Duality of stereotaxy in a digital age

October 2002

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Historically stereotactic and functional neurosurgery have always entertained a physiological and technological duality. Although all fields of medicine have aspects of both and many are deeply rooted in one, none shares them in as inextricable and defining a way as ours. It is explicit in the name of our joint section, our society's journal, and our meetings. Periodically, anxieties arise over the predominance of one or the other—that the neurophysiologists might usurp the discipline or, as in recent years, that biomedical engineering is receiving inordinate attention. The occasional organizational awkwardness of defining a field by a technology (a half-truth), however, generally passes rapidly given the synergy the pairing provides. The association has historical roots but is hardly accidental. Recognition and preservation of that duality have served the specialty well.

In this issue of *Neurosurgical Focus*, that duality is manifest. Two of these papers deal directly with stereotactic principles. Gerszten and colleagues report their experience with the Accuray Cyberknife in treating 46 patients with spinal lesions. Although it is a very preliminary report, the development of this radiosurgical tool—fully capable of maintaining coregistration of a robotically positioned linear accelerator with preoperative imaging and the patient—and its clinical use in such an application is a remarkable and exciting advance. It is at the forefront of a revolution in the delivery of radiation.

On a different note, Ferrandez-Sempere and Eiras-Ajuria describe their methodology of creating individualized anatomical maps based on the Schaltenbrand and Wahren atlas. It is a straightforward how-to guide, providing step-by-step instruction by using a readily available commercial software, Microsoft PowerPoint. Graphic display of functionally relevant anatomy is invaluable, and the stereotactic principle underlies its importance.

In the two papers from the University of California at Los Angeles, the authors focus on new tools to explore cortical function. In the overview of intraoperative optical signal imaging, the technique's methodology, the underlying principles, comparison of its capabilities with other functional mapping techniques, its potential, and its limitations are presented. Optical imaging is in transition from a modality used in the investigative setting to one in the clinical arena.

Functional magnetic resonance (fMR) imaging, on the other hand, has been in use for a while and its refinement and application are more evolved. Pouratian and colleagues describe their experience validating the technique against the older, more established methodology of electrical stimulation in identification of language cortex in patients with vascular malformations. The computational resources that have made coregistration more sophisticated and capable of tracking extracranial targets for radiosurgery have also en-

abled the computationally intense signal processing and display that provide us a window into the functioning of the human brain. The armamentarium becoming available to assess critical brain tissue continues to increase our surgical capability and safety.

These two functional tools, however, are very much dependent on coregistration methodology. The knowledge gleaned from fMR imaging and optical imaging, to be most useful in the laboratory or the operating room, must relate to imaging demonstrating normal or pathological structure. In turn, for operative applications it must spatially relate to the surgical field.

This is an inspiring time for stereotactic and functional neurosurgery. The digital revolution providing us extraordinary neuroimaging also propels the technical and the functional aspects of our field, while linking them ever more. In terms of coregistration, computational capabilities have driven the most visible developments of image-guided surgery, stereotactic atlases, radiosurgery, and robotics. Rigid-body transformations, the workhorses of current implementations, are being supplemented with newer elastic “morphing” algorithms that will begin to address issues of tissue deformation and displacement. Shift has had to be characterized, and solutions to potential problems are now emerging. Intraoperative imaging is a major thrust in this direction, eliminating shift by the acquisition of new data altogether. There are alternative strategies to manage this, but real-time images can show changes other than shift, such as the amount of resection. Coregistration also has a role to play, however, and as other strategies—be they ultrasonography, computerized tomography, or low-field strength MR imaging—evolve, optimized utilization of resources will surely incorporate stereotactic principles.

Such capabilities are leading to widespread adaptation of stereotaxy well beyond neurosurgery. Radiotherapy, taking a cue from radiosurgery, is becoming an entirely stereotactic discipline; otolaryngology, general surgery, orthopedics, and plastic surgery are not far behind.

In terms functional neurosurgery, the strides being made in neuroscience will require clinical grounding in our operating rooms. Many of the breakthrough discoveries in molecular biology and stem cell research will require or greatly benefit from knowledge of their spatial context, and this is stereotactic. Just as our technology is spreading across medical disciplines, the primacy of functional orientation within neurosurgery is becoming apparent. The degree of sophistication in both has increased greatly over the last half century but will pale in comparison with what the next generation of neurosurgeons will see. As this future unfolds, the underlying duality of the discipline remains a constant and a strength.