Seizure 1999; **8**: 241–245
Article No. seiz.1999.0291, available online at http://www.idealibrary.com on IDEAL®

An analysis of neuropsychological change scores following selective temporal resection of the non-dominant temporal lobe

N. H. WALTON*, C. GOODSMAN*, R. McCARTER*, D. R. SANDEMAN† & J. M. BIRD‡

**Department of Neuropsychology, Frenchay Healthcare NHS Trust, Bristol, UK; †Department of Neurosurgery, Frenchay Healthcare NHS Trust, Bristol, UK; ‡Department of Neuropsychiatry, Frenchay Healthcare NHS Trust, Bristol, UK*

Reliable change in neuropsychological test scores was examined in patients undergoing right-sided, selective temporal resections for the relief of intractable epilepsy. Measures were taken prior to surgery, 1-month post-operatively and 1-year post-operatively. Non-verbal memory performance was more robustly measured than in previous studies. Results failed to replicate previous studies which report verbal memory deficits even following right-sided surgery. No strong evidence of a material-specific, non-verbal memory deficit was found on commonly used tests of non-verbal memory. The majority of patients failed to show reliable decline in performance following surgery indicating that fears of post-operative memory decline may be unfounded.

Key words: neuropsychology; epilepsy surgery; memory; amygdalo-hippocampectomy.

INTRODUCTION

Memory deficits continue to be regarded as the most salient neuropsychological consequence of surgery for the relief of intractable epilepsy[1, 2]. Fear of post-surgical neuropsychological deficit continues to deter many clinicians from referring their patients for surgery, which is still regarded by many as a last resort, rather than as an effective 'treatment of choice' following failure of first line anticonvulsant medication[3]. This is despite the fact that more surgery for the relief of epilepsy is now being undertaken than ever before and it is now regarded as being safer and more effective than previously[4].

Reports have traditionally suggested that deficits are more profound and more likely to occur following left-sided or dominant hemisphere operations rather than right-sided, non-dominant procedures[5–8]. More recently, the absence of the mesial temporal lobe epilepsy (MTLE) syndrome, which includes hippocampal sclerosis, has been invoked as a powerful predictive variable in determining the likelihood of pre- to post-operative memory decline. Again deficits have been reported to predominantly affect verbal memory following both left-sided and to a lesser extent, right-sided, anterior temporal lobectomy[2].

* Accepted for publication 7 April 1999.

Research has yet to adequately demonstrate whether this is actually the case, or whether the inherent difficulties in the measurement of non-verbal memory account for the apparent differences between left- and right-sided operations. It is generally acknowledged that the measurement of 'non-verbal' memory remains problematic and there are few of the widely utilized tests that stand up to rigorous examination in this regard[9, 10]. Despite this, material-specific memory deficits continue to be reported based on tests with poor reliability and questionable validity[9, 11].

Traditionally, results have been presented in terms of group mean differences. Few groups have examined pre- and post-operative neuropsychological change in a manner that accounts for individual variation. Hermann and Wyler[12] redressed this to some degree by examining changes in pre- and post-surgical neuropsychological functioning using an operationally defined significant change score as being equal to, or greater than, one standard deviation on a particular test. They found that neuropsychological test scores were predominantly stable across surgery and where there was significant change, there was a trend for this to be a 'gain' in cognitive functioning rather than a 'loss'. The exception to this was in the area of learning and memory where there was a greater degree of loss in the non-dominant group, contrary to the established pattern of greater deficits following dominant hemisphere oper-

1059–1311/99/040241 + 05 $12.00/0

ations. Their findings may have reflected the greater extent of surgical resection in this population.

Phillips and McGlone[13] examined change scores in a group of epilepsy surgery patients at 1-year post-surgery. They again utilized one standard deviation as an arbitrarily determined level of significance but additionally used an index of material-specific memory loss based on the number of purported material-specific memory tests that showed deficit. They suggest that any patient showing an impaired performance on 25% of tests within the verbal or non-verbal domain, was demonstrating a material-specific memory deficit. Given that they used four measures of non-verbal memory this means that poor performance on only one test would be sufficient to classify a given patient as having a non-verbal material-specific memory loss. This contradicts sound neuropsychological practice where aberrant performance on only one test would not typically be regarded as sufficient grounds for diagnosis[9,14].

Phillips and McGlone[13] claim to have employed more extensive measures of verbal and non-verbal memory than previous studies. However, six of the seven measures used to measure verbal memory were from two subtests of the now revised Wechsler Memory Scale (WMS). This test is known to have poorer psychometric properties than the revised version[15,16] and its use is therefore difficult to justify.

Of the 'non-verbal' memory tests used by this group, one was the Visual Reproduction subtest from the now revised WMS, which is known to be susceptible to verbal encoding and is regarded as insufficient for lesion lateralization[14]. Another was the Warrington Recognition Memory Test for Faces which utilizes a two-alternative, forced choice, recognition paradigm which may be less sensitive than tests of delayed recall as tests of recognition are inherently less demanding of retrieval capabilities than free recall measures[14].

Chelune *et al.*[7] published 'Reliable Change Index Scores' (RCIS) based on the performance of a non-surgical, seizure control group tested twice over a 7-month period. These robust scores allow base-rate data and practice effects to be taken into account when interpreting reliable change across surgery. Chelune *et al.*[7] reported that 45% of their left temporal lobectomy (LTL) group and 14% of their right temporal lobectomy (RTL) group showed reliable decline in verbal memory as measured by the Verbal Memory Index from the Wechsler Memory Scale—Revised (WMS-R). The Verbal Memory Index summary score comprises the Logical Memory subtest and the Verbal Paired Associate Learning subtest. The former has been criticized as being susceptible to attentional deficits rather than memory *per se*[17]. It is conceivable then that the findings of this group were confounded by attentional factors.

Unfortunately, RICS were only developed for the Wechsler Adult Intelligence Scale-Revised (WAIS-R) and for the WMS-R. Whilst these tests are widely used, they are of questionable sensitivity in terms of lateralized dysfunction[11,15].

Seidenberg *et al.*[2] have also utilized a non-operated control group to produce measures of reliable change. They found deficits most apparent in their non-mesial temporal lobe epilepsy group (i.e. in those not showing hippocampal sclerosis). They also report deficits predominantly in the left-sided group, though their right-sided group did show some decline in verbal memory. These authors used the Visual Reproduction subtest from the WMS as their sole measure of non-verbal memory, which as mentioned above, is seriously flawed[14]. This may have accounted for the lack of material-specific memory deficits in their group.

To date, the problems inherent in measuring the sequelae of non-dominant hemisphere operations on non-verbal learning and memory have not yet been systematically addressed. This, in our view, precludes reliable conclusions as to the effects of non-dominant hemisphere resections.

The majority of studies have involved patients undergoing left- or right-sided temporal lobectomies. The surgical resections were therefore relatively extensive. Typically, temporal lobectomy involves an *en bloc* resection of 5.5–6.5 cm of temporal lobe including lateral cortex as well as amygdala and hippocampus[18,19]. The current availability of three-dimensional imaging technology has lead to an increased implementation of more selective surgical techniques such as amygdalo-hippocampectomy (AH) and selective temporal resection (STR). In these operations only the amygdala and hippocampus are resected and in the latter technique, the extent of resection may be limited to a disconnection of the amygdala from the pes hippocampus. The lateral cortex and remainder of the medial temporal structures are spared.

Our centre has pioneered the use of STR and to our knowledge this is the first study to investigate reliable change in neuropshychological performance following this surgical technique. Additionally, we have specifically examined the neuropsychological sequelae of non-dominant hemisphere surgery for the relief of epilepsy. We have extended the breadth of assessment carried out in previous studies and have used current versions of tests. In particular, we have attempted to measure non-verbal memory in a more robust fashion than has been done previously. This has been achieved by the inclusion of a spatial, maze-learning task, the Burden Maze which has shown promise in terms of sensitivity to right hemisphere dysfunction[20]. We have measured significant change outcome both acutely (1-month post-operatively) and at long-term follow-up (1-year post-operatively).

Table 1: Means, standard deviations and ranges for age, education, age at onset and Full Scale IQ.

	Mean	SD	Range
Age	32.9	9.3	19–52
Education (Yrs)	12.1	2	10–16
Age at onset	10.4	9.5	1–38
WAIS-R FSIQ	97.3	14.5	81–132

MATERIALS AND METHODS

Subjects

These comprised 19 patients with intractable temporal lobe epilepsy who underwent right-sided, image-guided, selective temporal resections as part of the epilepsy surgery programme at Frenchay and the Burden hospitals in Bristol, UK. Demographic information is summarized in Table 1.

All but one of the patients were left hemisphere dominant for language as assessed by intracarotid amobarbital procedure (IAP). The one patient that did not undergo IAP was deemed to have normal dominance on the basis of handedness and clinical history.

Patients were evaluated for their suitability for surgery on the basis of routine (interictal), video (ictal) and activated sphenoidal EEG; MRI; interictal SPECT; Neuropsychology and Neuropsychiatric interview. When necessary in-dwelling electrodes were used.

NEUROPSYCHOLOGICAL ASSESSMENT

Patients were assessed with an extensive neuropsychological assessment battery prior to surgery, approximately 1-month post-operatively and again at approximately 12-months post-operatively. The tests used in the current analyses are presented in Table 2. Whilst we examined neuropsychological function on a total of 23 individual measures, including nine verbal and 10 non-verbal memory measures, we included only 15 measures in the final analysis in an effort to maximize reliability. Individual subtests from the WMS-R were excluded because they lack sufficient statistical reliability to allow meaningful interpretation[11]. We therefore used only the summary memory indices from the WMS-R in our analyses. Even so, the number of material-specific measures in our study compares favourably to that of Phillips and McGlone[13] and Seidenberg *et al.*[2]

Surgery

Trans-sulcal medial temporal resection

Patients underwent 'selective temporal resection' under image guidance. The Elekta Viewing Wand™ was used in the majority of cases. In those operated on more recently, the Sofomor Danek software and StealthStation™ was used. T1-weighted MRI scans were obtained on a Phillips 1.5 Tesla machine reconstructing the volume as 2-mm-thick contiguous slices from which were generated three-dimensional images.

The optimum trajectory from the skin to the inferior horn of the lateral ventricle was determined, following an appropriate sulcus. *En bloc* resection of the pes hippocampus was undertaken. The anterior margin of the dissection was determined by the junction of the pes with the amygdala. Sufficient hippocampus was removed so as to disconnect the amygdala from the posterior hippocampus. Between 1 and 3 cc's of brain were removed.

RESULTS

For the WAIS-R and WMS-R summary IQs and Memory Indices, Reliable Change Index Scores[7] were used to determine meaningful loss or gain. Where published normative data exist, these were used and one standard deviation was taken as an index of clinically meaningful change. Where no published norms exist (e.g. for the Burden Maze test), one standard deviation based on pre-operative performances was used.

Table 2: Neuropsychological test battery.

Test	Measures included in analysis
Wechsler Adult Intelligence Scale—Revised	
	Verbal IQ*
	Performance IQ**
	Full Scale IQ
Wechsler Memory Scale—Revised	
	Verbal Memory Index*
	Visual Memory Index**
	General Memory Index
	Attention/Concentration Index
	Delayed Recall
Warrington Recognition Memory Test	
	Words*
	Faces**
Verbal Selective Reminding Test	
	Consistent long term retrieval*
	Long-term storage*
Complex Figure of Rey	
	Copy
	Delay**
Burden Maze Test	
	Errors for 10 trials**

* = verbal
** = non-verbal

The results are summarized in Table 3. The results are presented in terms of percent of patients who showed meaningful loss, meaningful gain or no change between pre-operative and post-operative scores.

The results show that in the majority of cases no significant change occurred as a consequence of surgery. Where there was change, it was qualitatively more

Table 3: Percentages of patients showing no change, gain or loss over all measures.

Test	Measure	1-month follow-up				1-year follow-up			
		n	% No. change	% Gain	% Loss	*n*	% No. change	% Gain	% Loss
WAIS-R	VIQ	18	83.3	0.0	16.7	14	92.9	7.1	0.0
	PIQ	18	66.7	27.8	5.6	14	64.3	35.7	0.0
	FSIQ	19	63.2	15.8	21.1	15	60.0	26.7	13.3
WMS-R	Verbal Ml	14	100.0	0.0	0.0	12	83.3	8.3	8.3
	Visual Ml	14	92.9	7.1	0.0	12	83.3	16.7	0.0
	General Ml	19	89.5	0.0	10.5	15	80.0	13.3	6.7
	Attn/Conc	13	100.0	0.0	0.0	11	100.0	0.0	0.0
	Delayed Recall	19	84.2	15.8	0.0	15	86.7	13.3	0.0
WRMT	Words	5	80.0	20.0	0.0	9	44.4	33.3	22.2
	Faces	5	60.0	20.0	20.0	9	77.8	11.1	11.1
VSRT	CLTR	16	56.3	43.8	0.0	14	64.3	35.7	0.0
	LTS	16	43.8	56.3	0.0	14	42.9	57.1	0.0
Rey Figure	Copy	18	44.4	27.8	27.8	14	21.4	64.3	14.3
	Recall	18	83.3	11.1	5.6	14	78.6	21.4	0.0
Maze	No. errors	17	82.4	5.9	11.8	12	83.3	8.3	8.3

likely to be in the direction of gain rather than loss. Of the 15 measures taken at 1-month post-operatively, 13 showed more stability than change. At 1 year, 12 showed a greater tendency for stability than change. On all tests at 1 month and 1 year, the percentage of patients showing either no change or gain far outweighed those showing loss.

At 1-month post-operatively there was no consistent evidence of a decline in any verbal memory measures, contrary to previous reports. Indeed, we found that a large proportion of patients showed improved performance on the Verbal Selective Reminding Test. At 1-year post-operatively, 8% of patients showed a decline in their Verbal Memory Index, though equally 8% showed a gain.

On the Visual Memory Index no patients showed a loss either at 1 month or 1 year. Similarly, on the Delayed Recall of the WMS-R no patients showed a reliable decline in performance whilst 16% and 13% showed gain at 1-month and 1-year follow-up, respectively.

On the delayed recall of the Complex Figure of Rey Test there was no evidence of consistent decline in performance following surgery and, in fact, gains were seen in 11% of patients at 1-month and 21% at 1-year post-surgery.

On the Burden Maze Test, 12% of patients showed decline in performance at 1 month and 8% at 1 year.

The results from the Warrington Recognition Memory Test showed a relatively high percentage in either direction but the small numbers in these groups precluded meaningful interpretation of these changes.

Overall, test indices that showed more loss than gain were VIQ, FSIQ and General Memory Index at 1 month. This loss did not persist to 1-year follow-up, indeed these indices all showed more gain than loss at 1 year. The Burden Maze showed greater loss than gain at 1 month and equal gain and loss at 1 year.

DISCUSSION

The result of the present study suggest that there is little convincing evidence of sustained deterioration in intellectual function or memory following minimally invasive surgery for epilepsy. Whilst some indices did show a trend for more loss than gain, this was generally unconvincing as evidence of true material-specific memory deficit from both a quantitative and clinical/qualitative viewpoint. Loss tended to occur in only a few patients and on tests that had either intellectual or attentional components rather than memory *per se* and deficits typically failed to persist at 1-year follow-up.

In contrast to previous reports we found tests of verbal new learning and memory tended to show gain rather than loss. This gain was evident both at 1-month and 1-year follow-up. Why removal of dysfunctional tissue from the non-dominant hemisphere should improve verbal memory is unclear. It has been suggested that the activity from an epileptogenic focus may exert an inhibitory effect on both proximal and distal regions of the brain. The removal of this focus may therefore facilitate function in the previously affected regions.

This finding differs from that of Phillips and McGlone[13] where almost 60% of the right-sided group showed losses in verbal memory. This disparity may in part reflect their inclusion of the individual subtests from the WMS in their analysis whereas we used only the more reliable WMS-R indexes. Additionally, the patients in the Phillips and McGlone[13] study underwent temporal lobectomy. The relatively benign effects of surgery on verbal memory in our group may reflect the less extensive resection.

Our study, in line with previous studies, failed to detect clear evidence of a non-verbal, material-specific memory loss following non-dominant hemisphere resection. This may be due to the insensitivity of many of the clinical tests of non-verbal memory traditionally employed in this group of patients. If so, our study could be seen to provide further evidence to support the claim of Jones-Gottman[21] that the most commonly used tests of non-verbal function, namely the WMS Visual Reproduction and CFRT recall, do not adequately measure non-dominant hemisphere dysfunction. However, the sensitivity of our test battery to non-verbal memory deficits was increased by the inclusion of a spatial maze learning task, the Burden Maze Test. Previous research has suggested that this test may be more sensitive than traditional measures in detecting non-verbal memory function[20]. Despite this we still failed to detect clear evidence of non-verbal material-specific memory loss. This suggests that in non-dominant selective temporal resection there may be no significant adverse consequences for memory.

The results of this study have major implications for the counselling of patients prior to surgery. It is still common practice for material-specific memory deficits to be regarded by health professionals and patients as a probable and disadvantageous consequence of surgery. Our results suggest that some patients may be receiving unnecessarily negative advice concerning the consequences of surgery for the relief of epilepsy. This study suggests that clinicians can be reasonably confident that patients being considered for selective temporal resection of the non-dominant hemisphere are at low risk of cognitive decline post-surgery.

Nonetheless, some measures did demonstrate a meaningful loss in a small minority of patients. Further research is required to determine whether these changes represent stable and ecologically valid neuropsychological decline.

Our results also suggest that less invasive surgical techniques may be less disruptive to cognitive function than more invasive temporal lobectomy. However this potential advantage will have to be carefully evaluated in the light of our experience of seizure recurrence in long-term follow-up of amygdalo-hippocampectomy patients.

REFERENCES

1. Herman, B. P., Seidenberg, M., Dohan, F. C. *et al.* Reports by patients and families memory change after left anterior temporal lobectomy: relationship to degree of hippocampal sclerosis. *Neurosurgery* 1995; **36/1**: 39–45.
2. Seidneberg, M., Hermann, B., Wyler, A. R., Davies, K., Dohan, F. C. and Leveroni, C. Neuropsychological outcome following anterior temporal lobectomy in patients with and without the syndrome of mesial temporal lobe epilepsy. *Neuropsychology* 1998; **12**: 303–316.
3. Engel, J. and Shewmon, D. A. Who Should be Considered a Surgical Candidate? In: *Surgical Treatment of the Epilepsies*. 2nd Edition (Ed. J. Engel). New York, Raven Press, 1993.
4. NIH Consensus Panel. Consensus conference on surgery for epilepsy. *Journal of the American Medical Association* 1990; **264**: 729–733.
5. Milner, B. Psychological aspects of focal epilepsy and its neurosurgical management. *Advances in Neurology* 1975; **8**: 299–321.
6. Blakemore, C. B. and Falconer, M. A. Long-term effects of anterior temporal lobectomy on certain cognitive functions. *Journal of Neurology, Neurosurgery and Psychiatry* 1967; **30**: 364–367.
7. Chelune, J., Naugle, R. I., Luders, H., Sedlak, J. and Awad, I. A. Individual change after epilepsy surgery practice effects and base-rate information. *Neuropsychology* 1993; **7**: 41–528.
8. Seidenberg, M., Hermann, B. P., Dohan, F. C., Wyler, A. R., Perrine, A. and Schoenfeld, J. Hippocampal sclerosis and verbal encoding ability following anterior temporal lobectomy. *Neuropsychologia* 1996; **34**: 699–708.
9. Walsh, K. W. *Understanding Brain Damage: A Primer of Neuropsychological Evaluation*. Edinburgh, Churchill-Livingstone, 1985: p. 27.
10. Heilbronner, R. L. The search for a ‘pure’ visual memory test Pursuit of Perfection. *The Clinical Neuropsychologist* 1992; **6**: 105–112.
11. Kaufman, A. S. *Assessing Adolescent and Adult Intelligence*. Boston, MA, Allyn and Bacon, 1990.
12. Herman, B. P. and Wyler, A. R. Neuropsychological outcome of anterior temporal lobectomy. *Journal of Epilepsy* 1988; **1**: 35–45.
13. Phillips, N. A. and McGlone, J. Grouped data do not tell the whole story: individual analysis of cognitive change after temporal lobectomy. *Journal of Clinical and Experimental Neuropsychology* 1995; **17**: 713–724.
14. Lezak, M. D. *Neuropsychological Assessment, Third Edition*. New York, Oxford University Press, 1995.
15. Wecshler D. Wecshler memory scale—revised manual. New York, The Psychological Cooperation, 1987.
16. Loring, D. W. The Wecshler memory scale—revised, or the Wecshler memory scale revisited. *The Clinical Neuropsychologist* 1989; **3**: 59–69.
17. Schmidt, J. P. and Tombaugh, T. *LAMB Learning and Memory Battery* (Manual). Canada, Multi-Health Systems Inc., 1995: p. 19.
18. Falconer, M. A. Surgical treatment of temporal lobe epilepsy. In: *Current problems in Neuropsychiatry*. (Ed. R. N. Hetherington). Ashford, Headley Brothers; 1969: pp. 95–100.
19. Falconer, M. A. Anterior temporal lobectomy for epilepsy. In: *Operative Neurosurgery*. (Ed. V. Logue). London, Butterworths, 1971; **14**: 142–149.
20. Walton, N. H., Goodsman, C. S., Bird, J. M., Sandeman, D. R., Butler, S. R. and Curry, S. H. The Burden maze as a measure of non-verbal memory in epilepsy surgery cases. *Epilepsia* 1996; **37**: 30.
21. Jones-Gotman, M. Psychological evaluation for epilepsy surgery. In: *Surgical Treatment of the Epilepsies*. (Ed. J. Engel, Jr). New York, Raven Press, 1996.