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Are there changes in intelligence and memory functioning following surgery for the treatment of refractory epilepsy in childhood?

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Abstract *Materials and methods:* A retrospective review of the neuropsychological and medical variables of 26 children who underwent a cortical resection as part of the management of their medically refractory epilepsy was conducted. Neuropsychological variables included pre- and postoperative measures of intelligence (Wechsler Scales) and memory functioning (Wide Range Assessment of Memory and Learning). Medical variables included age at onset of seizures, age at surgery, site of resection, and degree of seizure control postoperatively. *Results:* Twenty patients had temporal resections (13 left-sided). Six had extratemporal resections. In this series, cortical resection as treatment of epilepsy in children did not result in a significant change in performance on measures of intelligence or memory functioning. No significant correlation was found between the medical variables and the neuropsychological outcome.

Keywords Intractable epilepsy · Cortical resection · Intelligence · Memory

Introduction

Cortical resection has been used in the treatment of medically refractory epilepsy in adults for several decades. Recently it has been used more frequently in children and adolescents, in whom it has been shown to decrease the occurrence of seizures significantly [1, 2, 3, 5, 11, 14, 19]. When successful, it has been shown to improve the patients' quality of life overall [14, 15]. Patients' responses to rating scales have suggested a high level of satisfaction with this intervention [7, 16]. The procedure has also been shown to be cost effective [13, 23].

Several outcome studies of neuropsychological functioning comparing pre- and postoperative functioning in adults have suggested that declines in verbal memory and language-based tasks may follow left temporal resection [8, 9, 18, 21]. Similar studies of neuropsychological outcome in children and adolescents are scarce. In part, this paucity of studies may be due to the lack of good standardized measures of verbal and visual memory for use with children before 1990. The purpose of this paper is to report on a retrospective review of standardized measures of intelligence and memory functioning obtained pre- and postoperatively in a group of children and adolescents who underwent cortical resection in an attempt to control their medically refractory epilepsy.

Materials and methods

This retrospective study was approved by the institutional ethics committee at the Children's Hospital of Eastern Ontario where it was carried out. All patients under the age of 19 years who underwent a single cortical resection at the Children's Hospital of Eastern Ontario in an attempt to control their medically refractory epilepsy were eligible for inclusion in this review. In addition, all patients had to have had partial complex epilepsy.

Charts were reviewed to obtain the pre- and postoperative estimates of intelligence and memory functioning. To be included in this review, each patient must have been assessed using one of the following standardized measures of intelligence: WPPSI-R, WISC-III, WAIS-R, and WAIS-III. Intelligence quotients are derived from composite scores based upon each child's performance across several subtests. Some of these subtests assess skills that rely heavily on language abilities. These subtests contribute to the Verbal Intelligence Quotient (I.Q.). The remaining subtests measure ability to solve visual-spatial problems quickly. These subtests contribute to the Performance I.Q. When available, a standardized measure of memory functioning, the Wide Range Assessment of Memory and Learning (WRAML), was included. The Verbal Memory Index is a composite score that is derived from performance on three immediate recall tasks: story recall; sentence repetition; and verbatim recall of sentence/number sets. The Visual Memory Index is also a composite score that is derived from performance on three immediate recall tasks: memory for details from pictures; drawings of geometric designs from memory; and memory for sequences of locations. All preoperative neuropsychological assessments had to have been administered within 1 year before surgery. Postoperative assessments had to have been performed within 5–15 months after surgery.

Patients' medical charts were reviewed to obtain the age at the onset of seizures, age at surgery, site and size of cortical resection, including whether the hippocampus and/or amygdala had been removed, and seizure outcome at the time of the postoperative neuropsychological assessment.

The data for the group as a whole were analysed. The group was then divided into those with temporal and those with extratemporal sites of resection. The temporal group was further subdivided by side of the resection. Pre- and postoperative measures of intelligence and memory functioning were compared using paired *t*-tests ($P<0.05$). The influence of medical variables on psychological outcome was examined using correlation analyses.

Results

Twenty-six patients met the criteria for this review. Sixteen were male. Twenty-two were right-hand dominant, 3 were left-hand dominant, and 1 was ambidextrous. All had partial complex epilepsy that had proven refractory to two or more antiepileptic drugs. All patients were receiving anticonvulsant medication at the time of the preoperative assessment. The mean duration of seizures prior to surgery was 5.8±5.8 years. The age at the time of surgery was 11.9±3.7 years. Fifteen patients (58%) were seizure free postoperatively. Six (23%) had a greater than 75% reduction in their seizure frequency. In the remainder, the seizure frequency was unchanged.

For the whole group, no significant differences were found between pre- and postoperative means on measures of intelligence. The mean preoperative Verbal Intelligence Quotient (I.Q.) was 93.2±16.9; the Performance I.Q. was 93.0±16.6; and the mean Full Scale I.Q. was 92.3±16.8. The mean postoperative Verbal I.Q. was 92.2±18.1; the Performance I.Q. was 95.9±18.0; and the mean Full Scale I.Q. was 93.2±18.7.

Twenty patients had temporal resections. Thirteen were male. Seventeen were right-hand dominant, 2 were left-hand dominant, and 1 was ambidextrous. Their mean duration of seizures prior to surgery was 6.8±6.2 years. The mean age at the time of surgery was 12.9±3.2 years. Eleven patients (55%) were seizure free postoperatively. Five (25%) were not free of seizures but had a greater than 75% reduction in their seizure frequency. In 4 (20%), the seizure frequency was unchanged.

For patients who underwent a resection involving the temporal lobe, no significant differences were found between pre- and postoperative means on measures of intelligence. The mean preoperative Verbal I.Q. was 89.7±15.1; the Performance I.Q. was 90.3±17.2; and the mean Full Scale I.Q. was 89.0±16.3. The mean postoperative Verbal I.Q. was 89.4±15.7; the Performance I.Q. was 91.6±16.8; and the mean Full Scale I.Q. was 89.3±16.8.

Thirteen patients had a left temporal lobectomy. Eight of these were males. Eleven were right-hand dominant, 1 was left-handed, and 1 was ambidextrous. The mean duration of seizures preoperatively was 6.6±5.9 years. Age at the time of surgery was 12.9±2.8 years. The mean size of cortical resection, measured from the anterior tip of the temporal lobe, was 4.95±0.37 cm. In 5 patients the surgery included removal of the hippocampus and the amygdala. Six patients had only the amygdala removed. Eight patients (61.5%) were seizure free postoperatively. Two (15.4%) still had seizures but had a greater than 75% reduction in seizure frequency. In 3 (23.1%), the seizure frequency was unchanged.

No significant differences were observed between pre- and postoperative means for Verbal, Performance, and Full Scale Intelligence. The mean preoperative Verbal I.Q. was 92.2±13.7; the Performance I.Q. was 91.9±18.0; and the mean Full Scale I.Q. was 91.2±15.8. The mean postoperative Verbal I.Q. was 91.5±15.5; the Performance I.Q. was 92.3±17.5; and the mean Full Scale I.Q. was 91.3±16.7.

No significant differences were observed between pre- and postoperative means for measures of verbal and visual memory. The mean preoperative verbal memory score (84.0±19.7) was lower than the mean preoperative visual memory score (97.4±19.3). This difference approached significance ($t(1, 11)=-2.04$, $P=0.067$). The postoperative mean for Verbal Memory was 82.9±18.9; the mean for Visual Memory was 100.2±18.0. The difference between postoperative means for Verbal and Visual Memory was significant [$t(1, 12)=-3.34$, $P\leq0.01$].

In the left temporal group, no significant correlation was found between the size of cortical resection and the difference between pre- and postoperative scores on

measures of intelligence and memory. No significant difference was found between pre- and postoperative scores on measures of intelligence and memory in patients who had a hippocampal resection as opposed to those who did not.

Seven patients had a right temporal lobectomy. Five of these were males. Six were right-hand dominant, and 1 was left-handed. The mean duration of seizures preoperatively was 7.3±7.3 years. Age at the time of surgery was 13.1±4.0 years. The mean size of cortical resection, measured from the anterior tip of the temporal lobe, was 5.6±0.89 cm. In all patients, the surgery included removal of the hippocampus and the amygdala. Three patients (42.9%) were seizure free postoperatively. Three (42.9%) were not free of seizures but had a greater than 75% reduction in seizure frequency. In 1 (14.3%), the seizure frequency was unchanged.

No significant differences were observed between pre- and postoperative means for Verbal, Performance, and Full Scale Intelligence. The mean preoperative Verbal I.Q. was 85.0±17.5; the Performance I.Q. was 87.4±16.3; and the mean Full Scale I.Q. was 84.7±17.7. The mean postoperative Verbal I.Q. was 85.3±16.6; the Performance I.Q. was 87.7±16.4; and the mean Full Scale I.Q. was 85.6±18.8. The size of this group was not large enough to allow for statistical comparisons of pre- and postoperative means of memory functioning. Both measures were available for only 3 of 7 patients.

Six (3 male, 3 female) patients had extratemporal resections (4 frontal, 1 parietal, 1 parietal-occipital). Five were right-hand dominant, and 1 was left-hand dominant. The mean duration of seizures preoperatively was 2.5±2.5 years. The mean age of these patients at the time of surgery was 8.6±3.7 years. None had hippocampectomy or amygdalectomy. Four patients (66.7%) were seizure-free postoperatively. One (16.7%) had a greater than 75% reduction in seizure frequency. In 1 (16.7%), the seizure frequency was unchanged.

No clinically significant deterioration in means was apparent. The mean preoperative Verbal I.Q. was 105.2±18.5; the Performance I.Q. was 102.3±11.6; and the mean Full Scale I.Q. was 103.8±14.0. The mean postoperative Verbal I.Q. was 101.8±23.7; the Performance I.Q. was 110.2±15.5; and the mean Full Scale I.Q. was 106.2±20.0.

Discussion

Though the number of patients in the extratemporal resection group was too low for us to perform meaningful statistical analyses, no clear differences were apparent between the pre- and postoperative means on standardized measures of intelligence and memory in this clinical population. For patients who underwent a temporal resection, the preoperative mean Verbal, Performance, and Full Scale I.Q. scores of patients with left temporal resection did not differ significantly from those of patients with right temporal resection. Furthermore, there were no significant changes in the mean intelligence scores following surgery, regardless of the side of resection. These means fell within the Average range, but there was considerable group variability.

Owing to the small numbers of patients in the right temporal group who had both pre- and postoperative measures of memory functioning, statistical analyses could not be performed. Comparisons of pre- and postoperative memory functioning were therefore limited to the patients who had a left temporal resection.

Differences between pre- and postoperative means on measures of Verbal and Visual Memory were not significant for those who underwent a left temporal lobectomy. Preoperatively, there was no significant difference between the mean scores for Verbal and Visual Memory. Postoperatively this difference, which was significant, appeared to result from a slight decline in Verbal Memory, together with a slight improvement in Visual Memory. This finding would support the hypothesis that removing the epileptic zone in children may result in an improvement in some aspects of their memory functioning, and hence learning. Given the number of children included in this retrospective study it was not possible to examine whether postoperative seizure status was correlated with outcome on measures of memory functioning.

Current models of memory functioning [22] distinguish between procedural and declarative memory, with procedural memory referring to skill acquisition, while declarative memory refers to knowledge-based memory. Declarative memory is divided into semantic memory (memory for facts) and episodic memory (biographic event-related memories). It has been proposed [10] that the mesial temporal and frontal cortices contribute to the formation of episodic memories, whereas the associative areas of the cerebral cortex contribute to the formation of semantic memories. Depending on the site and size of resection, different aspects of memory functioning may be expected to be affected.

This model of memory functioning has gained support from outcome studies in adults in whom a temporal lobectomy has been performed. Adult studies suggest that removal of the right temporal lobe leads to significant interference with visual learning [12, 17], while removal of the left temporal lobe interferes with verbal learning [4, 6, 8, 9]. The size of cortical resection and the degree of hippocampal resection have been shown to have an important role in the determination of neuropsychological outcome. Corsi, using a consonant trigram recall task, reported a correlation between the degree of hippocampal resection and the degree of memory loss [18]. Rausch and Babb [21], using unrelated word pairs, examined the relationship between hippocampal neuronal loss and intellectual and memory functioning before

and after temporal lobe resection. They noted that the degree of hippocampal loss was correlated with a deterioration in learning of unrelated word pairs in patients with left, but not right temporal lobe seizures. Patients with severe neuronal loss performed worse than those with moderate loss. The authors concluded that patients with severe hippocampal neuronal loss were at greater risk of memory impairment postoperatively. In contrast, Ojemann and Dodrill [20], using a story recall task, noted a correlation between verbal memory deficits after temporal lobectomy and the size of cortical resection. The larger the resection the greater the impairment.

The discrepancy in the findings of the previously described studies may be attributable to differences in the choice of memory tests used. There is an obvious difference in the meaningfulness and novelty of the information that these patients were asked to learn. Although all of these tasks are considered to be measures of episodic memory, information that is more meaningful and familiar, such as the story recall task, may also draw upon semantic memory.

Hermann et al. [10] reported a correlation between age at surgery and degree of memory deterioration postoperatively. The older the patient at the time of surgery, the more striking the deterioration. Patients who underwent surgery before the second decade of life did not show a significant deterioration in memory functioning. These findings are consistent with those of the retrospective review in our paediatric population. Our clinical impression of the children in our review was that those who had cognitive deficits prior to surgery did not show a further deterioration postoperatively. Patients who were functioning within the average range preoperatively continued to do so postoperatively.

In conclusion, the findings of this review support the hypothesis that surgical treatment of medically refractory epilepsy in childhood and adolescence can be performed without adverse effects on intelligence or memory functioning. Long-term effects of cortical resection in this population were not examined in this paper. It is possible that over time changes in functioning may be observed. It is for this reason that long-term neuropsychological follow-up studies need to be conducted.

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References

1. Adelson P, Peacock W, Chugani H, et al (1992) Temporal and extra temporal resections for the treatment of intractable seizures in early childhood. Pediatr Neurosurg 18:169–178
2. Chelune GJ, Naugle RI, Luders H, et al (1991) Prediction of cognitive change as a function of preoperative ability status among temporal lobectomy patients seen at 6-month follow-up. Neurology 41:399–404
3. Davidson S, Falconer M (1975) Outcome of surgery in 40 children with temporal-lobe epilepsy. Lancet I:1260–1263
4. Davies KG, Bell BD, Bush AJ, et al (1998) Prediction of verbal memory loss in individuals after anterior temporal lobectomy. Epilepsia 39:820–828
5. Duchowny M, Levin B, Jayakau P, et al (1992) Temporal lobectomy in early childhood. Epilepsia 33:298–303
6. Frisk V, Milner B (1990) The relationship of working memory to the immediate recall of stories following unilateral temporal or frontal lobectomy. Neuropsychologia 28:121–135
7. Guldvog B, Loyning Y, Harglie-Hanssen, et al (1994) Surgical treatment for partial epilepsy among Norwegian children and adolescents. Epilepsia 35:554–565
8. Helmstaedter C, Elger CE (1998) Functional plasticity after left anterior temporal lobectomy: reconstitution and compensation of verbal memory functions. Epilepsia 39:399–406
9. Helmstaedter C, Elger CE, Hufnagel A, et al (1996) Different effects of left anterior temporal lobectomy, selective amygdalohippocampectomy, and temporal cortical lesionectomy on verbal learning, memory, and recognition. J Epilepsy 9:39–45
10. Hermann BP, Seidenberg M, Haltiner A, et al (1995) Relationship of age at onset, chronologic age, and adequacy of preoperative performance to verbal memory change after anterior temporal lobectomy. Epilepsia 36:137–145
11. Hopkins I, Klug G (1991) Temporal lobectomy for the treatment of intractable complex partial seizures of temporal lobe origin in early childhood. Dev Med Child Neurol 33:26–31
12. Jones-Gotman M (1987) Psychological evaluation: testing hippocampal function [commentary]. In: Engel J Jr (ed) Surgical treatment of the epilepsies. Raven Press, New York, pp 203–211
13. Keene DL, Ventureyra ECG (1999) Epilepsy surgery for 5 to 18 year old patients with medically refractory epilepsy. Is it cost efficient? Childs Nerv Syst 15:52–55
14. Keene DL, Higgins MJ, Ventureyra ECG (1997) Outcome and life prospects after surgical management of medically intractable epilepsy in patients under 18 years of age. Childs Nerv Syst 13:530–535
15. Keene DL, Loy-English I, Ventureyra ECG (1998) Long term socioeconomic outcome following surgical intervention in the treatment of refractory epilepsy in childhood and adolescence. Childs Nerv Syst 14:362–365
16. Keene DL, Loy-English I, Ventureyra ECG (1998) Patient satisfaction with surgical treatment of refractory epilepsy done in childhood and early adolescence. Childs Nerv Syst 14:30–32
17. Milner B (1968) Visual recognition and recall after right temporal-lobe excision in man. Neuropsychologia 6:191–209

18. Milner B (1971) Interhemispheric differences in the localization of psychological processes in man. Br Med Bull 27:272–277
19. Novelly RA, Augustine EA, Mattson RH, et al (1984) Selective memory improvement and impairment in temporal lobectomy for epilepsy. Ann Neurol 15:64–67
20. Ojemann GA, Dodrill CB (1985) Verbal memory deficits after left temporal lobectomy for epilepsy. J Neurosurg 62:101–107
21. Rausch R, Babb TL (1993) Hippocampal neuron loss and memory scores before and after temporal lobe surgery for epilepsy. Arch Neurol 50:812–817
22. Tulving E (1994) Memory systems of 1994. In: Tulving E, Schacter DL (eds) What are the memory systems of 1994? Raven Press, New York, pp 11–38
23. Wiebe S, Gafri A, Blume W, et al (1995) An economic evaluation of surgery for temporal lobe epilepsy. J Epilepsy 8:227–235