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Imaging Intractable Epilepsy: How Many Tests Are Enough?

Mauricio Castillo M.D

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tential of distal emboli with biologically active coils, devices used to protect the aneurysmal neck (i.e. neck bridges) are concurrently being developed to reduce this possibility.

The delivery of coated or biologically altered coils into the aneurysmal lumen seems to be a promising method for producing intravascular scars, and may represent a revolution in the management of presently unmanageable lesions. In the future, GDCs may serve as a delivery vehicle for biologically or chemically active substances. These works demonstrate the great potential of minimally invasive techniques for becoming the primary method of treatment of cerebral aneurysms.

ALEX BERENSTEIN, M.D.
Beth Israel Medical Center
New York, NY

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Imaging Intractable Epilepsy: How Many Tests Are Enough?

The challenge faced when choosing the best diagnostic studies for the evaluation of patients with intractable epilepsy reminds me of playing Monopoly. As beginners, we have less experience and tend to ''buy'' all properties (or studies as is the case here). As we become better players, we choose only those options that yield the highest return. In the imaging of epilepsy, there are many studies from which we can choose including CT, MR imaging, proton MR spectroscopy (MRS), functional MR (fMR), T2 relaxometry, single photon emission tomography (SPECT), positron emission tomography (PET), and Wada testing. As seasoned players, neuroradiologists are expected to narrow down the number of examinations obtained in the seizure patient if we are to remain in control of the practice of neuroimaging. Otherwise we risk depleting the ''Community Chest,'' and are forced to pay more ''luxury taxes.''

When evaluating potential surgical candidates, the neuroradiologist should 1) confirm lateralization (left- vs. right-side disease), particularly when this cannot be done clinically, 2) identify focal lesions that may be amenable to tailored resections, and 3) establish the relationship between seizure foci and eloquent brain regions. Most of our imaging tests accomplish the first two objectives, whereas the evaluation of eloquent brain regions still depends on the Wada test (fMR, however, is being increasingly used for this purpose, but has yet to replace the Wada test). Multitechnique imaging studies are considered critical for evaluating patients in whom electroencephalography (EEG) and MR imaging findings are discordant (about 40% of them). How do all of these techniques compare?

In the evaluation of intractable lobe epilepsy, MR imaging has a sensitivity of 85–98% in the detection of an abnormal hippocampus (1). MR is easy to perform, and is readily accessible, but requires high-resolution sequences to image the hippocampus adequately. SPECT, using ^{99m}Tc-HMPAO, is available in most hospitals, and has a sensitivity in lateralizing that is greater than 90% if the radiotracer is injected intraictally or periictally (2). PET with fluorodeoxyglucose, when given interictally, has a sensitivity of 84% (2). Recent studies regarding proton MR spectroscopy report this technique can lateralize an abnormal temporal lobe in over 90% of cases (3). From these data it is obvious that we have become proficient in the multitechnique imaging of patients with intractable epilepsy. Nonetheless, we now need to decide which of these tools is best for ''buying or selling''; which ones should we build on, and which ones bypass?

In this issue of the *AJNR*, Won et al (page 593) compared results of MR imaging, PET, and SPECT in 118 patients with intractable epilepsy, using pathologic diagnoses as their standard of reference. Several aspects of their investigation are important. When these three most widely used imaging techniques were compared to each other, MR imaging findings had a greater concordance with PET than with SPECT. When compared with histologic findings, MR imaging correctly lateralized the epileptogenic foci in 72% of patients (very similar to their results with SPECT), whereas PET lateralized the focus in 85% of patients. In my opinion, the results of MR imaging in this series are disappointing, and in my experience, MR performs much better than portrayed in this article. The MR techniques the authors used are not significantly different from what we routinely use at our institution. Our protocol includes coronal 3-mm sec-

tions with FLAIR, but I have not seen an abnormality on them that I did not see on fast spin echo T2-section coronal images. Regardless, FLAIR has been reported to be a better technique than conventional spin-echo T2-weighted images for the evaluation of mesial temporal sclerosis. It is not clear from the data provided by Won et al what abnormalities they were evaluating on their images. Although patients with mesial temporal sclerosis most commonly show hippocampal diminished volume and increased T2 signal intensity on images, there are other abnormalities that may assist in establishing correct lateralization. These abnormalities include loss of internal structures, undulations in the pes, decreased volume of collateral white matter, decreased volume of a temporal lobe with dilatation of CSF-containing spaces, and diminished size of the ipsilateral fornix/mamillary body. In addition, the authors do not define an abnormal percentage of asymmetry in the uptake of radiotracers used for PET and SPECT (we use 15%). When compared with the histologic diagnosis, MR imaging diagnosis was correct in 78% of their cases, and was ''apparently'' normal in 22%. Abnormalities not detected on MR but seen on PET included mostly cortical dysplasias and microdysgenesis, a few cases of hippocampal sclerosis, and one focal neuronal loss (whether this is the case defined as ''malacia'' is not clear). If one analyzes each of these disease categories by using all three imaging techniques, the correct diagnosis was made in 97.2% cases of hippocampal sclerosis, but in only 61% of cortical dysplasia/microdysgenesis. The authors' inclusion of often difficult-to-define dysplasias decreased the overall sensitivity of the imaging techniques that were used. For evaluating hippocampal sclerosis only, their imaging techniques were excellent. Twenty-six of their patients with extrahippocampal seizure foci, however, did poorly. Although not stated, dysplasia/microdysgenesis more commonly occurs outside the hippocampi. MR imaging was the least accurate test for patients with extrahippocampal epilepsy, revealing a histology-imaging concordance of only 50%, with PET and SPECT performing slightly better. I am not surprised at this finding, and their results are similar to those I've experienced. Nonetheless, diagnosis of patients with extrahippocampal epilepsy can be improved. Using dedicated surface coils, high-resolution imaging of the cortex may be performed in patients with EEG-localized foci, and this technique may permit identification of small areas of cortical dysplasia (4).

Won et al found that by using Engel's outcome class as their standard of reference, MR imaging and SPECT performed similarly, whereas PET did better. It is known, however, that a quality-of-life improvement for these patients may not be evident until 2 years after surgery; the follow-up offered by Won et al only extended to 12 months (5).

What can we glean from the data presented by Won et al? When performed similarly, MR imaging and SPECT yielded concordant results for patients with hippocampal epilepsy, but PET was better for lateralization (the ''Boardwalk'' of all studies). If EEG video monitoring and MR imaging are concordant, there is no need for other imaging studies (a Wada test would be the next step if findings were divergent). If these two techniques are discordant, it is still not clear if we need PET only, SPECT only, both, or alternative tests to establish diagnosis. For imaging extrahippocampal seizures, all three techniques used in Won et al's study yielded disappointing results, though the investigation begins to point us in the right direction. Studies that incorporate other diagnostic tests such as proton MR spectroscopy are needed to determine the usefulness of all diagnostic tools applicable to patients with intractable epilepsy. At present, we can think of MR imaging, SPECT, and PET as Pennsylvania Avenue, Park Place, and Boardwalk respectively; they are all expensive and return high yields, but time has come to choose where we will place our ''houses and hotels.''

MAURICIO CASTILLO, M.D.
Member, Editorial Board

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