS** Sixteen neurosurgeons, 15 residents, and 84 medical students participated in the study. Neurosurgeon, resident and medical student groups displayed easily distinguishable 3D “force pyramid fingerprints.” Neurosurgeons had the lowest force pyramids, indicating application of the lowest forces, followed by resident and medical student groups. Handedness, ergonomics, and visual and haptic tumor characteristics resulted in distinct well-defined 3D force pyramid patterns.

Force pyramid fingerprints provide 3D spatial assessment displays of instrument force application during simulated tumor resection. Neurosurgeon force utilization and ergonomic data form a basis for understanding and modulating resident force application and improving patient safety during tumor resection <sup>1)</sup>.

<sup>1)</sup>

Azarnoush H, Siar S, Sawaya R, Zhrani GA, Winkler-Schwartz A, Alotaibi FE, Bugdadi A, Bajunaid K, Marwa I, Sabbagh AJ, Del Maestro RF. The force pyramid: a spatial analysis of force application during virtual reality brain tumor resection. J Neurosurg. 2017 Jul;127(1):171-181. doi: 10.3171/2016.7.JNS16322. Epub 2016 Sep 30. PubMed PMID: 27689458.

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