Computerized Axial Tomography in Aphasiology

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Freud quipped shortly after perimetry's development for quantifying visual fields that no subsequent research would be publishable unless perimetry results were included. He was exaggerating, but with characteristic perspicasity he had identified a common quirk in medical science -- the popularity and instant preeminence of new devices. In the 1970's computerized axial tomography (CT) of the head burst on aphasiology's scene, and a rash of papers appeared. Researchers into neurogenic communication disorders quickly discovered that lesion data from CT scans enhanced the chance of funding for research and publication of the resulting data.

With experience has come critical sense. Now, only the naive principal investigator or journal reviewer is content to promise or accept the usual clinical CT scan of the brain as anything but one more piece of evidence that a patient has had brain damage and even that promise is contingent on the scan's administration having been intelligently timed. Research scans, on the other hand, and even prospective studies using large patient samples, clinical scans, and sophisticated computer analyses of the scan data can and have been used for more.

This paper's purpose is to review the research documenting the CT scan's contributions to aphasiology. Major emphasis will be on what we know and think about aphasia and the aphasic speaker as a result of CT scan data. The technique and its proper timing for studying the aphasic speaker will also be described briefly.

The Technique. Typical clinical CT scans are x-rayed in 8-10 mm thick slices at 8-10 mm intervals at the 15° transverse angle called the orbitomeatal line. The usual number of slices for visual or computer analysis ranges from 9 to 18. Lesions are pictured in the anterior and posterior dimensions. The typical clinical scan is inadequate for clinical research unless large patient samples are used (Kertesz, 1979) or unless sophisticated computer analyses of the scans are done. Research scans vary from laboratory to laboratory but may be taken in 2 mm slices at 4 mm intervals in 3 dimensions: transverse, sagittal and coronal (Knopman, Selnes, Niccum, Rubens, Yock, and Larson, 1983). At least 32 slices are available for visual or computer analysis.

Appropriate Timing. CT scans are not infallible. Small lesions may go undetected, and large lesions may escape notice unless the scan is completed at the proper time post onset. Timing depends on the type of lesion. This discussion will be confined to infarcts. Infarcts are most easily detected after 3 weeks post onset when they show as well-demarcated low density areas (Gado, Coleman, Merlis, Alderson, and Lee, 1976; Rubens, 1984), although they may be detectable within the first week post onset. A CT scan done with a contrast dye can be used to improve the likelihood of detecting an infarct during the period from 7 to 21 days (Kertesz, 1979; Weisberg, 1980; Cummings and Benson, 1983; Rubens, 1984).

For correlation with aphasia, additional timing considerations are at work. Soon after onset, because of diaschisis, language deficits are more severe than lesion size would lead one to predict. Later on, because of compensation, speech and language performance is better than one would predict from the CT image. Mazzocchi and Vignolo (1979) say "Aphasia presumably mirrors the effect of the lesion most faithfully in the period between the 21st and 60th day after onset -- when not only is the lesion stabilized but diaschisis is disappearing and compensation is still minimal" (P. 631).

Locus of Lesion and Type of Aphasia. Most of the earliest experimental efforts were to establish the correlation of site of lesion (as determined by CT) with type of aphasia (Hayward, Naeser, and Zatz, 1977). A 1978 study by Naeser and Hayward is a typical seminal effort and the results were predictable for the time. For example, patients with Wernicke's aphasia (N = 4) had temporal-parietal lesions and conduction aphasic speakers (N = 4) had primarily postrolandic lesions sparing Broca's and Wernicke's area that were smaller than those causing Broca's aphasia.

Methods and experimental questions quickly got more sophisticated. For example, Naeser, Hayward, Laughlin, and Zatz (1981) examined the relationship of lesion size and CT numbers to type and severity of aphasia. Lesion size was measured in pixels. The pixel is a unit of volume, in this case a 1 x 1 mm square taken from a 10 mm thick slice. CT numbers identify the density of tissue. Naeser and her colleagues report that four kinds of CT data are essential to predicting severity of aphasia; number of slices on which a lesion appears, the size of lesion on each slice, the average CT numbers of the lesion, and the neuroanatomical locus of the lesion.

A subsequent study (Naeser, Hayward, Laughlin, Becker, Jernigan, and Zatz, 1981) was a comparison of CT scan data from left and right hemispheres of 32 aphasic speakers. To appreciate this study one must understand "percentage Lo Pix." They say it best: "Percentage Lo Pix (RH or LH) refers to the percentage of the total number of pixels within either the right or the left cerebral hemisphere at any given CT slice level which has statistically significant low CT number values" (P. 166). RH percentage LoPix for aphasic people will predominantly reflect the amount of fluid in ventricles, fissures, and sulci. LH percentage LoPix includes, in addition to those structures and fluids, tissue or fluid within the infarcted area.

They report that the relative amount of left hemisphere tissue loss in the language areas, with anterior-posterior locus controlled, could classify 89-100% of patients. These data make one wonder about the possibility that some aphasic types may be only a function of severity of aphasia. Their data even raise the possibility advocated by Poeck (1983) that syndromes are "to a large extent, artifacts produced by the vascularization of the language areas" (P. 84). Their data on the right hemispheres of aphasic patients are expecially exciting. Their finding of a parallel between RH percentage LoPix and severity of aphasia implicates the right hemisphere's integrity in aphasic symptomatology. They hypothesize that right hemisphere differences among aphasic patients may result from several influences, including age, diaschisis, transient or prolonged diminished bilateral cerebral blood flow, or undetected right hemisphere lesions.

Revisionism

Early data in most fields often confirm popular beliefs, perhaps because advocates are quick to seize upon new technology. Then the uncommitted arrive and with them sometimes come unsettling data. This section highlights the unsettling, especially about localization and aphasia type.

The CT Scan and Broca's Aphasia. The most extensive study of Broca's aphasia is by Mohr and colleagues (1978). Two of their findings should -- but may not -- gag the classicists who continue to teach that Broca's aphasia results from Broca's area lesions. Their data demonstrate that a lesion confined to Broca's area produces, not aphasia, but transient speech apraxia. Broca's aphasia requires a large lesion to the "Sylvian region, encompassing much of the operculum, insula, and subjacent white matter in the territory of the upper division of the middle cerebral artery" (P. 322). Mohr and colleagues observe that the clinical fallacy of reasonably intact comprehension in Broca's aphasia is a vestige of the traditional view of localization. The clinical reality is that comprehension, like speech, is impaired in Broca's aphasia, a reality easier to see if one's vision is not obscured by Broca's area. Mazzocchi and Vignolo (1979) would ask clinicians to make yet a different revision in the view about Broca's aphasia. They say "Our findings indicate that Broca's aphasia may exist without destruction of the posterior part of F3..." (P. 648).

The CT Scan and Global Aphasia. Broca's aphasia has always been a bit controversial, so further controversy takes few of us by surprise. Global aphasia is another matter. Mazzocchi and Vignolo (1979) included several globally aphasic people in their CT study. They say "oddly enough, the worst difficulties were raised by the simplest type of aphasia, i.e., global aphasia" (P. 651). They posit that global aphasia does not necessarily result from large lesions involving both Broca's and Wernicke's areas. Indeed, Wernicke's area may be spared even in chronic, global aphasia with persisting comprehension deficit. Other researchers suggest that global aphasia is not necessarily even one syndrome. Poeck, De Bleser, Graf von Keyserlingk (1984), for example, have identified both fluent and nonfluent globally aphasic speakers with apparently similar lesions. As part of their research into the fluent global aphasic with consonant-vowel recurring utterances they completed sophisticated scans and analyses. They say "Both in standard global aphasia and global aphasia with CV, the individual lesions are large and small, anterior and posterior, single and multiple" (P. 210). And finally one more surprise. Mazzocchi and Vignolo (1979) report that the insula was the only common area of damage for their group of globally aphasic people.

The CT Scan and Subcortical Aphasia. The CT scan has also led to revision in the concepts that aphasia is a cortical disorder and that the cortex is the primary neural substrate of language. While caution is still in order, it is becoming increasingly likely that aphasic syndromes can accompany subcortical lesions (Damasio, Damasio, Rizzo, Varney, and Gersh, 1982; Cappa, Cavallotti, Guidotti, Papagno, and Vignolo, 1983). Naeser, Alexander, Helm-Estabrooks, Levine, Laughlin, and Geschwind (1982), report on nine cases of aphasia resulting from predominantly subcortical lesions. They identified three syndromes. The first resembled Broca's aphasia and resulted from capsular-putaminal (C-P) lesions with anterior-superior extensions into the white matter. The second resembled Wernicke's aphasia and resulted from C-P lesions with posterior extensions. The third resembled global aphasia and resulted from C-P lesions with both anterior and posterior extensions. These subcortical syndromes differed from the traditional cortical ones, but careful testing is crucial to their exposure.

The CT Scan and Evolution in Aphasia. Because aphasic people may pass through two or more types or syndromes on their way toward improvement, the concept of evolution in aphasia and the convention of typing patients interact. They have been separated in this paper only as a reasonably harmless convenience. Yarnell, Monroe, and Sobel (1976) were among the first to demonstrate that CT data might help predict improvement from aphasia. Since their landmark publication, a wealth of other data have appeared, although untreated rather than treated cases have been studied primarily.

Evolution from Global Aphasia. Clinical experience confirms that a small proportion of globally aphasic people evolve into less mild aphasic speakers -- usually with Broca's aphasia residuals. Clinicians usually take a "treat and see" stance when asked to predict which globally aphasic people will improve significantly. And well they should, because data on learning, generalization, and retention are powerful predictors of change.

The CT scan may eventually provide additional data, however. Pieniadz, Naeser, Koff, and Levine (1983) studied cortical asymmetries in 14 globally aphasic people. They comment that "atypical CT scan cerebral hemispheric asymmetries among right-handers may be associated with superior recovery on the one-word level in comprehension, repetition and naming" (P. 387). They speculate that the occipital asymmetries they found in the improving globally aphasic speakers "May signify some anomalous language dominance" (P. 387) and that the right hemispheres of these asymmetrical patients perhaps "can aid in language recovery by complementing or cooperating with the few preserved areas of the left hemisphere in some unique manner not ordinarily utilized by 'unrecovered' global aphasia cases with typical asymmetries" (p.388-389). Other correlates of recovery may be the percentage LoPix in the right hemispheres of globally aphasic people (Naeser, Hayward, Laughlin, Becker, Jernigan, and Zatz, 1981), the extent of the left hemisphere lesion (Kertesz, Harlock, and Coates, 1979), and the locus of the lesion (Poeck, De Bleser, Graf von Keyselingk, 1984). Since globally aphasic people are the majority of aphasic speakers referred to the aphasiologist (Sarno and Levita, 1981), predicting their evolution is especially important.

Evolution in Selected Characteristics. Knopman, Selnes, Niccum, Rubens, Yock, and Larson (1983) studied the resolution of dysfluency in 54 aphasic people. They observe first of all that resolution of dysfluency is rare. Of even greater clinical interest is their statement that "Prediction of outcome early in the course of recovery seems best accomplished by analysis of the fluency deficits themselves rather than analysis of the CT data" (P. 1177). Clinicians continue to suspect that observation of fluency and other kinds of performance as well offers the best prognostic data. It is reassuring to have the suspicion confirmed.

This same lab (Selnes, Knopman, Niccum, Rubens, and Larson, 1983) did a similar study of recovery in auditory comprehension of sentences. Three results are of special interest. Patients with lesions in the posterior, superior temporal area and infrasylvian supramarginal gyrus (PST-ISM) area usually, but not inevitably, had poor or moderate recovery from comprehension deficit. Some patients without lesions to this area had severe deficits initially but tended to recover significantly and quickly. Lesion size was less significant than lesion location, unless the lesions were very large or very small.

The clinical interest in such a study comes at least as much from the analysis of individual cases as from that of the groups. Several startling (at least to us) findings emerge from the individual data. The authors point out that a PST-ISM lesion is not necessarily synonymous with poor prognosis. They report five cases with "near-normal" comprehension at six months despite lesions in PST-ISM. These data can bolster an argument that the CT scan should not be used to seal a patient's fate or to justify a failure to refer for speech and language rehabilitation. This study, as the authors themselves point out, also has implications for management. Patients with early severe deficits secondary to lesions outside PST-ISM may be suffering the effects of what the authors call "Transient synaptically mediated temporal lobe dysfunction (diaschisis)" (P. 564). They suggest "early intensive therapy to facilitate recovery and ward off emotional problems arising from early comprehension deficits" (P. 565). Those with strategic loci to PST-ISM, on the other hand, "may benefit the most from nonverbal therapy or therapy that stresses single-word comprehension" (P. 565). While some aphasiologists may quarrel with these treatment suggestions, their presence is welcome because treatment cannot help but be enhanced by creative hypothesizing.

This same group (Selnes, Niccum, Knopman, and Rubens, 1984) also studied CT scan correlates of single word auditory and written comprehension. Among their findings are these two. Word comprehension is likely to be disturbed in the acute stage of aphasia, whether or not the lesion involves Wernicke's area. Second, single-word comprehension recovers significantly and equally in patients with Wernicke's area lesions and those without Wernicke's area involvement when lesion volume is controlled.

Conclusions

CT scan data have been used to reinforce some traditional concepts in aphasiology, to revise others, and to support some new ones. The CT scan has not put either the neurologist or the speech pathologist out of business. If anything, it has made careful clinical examination more essential and creative hypothesizing more rewarding. Perhaps the healthiest attitude for the clinical and scientific communities to have about the scan is that it is but one more tool. Like other tools, including the traditional language examination, it is primarily a perceptual test, subject to the same influences as any other such test. As one radiologist was heard to say of the lesion he was identifying for the residents and after he had reviewed the clinical findings outlined in the chart, "If I hadn't known it was there, I wouldn't have seen it."

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