Neuronavigation in Small Animals

Development, Techniques, and Applications

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KEYWORDS

• Stereotaxy • Localization • Brain • Central nervous system • Biopsy • Intracranial • Tumor

KEY POINTS

- Localization of lesions for minimally invasive biopsy of the brain is challenging.
- Modern techniques for navigation within the central nervous system rely predominantly on frameless systems and depend on cross-sectional imaging by CT or MRI.
- Rigidly affixed external markers define relationships between landmarks within and outside the cranial vault and are used to plan surgical trajectories.
- Surgical instruments can be labeled so as to provide real-time feedback on positioning within sites of minimal surgical access.
- Modern neuronavigation techniques have huge potential to revolutionize diagnosis, and therefore treatment, of intracranial lesions and will likely play a role in the development of minimally invasive techniques for spinal stabilization.

THE NEED FOR NEURONAVIGATION

The central nervous system is characterized by an intricate anatomy that necessitates precise localization methods to acquire representative biopsy material (**Figs. 1–5**). The brain is opaque; some regions are convoluted into gyri and sulci, and it is enclosed by the boney opaque calvarium that is inconsistently spatially matched with the content and has few identifiable prominences. Furthermore, it is segmented into specific white matter tracts and nuclei, all difficult to identify grossly, but most with independent essential functions. Localization within this uniquely complex structure is further complicated by pulsatile deformation of shape associated with blood flow and permitted by the surrounding cerebrospinal fluid. These obstacles, coupled with its poor handling quality and a lack of forgiveness to manipulation, make it perhaps the most difficult structure to surgically navigate in the entire body.[1]

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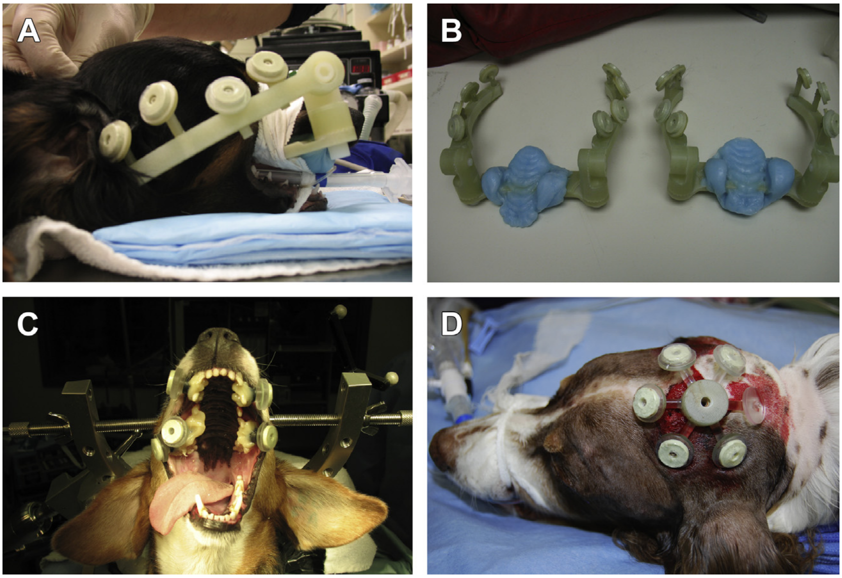

Fig. 1. Examples of artificial fiducial arrays. (*A, B*) Temporary bite arrays are easily fitted to patients, are minimally invasive, and can be removed between procedures. (*C*) More rigid dental arrays may improve accuracy but require a single anesthetic event. (*D*) Implantable arrays are more invasive but otherwise provide greater accuracy and confidence of neuronavigation. The illustrated array can be removed and the calvarial plug covered by the skin.

Localization aids for neurosurgery have been an essential part of successful intervention since its functional anatomy has been defined. This concept is considered essential in veterinary neurology: localization based on clinical presentation and physical examination findings is the crux of the discipline. The identification of "eloquent cortical regions" by Paul Broca and Carl Wernike, in which lesions would have serious consequences for the patient, is arguably the initiator of neuronavigation. Although dogs do not have eloquent cortex per se, the dog and cat homunculus is mostly known and surgical manipulation of specific supratentorial structures can cause important clinical consequences.[2,3] Because domestic animals' primary motor functions are thought to be largely extrapyramidal, compromise of basal nuclear and other subcortical structures may be of relatively greater importance.[4]

Development of Neuronavigation Devices

Initial neuronavigation techniques relied on the "terrestrial globe model" developed in humans, who have a spherical head of stereotypical size and proportions. Kocher and Kronlein's "Craniometer" and Zernov's "Encephalometer" used these proportions along with external craniofacial landmarks to target internal brain structures for symptomatic resection.[5] Because imaging other than radiography was not available at that time, intervention was based largely on the symptoms of the patient and functional neuro-anatomic atlases. Techniques relying on specific correlation of extracranial and intracranial structures are not applicable to many animal models because of craniofacial variability and nonuniformity of brain proportions.

The earliest image-based neuronavigation techniques were termed "stereotaxy," a term derived from the latin *stereos* = (geometric) solid and *taxis* = positioning