Brainstem safe entry zones

Several microsurgical approaches involving safe entry zones have been developed to optimize the exposure and minimize complications in different portions of the brainstem, but require extensive drilling and manipulation of neurovascular structures. With recent advancements, the endoscopic endonasal approach (EEA) can provide direct visualization of ventral brainstem.

Many experience-based “safe entry zones (SEZs)” into brainstem lesions have been proposed in the existing literature. The evidence for each one seems limited. English-language publications were retrieved using PubMed/MEDLINE. Studies that focused only on cadaveric anatomy were also included, but the clinical case number was treated as zero. The clinical evidence level was defined as “case report” when the surgical case number was ≤ 5, “limited evidence” when there were more than 5 but less than 25 cases, and “credible evidence” when a publication presented more than 25 cases. Twenty-five out of 32 publications were included, and 21 different SEZs were found for the brainstem: six SEZs were located in the midbrain, 9 SEZs in the pons, and 6 SEZs in the medulla. Case report evidence was found for 10 SEZs, and limited evidence for 7 SEZs. Four SEZs were determined to be backed by credible evidence. The proposed SEZs came from initial cadaveric anatomy studies, followed by some published clinical experience. Only a few SEZs have elevated clinical evidence. The choice of the right approach into the brainstem remains a challenge in each case.

Twelve BSEZs were simulated in eight, formalin-fixed, cadaveric brains. Specimens then underwent radiological investigation including T2-weighted imaging and DTT using 4.7 T MRI to verify internal anatomic relationships between simulated BSEZs and adjacent critical white matter tracts and nuclei. The distance between simulated BSEZs and pre-defined, adjacent critical structures was systemically recorded. Entry points and anatomic limits on the surface of the brainstem are described for each BSEZ, along with a description of potential neurological sequelae if such limits are violated. With high-resolution imaging, we verified a maximal depth for each BSEZ. The relationship between proposed safe entry corridors and adjacent critical structures within the brainstem is quantified. In combination with tissue dissection, high-resolution MR diffusion tensor imaging allows the surgeon to develop a better understanding of the internal architecture of the brainstem, particularly as related to BSEZs, prior to surgical intervention. Through a careful study of such imaging and use of optimal surgical corridors, a more accurate and safe surgery of brainstem lesions may be achieved.

Five cadaveric heads were dissected using 10 surgical approaches per head. Stepwise dissections focused on the actual areas of brainstem surface that were exposed through each approach and an analysis of the structures found, as well as which safe entry zones were accessible via each of the 10 surgical windows.

Thirteen safe entry zones have been reported and validated for approaching lesions in the brainstem, including the anterior mesencephalic zone, lateral mesencephalic sulcus, intercollicular region, peritrigeminal zone, supratrigeminal zone, lateral pontine zone, supracollicular zone, infracollicular zone, median sulcus of the fourth ventricle, anterolateral and posterior median sulci of the medulla, olivary zone, and lateral medullary zone. A discussion of the approaches, anatomy, and limitations of these entry zones is included.

CONCLUSIONS A detailed understanding of the anatomy,
area of exposure, and safe entry zones for each major approach allows for improved surgical planning and dissemination of the techniques required to successfully resect intrinsic brainstem lesions

Fifteen formalin and alcohol-fixed human brainstems were dissected using fiber dissection techniques, X6-X40 magnification, and three-dimensional photography to define the anatomy and the safe entry zones. The entry zones evaluated were the perioculomotor, lateral mesencephalic sulcus, and supra and infracollicular areas in the midbrain; the peritrigeminal zone, supra and infrafacial approaches, acoustic area, and median sulcus above the facial colliculus in the pons; and the anterolateral, postolivary, and dorsal medullary sulci in the medulla.

The safest approach for lesions located below the surface is usually the shortest and most direct route. Previous studies have often focused on surface structures. In this study, the deeper structures that may be at risk in each of the proposed safe entry zones plus the borders of each entry zone were defined. This study includes an examination of the relationships of the cerebellar peduncles, long tracts, intraaxial segments of the cranial nerves, and important nuclei of the brainstem to the proposed safe entry zones.

Fiber dissection technique in combination with the 3-D photography is a useful addition to the goal of making entry into the brainstem more accurate and safe.

Ten formalin-fixed and frozen brainstem specimens (20 sides) were analyzed. The white fiber dissection technique was used to study the intrinsic microsurgical anatomy as related to safe entry zones on the brainstem surface. Three anatomic landmarks on the anterolateral brainstem surface were selected: lateral mesencephalic sulcus, peritrigeminal area, and olivary body. Ten other specimens were used to study the axial sections of the inferior olivary nucleus. The clinical application of these anatomic nuances is presented.

The lateral mesencephalic sulcus has a length of 7.4 to 13.3 mm (mean, 9.6 mm) and can be dissected safely in depths up to 4.9 to 11.7 mm (mean, 8.02 mm). In the peritrigeminal area, the distance of the fifth cranial nerve to the pyramidal tract is 3.1 to 5.7 mm (mean, 4.64 mm). The dissection may be performed 9.5 to 13.1 mm (mean, 11.2 mm) deeper, to the nucleus of the fifth cranial nerve. The inferior olivary nucleus provides safe access to lesions located up to 4.7 to 6.9 mm (mean, 5.52 mm) in the anterolateral aspect of the medulla. Clinical results confirm that these entry zones constitute surgical routes through which the brainstem may be safely approached.

The white fiber dissection technique is a valuable tool for understanding the three-dimensional disposition of the anatomic structures. The lateral mesencephalic sulcus, the peritrigeminal area, and the inferior olivary nucleus provide surgical spaces and delineate the relatively safe alleys where the brainstem can be approached without injuring important neural structures.

References


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Last update: 2019/12/29 17:51