Target Localization in Movement Disorders Surgery

Michael G. Kaplitt, William D. Hutchison, and Andres M. Lozano

1. INTRODUCTION

The success of a stereotactic neurosurgical procedure is influenced by a number of factors. Proper patient selection is important in order to avoid treating patients unlikely to benefit from the procedure. Careful preoperative evaluation should identify factors that may result in avoidable complications or a difficult postoperative course. When surgery is deemed appropriate, the choice of anatomic target and method of treatment (lesion vs deep brain stimulation [DBS]) are the next major determinants of outcome.

Following these evaluations, effective target localization is necessary to maximize therapeutic efficacy while minimizing unwanted adverse effects. The accuracy of target localization can be influenced by a variety of factors, including the choice and placement of stereotactic frames, imaging modality and method of image-based targeting, and use of electrophysiological methodologies. No study has definitively proven that any single approach influences outcome, and methods of target localization therefore continue to vary widely among practitioners. Nonetheless, numerous studies have evaluated each of these factors and have provided data that can serve to guide surgeons in choosing effective methods for target localization. This chapter will review the use of different imaging modalities for initial target identification, factors that may influence the accuracy of each modality, the use of intraoperative electrophysiological methods for target refinement including the use of microelectrode recording and macrostimulation, and methods and indications for lesioning and DBS.

2. IMAGING

Until recently, ventriculography was considered the gold standard imaging technique for functional neurosurgery, because it has been used and refined over several decades (1–3). Among the possible imaging modalities, this approach is perhaps least subject to distortions secondary to computer reconstruction of images. Obviously, visualization of only the ventricular system prohibits direct visual targeting of intraparenchymal structures and imaging accuracy is dependent on the experience of the surgeon. Ventriculography is also an invasive procedure, and significant morbidity has been associated with gaining ventricular access and infusion of air or contrast medium into the ventricular system (4). With the advent of modern noninvasive imaging, localization by computerized tomography (CT) and magnetic resonance imaging (MRI) have become increasingly popular. Several studies have now confirmed equivalent accuracy of CT and MRI compared with ventriculographic methods of target localization (2–4). These results together with the ease, familiarity, and low-morbidity of noninvasive imaging have reduced the need for ventriculography and eliminated its use in most centers.
In addition to reducing morbidity, the development of modern imaging techniques has created new methods of target localization. Ventriculography resulted in identification of periventricular structures, in particular the anterior commissure (AC) and posterior commissure (PC). Deep brain structures could then be indirectly targeted using fixed distances from these coordinates and the resulting intercommissural line (5). CT and MRI permit highly accurate localization of these same structures, thereby facilitating indirect targeting in a more standardized fashion that is also associated with lower morbidity (4,6) (Figs. 1 and 2). The anatomic resolution of CT is limited, however, and images can only be obtained in the axial plane (although even poorer resolution 3D reconstructions are now available). Another method of indirect targeting uses an atlas-based method (7,8) (Fig. 3). Since the atlas is adjusted to the intercommissural distance of a specific patient, it is also subject to errors in imaging AC and PC. Although the Schaltenbrand-Wahren atlas (7) is clearly the most popular among functional neurosurgeons, it has been suggested that other atlases may improve the accuracy of this technique since they may more closely correlate with functional activity (9).

Direct visual localization of deep brain targets only became a reality with the widespread use of high field strength MRI (Fig. 4). MRI has sufficient resolution for visual targeting as well as flexibility with respect to plane of image and image modality, which can be adjusted to highlight specific locations (2,3, 10,11). However, this does not guarantee that a visually identified target is functionally significant. This issue will be further discussed later. A recent study also demonstrated that indirect targeting of the subthalamic nucleus (STN) using standard distances from the midcommissural point appeared to correlate more closely with the final target than was the case with direct visual targeting (9). This was surprising, given the widely held view that the STN on a T2 or “spoiled grass” coronal image is readily visible. This suggests either that imaging errors may produce a visually “obvious” target that is not anatomically accurate and/or that functionally significant regions do not necessarily correlate with anatomic appearance.