J Am Acad Audiol 7: 289–295 (1996)

Changes in Central Auditory Processing Following Temporal Lobectomies in Children

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Abstract

Unilateral temporal lobe ablations have become a common treatment procedure for intractable epilepsy. Five children, ranging in age from 11 to 16 years, received a battery of tests to evaluate possible postoperative changes in central auditory processing functions. Children were tested before surgery and at 1 year following surgery. Tests included the SCAN test for central auditory processing, the duration pattern and dichotic digits tests, and the P300 event-related potential. With each test, some children exhibited postoperative improvement, while others exhibited either no changes or poorer postoperative performances. These results indicate that temporal lobectomies, while controlling seizures, may not always result in improved central auditory processing.

Key Words: Central auditory processing, children, temporal lobectomy

While temporal lobectomy has long been considered a viable means of controlling intractable epileptic seizures (Penfield and Flanigan, 1950), in recent years, this surgical option is increasingly being used with children when medication fails. A recent National Institutes of Health Consensus Development Conference on Surgery for Epilepsy (National Institutes of Health, 1990) concluded that, while surgery is a viable option for children, increased research efforts are needed to identify any possible detrimental effects related to "cognitive-linguistic-academic achievement in school, and psychosocial adaptation of the child and family."

Although a large number of studies (e.g., Olivier, 1988; Duchowny, 1989; Mizrahi et al, 1990; Wyllie, 1991; Fish et al, 1993; Villemure and Rasmussen, 1993) have reported positive benefits of epilepsy surgery in children, most published reports have been anecdotal in nature rather than involving controlled research studies. Studies that compare pre- and postoperative test performances using more objective and standardized test instruments are needed. This research must control for possible confounding variables, such as postoperative changes in medications, age-related maturational effects, and factors associated with the psychosocial adjustments and expectations of the family and child. Any or all of these variables could dramatically influence the manner in which the child responds to the test instruments following surgery, and lead to erroneous conclusions regarding changes in basic neural functioning.

Since the temporal lobe is known to be intimately involved with the higher level perceptual processing of sounds, a number of studies have focused on identifying possible postoperative changes in hearing functions. The majority of these studies investigated the effects of temporal lobectomies on various measures of dichotic listening. Following surgery, most of the studies reported poorer discrimination performances at ears located contralateral to the operated hemispheres (Kimura, 1961; Berlin et al, 1972; Lynn et al, 1972; Jerger and Jerger, 1975; Olson, 1983). In some patients, the contralateral ear deficits were combined with improved postoperative discrimination at the ipsilateral ears (Oxbury and Oxbury, 1969; Mazzucchi and Parma, 1978; Olson, 1983; Collard et al, 1986; Senbongi et al, 1990). Taken as a whole, however,

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these studies indicate that very little, if any, improvements in central auditory functioning can be expected following temporal lobe surgery. In contrast, a recent case study (Musiek et al, 1990) found evidence for significant improvement in central auditory function following temporal lobe surgery. This patient showed dramatic improvement with both the dichotic digits test and the P300 event-related potential.

The present investigation compared the pre- and postoperative performances of a group of five children using a battery of behavioral and electrophysiologic tests. While some children exhibited evidence for some small degree of improvement in central auditory function, others showed little or no improvement. The present study also found unexpected evidence that, in some patients, severe discrimination deficits seen at ears located contralateral to the diseased hemisphere may be ameliorated following surgery.

METHOD

Subjects

Five children (three males, two females) were tested 1 to 2 weeks prior to surgery, and retested approximately 12 months following surgery. At the time of surgery, the children ranged in age from 11 to 16 years. Four children had multiple-year histories of seizure activity that could not be satisfactorily controlled with medications. One child (JR) had intractable unilateral, multifocal epilepsy associated with infantile hemiplegia. Table 1 shows the demographic information for each child.

The four children with complex partial seizures of temporal lobe origin received similar surgeries involving excision of the anterior 4 to 4.5 cm of the temporal lobe. The dissection extended medially down to the ventricular system with removal of the approximate anterior two-thirds of the hippocampus along with the amygdala. Subject JR received a modified right-sided hemispherectomy. The entire temporal lobe was removed, followed by removal of the frontal lobe anterior to the motor strip. The occipital lobe was left in place, but surgically detached from the remainder of the brain.

Table 1 Description of Five Research Subjects

Subject	*Age (yr)/Gender*	*Surgery Type*
JR	12/male	Right modified hemispherectomy (R-Hem)
BH	11/female	Right anterior temporal lobectomy (R-Temp)
SR	16/male	Right anterior temporal lobectomy (R-Temp)
KJ	12/female	Left anterior temporal lobectomy (L-Temp)
DE	11/male	Left anterior temporal lobectomy (L-Temp)

With respect to seizure medications, although the type and dosage (i.e., either Depakote, Dilantin, or Tegretol, with dosages from 400 to 1000 mg/day) varied from child to child, all but one child remained on the same regimen during the pre- and postoperative test periods. Subject JR was changed from Depakote (650 mg/day) to phenobarbital (120 mg/day), postoperatively.

Test Protocol

All subjects received the same battery of tests before and after surgery. The children were brought to the Comprehensive Epilepsy Center at St. Francis Regional Medical Center for testing approximately 1 to 2 weeks before surgery. The tests were administered over the period of 1 8-hour work day. To minimize the possibility of fatigue, frequent rest breaks were interspersed among the tests. The same test battery was repeated approximately 1 year following surgery. In addition to a standard audiometric evaluation, which included air- and bone-conducted pure-tone thresholds (250 to 8000 Hz), speech reception thresholds (SRTs), speech recognition testing (Auditec recordings of CID W-22 monosyllabic word lists), and tympanometry, the children received the following specialized tests:

1. SCAN test for central auditory processing in children. The SCAN test was administered according to the published protocol of Keith (1986). The test included the filtered words, auditory figure ground, and competing words subtests. The taped materials were presented at 50 dB SL (re: SRT) and routed through the speech circuit of a Grason Stadler 1701 audiometer to TDH-49 headphones. All testing was performed with the child seated inside a sound-treated test booth (IAC).
2. Dichotic digits. The dichotic digits test was administered using Musiek's (1983) published protocol. The test is composed of recordings of naturally spoken digits from 1 to 10, excluding the number 7. The early portion of the tape contains six practice items for each ear to familiarize subjects with the task requirements. The test consists of the presentation of 20 digit pairs for a total of 40 test items for each ear. Subjects were asked

to repeat all of the digits they heard and to guess if unsure of a response. Digits were presented dichotically at 50 dB SL (re: SRT). A percent correct response score was determined for each ear.

3. Duration pattern test. The duration pattern test consisted of tape-recorded sequences of three consecutive tones, one of which was either longer (L) or shorter (S) in duration than the other two tones. The frequency of each tone was 1000 Hz. The long tones were 500 msec in length while the short tones were 250 msec. Each tone had a rise/fall time of 10 msec and the interpulse interval was 300 msec. Subjects were asked to verbally indicate the sequence of tones they heard (e.g., "long-long-short," "short-long-short," etc.), and to guess if unsure of what was heard. Following a short practice session, a total of 30 test sequences were presented to each ear. Stimuli were presented at 50 dB SL (re: SRT), and a percent correct score was obtained for each ear. Other details of the test procedures were the same as that reported by Musiek et al (1990).
4. P300 event-related potential test. For evoked potential testing, a BioLogic Brain Atlas System III was used for acquisition of data and for generation of the different probe stimuli. Cortical activity was amplified (50,000×) and filtered (3–100 Hz). Vertex-positive electrodes were placed at C_z and F_z (10-20 system) and referenced to linked mastoids, with F_{pz} as common. Using a standard oddball paradigm (Squires and Hecox, 1983), the subject was required to count the number of occurrences of infrequent tones (2000 Hz tones, 40-msec duration) randomly interspersed among frequent tones (1000 Hz). The probability ratio of the frequent and rare tones was 80:20. Tones were presented at 70 dB nHL. Two repeated test runs were obtained in response to binaural stimulation. Other aspects of the stimulus and response acquisition procedures can be found in Cranford and Martin (1991).

RESULTS AND DISCUSSION

Audiometric Findings

Three of the children (BH, KJ, and DE) exhibited pure-tone thresholds (≤ 25 dB HL, 250 to 8000 Hz), speech recognition scores (≥ 92%), and middle ear pressure and compliance (±50 daPa) that were within normal limits bilaterally both before and after surgery.

Two subjects exhibited abnormal audiometric findings. The right-sided hemispherectomy subject (JR) exhibited a postoperative elevation of thresholds at 4000 and 8000 Hz at the ear located contralateral to the operated hemisphere, combined with decreased thresholds at 4000 Hz at the ipsilateral ear. This subject also exhibited impaired speech recognition preoperatively, which was relatively poorer at the contralateral ear. Following surgery, speech recognition scores were essentially normal at both ears. Subject SR (right TL), while having normal speech recognition at both ears before and after surgery, exhibited a moderate-to-severe high-frequency sensory loss preoperatively at the ear located contralateral to the diseased hemisphere, which remained essentially unchanged following surgery. While the audiometric findings with JR might possibly reflect some form of compromised central functioning, the results with SR are more likely due to peripheral rather than central factors. Table 2 shows the audiometric findings obtained with JR and SR.

Table 2 Audiometric Findings with Subjects JR and SR

	Pure-Tone Threshold (dB)						*Speech Discrimination (%)*
	250 Hz	*500 Hz*	*1000 Hz*	*2000 Hz*	*4000 Hz*	*8000 Hz*	
Subject JR = R-Hem)							
LE-Preop	5	0	0	0	0	0	56
LE-Postop	10	10	5	0	25	30	88
RE-Preop	0	5	10	5	25	5	76
RE-Postop	10	10	0	0	0	10	96
Subject SR - R-Temp							
LE-Preop	10	15	10	5	30	65	100
LE-Postop	15	15	5	5	30	70	96
RE-Preop	15	10	5	0	0	10	100
RE-Postop	15	10	5	5	5	5	96

R-Hem=right hemispherectomy; R-Temp=right anterior temporal lobectomy; LE = left ear; RE = right ear.

SCAN Test for Central Auditory Processing

The child version of the SCAN used in the present investigation is normed only to a level of 11 years, 11 months, and 30 days. Since some of the present children were older than this at the time of either pre- or postoperative testing, only standard scores, and not percentile ranks, are presented. Each subtest uses a mean standard score of 10 with a standard deviation of 3, while the composite score is based on a mean standard score of 100 and a standard deviation of 15. Table 3 summarizes the individual pre- and postoperative findings with the SCAN test. As a group, the five children showed a small but significant postoperative improvement on the three subtests ($F[1,12] = 13.82$, $p = .003$), as well as with the composite score ($t[4] = 3.184$, $p < .05$). In spite of the significant group effect, considerable intersubject differences were found with this test. Subject KJ demonstrated decreased performance postoperatively on the competing words subtest and only a small degree of improvement with the composite score. KJ was the only child who was exhibiting postoperative seizure activity. Subject JR, who received the right modified hemispherectomy, also exhibited little evidence of postoperative improvement with either the subtest or composite measures. However, the remaining three temporal lobectomy subjects (BH, SR, and DE) exhibited greater degrees of improvement with the different SCAN measures.

Table 3 Pre- and Postoperative Findings with the SCAN Test

Subject	*Test*	*Preop Score*	*Postop Score*
JR	Filtered words	9	9
	Figure/ground	3	4
	Competing words	4	5
	Composite	65	72
BH	Filtered words	9	10
	Figure/ground	5	7
	Competing words	6	13
	Composite	78	101
SR	Filtered words	3	9
	Figure/ground	3	7
	Competing words	8	10
	Composite	65	94
KJ	Filtered words	5	9
	Figure/ground	5	6
	Competing words	8	6
	Composite	78	81
DE	Filtered words	7	10
	Figure/ground	5	7
	Competing words	5	11
	Composite	65	98
Mean Scores	Filtered words	6.6	9.4
	Figure/ground	4.2	6.2
	Competing words	6.2	9.0
	Composite	70.2	89.2

Duration Pattern and Dichotic Digits Tests

Considerable intersubject variability was also found with both of these tests, both before and after surgery. The findings with individual children for each test are shown in Table 4. Two-way repeated measures ANOVAs were first performed to investigate possible group effects in the data. With both tests, no significant differences were found in mean performances between ears located contralateral and ipsilateral to the operated hemispheres, either before or after surgery ($p > .22$). In contrast to the digits test, it is not uncommon to find binaural deficits with the duration pattern test following unilateral cortical lesions (Musiek, personal communication). The data in Table 4 shows evidence of bilateral effects. Finally, the small amount of postoperative improvement in mean group performance found with the present subjects was not statistically significant with either test measure ($p > .07$). This group data is shown in Table 5.

Despite the failure to find evidence of improved group performances following surgery on the dichotic digits and duration pattern tests, two subjects (DE and SR) exhibited unexpected improvement in postoperative test scores at the ears located contralateral to the operated hemisphere. With DE, this effect was found only with

Table 4 Findings with Duration Pattern and Dichotic Digits Tests*

		Duration Pattern Test		*Dichotic Digits Test*	
Subject	*Ear*	*Preop (%)*	*Postop (%)*	*Preop (%)*	*Postop (%)*
JR (R-Hem)	Left	24	24	83	70
	Right	24	24	83	85
BH (R-Temp)	Left	15	21	75	95
	Right	21	21	80	100
SR (R-Temp)	Left	57	90	15	85
	Right	53	90	100	95
KJ (L-Temp)	Left	23	20	80	95
	Right	33	30	90	98
DE (L-Temp)	Left	72	80	100	98
	Right	41	80	100	90

*Scores achieved by each subject both before and after surgery.

R-Hem = right modified hemispherectomy; R-Temp = right anterior temporal lobectomy; L-Temp = left anterior temporal lobectomy.

Table 5 Means and Standard Deviations of Test Performances Before and After Surgery*

	Duration Pattern Test			
	Preoperative		*Postoperative*	
	Ipsilateral	*Contralateral*	*Ipsilateral*	*Contralateral*
Mean	38.6%	34.0%	47.0%	49.0%
SD	22.9	16.1	34.9	33.2
	Dichotic Digits Test			
Mean	88.6%	72.6%	94.6%	87.6%
SD	10.5	33.5	5.8	11.0

*Scores for ears located ipsilateral or contralateral to side of operated hemisphere.

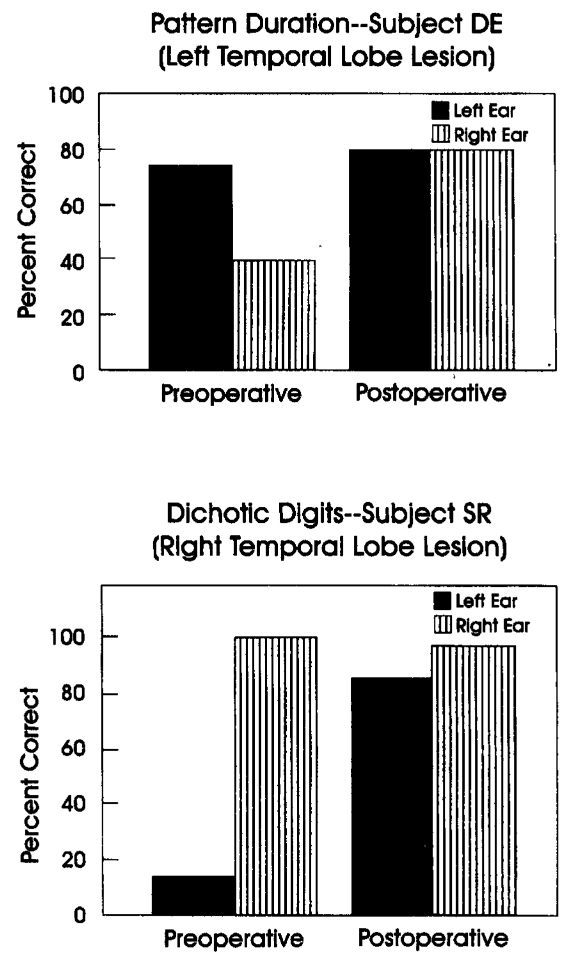

Figure 1 Unexpected disappearance of contralateral ear deficits following temporal lobectomies in subjects DE and SR.

the duration pattern test, while SR exhibited the effect only with the dichotic digits test. These results are depicted in Figure 1. This finding was unexpected in view of the large number of earlier investigations (e.g., Kimura, 1961; Berlin et al, 1972; Olson, 1983; Collard et al, 1986) that found impaired performances at ears located contralateral to the effected hemisphere both before and after anterior temporal lobectomies. These results suggest that the present surgery may have acted to free more posteriorly located temporal lobe auditory areas (e.g., Brodmann's areas 41 and 42) of neuronal interference effects produced by the anterior epileptic foci. The surgical resections in subjects DE and SR may also have spared these posterior auditory areas to a greater extent than was the case in the above cited investigations. The earlier studies reported that the maximal posterior extent of lesions in their test subjects ranged from 6 to 10 cm, in contrast to 4.5 cm in the present study. In this regard, it is noteworthy that the patient described by Musiek et al (1990) who exhibited marked postoperative improvement in CANS function also had a more anteriorly placed temporal lobe resection.

P300 Event-related Potentials

Similar to the behavioral tests, the N_1, P_2, and P300 components of the late potential exhibited considerable variability from subject to subject. Subject JR, who had a right modified hemispherectomy, exhibited questionable responses both before and after surgery. Of the four temporal lobe cases, DE exhibited the most postoperative improvement. This subject's N_1, P_2, and P300 components were considerably larger in amplitude and more repeatable following surgery than they were preoperatively. Subjects BH and SR exhibited repeatable N_1, P_2, and P300 responses that were essentially unchanged before and after surgery. Subject KJ (who still exhibited postoperative seizure activity) had questionable responses before surgery, but may have exhibited a low amplitude P300 following surgery. Thus, with the exception of subject DE, the P300 test did not provide much evidence of improved central auditory processing. The auditory evoked potential findings with each subject are shown in Figure 2.

This investigation indicates that the primary goal of temporal lobe surgery, to control or eliminate seizure activity, was achieved with the present group of children. At approximately 1 year following the surgery, four of the five children, although still receiving seizure medications, were seizure free. One child (KJ) was still exhibiting seizures, although the severity and frequency of the episodes were markedly

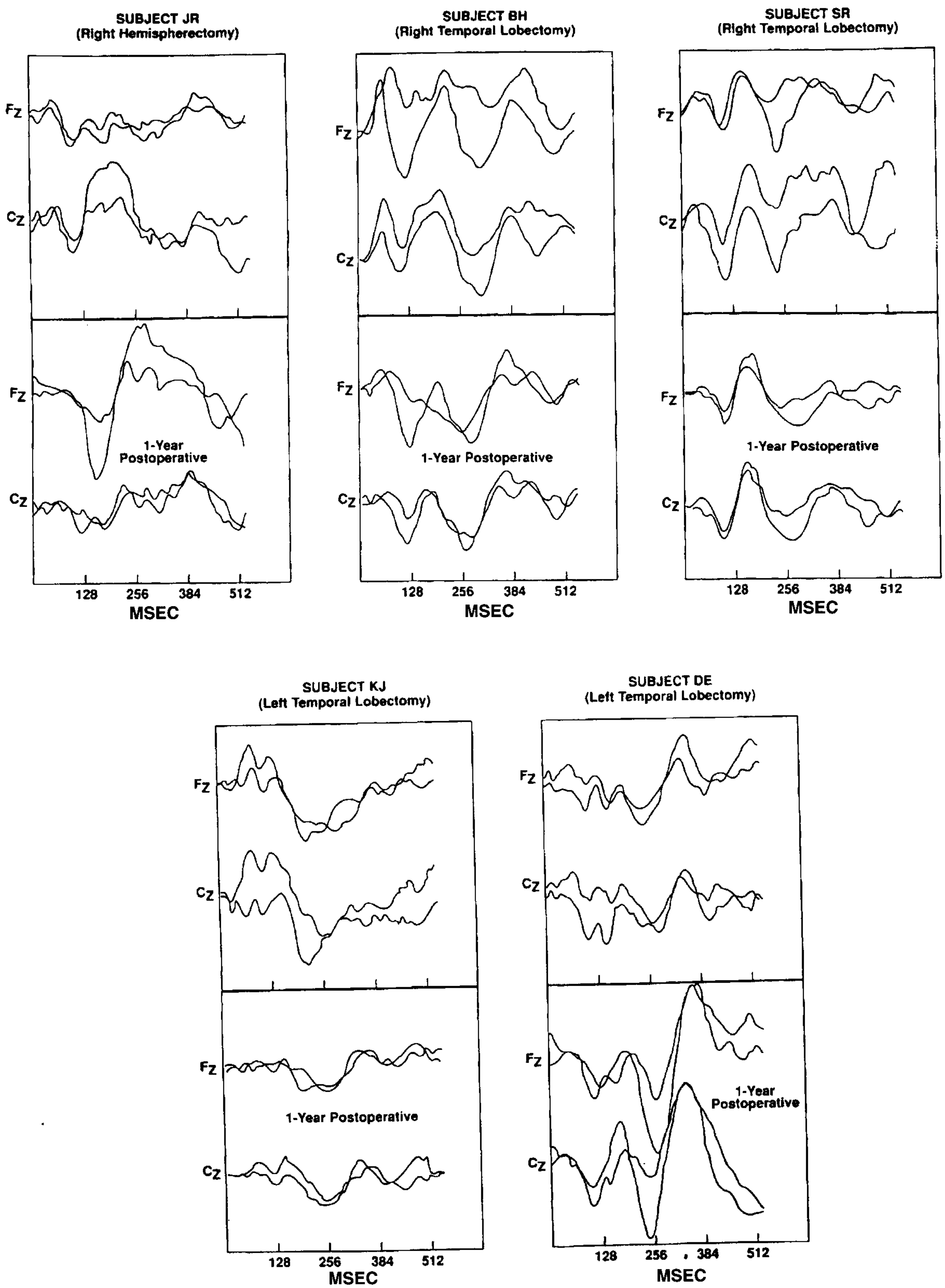

Figure 2 P300 event-related potential findings with each subject. Shown are vertex positive responses to the infrequent stimulus events.

reduced. The equally important goal of not worsening the neurologic, cognitive, or psychosocial status of the child also appears to have been achieved. This conclusion was supported by additional pre- and postoperative evaluations performed on the present children by medical center neurologists, neuropsychologists, occupational therapists, and social case workers. With few exceptions, the performances of individual children on all test measures were no poorer following the surgery than before surgery. However, the degree of improvement in central auditory processing functions was not as pervasive as we had hoped. This variable outcome occurred in spite of the fact that the surgical protocol in the four temporal lobectomy subjects were, according to the neurosurgeon (Allen Wyler, MD, personal communication), very similar.

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