Approach selection for intrinsic brainstem pathologies

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With the exception of lesions treated at select specialty centers, lesions in the brainstem are not routinely removed. This reluctance to treat these lesions is based on the premise that the surgeon’s intervention should improve upon the natural history of the pathology being treated and should not add morbidity to the patient without improving this natural history. Operating in these regions is made challenging by the need to traverse a high density of critical neural pathways; interruption of these pathways often results in temporary or, more rarely, permanent deficits in patients. Unlike intrinsic infiltrative tumors of the neuroaxis (some of which may be resected when exophytic), noninfiltrative pathologies in the brainstem can frequently be resected with acceptable morbidity.1,8,14,32 To optimize the resection of lesions while decreasing operative risk to the patient, the surgeon must select an approach that allows direct access to the lesion. Ideally, the approach uses the shortest distance, although this is not possible in every case, while minimally disturbing adjacent neural pathways. In this report, based on 40 years of experience with brainstem surgery, we describe the technique of combining safe-entry zones7 and the two-point method6 to select the optimal approach to brainstem lesions and we highlight pitfalls of surgical techniques.

Preoperative Planning

The ultimate success of an operation in the brainstem depends largely on preoperative planning and preparation. Selection of the proper approach is certainly a key component of preparation.

Monitoring for Brainstem Surgery

We monitor somatosensory evoked potentials and motor evoked responses for all brainstem cases. We monitor the function of cranial nerves on the basis of lesion location, and several studies have documented the importance and utility of monitoring modalities.24,37 The intraoperative monitoring of the cranial nuclei is based on intraoperative electrophysiological findings and the compound muscle action potentials from related muscles. The treatment of pontine lesions located close to the floor of the fourth ventricle requires the precise identification of the facial nerve to avoid injury to this nerve before entering the floor of the fourth ventricle. A very large variability in size and position of the facial nerve response has been demonstrated, even in patients with a brainstem lesion located far from the facial colliculus.3 In the case of a tegmental lesion, intraoperative monitoring of the oculomotor and trochlear nuclei may allow for more accurate and safe surgical removal of the lesion.17

Image Guidance for Brainstem Surgery

Operative image guidance is indispensable in planning approaches and in treating brainstem lesions. The ability to fuse preoperative fine-cut magnetic resonance imaging (MRI) studies with the operating microscope allows the microscopic image to be correlated with the anatomical MRI study. The use of image guidance often directs intraoperative decision making as to the location of the lesion and the boundary of pathology with normal tissues. In cases where the lesion does not abut a pial surface, neuronavigation can assist with the selection of entry points. Recent developments and innovations from combining neuronavigation and microscope technologies have allowed our group to develop automatic positioning of the operating microscope onto a set target with a planned trajectory.30 The integration of this automatic microscope positioning has greatly improved operative efficacy and safety.

Surgical Tools for Brainstem Surgery

Brainstem surgery is necessarily carried out through

**ABBREVIATIONS** CN = cranial nerve; MCP = middle cerebellar peduncle; MRI = magnetic resonance imaging; SCIT = supracerebellar infratentorial.

INCLUDE WHEN CITING Published online September 23, 2016; DOI: 10.3171/2016.6.JNS161043.

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deep, narrow corridors. Because the visual axis and light source of the microscope are 3° to 6° apart, depending on the focal length used, the small deep exposure is frequently poorly illuminated. Lighted suction and bipolar devices eliminate this problem. Other innovations in surgical tools that allow surgeons to operate in the brainstem include low-profile bayonetted microinstruments and microdissectors (Fig. 1). The addition of lighted instruments allows the surgeon to use the instrument for illumination in addition to its original intended purpose. A lighted suction device, for example, functions not only as a source of suction but also as a source of illumination and dynamic retraction.

Retractorless Brainstem Surgery

Proper patient positioning, appropriately sized and placed craniotomies, and microinstruments now obviate the need for retractors in virtually all cases. The implementation of dynamic retraction using the shaft of the bipolar, suction, or microinstruments allows the surgeon to perform the necessary operation with better visualization and less trauma to the surrounding brain (Fig. 2).

The Two-Point Method

The two-point method describes a general strategy for selecting an approach that optimally gains access to lesions while minimizing transgression of brain². This method can be applied to lesions anywhere in the brain, but it is most commonly used for brainstem lesions when the approach allows entry to the lesion using a pial or an ependymal surface with minimal brain transgression. Using MRI sequences, the neurosurgeon identifies the geometrical center of the lesion and places a point at the center (Point A). A second point (Point B) is identified as the point where the lesion is most superficial or where the entry point defines the safest surgical corridor. A line is then drawn from the first point to the second point and onward to the skull. The trajectory of the line dictates the approach.

As with any simplification of a complex decision strategy, there are caveats to the routine use of the two-point method (Fig. 3). First, the two-point method should be used in the context of defined safe-entry zones; the use of a safe-entry zone may be advantageous relative to simply traversing eloquent brain tissue along a two-point trajectory. An example of this strategy is the resection of a dorsal mesencephalic lesion, where openings are tolerated, because of the sparse nature of eloquent pathways and perforators in these regions, and because access through these zones results in minimal or acceptable morbidity. Fourteen safe-entry zones have been reported for resection of intrinsic brainstem pathology. Surgical approaches to each safe-entry zone are described in Table 1, and approach selection for each safe-entry zone is summarized in Table 2.

Location-Specific Considerations

Midbrain Pathology

Generally, we use three different surgical routes to reach mesencephalic pathology: anterolateral, posterolateral, and posterior. Three safe-entry zones have been described for resection of intrinsic mesencephalic lesions, depending on the surface of the midbrain that the lesion most closely approximates. Approach selection should simultaneously consider the merits of the two-point method and the available safe-entry zones. For lesions that already abut a pial or an ependymal surface, direct entry into the lesion is naturally least likely to cause further morbidity, often because the pathology has already caused the morbidity that the surgeon was likely to cause by the approach.

Anterolateral Surgical Route

Our preferred approach for lesions located ventrally in the midbrain and mesencephalopontine junction is the modified orbitozygomatic craniotomy. We determine an entry zone based on the location of the lesion and displacement of critical structures, which are the intramesencephalic segment of the third cranial nerve (CN III) and the motor fibers (pyramidal tract) in the cerebral peduncle. The intramesencephalic fibers of CN III arise from the oculomotor nuclei and travel medial to and inside the red nucleus, exit the brainstem at the interpeduncular fossa. However, motor fibers (pyramidal tract) are not distributed equally in the cerebral peduncles; the majority travel in the middle three-fifths of the peduncle. The intramesencephalic fibers of CN III and the pyramidal tract may be distorted medially (most commonly) or laterally by the pathology. When the anterior mesencephalic zone (also known as the perioculomotor zone) is used, the brainstem is entered lateral to CN III between the posterior cerebral and superior cerebellar arteries (Fig. 5). Of note, from...