Short-term cognitive changes after unilateral temporal lobectomy or unilateral amygdalo-hippocampectomy for the relief of temporal lobe epilepsy

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Abstract
Forty two patients who had unilateral temporal lobe surgery (either temporal lobectomy or amygdalo-hippocampectomy) were evaluated using a selection of cognitive tests before and soon after surgery, to examine whether the amygdalo-hippocampectomy produces less cognitive impairment than the standard *en bloc* resection. On specific indices of cognitive functioning an amygdalo-hippocampectomy rather than a temporal lobectomy, undertaken on the temporal lobe thought to mediate that particular function, produced less impairment, in terms of change in cognitive function resulting from the operation. An amygdalo-hippocampectomy carried out on the temporal lobe not thought to mediate such skills, however, resulted in less improvement or more deterioration in these functions than a temporal lobectomy, except in the case of delayed prose recall, where a right amygdalo-hippocampectomy led to more improvement than a right temporal lobectomy. Overall there were few scores which distinguished between the different surgical procedures for cognitive outcome.

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Neurosurgical treatment of temporal lobe epilepsy by unilateral anterior temporal lobectomy results in selective memory impairment.[1-10] Verbal learning and memory impairments have been found following dominant temporal lobe resections and visuospatial learning and memory impairments following non-dominant temporal lobe resections. Where variable amounts of hippocampal tissue have been resected, different patterns of impairment, related to the size of the resection have been reported on some tasks.[11]

Short-term cognitive sequelae of unilateral temporal lobectomy were reported for the Maudsley series by Powell *et al.*[12] Left temporal lobectomy resulted in significantly lower immediate verbal recall than did right temporal lobectomy. Patients who were younger at the time of surgery, who were less intellectually able pre-operatively, and had early onset epilepsy tended to show no deterioration or even improvement as a result of the operation. Neuropathology also determined pre- and post-operative cognitive status.[13]

The *en bloc* temporal lobectomy performed at the Maudsley Hospital[14] involves the removal of between 5·5 and 6·5 cm of temporal lobe from the pole and includes the mesial temporal lobe structures. In dominant hemisphere resections only the anterior 1–2 cm of the superior temporal gyrus is removed. A less radical surgical intervention, selective amygdalo-hippocampectomy (AH)[15-17] has been described for patients in whom the epileptogenic focus can be localised to unilateral mesiobasal limbic structures. In this operation approximately 2–3 centimetres of hippocampus and a large part of the amygdala are removed together with the parahippocampal gyrus leaving less amygdala (a small portion of the antero-medial part) than in the standard *en bloc* procedure. Little comparative data on the cognitive sequelae of the two operations have been published. A report from Zurich compares six patients who had selective AH with five who had complete unilateral removal of the anterior two-thirds of the temporal lobe.[17] A verbal memory deficit was found following left temporal lobectomy but not following left AH. Visual maze learning was impaired after right temporal lobectomy whereas the deficit was less after right AH.

In view of the need to minimise cognitive deficits as well as achieve good seizure control by temporal lobe surgery a larger scale comparison of the two operations is required. Short-term cognitive outcome data will be presented on a preliminary series of 42 patients who have had either temporal lobectomy (TL) or AH since 1987 at the Maudsley Hospital.

Method

Subjects

We describe 42 patients who were right handed or had left hemisphere language dominance revealed during the intracarotid sodium amytal (Wada) procedure, who had temporal lobe surgery between 1987–90. All were aged above 16 years at time of surgery.

Characteristics are given in table 1 for the patients who had either a left or right temporal lobectomy (LTL or RTL) or a left or right amygdalo-hippocampectomy (LAH or RAH). Of the 42, 11 had RTL, 8 LTL, 9 the RAH operation and 14 the LAH operation.

Pre- and Postoperative investigations

All patients had a neuropsychologial assessment (see below), a CT scan and routine and

Table 1 Patient characteristics for those having right or left amygdalo-hippocampectomy or temporal lobectomy and differences in mean values (p < 0·05)

	RTL	LTL	RAH	LAH	
N	11	8	9	14	
Sex	5F, 6M	5F, 3M	6F, 3M	7F, 7M	Difference
Age at surgery (years-months) (AS)	32 yr 1 m (SD 11 yr 1 m)	28 yr 10 m (SD 6 yr 9 m)	29 yr 5 m (SD 8 yr 5 m)	25 yr 9 m (SD 6 yr 0 m)	NSig
Age at first seizure (years-months) (AOS)	12 yr 2 m (SD 7 yr 9 m)	7 yr 1 m (SD 5 yr 7 m)	12 yr 6 m (SD 10 yr 11 m)	6 yr 5 m (SD 6 yr 8 m)	left <right
Age of onset of chronic epilepsy (years-months) (AOCS)	14 yr 2 m (SD 8 yr 5 m)	8 yr 9 m (SD 5 yr 7 m)	12 yr 8 m (SD 10 yr 9 m)	7 yr 3 m (SD 7 yr 6 m)	left< Right
Time between chronic onset and surgery (years-months) (TCS)	18 yr 4 m (SD 10 yr 4 m)	20 yr 1 m (SD 4 yr 8 m)	16 yr 10 m (SD 3 yr 7 m)	18 yr 6 m (SD 8 yr 7 m)	NSig
Preoperative partial seizure frequency (per month) (PSF)	31·8 (SD 68·17) (range 4–200)	14·0 (SD 10·56) (range 8–32)	18·0 (SD 17·41) (range 15–60)	26·6 (SD 36·35) (range 4–100)	NSig
Postoperative seizure total before repeat Neuropsychological assessment (PST)	8·55 (SD 19·24) (range 0–60)	1·5 (SD 1·69) (range 0–4)	1·11 (SD 3·33) (range 0–10)	1·071 (SD 2·16) (range 0–6)	NSig
Neuropathology	2 MTS 2 Tumour 1 CD 5 NS 1 hamartoma	5 MTS 1 Tumour 1 NS 1 hamartoma	8 MTS 1 NS	12 MTS 2 NS	

Key: RTL right temporal lobectomy; RAH right amygdalo-hippocampectomy; LTL left temporal lobectomy; LAH left amygdalo-hippocampectomy; MTS mesial temporal sclerosis; CD cortical dysplasia; NS non-specific pathology; NSig non-significant.

sleep EEG. Where the results of any of these investigations suggested the possibility of bilateral temporal lobe damage, they then had an intracarotid Sodium Amytal (WADA) test (to determine the likelihood of surgery producing unacceptable memory deficits) and the implantation of foramen ovale electrodes with video telemetry to further determine the side of onset of seizures. Where foramen ovale electrode implantation did not provide conclusive lateralisation and localisation of the epileptic focus, depth electrode implantation was carried out. Patients were selected for operation on the basis of a combination of the following: a) Those with a structural lesion shown to be outside mesial temporal lobe structures were usually selected for temporal lobectomy; b) Patients in whom the onset of seizures was seen to be in mesial temporal structures by foramen ovale/depth electrode recordings and in whom the unoperated temporal lobe would not be able to support memory on the basis of the Sodium Amytal test, were normally offered an amygdalo-hippocampectomy; c) In doubtful cases, the decision was made at operation on the basis of the electrocorticography pattern.[18]

Pre- (and post) operative neuropsychological assessment included the following measures: a) A short form of the WAIS-R[19] using the Vocabulary Comprehension, Similarities, Block Design and Object Assembly subtests. Prorated Verbal and Performance IQ values, as well as "General Ability IQ" and "Verbal-Spatial Contrast IQ"[20] were computed. The last two measures are derived from a principal components analysis of the WAIS-R. "General Ability", a single component, accounts for most of the variance in WAIS-R subtest scores. Derived IQ values have a mean (SD) of 100 (15). "Verbal-Spatial Contrast" a second component, contrasts verbal and performance subtest scores; scores above 100 indicate relative superiority of spatial over verbal abilities, the converse applying to scores below 100; b) The Logical Memory (LM) passages (immediate and one hour delayed recall) and the Verbal Paired Associates test from the Wechsler Memory Scale.[21] Total ideas recalled for the LM passages were summed across the two stories. Delayed recall was also expressed as a percentage of immediate recall;[22] c) Immediate recall of visuospatial material (the Benton Visual Retention Test : BVRT[23] 10 s stimulus presentation) and delayed recall (45 minutes) of the Rey Ostereith Complex figure. The latter provided a measure of percentage recall;[22] d) Digit Span (from the WAIS-R) and Spatial Span using the Corsi block tapping test.[24]

The neuropsychological assessment and routine EEGs were repeated between one and four months post-operatively. Parallel forms of the learning and memory tests were used.

Statistical analysis

Analyses of variance (ANOVAs) and of covariance (ANCOVAs) were carried out using SPSS-PC$^+$.[25] Subjects' data were classified according to side (right or left) and type (AH or TL) of operation. ANCOVAs incorporated epilepsy-related variables (age at surgery (AS), age at onset of seizures (AOS), age at onset of chronic seizures (AOCS), time between onset of chronic seizures and surgery (TCS), and pre- and post-operative seizure frequency/total) as covariates. Pre-operative seizure frequency (PSF) was covaried with pre-operative cognitive measures and post-operative seizure total (PST) with post-operative and change measures. The extent of change in scores resulting from the operation was computed by subtracting the post-operative scores from pre-operative values. The significance of results was assessed for $p < 0·05$. Pearson Product-Moment correlations were also assessed at this level.

As the data are preliminary, no correction was applied for multiple tests.

Results

1) Patient characteristics

The patient groups did not differ on mean age at surgery. Mean age at first seizure and age at

Table 2 Pre- and postoperative mean (SD) values of verbal IQ (VIQ), Performance IQ (PIQ), General Ability and Verbal-Spatial Contrast IQs and differences in mean values (p < 0·05)

	RTL	*LTL*	*RAH*	*LAH*	*Difference*
Preoperative VIQ	92·55 (12·98)	88·50 (12·42)	88·11 (17·49)	89·29 (11·45)	NSig
Postoperative VIQ	94·09 (13·66)	86·25 (14·49)	89·33 (19·15)	87·57 (11·38)	NSig
Preoperative PIQ	95·91 (13·49)	90·00 (14·32)	97·56 (20·92)	97·86 (20·36)	NSig
Postoperative PIQ	98·91 (15·85)	98·38 (13·50)	96·11 (17·93)	96·14 (15·87)	NSig
Preoperative General Ability IQ	92·27 (9·36)	89·38 (12·26)	92·63 (14·67)	91·07 (9·01)	NSig
Postoperative General Ability IQ	94·55 (12·36)	90·38 (9·79)	93·63 (15·16)	90·14 (11·04)	NSig
Preoperative Verbal-Spatial Contrast IQ	103·91 (12·64)	99·63 (11·19)	108·00 (21·35)	105·71 (15·56)	NSig
Postoperative Verbal-Spatial Contrast IQ	101·82 (14·58)	109·25 (12·99)	107·13 (17·80)	108·86 (14·05)	NSig

onset of chronic seizures was less for those having left-sided operations than for those having right-sided surgery (AOS; F (1,38) = 5·51; AOCS F (1,38) = 4·69 $p < 0·05$ in each case) but there was no significant difference for the type of operation received. There was neither a main effect of SIDE nor OP when considering TCS, PSF and PST.

2) Intelligence

Pre- and postoperative measures of Verbal and Performance IQ (VIQ and PIQ), General Ability IQ and Verbal-Spatial Contrast IQ are given in table 2.

Preoperative mean scores for VIQ and PIQ were all within one standard deviation of the mean. No differences between groups were revealed by ANOVA for either measure although the LTLs tended to score lower than the RTLs on pre- and postoperative VIQ. No differences between groups were established when the epilepsy variables were included in the analyses. No differences between groups were found for postoperative VIQ and PIQ, General Ability and Verbal-Spatial contrast IQ measures.

There were no differences between groups on mean change scores for VIQ. For PIQ, AH resulted in mild deterioration, whereas TL was followed by an improvement [F (1, 36) = 4·72, $p < 0·05$]. This finding also held when the epilepsy variables were included as covariates. No differences between groups were seen on change scores for the General Ability IQ measure, but for the Verbal-Spatial Contrast IQ measure, a SIDE effect was found; right-sided surgery produced a lower score (reflecting a relative deterioration of visuospatial with respect to verbal ability), and left-sided surgery produced an increased score [F (1, 36) = 4·33, $p < 0·05$]. This finding was upheld when patient epilepsy-related variables were included as covariates.

Thus pre- and postoperatively absolute VIQ and PIQ measures did not distinguish between the TL and AH operations. Change scores on PIQ did differentiate between type of operation, with the AH leading to a mild deterioration and TL to improvement.

3) Memory

A) *Verbal material*

Pre- and postoperative scores on immediate delayed and percentage recall of the LM passages, and verbal paired associate learning are given in table 3.

Preoperatively a SIDE x OP interaction approached significance for mean scores on the immediate LM recall [F (1,36) = 3·55, p = 0·068] and when the epilepsy variables were included in the ANCOVAs. Thus RAHs tended to score less well than RTLs, but LAHs tended to score better than LTLs on this measure. No main effects or interactions were found for preoperative delayed or percentage recall. For preoperative verbal paired associate learning, the SIDE effect approached significance [F (1,36) = 3·25, p = 0·08]. This reached significance when AOS, AOCS, TCS were included as covariates ($p < 0·05$ in each case). Thus surprisingly, patients receiving left-sided operations scored better on this test of verbal learning before surgery than the right-sided cases.

Postoperatively no significant main effects or interactions were found for immediate, delayed or percentage recall of the LM passages, despite the tendency for those receiving left-sided surgery to perform worse than right-sided cases on these tests. For verbal paired associate learning, a main effect of SIDE [F (1,36) = 5·37, $p < 0·05$] and a SIDE × OP interaction [F (1,36) = 5·52, $p < 0·05$] were obtained. These were also found when AS, TCS and PST were included as covariates; only the SIDE effect remained when AOS and AOCS were covaried.

For change scores, an effect of SIDE was found for immediate story recall [F (1,36) = 5·37, $p < 0·05$]; left-sided cases showed clear deterioration as a result of surgery. ANCOVAs revealed a similar pattern of results. Delayed recall change scores yielded a main effect of SIDE when AOS, AOCS, TCS and PST were considered ($p < 0·05$ in each case). No significant main effects or interactions were found for percentage recall change scores. Change scores on verbal paired associate learning yielded a significant effect of SIDE [F (1,36), 18·67, $p < 0·001$] and the SIDE × OP effect approached significance [F (1,36) =

Table 3 Pre- and postoperative mean (SD) immediate, delayed and percentage recall of the Logical Memory Passages and learning score on Verbal Paired Associates and differences in mean values (p < 0·05)

	RTL	*LTL*	*RAH*	*LAH*	*Difference*
Preoperative LM Immediate Recall	19·91 (8·48)	16·44 (7·31)	13·28 (7·79)	19·50 (5·42)	SIDE × OP p = 0·068 (ANOVA)
Postoperative LM Immediate Recall	18·55 (9·01)	12·13 (6·31)	15·72 (9·47)	14·29 (5·17)	NSig
Preoperative LM Delayed Recall	15·45 (6·49)	12·25 (8·04)	9·06 (8·27)	13·27 (7·34)	NSig
Postoperative LM Delayed Recall	15·68 (7·74)	9·00 (7·04)	11·16 (9·38)	9·14 (5·51)	NSig
Preoperative LM Percent recall	79·00 (10·22)	69·63 (22·04)	54·89 (28·67)	83·92 (62·57)	NSig
Postoperative LM Percent recall	80·64 (15·02)	59·25 (22·56)	66·11 (27·03)	59·57 (26·45)	NSig
Preoperative Paired Associate Learning (max 21)	12·45 (3·08)	13·75 (2·43)	12·00 (4·30)	14·61 (3·49)	SIDE (L > R) (ANCOVA)
Postoperative Paired Associate Learning (max 21)	14·86 (2·26)	8·77 (4·17)	12·81 (3·92)	12·61 (4·49)	SIDE (L < R) and SIDE × OP

Table 4 Pre- and postoperative mean (SD) correct and error scores on the Benton Visual Retention Test (BVRT) and percentage recall of the Rey figure and differences in mean values (p < 0·05)

	RTL	LTL	RAH	LAH	Difference
BVRT Preoperative Correct	6·91 (2·11)	6·25 (1·17)	4·89 (1·76)	6·86 (1·35)	SIDE × OP
BVRT Postoperative Correct	5·64 (1·50)	6·25 (1·67)	4·67 (2·00)	5·78 (1·31)	NSig
BVRT Preoperative Errors	4·64 (3·61)	5·00 (1·93)	7·67 (3·20)	4·79 (2·49)	SIDE × OP 0·084 (ANOVA) SIDE × OP OP (R > L) (ANCOVA)
BVRT Preoperative Errors	6·09 (2·34)	4·63 (2·88)	8·22 (4·74)	5·79 (2·15)	SIDE (R > L)
Preoperative Rey Percentage Recall	54·09 (14·47)	50·88 (13·35)	47·11 (18·25)	57·14 (17·77)	NSig
Postoperative Rey Percentage Recall	53·55 (11·12)	51·25 (9·48)	46·11 (21·97)	59·50 (10·79)	NSig

3·37, p < 0·06]. Thus left-sided surgery was accompanied by deterioration on this test, and this held when the epilepsy variables were included as covariates; the SIDE × OP interaction reached significance for the covariate of TCS.

B) Visuospatial material

Two scores were derived from the BVRT, the number of correct figure reproductions (maximum 10) and the number of errors. Pre- and postoperative correct and error scores and pre- and postoperative recall of the Rey figure are shown in table 4.

Preoperatively a significant SIDE × OP interaction was obtained for the Benton correct scores [F (1,38) = 6·39, p < 0·05] and the same interaction approached significance for the error score [F (1,38) = 3·15, p = 0·084]. When AS was included as a covariate, the OP effect approached significance [F (1,38) = 8·76, p = 0·057] and the interaction became significant [F (1,38) = 7·67, p < 0·01]. The interaction and/or the OP effect reached significance when the epilepsy variables were included as covariates. No significant main effects or interactions were obtained for the pre-operative Rey figure percentage recall measure.

Postoperatively no main effects or interactions were significant for the BVRT correct scores. Analysis of error scores yielded a main effect of SIDE [F (1,38) = 4·32, p < 0·05] with right-sided surgery resulting in a greater number of errors than left-sided surgery. This held when AS, TCS, and PST were included as covariates. As with pre-operative scores, no significant main effects or interactions were obtained for the Rey percentage recall scores.

Table 5 Pre- and postoperative mean (SD) Digit Spans (forwards and backwards) and Spatial Spans (forwards and backwards) and differences in mean values (p < 0·05)

	RTL	LTL	RAH	LAH	Difference
Digit Span Forwards Preoperative	6·64 (1·21)	6·13 (0·99)	6·22 (1·09)	6·79 (1·31)	NSig
Digit Span Forwards Postoperative	5·90 (1·10)	6·00 (0·76)	5·78 (1·20)	6·71 (1·64)	SIDE (L > R) (ANCOVA)
Digit Span Backwards Preoperative	4·09 (1·30)	4·75 (0·89)	4·44 (1·94)	4·93 (1·33)	SIDE (L > R) (ANCOVA)
Digit Span Backwards Postoperative	4·40 (0·97)	4·75 (1·17)	4·44 (1·42)	5·79 (1·25)	SIDE (L > R)
Spatial Span Forwards Preoperative	5·27 (1·49)	5·63 (0·92)	5·13 (0·83)	5·79 (1·12)	NSig
Spatial Span Forwards Postoperative	5·00 (1·09)	5·50 (1·51)	4·89 (1·05)	5·36 (0·74)	NSig
Spatial Span Backwards Preoperative	5·18 (1·66)	5·38 (1·06)	5·29 (0·76)	4·93 (0·99)	NSig
Spatial Span Backwards Postoperative	5·09 (1·04)	5·50 (1·19)	4·50 (1·31)	5·36 (0·93)	NSig

BVRT correct change scores showed a significant SIDE × OP interaction [F (1·36) = 4·98, p < 0·05] with RTLS showing more deterioration than RAHs, and LTLs showing less deterioration than LAHs across the operation. This interaction held for all epilepsy variable covariates.

Error change scores yielded no main effects. The SIDE × OP interaction approached significance when TCS was included as a covariate. Thus RTLs tended to show greater deterioration than RAHs, and LAHs tended to show greater deterioration than LTLs on this measure.

No significant differences or interactions were found for the Rey change scores.

C) Digit and spatial spans

Mean digit and spatial spans (forwards and backwards) pre- and postoperatively are shown in table 5.

Preoperatively no main effects or interactions were detected for digit span forwards (DSF). This was also true for digit span backwards (DSB) except when AS was included as a covariate, when a main effect of SIDE was obtained [F (1,34) = 4·69, p < 0·05]. No main effects or interactions were revealed for spatial span forwards (SSF) or backwards (SSB).

Postoperatively DSF scores yielded a significant effect of side of operation with postoperative seizure frequency as a covariate [F (1,36) = 5·77, p < 0·05]. DSB yielded a main effect of SIDE [F (1,36) = 5·32, p < 0·05] and for both DSF and DSB, right-sided cases scored less well than left-operated patients. The DSB SIDE effect held with AS and TCS covariates, and approached significance with other epilepsy-related covariates. No main effects or interactions were found for postoperative measures of SSF or SSB.

Change scores for the span measures yielded only SIDE effects for DSF, when AS and PST were covaried, with the right-sided cases showing greater deterioration than the left-sided cases. No significant differences between the groups' mean change scores were found for DSB, SFF or SFB measures.

Relationship between epilepsy variables and cognitive performance

For each of the four operated groups, correlations were computed between the cognitive scores (pre- and postoperative) and in turn AOS, AOCS, TCS and AS. Correlations were undertaken between PSF and preoperative scores, and between PST and postoperative scores on cognitive tests. In view of the small numbers in each group, results can provide only initial impressions concerning the relationships between these variables and cognitive measures.

Different patterns of correlations emerged for those undergoing left- or right-sided surgery. Thus for right-sided cases, AOS or AOCS were related to some index of verbal learning or memory: (RAHs: postoperative delayed LM recall, postoperative verbal paired associative learning $p < 0{\cdot}01$; RTLs: postoperative percentage LM recall). Thus later epilepsy onset was related to better performance on these verbal tests. Age at surgery was negatively correlated with postoperative General Ability IQ (RAHs). This probably reflects a change in the relative superiority of visuospatial over verbal skills since for RAHs, younger age at surgery was associated with a greater superiority of visuospatial over verbal skills than was an older age at surgery. Later surgery for the RTLs was associated with poor postoperative recall of the Rey figure whereas those RAHs who were older at surgery had better preoperative recall of the figure than those who were younger at the time of operation.

For left-sided cases, no verbal learning or memory measures correlated with epilepsy-related variables. Instead BVRT correct and error scores seemed more sensitive to the effects of prolonged seizure activity: AOCS correlated negatively with postoperative BVRT errors for the LTLs and with preoperative error scores for the LAHs, and positively with BVRT preoperative correct scores for the LAHs. Preoperative BVRT correct and error scores, correlated with TCS negatively and positively respectively for the LAHS. Poor postoperative seizure control in the LTLs was associated with poorer recall of verbal (immediate LM recall, paired associate learning) and some visuospatial material (percentage recall of the Rey figure), suggesting that for these patients at least, ongoing seizure activity was disrupting information storage.

Discussion

This study documents pre- and short term postoperative cognitive functioning, and change in cognitive performance in 42 adults who had either a standard temporal lobectomy or a selective amygdalo-hippocampectomy for the relief of chronic temporal lobe epilepsy, and considered whether AH produces less cognitive impairment than TL. As yet numbers for each of the four operations are relatively small so the current findings are preliminary.

Although no differences between groups were found on pre- or postoperative IQ measures, change scores indicated that while TL (irrespective of side) was followed by an improvement in PIQ, AH was followed by mild deterioration. Right-sided surgery was followed by a relative lessening of the superiority of visuospatial over verbal skills, while the converse was true for left-sided operations. This is consistent with predictions based on side of surgery.

As found by Powell *et al*,[12] immediate recall of the LM stories was in general a more sensitive measure than delayed or percentage recall. Although Powell *et al* had found a significant postoperative effect of side of TL on this measure, only change scores resulting from the operation revealed an effect of side here, and also for delayed recall. For immediate recall, left-sided surgery resulted in deterioration; RTL also led to deterioration (but to a lesser degree) whereas RAH produced a mild degree of improvement. For delayed recall both left-sided groups' scores fell, whereas both right-sided groups (AH more than TL) showed some improvement. Thus on these measures there is only minimal evidence that AH and TL have different outcomes, and then only for the right-sided cases.

For verbal paired association, not reported earlier,[12] there was a clear postoperative effect of side of lesion and an interaction between side and type of surgery. Thus RTLs performed better than RAHs, but LTLs performed worse than LAHs. Left-sided surgery produced clear deterioration on this test (LTLs showing more deterioration than LAHs) and right-sided surgery produced some improvement (RAHs showing less improvement than RTLs). The SIDE × OP interaction approached or reached significance depending upon the covariates. Thus on this measure there is some indication that LAH will produce marginally less cognitive impairment than LTL, but that RAH will result in less improvement than RTL.

As reported earlier,[12] delayed recall of the Rey Complex figure did not distinguish between right- or left-sided surgery and there was no differential effect of the two types of operation. The BVRT scores were more sensitive. For "correct" change scores, the RTLs showed more deterioration than the RAHs, but the LTLs showed less deterioration than LAHs, suggesting marginal superiority of RAH over RTL on this measure. This interaction approached significance for error scores. Postoperatively only a significant effect of side of operation was found, and only for error scores, with right-sided cases making more errors than left-sided cases.

No differential effect of type of operation (AH or TL) was found for the span measures. A significant postoperative effect of side of surgery was found for DSF and DSB, and right-sided cases showed more deterioration across the operation on DSF than did those with left-sided surgery.

The observation of SIDE × OP interactions (either reaching or approaching statistical significance) for preoperative measures, suggests that some patients' characteristics may be affecting cognitive performance. It is conceivable that underlying neuropathology may relate to performance on the memory tests. As can be seen from table 1, unlike the TL cases, most of the AH cases were found to show mesial temporal sclerosis (MTS). McMillan *et al*[13] noted that preoperative differences in verbal memory in MTS patients were unremarkable for side of lesion, and the overall level of verbal recall fell between that of the right- and left-sided groups with tumour-like pathology, with the right-sided cases showing above average and the left-sided cases below average verbal memory. Although the present numbers are small it is possible that the SIDE × OP interactions could be accounted for by the tumour-like pathology cases in the TL groups (in addition to the MTS cases) and the absence of such tumour-like pathology cases in the AH groups.

As with Powell *et al's* study[12] AOCS again predicted cognitive scores more consistently for right-sided than left-sided cases. Age at surgery showed a stronger association with cognitive performance for the right-sided than for the left-sided cases, as was previously reported. In our study right-sided cases with later onset seizure activity developed better verbal learning and memory suggesting that it is not only verbal intellectual abilities[12] that can develop better in the absence of early right-sided seizures. Similarly, considering BVRT scores, some aspects of non verbal activities develop better in the absence of early left-sided seizures. These findings are relevant when assessing patients for epilepsy surgery since early onset epilepsy may be expected to influence the likelihood of finding impairment in both verbal and non-verbal memory skills.

Postoperative seizure total related to few cognitive measures. For the RTLs and LTLs poor seizure control affected performance on material specific tests related to the side of lesion (although a more generalised effect on cognitive performance was found for the LTLs). The RAHs and LAHs, overall showed little seizure activity before the postoperative assessment, thereby reducing the possibility of eliciting correlations.

In conclusion, there is some indication that on specific measures of cognitive functioning (verbal paired associate learning, immediate recall of visuospatial material) an AH rather than a TL performed on the temporal lobe thought to mediate that particular function will produce less pronounced impairment in terms of change resulting from operation, as indicated by short-term cognitive evaluation. Equally, however, an AH carried out on the temporal lobe not thought to mediate these skills appears to result in less improvement or more deterioration in that skill than will a TL, except in the case of delayed story recall, where RAH overall produced more improvement than RTL. Longer term outcome, for formal and everyday cognitive functioning and seizure control must, however, be evaluated.

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