Language outcomes following neurosurgery for brain tumours: A systematic review

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Abstract

BACKGROUND: Language function is susceptible to the effects of brain tumours during both the tumour growth phase and during neurosurgical resection.

AIM: This paper aimed to systematically review existing literature to determine the current status of knowledge about language outcomes following neurosurgery.

METHODS: A systematic review was conducted involving a detailed literature search using online databases, quality assessment of relevant articles and data extraction.

RESULTS: Of the 1449 articles retrieved, nine articles satisfied the study criteria. Overall, these studies reported variable patterns of language function post-surgery, however, there was a trend towards an early post-surgical decline in language function that greatly improved by 3 months. The likelihood of developing post-surgical communication impairments was influenced by a number of factors including pre-operative aphasia and the identification of sub-cortical language tracts inside the tumour margin, however, further research is required to fully elucidate pertinent predictors.

CONCLUSION: These findings have implications for rehabilitation programs following brain tumour surgery and suggest that there are a number of key gaps warranting further investigation.

Keywords: Brain tumour, aphasia, language, language impairment, neurosurgery, systematic review

1. Introduction

While brain tumours have a lower incidence rate than other forms of cancer, brain tumours can potentially produce greater functional impairments due to their involvement with the central nervous system (Owensworth, Hendersen, Chambers & Shum, 2009). Brain tumours in adults are often located in or adjacent to language areas, creating a risk of language impairments during the tumour growth process as a result of displacement or infiltration of language areas by the invading tumour (Anderson, Damasio, & Tranel, 1990).

Given the slow growing nature of many brain tumours (in comparison to more sudden neurological events such as stroke), neural reorganization can occur during this tumour growth process, however, the extent of this reorganization can vary substantially between individuals (Desmurget, Bonnemblanc, & Duflau, 2007). In addition to potential impairments stemming from the tumour growth process, neurosurgical interventions have the potential to pose a significant threat to an individual’s language function (Bartha, Knoepf, Pfisterer, & Benke, 2000). The primary aim of neurosurgery for tumours is to preserve brain function while maximising tumour resection (Tieleman, Deblaere, Van Roost, & Van Damme, 2009; Wilkinson, Romanowski, Jelinek, Morris, & Griffiths, 2003; Zimmermann, Seifert, Tran-Takis, & Raabe, 2001). To increase the chances of
survival for patients, as much tumour tissue as possible is resected during surgery (Hall, Kim, & Tew, 2008; Wilkinson et al., 2003). As a result, there is a high chance of post-surgical neurological impairment. Language function is particularly vulnerable to damage due to the wide representation of language function in the brain and the high variability in brain localization between individuals (Bartha et al., 2000). It has been estimated that as many as one third to one half of individuals who undergo surgery for a left-sided brain tumour will experience a post-surgical language disturbance (Davie, Hutchison, Barringer, Weimberg, & Lewin, 2009). Language impairments can have a significant detrimental impact upon quality of life (Gulati et al., 2009) and return to employment post-surgery. This latter point is particularly pertinent given the typically higher survival rates for young adults with brain tumours relative to older adults (CBTRUS, viewed 2 February 2012). Therefore, it is vital that we understand the precise nature of communication changes following brain tumour surgery in order to provide targeted and effective rehabilitation programs. Consequently, the aim of this paper was to conduct a systematic review to determine the current status of knowledge about language outcomes following neurosurgery.

2. Methods

2.1. Identification of studies

To answer the research question “What are the effects of neurosurgery on language outcomes in individuals with brain tumours compared with pre-surgical language status?” online database searches were conducted using Web of Science, Pubmed, CINAHL, Embase and the Cochrane library (See Appendix 1 for a list of search terms for each database). Searches were limited to: 1990- February 2012, humans, adults, and English. The time period of 1990- February 2012 was selected due to changes in surgical techniques over time. Following the removal of duplicate articles, titles and abstracts were screened for suitability by EF. Hand searches using the reference lists of potentially suitable articles were also conducted to find additional articles. Full text versions of all potentially suitable articles were then retrieved and reviewed (See Fig. 1 for a flow chart of the review process).

The suitability of each paper for inclusion in the review was based on the following inclusion and exclusion criteria. The inclusion criteria for articles in the review were: (1) studies published from 1990-February 2012 that investigated the effects of a single neurosurgery on language functioning in adults with a single brain tumour in either cerebral hemisphere, and (2) studies that used standardised language assessments recognised for measuring language comprehension and expression (articles that only listed a communication impairment e.g., aphasia were excluded due to lack of objective information about the communication diagnosis). Exclusion criteria included: (1) single case studies and case series which reported data for participants individually (due to the potential to report individuals with unusual clinical outcomes), (2) studies that focused on bilingual or multilingual participants (due to the potential confounding influence upon communication assessments), (3) the absence of a pre or post surgery language measure (e.g., articles that reported only pre surgery or only post surgery measures), (4) articles that specifically focused on individuals with specific types of communication impairments post surgery (these studies may have biased the review results due to potential inflation of unusual communication impairments post surgery), (5) studies reporting individuals with acoustic neuromas or cerebellar tumours, and (5) studies targeting cognitive function rather than language function.

2.2. Quality assessment

All articles in the final list of studies deemed suitable for inclusion in the review underwent a quality assessment. The quality assessment was conducted by two reviewers independently (EF and KH). Results of the quality assessments were compared and any potential differences in ratings were discussed until a consensus was reached. The quality assessment used for the review was based upon the McMaster University Critical Review form for quantitative studies (Law, Stewart, Pollock, Leits, Bosch, & Westmorland, 1998). The McMaster University Critical Review form assesses study quality by evaluating areas such as the study purpose, potential bias (stemming from participant selection, measurement and intervention domains), sample characteristics, intervention details, analysis of results, description of participant drop-outs, identification of clinical implications, and conclusions reached, using a series of questions (Law et al., 1998). Each reviewer independently rated each of the studies according to these questions. Responses were categorised as ‘yes’, ‘no’, or ‘unknown’. With the exception of questions pertaining to bias, ‘yes’ responses were...
Fig. 1. Systematic review process.

coded as ‘1’ while ‘no’ and ‘unknown’ responses were coded as ‘0’. For questions relating to study bias, ‘no’ responses were coded as ‘1’ while ‘yes’ and ‘unknown’ responses were coded as ‘0’. Each study was then given an overall quality rating by summing the number of ‘1’ scores. The quality rating was out of a maximum value of 19. Inter-rater agreement for each of the ratings was calculated using the Kappa measure of agreement with IBM SPSS statistics 20.

2.3. Data extraction

Data extraction was undertaken independently by EF and was checked by KH. Data extracted included: number of participants and demographic characteristics, tumour location, surgery details, formal assessment scores, statistics used, length of follow-up, and details about communication rehabilitation post-surgery (See Tables 1 and 2).

3. Results

3.1. Identification of relevant studies

Of the 1449 articles retrieved (2121 prior to removal of duplicates), only nine articles satisfied the study criteria (see Fig. 1). The main reasons for exclusion from the study were being a case study or case series (e.g., Bartha et al., 2000), absence of pre or post-surgical communication assessments (i.e., reporting assessment results at one time point only) (e.g., Davie et al., 2009), and omission of specific assessment scores (e.g., Duffau, Denvil, & Capelle, 2002). Studies that reported only cognitive measures were not included. The two reviewers agreed that the nine articles included for review met all of the study inclusion criteria. The nine articles selected for inclusion in the review consisted primarily of before-after study designs (n = 7), with one cohort study and one case-control study.

3.2. Quality assessment

A Kappa measure of agreement value of 0.754 (p < 0.001) was obtained, suggesting a good level of agreement between the two quality raters. Out of a possible score of 19 (calculated by adding all ‘1’ responses), the median study quality rating was 10 (range 6 – 14) (See Table 1).

3.3. Participant demographic factors

In total, the combined studies investigated language function in 499 individuals who underwent neurosurgical resection of a brain tumour. This figure included only the 30 patients tested by Signorelli et al. (2007) who completed language assessments (as not all patients received language assessments) and the 20
Table 1: Methodological and surgical details of reviewed studies

<table>
<thead>
<tr>
<th>Authors</th>
<th>Design</th>
<th>Quality</th>
<th>N</th>
<th>Age, Gender</th>
<th>Hand</th>
<th>Grade</th>
<th>Tumor site</th>
<th>Surgery details</th>
</tr>
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<tbody>
<tr>
<td>Bello et al.</td>
<td>BA</td>
<td>11</td>
<td>88</td>
<td>32-68 y</td>
<td>M, F</td>
<td>44 HG, 44 LG</td>
<td>frontal lobe (59), parietal lobe (10), temporal lobe (32)</td>
<td>Awake/parietal craniotomy with cortical and subcortical language stimulation 64 pts (all of the LG pts had pre-op fMRI scans with language tasks)</td>
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<tr>
<td>Duffau et al.</td>
<td>BA</td>
<td>8</td>
<td>25</td>
<td>27-57 y</td>
<td>M, F</td>
<td>All LG</td>
<td>Left dominant cortex: superior frontal gyrus (17), middle frontal gyrus (4), inferior frontal gyrus (4)</td>
<td>Intra-op language and sensori-motor mapping</td>
</tr>
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<td>Ilmberger et al.</td>
<td>BA</td>
<td>10</td>
<td>149</td>
<td>15-62 y</td>
<td>M, F</td>
<td>All LG</td>
<td>Frontal (55), frontotemporal and insular (3), frontoparietal (4), parietal (4), temporal (8), temporal and insular (3), temporal and parietal (4)</td>
<td>Intra-op cortical language mapping for all patients. Some patients also received subcortical pathway mapping Complete tumor resection for 48.4% of patients. Some pts received adjuvant radiotherapy and/or chemotherapy.</td>
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<td>Study</td>
<td>Design</td>
<td>N</td>
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<tr>
<td>Teixidor et al. (2007)</td>
<td>BA 14 23</td>
<td>19 R, 2 L, 2 A</td>
<td>LG gliomas in language areas; 6 SMA (1 R, 5 L), 3 L prefrontal cortex, 1 L frontal/occipital, 4 L opercular-insular region, 4 sole insula (2 R, 2 L), 1 L parieto-occipital area, 4 parieto-temporo-occipital junction (3 L, 2 R)</td>
<td>1 R hem, rest L hem</td>
<td>For language area pts: complete resection 22 pts</td>
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<tr>
<td>Thomson et al. (1997)</td>
<td>CC 7</td>
<td>12 M, 11 F</td>
<td>BT: 33-77y, 12 M, 8 F</td>
<td>All R</td>
<td>15 gliomas, 3 metastases, 2 meningiomas</td>
<td>R cerebral hem brain tumour in the frontal, temporal or parietal lobes (precise sites not described)</td>
<td>Intra-op electrical stimulation, Presurgical fMRI with semantic fluency, covert sentence repetition and story listening to determine language hem dominance</td>
<td></td>
</tr>
<tr>
<td>Thomson et al. (1998)</td>
<td>BA 13 33</td>
<td>All R</td>
<td>BT: 33-71y, 10 M, 16 F</td>
<td>All R</td>
<td>WAB: 8 metastases, 6 GBM, 5 anaplastic astrocytomas, 5 meningiomas, 2 LGG</td>
<td>WAB: R hemisphere tumor. Frontal (9), temporal (7), parietal (11), fronto-temporal (2), ponto-parietal (3), parieto-temporal (2)</td>
<td>Variety of surgical techniques (classical craniotomy and lesoectomy, stereotactic craniotomy with cortical stimulation of awake pt prior to resection)</td>
<td></td>
</tr>
<tr>
<td>Whittle et al. (1998)</td>
<td>BA 14</td>
<td>18-75y; 26 M, 16 F</td>
<td>All R</td>
<td>GBM (4), meningioma (10), metastasis (7), anaplastic glioma (7), LG glioma (2)</td>
<td>Solitary L sided supratentorial intracranial tumor, 25 tumours involved Broca’s or Wernicke’s area</td>
<td>Classical craniotomy or stereotactic guided microsurgery, resection with ultrasonic aspirator, lesoectomy for cerebral metastases, cytoreductive surgery for LG or HG gliomas, Simpson grade I or II excision of meningiomas. Excised all visibly abnormal tumour tissue. 6 pts had awake cortical stimulation and language mapping.</td>
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Note: BA = before-after study design; CC = case-control study design; N = number of participants; LPA = Left Perisylvian Area; pt = participant; op = operation; L = left; R = right; A = ambidextrous; M = male; F = female; y = age; LG = low grade; HG = high grade; hem = hemisphere; fMRI = functional magnetic imaging; DTI = diffusion tensor imaging; GBM = glioblastoma multiforme; WAB = Western Aphasia Battery (Kertesz, 1982); BNT = Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983); SMA = supplementary motor area.
brain tumour patients tested by Thomson et al. (1997) (i.e., the non-tumour control group was excluded due to the absence of a brain tumour). Ilmberger et al. (2008) reported that 4 patients in their series received two surgeries, and reported the results of these patients as 8 patients rather than reporting the results separately. The remaining patients in the study received only a single surgery (Ilmberger et al., 2008). The overall ages of patients included in the studies ranged from 9–79 years. Signorelli et al. (2007) included a 9 year old patient, while Teixidor et al. (2007) included a 15 year old patient. All other studies involved only patients aged over 18 years. The majority of participants were male and right handed (see Table 1). Two studies exclusively investigated patients with low grade gliomas, while the remaining studies included both high and low grade gliomas. Only two studies (Thomson et al., 1997, 1998) examined patients specifically with right hemisphere lesions. The remaining studies investigated patients with left hemisphere tumours only (n = 3), or both left or right hemisphere tumours (n = 4).

3.4. Surgery details

The study by Thomson et al. (1997) did not provide any details about the surgical resection procedure. Of the remaining 8 studies included in the review, all reported using intra-operative electrical stimulation to assist in the identification of eloquent areas (however, not all of the studies used the technique with all patients). Three studies (Bello et al., 2007; Teixidor et al., 2007; Papagno et al., 2011) also reported using pre-surgical functional magnetic imaging (fMRI) language mapping techniques (See Table 1).

3.5. Outcome measures used for recording post-surgical changes

In terms of outcome measures, a variety of assessments were used in the studies (See Table 1). Two studies (Thomson et al., 1998; Whittle, Borthwick, & Haq, 1998) used the Western Aphasia Battery (WAB) (Kertesz, 2006) and the Boston Naming Test (BNT) (Kaplan et al., 1983). However, Whittle et al. (1998) administered the battery to patients with left sided tumours, while Thomson et al. (1998) administered the battery to patients with right sided tumours. The other study that exclusively investigated right sided tumours (Thomson et al., 1997) used an assessment designed specifically for measuring right hemisphere language function, the Right Hemisphere Language Battery (Bryan, 1989), but concluded that the battery was unsuitable for discriminating between right hemisphere language dysfunction and control patients, or for measuring changes in right hemisphere language function following right hemisphere tumour resection.

Two studies used the Boston Diagnostic Aphasia Examination (BDAE; Goodglass & Kaplan, 2001), with Signorelli et al. (2007) also using the Montreal-Toulouse Protocol (MT-86; Beland & Lecours, 1990) and Teixidor et al. (2007) also using the DO80 (Metz-Lutz, Kremin, Delche, Hannequin, Ferand, & Perrier, 1991). Ilmberger et al. (2008) utilized the Aachen Aphasia Test (AAT; Huber, Poock, Weniger, & Willmes, 1983), however, 12 patients at the first assessment post-surgery were assessed based on clinical report rather than the standardised assessment and at the second assessment post-surgery 25 patients were assessed by clinical report rather than the standardised assessment. The remaining three studies (Bello et al., 2007; Papagno et al., 2011; Duffau et al., 2003) used a self-selected mixture of formal and non-formal assessments.

3.6. Assessment results

3.6.1. Overall patterns of language function

Overall, the studies reviewed reported variable patterns of language function post-surgery; however, the predominant trend was towards an early post-surgical decline in language function that greatly improved (or even resolved) within three months. Duffau and colleagues (2003) reported that the majority of patients in their study experienced anoma and/or dysarthria shortly post-surgery, which resolved within 7 days to 3 months. Teixidor et al. (2007) also reported a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experienced a decline in language function immediately post-surgery, which by three months in a subset of patients retested had returned to pre-surgery language assessment scores (Teixidor et al., 2007). Signorelli et al. (2007) reported that 17 out of 28 patients experi...
Table 2

Assessment and language outcome details of reviewed studies

<table>
<thead>
<tr>
<th>Authors</th>
<th>Assessment</th>
<th>Results</th>
<th>Follow-up</th>
<th>Therapy</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bello et al. (2007)</td>
<td>Pre-op, intra-op, post-op</td>
<td>3 days post-op: Decline in language function in 67.3% of pts with identified subcortical language tract involvement vs no worsening of language function in pts without identified subcortical tract involvement.</td>
<td>3 days post-op, 1 and 3 month post-op</td>
<td>N/A</td>
<td>No long-term follow-up</td>
</tr>
<tr>
<td></td>
<td>Pre-op/post-op: Spontaneous speech, oral naming by phonemic cue or semantic category, famous face naming, object or action picture naming, word or sentence comprehension, transcoding, token test, digit span, counting</td>
<td>Intra-op: For pts with HG gliomas and had identified subcortical involvement had persisting language impairments post-op (anomia and phonemic paraphasias for 1 pt, semantic paraphasias for 1 pt).</td>
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<tr>
<td></td>
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<td>Frontal tumors: counting, oral naming.</td>
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<td></td>
<td></td>
<td>Temporal tumors: oral naming, word and sentence comprehension</td>
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<tr>
<td>Duffau et al. (2003)</td>
<td>Verbal comprehension, spont speech, naming, verbal fluency, narrative tasks, repetition.</td>
<td>Post-op the majority of pts had transient anomia and dysarthria. Tended to resolve within 7 days to 3 mths. Post-op pts who had superior frontal gyrus resections had severe anomia and mild dysarthria. Pts who had middle frontal gyrus resections had moderate anomia and dysarthria. Pts who had inferior frontal gyrus resections had severe dysarthria and 25% had mild anomia.</td>
<td>Immediately post-op, 3 months</td>
<td>All but no details</td>
<td></td>
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<tr>
<td>Ilmberger et al. (2008)</td>
<td>AAT</td>
<td>21 days post-op new aphasia was observed in 41 of the 128 pts who had no aphasia pre-op. In total, 60 pts had aphasia post-op.</td>
<td>2 post-op (1 within 21 days, medium = 7 days). 2nd 12 mths, median 29.5 weeks</td>
<td>N/A</td>
<td>German</td>
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<td></td>
<td></td>
<td>Pre-op (1–3 days prior) and 2 post-op (1st within 21 days, medium = 7 days, 2nd 12 mths, median 29.5 weeks)</td>
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<tr>
<td>Papagno et al. (2011)</td>
<td>Pre-op, 3–7 days post-op, 3 mths</td>
<td>Pts with uncinate fasciculus removed performed worse post-op than pts with uncinate fasciculus intact, no difference between the groups pre-op</td>
<td>Pre-op, 3–7 days and 3 mths post-op</td>
<td>N/A</td>
<td></td>
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<tr>
<td>Signorelli et al. (2007)</td>
<td>BDAE and MT/86</td>
<td>Language assessment only with the 30 pts with tumors in or near language areas. For all 30 pts, pre-op all subtest scores were below the minimum for their age and education level.</td>
<td>Immediately post-op, 3 and 12 mths post-op</td>
<td>N/A</td>
<td>1 pediatric (9 years old)</td>
</tr>
<tr>
<td>Teixidor et al. (2007)</td>
<td>BDAE and DO80 pre-op and immediate post-op period and 3 mths later</td>
<td>Immediately post-op: statistically significant reduction in auditory comprehension of commands, concrete phrase repetition, spelling and sentence dictation. The change in verbal working memory was not related to the extent of resection or tumor location in the primary or supplementary cortex. The 8 pts who were reassessed at 3 mths following rehabilitation did not display significant differences between their global BDAE or DO80 scores compared with pre-op</td>
<td>8 pts received 1 hr of therapy 3x weekly. Visual and auditory modality progressing up a hierarchy</td>
<td>Designed to assess the change in verbal working memory function, but used standardized language assessments so included in the systematic review</td>
<td>Assessment at 3 mth follow-up involved repetition of the pre-op assessments only for pts who received SP rehabilitation</td>
</tr>
<tr>
<td>Study</td>
<td>Test(s)</td>
<td>Timepoints</td>
<td>Scores Post-op</td>
<td>Notes</td>
<td></td>
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</tr>
<tr>
<td>Thomson et al. (1997)</td>
<td>RHLB</td>
<td>Tumor group did not differ from the control group on 67 assessment subtests; differed only on discourse analysis Pre and approx 5 days post-op for BT group</td>
<td>N/A</td>
<td>Only 26 of the 33 pts who completed the WAB did before and after surgery assessments</td>
<td></td>
</tr>
<tr>
<td>Thomson et al. (1998)</td>
<td>WAB and BNT</td>
<td>Pre-op and post-op (6 days post discharge) Pre-op and post-op (6 days post discharge) Median time between assessments = 6 days</td>
<td>N/A</td>
<td>High level language wasn’t assessed</td>
<td></td>
</tr>
<tr>
<td>Whittle et al. (1998)</td>
<td>WAB and BNT</td>
<td>Pre-op and post-op (before discharge: usually 4-5 days post-op) Pre-op anomic pts significantly improved post-op on the BNT but were still anomic. No significant change post-op for non-anomic pts on the BNT</td>
<td>N/A</td>
<td>High level language wasn’t assessed</td>
<td></td>
</tr>
</tbody>
</table>

Note. N = number of participants; LPA = Left Perisylvian Area; pt = participant; op = operation; AC = auditory comprehension; BNT = Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983); L = left; R = right; CVA = cerebrovascular accident; WAB = Western Aphasia Battery (Kertesz, 1982); BDAE = Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 2001); SMA = supplementary motor area; WNL = within normal limits; DO80 = standardized picture naming test (Metz-Lutz, Kerem, Delche, Harmaquin, Forand, & Perier, 1991); SMA = supplementary motor area; MCA = middle cerebral artery; AAT = Aachener Aphasie Test (Huber, Poeck, Weniger, & Willmes, 1983); RHLB = Right Hemisphere Language Battery (Bryan, 1989); MT-86 = Montreal Tractography protocol (Béliveau & Lecours, 1990); N/A = not available.
Papagno et al. (2011) observed that in general, patients experienced a decline in language performance shortly post-surgery. Three months later, patients with a frontal tumour (+/- uncinate fasciculus removed) often displayed improved assessment scores; however, patients with a temporal tumour and had the uncinate fasciculus removed tended to remain impaired or worsen by the three month follow-up (Papagno et al., 2011). Bello and colleagues (2007) reported that 3 days post-surgery a decline in language function was observed in 67.3% of patients with a tumour involving a subcortical language tract (exact tracts were not specified), but no worsening of language function in patients without identified subcortical language tract involvement. By one month post-surgery, all patients with low grade gliomas with identified subcortical language tract involvement and a post-surgical decline in language function experienced resolution of their language impairments. In contrast, patients with high grade gliomas and identified subcortical language tract involvement experienced persisting language impairments, with no further change at 3 months (Bello et al., 2007) (See Table 2).

In contrast with the above studies, Thomson et al. (1998) and Whittle et al. (1998) reported significant improvements in language function shortly (typically less than one week) post-surgery. An earlier study by Thomson et al. (1997) reported no change in language function in a group of patients with right hemisphere tumours resected, (See Table 2).

3.6.2. Specific communication impairments observed

Signorelli and colleagues (2007) noted that in the 17 patients with impaired language immediately post-surgery, all had expressive language difficulties, while only 6 patients experienced receptive language difficulties. Bello and colleagues (2007) reported that tumours in the precentral gyrus and supplementary motor area (SMA), and large tumours involving the superior and medial frontal gyrus and extending towards the SMA tended to result in anomia or phonemic paraphasias and reduced spontaneous speech. The researchers also noted that tumours in the middle frontal gyrus and paralimbic lesions tended to be associated with post-surgical dysarthria, while tumours in Broca’s area tended to result in post-surgical dysarthria and/or phonemic paraphasias. Temporal lobe tumours were associated with occasional anomia or semantic paraphasias and sometimes reduced spontaneous speech (Bello et al., 2007). Duffau and colleagues (2003) reported that patients who had superior frontal gyrus resections had severe anomia and mild dysarthria, patients who had middle frontal gyrus resections had moderate anomia and dysarthria, while patients who had inferior frontal gyrus resections had severe dysarthria and one quarter had mild anomia (See Table 2).

3.6.3. Factors predicting language outcomes post-surgery

Two of the studies included in the review had a specific focus on factors that predicted language outcomes post-surgery. Bello et al. (2007) found that the identification of subcortical language tracts during intra-operative stimulation and pre-operative language function predicted the occurrence of post-operative language impairments. Ilmberger et al. (2008) also found that post-operative language impairments were predicted by pre-operative aphasia and language-positive sites within the tumour, along with intra-operative complications and non-frontal lesion location. Additionally, Ilmberger et al. (2008) found that for patients without pre-surgical aphasia, low (albeit still within normal limits) naming performance pre-surgery was associated with post-operative aphasia. The researchers also investigated factors that predicted persisting language impairments, and found that persistent aphasia at seven months post-surgery was predicted by increased age and pre-operative aphasia (Ilmberger et al., 2008).

3.7. Follow-up

On the whole, the majority of studies included in the review employed relatively short follow-up timeframes. Of particular note, the median time between the pre and post surgical assessments in Thomson et al. (1998) was 6 days. Similarly, short timeframes were also used by Whittle and colleagues (1998) (4–5 days post-surgery) and Thomson et al. (1997) (4 days post-surgery). Three studies ceased following-up the communication function of patients 3 months post-surgery (Bello et al., 2007; Duffau et al., 2003; Papagno et al., 2010). Only two studies (Ilmberger et al., 2008; Signorelli et al., 2007) re-assessed patients 12 months post-surgery, however, Ilmberger et al. (2008) did not re-assess all patients with the standardised assessment at the 12 month point and while the assessment was designed to occur 12 months post-surgery, the median time was only 29.5 weeks. These results suggest that there is currently limited information about long-term communication outcomes
following surgical resection of brain tumours (See Table 2).

3.8. Post-surgical resection communication rehabilitation

Only two studies mentioned whether participants received communication rehabilitation following their neurosurgery. Duffau et al. (2003) reported that all 25 patients in their study received treatment post-surgery, however, no details were provided about the therapy type or intensity. Only one study (Teixidor et al., 2007) provided information regarding therapy frequency and general type of therapy. Seven studies did not mention whether participants received any behavioural intervention to remediate any communication difficulties (See Table 2).

3.9. Adjuvant therapy

Only one study (Ilmberger et al., 2008) reported that some patients received adjuvant therapy post-surgery. In this study, the authors reported that all patients with grade III gliomas or glioblastomas received conventionally fractionated external beam radiation. For patients with grade II gliomas, radiation therapy was only initiated when the tumour progressed and was unable to be successfully resected. The exact number of patients in this category was not reported. The authors commented that chemotherapy was employed as a second or third treatment option, but again did not specify the number of patients who received this form of adjuvant therapy (Ilmberger et al., 2008). No other studies in this review commented about whether or not patients received adjuvant radiation or chemotherapy post-surgery.

In terms of medications, Thomson et al. (1998) reported that all patients in their study received steroids pre-surgery, with the dose reduced by the time of the post-surgery assessment. Three studies (Ilmberger et al., 2008; Teixidor et al., 2007; Whittle et al., 1998) reported that some patients in their studies received anti-epileptic medications pre- and post-surgery but did not report specific patient numbers. Ilmberger et al. (2008) and Whittle et al. (1998) reported that there was a reduction in medication prescription by the post-surgery assessment, while Teixidor et al. (2007) reported that three patients had an increase in anti-epileptic medications post-surgery to control post-operative seizures. Four studies (Bello et al., 2007; Duffau et al., 2003; Papagno et al., 2011; Thomson et al., 1997) did not mention medication use.

4. Discussion

4.1. Patterns of language function post-surgery

Overall, the studies included in the review reported variable patterns of language function post-surgery, however, a large number of patients experienced new or worsening of existing language disorders shortly post-surgery which then improved (or resolved) by three months post-surgery (Bello et al., 2007; Duffau et al., 2003; Teixidor et al., 2007; Signorelli et al., 2007; Papagno et al., 2010). This pattern of initial worsening and then rapid improvement has been attributed to a number of potential factors including resolution of post-surgical oedema, transient retraction injury, initial displacement of neural structures, and neuroplastic mechanisms (Bello et al., 2007). In terms of neuroplastic mechanisms, Ilmberger and colleagues (2006) proposed that the change between follow-up assessment sessions may have reflected functional reorganisation, possibly by one or more of the perilesional areas, distant ipsilateral structures, or homologous contralateral regions. This proposal is supported by Desmurget and colleagues (2007) who suggested that the recovery of function post-surgery may involve the combination of a number of neuroplastic mechanisms. Concordantly, complementary and more comprehensive evidence from stroke patients also suggests that language recovery following stroke can be underpinned by a range of brain mechanisms (Hamilton, Chrysikou, & Coslett, 2011). Interestingly, Ilmberger et al. (2008) proposed that neuroplastic mechanisms may be less effective in older patient who may have already relied upon these mechanisms prior to neurosurgery, however, the influence of age on recovery mechanisms has not been examined extensively. Furthermore, Pillai (2010) argued that neuroplastic mechanisms (especially contralesional homologous reorganisation) can vary substantially between individuals. The results of the articles included in this review support this comment, as not all patients in all the studies displayed the same post-surgical language impairments and recovery patterns. It must be noted, however, that unlike stroke recovery literature, to date there has been minimal research into post-surgical language plasticity in adults and as a result the precise neuroplastic mechanisms underlying post-surgical recovery remain largely unknown (Desmurget et al., 2007; Pillai, 2010). Further research that relates neuroimaging data obtained during the recovery period with pre-post surgical behavioural data could help address this knowledge gap (Pillai, 2010).
Bello and colleagues (2007) and Ilmberger and colleagues (2008) found that the likelihood of post-surgical language impairments was increased for patients with pre-operative aphasia and who had subcortical language tracts that were likely to be impacted by surgery identified during intra-operative stimulation. Interestingly, post-operative language impairments were not predicted by tumour histology or location (Bello et al., 2007). This was supported by Teixidor et al. (2007) who also observed that changes in assessment scores post-surgery were not related to the extent of resection or tumour location in the primary or supplementary cortex. In contrast, Ilmberger et al. (2008) found that post-operative aphasia was associated with non-frontal lesion location, suggesting that further research is required in this area. Ilmberger et al. (2008) additionally found that post-operative aphasia was also predicted by the occurrence of intra-operative complications and for patients without aphasia pre-surgical naming performance that was low (but still within normal limits). It was suggested that the link between poor naming performance and post-operative language impairments may have reflected the link between naming and verbal intelligence, such that patients with higher verbal intelligence may be less likely to experience a decline in language function after neurosurgery (Ilmberger et al., 2008), however, this suggestion warrants further investigation. The mixed picture presented by these studies suggests that further research is required to identify factors that predict the occurrence of post-operative language impairments.

4.2. Assessments/evaluation measures

The outcome measures employed in the studies included in the review can be classified into two groups: (1) standardised aphasia assessments used primarily with stroke patients, and (2) self-selected tests not specifically designed for patients with aphasia and often normed on healthy adults. Two studies (Thomson et al., 1997; Whittle et al., 1998) used the WAB (Kertesz, 2006) which is a general measure of language function and does not provide information about potential higher-level language difficulties. This is particularly important given that the majority of patients experienced mild aphasia post-surgery on the language measure (thus, patients may have experienced high-level language difficulties that manifested as only mild language impairments on the general assessment). It must also be noted that Thomson et al. (1998) used the WAB (Kertesz, 1982) and the BNT (Kaplan et al., 1983) to measure language function in patients with right hemisphere tumours. The WAB may not have been sufficiently high level to detect the typical cognitive-communication impairments frequently associated with right hemisphere dysfunction. Of the two studies that specifically investigated language function in patients with right hemisphere tumours, only one study (Thomson et al., 1997) used an assessment designed specifically for measuring right hemisphere language function. The researchers used the Right Hemisphere Language Battery (Bryan, 1989), but concluded that the battery was unsuitable for discriminating between patients with right hemisphere language dysfunction and control patients, or for measuring changes in right hemisphere language function following right hemisphere tumour resection. Ilmberger et al. (2008) used the AAT, however, the assessment was not used routinely with all patients at all assessment points. The suitability of using aphasia assessments designed for use with stroke patients to assess patients with brain tumours is questionable, given that Anderson et al. (1990) found that patients with brain tumours and patients with strokes matched for lesion site differed greatly in terms of cognitive and neuropsychological profiles, with the brain tumour patients typically displaying milder impairments and greater variability in performance between individual patients. This suggests that standard stroke aphasia assessments may not adequately capture the more subtle language impairments potentially experienced by patients with brain tumours.

Three of the studies used a self-selected mixture of formal and non-formal assessments (Bello et al., 2007; Duffau et al., 2003; Papagno et al., 2010). Bello et al. (2007) reported that the researchers specifically did not use a standardised language battery because the patients did not belong to any classic aphasia subtypes and displayed only mild or no aphasia. However, the suitability of the measures for patients with brain tumours is unknown. Overall, it is possible that the different patterns of language impairments observed in the different studies included in the review may have reflected the different levels and focus of the assessments employed, in addition to tumour location and surgical resection factors. Thus, there is a need to see whether other language batteries that address general language (both receptive and expressive components), high level language and cognitive-communication employed in other patient populations are sufficiently sensitive in the brain tumour population.

The potential contribution of participant selection factors to the different assessment results reported in
the studies also warrants consideration. For example, Ilmberger et al. (2008) reported that 4 patients in their series received two surgeries, and reported the results of these patients as 8 patients rather than reporting the results separately. The impact of the relatedness of these scores and potential impact of the two surgeries on the assessment patterns reported by the authors cannot be discounted. The overall ages of patients included in the studies ranged from 9–79 years. The inclusion of children in the study cohort ranges questions about the reliability of the results using these two patients, given that the assessments used were designed (and standardised) for adults and that brain and language function and performance differs between children and adults due to maturation factors (Brauer, Anwander, & Friederici, 2011).

4.3. Adjuvant therapy

Only one study (Ilmberger et al., 2008) reported that some patients received adjuvant therapy post-surgery involving radiation therapy or chemotherapy. No other studies in this review commented about whether patients received any adjuvant radiation or chemotherapy post-surgery. To date, there appears to be a paucity of information about the effects of radiotherapy on language function. In the closely related cognitive arena, Douw and colleagues (2009) found that patients with low grade gliomas who received radiotherapy displayed reduced cognitive function (including executive function, attention and information processing) and radiological abnormalities when compared to patients who did not receive radiotherapy. However, the reverse has also been found, with Van Nieuwenhuizen and colleagues (2007) finding no significant difference in neurocognitive function between patients with grade I meningiomas who received radiotherapy and radiotherapy compared with patients who received only surgery. These results suggest that there are mixed results regarding the impact of radiotherapy on cognitive function in patients with brain tumours and that further research is required.

Concomitant medication usage varied between the studies both in terms of whether patients were reported to be receiving medications and whether there was a change in dosage post-surgery. Whittle et al. (1998) and Thomson et al. (1998), who both observed improved language performance post-surgery, noted that patients were receiving lower doses of steroids at the time of this assessment. The researchers suggested that the post-surgery improvements were unlikely to be due to drug effects as the patients were receiving lower medication doses, however, as research has suggested that some anti-epileptic medication can exert negative effects on cognition (Hamed, 2009), it is possible that the reduction in medications may have contributed in some capacity to the improved language performance. Thus, the potential impact of medications on language function warrants further consideration and research.

4.4. Implications for rehabilitation

The results of this systematic review have a number of implications for rehabilitation teams. Firstly, research uncovered in this review suggests that while mixed patterns of language function were reported post-surgery, a large number of patients experienced new or worsening of existing language disorders shortly post-surgery. The potential likelihood, therefore, of at least temporary post-surgical language impairments needs to be considered during pre-operative counselling to patients. Patients may also benefit from a detailed language assessment (including receptive and expressive language function) before and after surgery so that an effective, individually tailored rehabilitation program can be developed. This is particularly relevant given the potentially detrimental impact of acquired language impairments on employment, interpersonal relationships, and participation in everyday activities (Le Dorze & Brassard, 1995). Secondly, as the majority of individuals with post-surgical language impairments in the studies reviewed experienced a resolution of their language impairment within three months post-surgery, it suggests that any individuals with post-surgical language impairments that persist beyond this time window may require further tailored rehabilitation, as spontaneous post-surgical recovery appears to be less likely after this period. Thirdly, given that the precise factors that predict the likelihood of post-surgical language impairments and the exact neuroplastic mechanisms underpinning post-surgical language recovery are unclear, we cannot at this stage perfectly predict an individual’s language function post-surgery.

4.5. Potential questions for future research

The review has uncovered several key questions for future research, including:

- A need for more comprehensive data about the long term recovery of receptive and expressive
language function (especially beyond 12 months post-surgery)
- Given the lack of knowledge about the precise neuroplastic mechanisms underlying communication recovery following brain tumour resection, future research could include fMRI to identify correlations between neurological changes and behavioural language changes at multiple time points along the recovery process (Pilia, 2010)
- The need to validate measures obtained in other populations which may be more sensitive than standard aphasia batteries typically employed
- More information about any communication rehabilitation (for example the optimal tasks, time to commence rehabilitation post-surgery, frequency) to ascertain the impact on recovery
- Further research into the effects of radiotherapy and medications on language function
- A need for research with more rigorous study designs including blinded assessors

4.6. Limitations

This review is limited by the small number of studies that satisfied the review criteria and the variable quality of the studies. The restriction of the review to studies published in English may have served as a further limitation.

5. Conclusion

Despite the small number of studies that met the review criteria and variable quality of the studies, the available evidence suggests that variable patterns of language function occur post-surgery, with a tendency towards reduced language function at least during the first three months post-surgery. This review has identified several key gaps to help shape the direction of future research, including more long-term data, the development of a specific assessment battery, and a need to further investigate the cognitive-linguistic mechanisms and potential neuroplastic changes underlying post-surgical language impairments. Increasing our understanding about neuroplastic changes in brain function in patients with tumours may not only have implications for the rehabilitation of communication disorders in patients with neurological conditions but also for our understanding of brain plasticity in general.

Acknowledgments

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Declaration of interest

The authors report no conflict of interest.

References

Central Brain Tumor Registry of the United States (CBTRUS). www.cbtrus.org/factsheet/factsheet.html (accessed 2/2/2012)
Appendix I. Database search terms

Limits for all searches except Cochrane Library:

- 1990–2012
- Humans
- Adult (or not paediatric/children)
- Language = English

WEB OF SCIENCE

1. brain tumor OR brain neoplasm OR brain cancer
2. communication OR language OR aphasia OR speech
3. surgery OR craniotomy OR treatment OR postoperative OR resection OR resect OR management
4. #1 AND #2 AND #3

PUBMED

1. (((brain tumour OR brain neoplasm OR brain cancer) AND (communication OR language OR aphasia OR speech)) OR (surgery OR craniotomy OR treatment OR resection OR resect OR postoperative OR management))

All fields and MeSH terms used.
EMBASE (using Embase and medline)

- ‘brain tumour’/exp OR ‘brain neoplasm’/exp OR ‘brain cancer’/exp AND (‘communication’/exp OR ‘language’/exp OR ‘aphasia’/exp OR ‘speech’/exp) AND (‘surgery’/exp OR ‘craniotomy’/exp OR treatment OR ‘resection’/exp OR resect OR ‘management’/exp OR postoperative)
- ‘brain tumour’ mapped to ‘brain tumor’, term exploded
- ‘brain neoplasm’ mapped to ‘brain tumor’, term exploded
- ‘brain cancer’ mapped to ‘brain cancer’, term exploded
- ‘communication’ mapped to ‘interpersonal communication’, term exploded
- ‘language’ mapped to ‘language’, term exploded
- ‘aphasia’ mapped to ‘aphasia’, term exploded
- ‘speech’ mapped to ‘speech’, term exploded
- ‘surgery’ mapped to ‘surgery’, term exploded
- ‘craniotomy’ mapped to ‘craniotomy’, term exploded
- ‘resection’ mapped to ‘surgery’, term exploded
- ‘management’ mapped to ‘management’, term exploded

CINAHL

1. brain tumour OR brain neoplasm OR brain cancer
2. MH “brain neoplasms”
3. MH “brain neoplasms” and #1 OR #2
4. communication OR language OR aphasia OR speech
5. MH “communicative disorders”
6. MH “language disorders” OR MH “rehabilitation, speech and language” OR MH “language therapy”
7. MH “aphasia”
8. MH “speech disorders”
9. #4 OR #5 OR #6 OR #7 OR #8
10. surgery OR craniotomy OR treatment OR postoperative OR resection OR resect OR management
11. MH “neurosurgery”
12. MH “craniotomy”
13. #10 OR #11 OR #12
14. #3 AND #9 AND #13

COCHRANE LIBRARY

- All text searched using: brain tumour (and brain tumor) and communication.