Does Cognitive Function Influence Alaryngeal Speech Rehabilitation?

T. P. Ho, MRCS,1 J. Gray, PhD,2 A. A. Ratcliffe, MSc,3 S. Rees, BSc(Hons),4 J. Rockey, MRCS,1 R. G. Wight, FRCS1

1 Department of Otorhinolaryngology, Head and Neck Surgery, James Cook University Hospital, Middlesbrough, United Kingdom. E-mail: allanhoentsurgeon@blueyonder.co.uk
2 Department of Neuropsychology, St. Nicholas’ Hospital, Newcastle upon Tyne, United Kingdom
3 Department of Biological and Biomedical Sciences, University of Durham, Durham, United Kingdom
4 Department of Speech and Language Therapy, James Cook University Hospital, Middlesbrough, United Kingdom

Accepted 3 August 2005
Published online 14 November 2005 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/hed.20348

Abstract: Background. We sought to define the cognitive domains that influence valved speech rehabilitation.

Methods. Sixteen laryngectomees with primary tracheoesophageal punctures were randomly recruited from one head and neck unit. They were assessed by a consultant neuro-psychologist and a speech therapist. Speech therapy time was determined from speech therapy notes.

Results. The Digit Symbol Substitution Test, assessing learning speed and processing speed, correlated significantly with speech therapy time in the first (p = .002) and third (p = .014) postoperative years, respectively. Categorical fluency assessment correlated positively with speech therapy time in the first year (p = .009). Learning speed (p = .007) and categorical fluency (p = .041) correlated positively with the fall in speech therapy input between the first and third year after laryngectomy.

Conclusions. Learning speed, processing speed, and categorical fluency strongly influence alaryngeal speech rehabilitation. This study highlights the potential for pre-laryngectomy cognitive assessment to help plan alaryngeal speech rehabilitation. This has significant resource implications. © 2005 Wiley Periodicals, Inc. Head Neck 28: 413–419, 2006.

Keywords: laryngectomy; tracheoesophageal speech; alaryngeal speech; voice rehabilitation; cognitive function

The optimal method of facilitating alaryngeal speech after laryngectomy is with a tracheoesophageal speech valve.1 It is necessary to identify patients who will require more intense support to achieve maximum speech potential. Clinical means of identifying such patients would greatly facilitate the preoperative planning of appropriate postoperative speech rehabilitation designed to prevent speech rehabilitation failure. Considerable resource implications also exist. Clinical predictors can be used to help develop a speech rehabilitation service that is prepared to meet the demands required to optimize the speech potential of patients after laryngectomy. We have few predictors of the intensity of speech therapy input required to optimize the use of speech valves after...
laryngectomy. It has been the assumption that psychological factors including cognitive function play a role in speech rehabilitation after laryngectomy. Fagan et al noted a significant association between literacy and speech failure at final follow-up. Lentin et al observed that many patients who were thought to be poor candidates preoperatively, based on psychosocial factors, actually performed well postoperatively.

A lack of convincing evidence exists in the current literature about which cognitive domains actually influence valved speech rehabilitation. No evidence exists in the literature about a specific validated clinical cognitive test that can be used to enable prediction of the intensity of speech therapy required to facilitate effective valved speech.

In this study, we explored the correlation between cognitive function and the effective use of a tracheoesophageal speech valve. Of the huge spectrum of cognitive domains, we attempted to define which domains are plausibly related to difficulties with developing valved speech after laryngectomy. We seek to develop a cognitive protocol that is simple, inexpensive, and easy to administer that would help predict the intensity of speech therapy required to facilitate effective valved speech.

PATIENTS AND METHODS

South Tees Local Regional Ethics Committee granted ethical approval, and all patients in the study provided informed consent.

This study involved 16 patients who had laryngectomies, eight men and eight women. The age range was 48 to 78 years (mean, 64.5 years). The mean number of years after laryngectomy was 3.9 years.

All patients had a primary tracheoesophageal puncture with their total laryngectomy because of a primary laryngeal neoplasm. Patients who had neck dissections were not excluded from the study. One consultant head and neck surgeon operated on all the patients as the primary surgeon using a standard surgical technique. Patients who had a pharyngolaryngectomy or complex head and neck reconstructions were also excluded because of a higher incidence of anatomic difficulties encountered postoperatively with their speech valves. Patients with recurrence within 3 months of the procedure were also excluded from the study. Patients with a diagnosis of a neurologic disorder or any signs of a neurologic disorder that would compromise their cognitive function were excluded from the study.

A list of all eligible adult patients who had undergone laryngectomy in the past 10 years was compiled. A blinded independent party random selected patients using randomization tables. Twenty patients were selected from this list. Four patients refused to take part in the study. They declined cognitive testing despite our greatest efforts to assure them of their anonymity. These four patients were similar in age to the study sample. The 16 patients who agreed to take part in the study all commenced their postoperative speech therapy between 1998 and 2001. Visual acuity tests and a neurologic assessment were performed.

Our cognitive and speech rehabilitation outcome measures are discussed in the following.

The Cognitive Assessment. Each patient was tested separately by the same consultant neuropsychologist with a battery of cognitive tools over approximately 30 minutes. Four patients were interviewed in each research session.

The Spot-The-Word vocabulary test, Mini Mental State Examination (MMSE), and the Hospital Anxiety and Depression Scale (HADS) were performed on each patient. The Spot-The-Word test was chosen as an equivalent test to the National Adult Reading Test (NART). Unlike the NART, the Spot-The-Word scores are not influenced by verbal pronunciation of words. The results of the Spot-The-Word allow an estimate of intelligence. The NART and Spot-The-Word tests were devised to be resistant to the effects of stress or brain damage. We, therefore, used the Spot-The-Word test scores as a measure of premorbid intelligence.

Immediate and delayed recall of prose passages was also tested. Each patient was told the same short story. The patient was immediately invited to retell the story from memory. The accuracy of the immediate recall of the story was scored. The patient was then told that after a 20-minute period of distraction with other cognitive tests they would again be invited to retell the story as accurately as possible. The amount accurately recalled on both immediate and delayed recall and the percentage retained over the delay were scored and used as our measures of declarative memory.

Categorical (or semantic) fluency was tested. Each patient was given 60 seconds to list as many examples of four-legged animals as they
The score was the total number of correct responses. The Digit Symbol Substitution test\textsuperscript{11} was administered. In this test, the patient was presented with a template consisting of the digits from one to nine. Each digit was paired with a specific symbol. Below this template, on the same sheet was a random list of digits. The patient was asked to write the corresponding symbol below each digit. The score was the number of symbols correctly entered in 90 seconds. The Digit Symbol Substitution test was then repeated a further three times with the patient being distracted between trials by further cognitive testing. The difference (P2) between the first (P1) trial and the fourth trial was used as a measure of implicit learning capacity or learning speed. The first trial (P1) is a measure of psychomotor or processing speed. One patient was not able to perform the Digit Symbol Substitution test, because she forgot to bring her reading spectacles. This patient did complete the rest of the cognitive tests.

**Speech Assessment.** During all the cognitive assessments, a rating of tracheoesophageal speech was made by one speech and language therapist (SaLT) who specializes in surgical voice rehabilitation.

The speech therapy time spent with each patient up to 3 years postoperatively was determined in minutes. This was ascertained from detailed speech therapy notes. Any time spent with the patient specifically because of purely anatomic complications was not included in the count. This speech therapy rehabilitation time was divided into first, second, and third year after laryngectomy.

The Harrison–Robillard-Shultz (HRS) tracheoesophageal puncture rating scale\textsuperscript{2} (speech score) was used to assess the quality of tracheoesophageal speech and the patients’ use and care of their speech valves. The quality aspect of the speech score considers the ease of production and intelligibility of speech. It also considers fluency of the speech and ability of the patient to occlude the stoma (Table 1).

We modified the care and use aspects of the speech scale in our study. Hands-free devices were not widely available when the HRS scale was published. We have, therefore, revised the fifth point of the use aspect of the scale to read: ‘Uses tracheoesophageal speech (with a hands-free device) as main means of communication’ (Table 1). We believe that the care aspect of the HRS scale is an important criterion when measuring the effective use of a speech valve. The original care criterion assesses the patient’s independence from medical or other health care professionals for the following four behaviors: (1) removes and inserts prosthesis, (2) cleans prosthesis, (3) recognizes problems and seeks help immediately if required, (4) orders supplies. Our modified version of the care aspect of the scale was an addition of a fifth behavior. This fifth behavior was ‘the patient’s ability to adhere to advice given by a speech therapist.’ This fifth independent behavior in the care of a tracheoesophageal speech valve introduced the sixth point in the modified care criteria (Table 1).

<table>
<thead>
<tr>
<th>Score</th>
<th>Use of TOS</th>
<th>Quality of TOS</th>
<th>Care (the five behaviors are described under ‘The Speech Assessment’)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Never uses TOS</td>
<td>Unable to get sound, unable to use pulmonary air for speech</td>
<td>Unable to do any of the five behaviors</td>
</tr>
<tr>
<td>2</td>
<td>Uses TOS &lt;50% of the time</td>
<td>TOS is too strained to permit functional use in conversation</td>
<td>Independent for one of the five behaviors</td>
</tr>
<tr>
<td>3</td>
<td>Uses TOS in 50–80% communicative attempts</td>
<td>Stoma is poorly occluded with resultant air escape interfering with intelligibility or is a distraction to the listener</td>
<td>Independent for any two of the five behaviors</td>
</tr>
<tr>
<td>4</td>
<td>Uses TOS as main means of communication</td>
<td>TOS is mildly strained; continuous use in conversation is possible; occlusion is good; speech is intelligible</td>
<td>Independent for any three of the five behaviors</td>
</tr>
<tr>
<td>5</td>
<td>Uses TOS (with a hands-free device\textsuperscript{*}), as main means of communication</td>
<td>TOS is produced easily; occlusion is good; TOS is intelligible</td>
<td>Independent for any four of the five behaviors</td>
</tr>
<tr>
<td>6\textsuperscript{*}</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Independent for all five behaviors\textsuperscript{*}</td>
</tr>
</tbody>
</table>

Abbreviation: TOS, tracheoesophageal speech.
\textsuperscript{*}Modification of RHS scale for the purposes of this study.

---

Table 1. The Harrison-Robillard-Shultz (HRS) tracheoesophageal puncture rating scale\textsuperscript{2}.
**Statistical Analysis.** The Statistical Package for the Social Sciences (SPSS) was used for analysis of the data. The associations between cognitive test scores and outcome variables of speech therapy time and the HRS speech scores were considered using Spearman’s correlation coefficient (rs). Statistical significance was noted if \( p < .05 \).

**RESULTS**

**Harrison–Robillard-Shultz Speech Scores.** In each parameter, Harrison and Robillard-Shultz\(^2\) defined the scores of one or two as ‘nonfunctional,’ three as ‘marginal,’ and a score of four or five as ‘functional.’ How did our patients score on the HRS speech rating scale?

The quality aspect of the HRS speech score\(^2\) ranges from one to five. Speech is considered intelligible if it scores above three points. In our study, the quality of speech scores ranged from three to five points (median, four points). Thirteen of our 16 patients scored greater than three points.

The degree of use of the speech valves was scored from one to five points. Patients scored four points and above if they used their speech valves as their main means of communication. Our patients’ results ranged from two to five points (median, four points). Thirteen of our 16 patients scored greater than three points.

The degree of use of the speech valves was scored from one to five points. Patients scored four points and above if they used their speech valves as their main means of communication. Our patients’ results ranged from two to five points (median, four points). Thirteen of our 16 patients scored greater than three points.

Table 1 outlines this modified score. Our patients scored between two and six points (median, five points) in the care aspect of the speech valves. The spread of the care scores demonstrated a normal distribution. Eleven of the 16 patients scored above three points in the care of their valves, indicating that they were able to perform at least three of the specified care tasks reliably.

When considering all three parameters, a total score of 11 or less indicates a nonfunctional tracheoesophageal speaker. A total score of 12 or more is indicative of a ‘functional’ speaker. In our cohort the total of the three speech parameters had a median of 13 points. The interquartile range was 11 to 15; nine of 16 patients (56%) had a total score of 12 points and above.

**Cognitive Test Scores.** The MMSE score has a total of 30 points. The interquartile range in our group of patients was 27 to 30 (median, 29). Their global cognitive function was intact. The MMSE scores were unimpaired, indicating no gross effect of neurologic disease on cognition. A median MMSE score of 29 points corresponds with at least 9 years of schooling and 26 points for individuals with at least 5 to 8 years of schooling.\(^1\)\(^2\) Our patients, therefore, had a global intelligence equivalent to those having at least 5 to 8 years of schooling.

The Spot-The-Word test has a total of 60 points. The median score for British adults\(^5\) aged 48 to 64 (corresponding to an IQ of 100) is 50 (interquartile range, 47–53). The median score for our subjects was 51 (interquartile range, 38–54). Our cohort was, therefore, not significantly different from the average British adult of their generation.

The declarative memory score median was 11 (interquartile range, 9–15), which corresponds to the 51st and the 54th percentile for the reference population\(^8\) for immediate recall. Delayed recall score median was nine (interquartile range, 6–12), which corresponds to the 51st and the 58th percentile\(^9\) for the reference population.

A normal HADS score is zero to seven. The anxiety score of the HADS had an interquartile range of one to seven (median, 3). The depression scores of the HADS had an interquartile range of zero to four (median, 3).

Categorical (or semantic) fluency had a mean of nine with a standard deviation of four.

Psychomotor speed (P1) had a mean of 47 with a standard deviation of 13. Learning speed scores (P2) had a mean of 12 with a standard deviation of eight.

**Relationship between Cognitive Function and Speech Therapy Time.** The relationships between cognitive test scores and speech therapy time for each of the 3 years for which data was available are presented in Table 2. Premorbid intelligence (rs = −0.665, \( p = .013 \)) and declarative memory (rs = −0.565, \( p = .044 \)) are associated with alaryngeal speech rehabilitation in the third postoperative year. Patients with better learning speed (P2) required more speech therapy time in their first year after laryngectomy (rs = 0.743, \( p = .002 \)). By the third postoperative year, this relationship was reversed, and patients with better learning speed needed less speech therapy time (rs = −0.588, \( p = .044 \)). Similarly, patients with better processing speed (P1) required more speech therapy rehabilitation time in their first postoperative year (rs = 0.539, \( p = .047 \)) and less speech therapy input by their third postoperative year (rs = −0.683, \( p = .014 \)).

Patients who scored well in categorical fluency required more speech therapy time in their first...
postoperative year ($r_s = 0.647, p = 0.009$). This group required more speech therapy input in their first 2 years after laryngectomy ($r_s = 0.537, p = 0.037$).

**Relationship between Cognitive Function and Fall in Speech Therapy Requirements.** Patients who had better learning speeds demonstrated a greater fall in speech therapy time between the first and third postoperative years ($r_s = 0.756, p = .007$) (Table 3). Patients with better processing speed ($r_s = 0.633, p = 0.036$) and those with better categorical fluency ($r_s = 0.595, p = .041$) exhibited a sharper decline in speech therapy requirements between their first and third postoperative years. Intelligence and memory did not seem to play a significant role in predicting the fall in speech therapy requirements.

Further analysis of processing speed (P1) stratifies the patients into two groups. We used the mean score for psychomotor speed to divide our cohort into two groups. The first group of patients scoring less than 48 is compared with the second group who score 48 or more. Figure 1 demonstrates the steep fall in speech therapy time between the first and third postoperative years in the group scoring above the mean. This overall pattern compares favorably with the group who score below the mean. The group who scored below the mean actually required more speech therapy time in the third year than in the second postoperative year.

This similar phenomenon is also seen in patients whose learning speed scores (P2) are above the mean and those who score more than the mean in categorical fluency (Figure 2).

**Relationship between Cognitive Function and Speech Scores.** Cognitive function was not associated with the quality, use, or care parameters of treatment.
choesophageal speech; however, there was a significant relationship \( r_s = -0.677, p = 0.004 \) between the total HADS scores and the ability of the patients to care of their speech valves. Patients with more anxiety and depression were less able to care for their speech valves.

**DISCUSSION**

This exploratory study indicates for the first time that the cognitive domains of processing speed, learning speed, and categorical fluency have a significant relationship with alaryngeal speech rehabilitation. Speech therapy in the first postoperative year is associated with a dramatic fall in speech therapy requirements in the group who score well in the Digit Symbol Substitution Test and categorical fluency assessment. These domains characterize the executive control of psychomotor function.12

Perhaps patients who do have better learning speed, psychomotor speed, and categorical fluency have higher expectations of what their tracheoesophageal speech should be and, therefore, would demand more speech therapy time to optimize their speech in the first postoperative year. Patients with better scores in the Digit Symbol Substitution test and categorical fluency testing in the first year may engage better in rehabilitation postoperatively, especially when these domains reflect the functioning of the frontal network systems. They seem to learn faster and by the third postoperative year require less speech therapy support.

Intelligence and memory, to nonpsychologists, are generally considered synonymous with cognitive function. We have discovered that premorbid intelligence (as measured by the Spot-the-Word test scores) and declarative memory are associated with alaryngeal speech rehabilitation in the third postoperative year.

Our cognitive measures were taken at up to 3 years postoperatively. The possibility exists that these measures may have been different preoperatively. The temporal stability of these measures is well established, with excellent test–retest reliabilities.5,9 The effects of anesthesia are, with the possible exception of cardiac surgery, minor and short lasting.13

A lack of correlation exists between the P1 and P2 scores with the SaLT time in the second year after laryngectomy. The most likely reason for no correlations in the second year is that the correlations are moving from positive in the first year to negative in the third year passing through zero \( r_s = 0 \) on the way. The lack of correlation between the learning speed and psychomotor speed scores with the second postoperative year should not overshadow the more important overall pattern demonstrated by Figures 1 and 2.

The outliers affecting the statistical significance of the correlation all had adjuvant radiotherapy. Adjuvant radiotherapy can delay therapy progress. Patients receiving adjuvant radiotherapy often have more complex troubleshooting around their speech rehabilitation. This level of rehabilitation can often carry through to the patient’s second postoperative year. Furthermore, it is only at the end of the first year after laryngectomy, once patients have achieved the basics and functional alaryngeal speech, that attempts are made to try to ‘fine tune’ alaryngeal speech. This includes activities such as trying various types of voice prostheses with differing resistances to achieve optimal alaryngeal speech.

Some individuals refused to consent to take part in the study because of their lack of confidence to undergo cognitive testing. A prospective study may not encounter this problem.

No relationships were found between any of the three criteria of the speech scores and the cognitive tests. As a consequence of the intensity of speech therapy rehabilitation the patients had received, this study found that the tracheoesophageal speech of many of our patients had already been optimized and that there was little variation in the scores on the quality of speech and their degree of use of their speech valves. Although each
of the cognitive tests was considered for associations, it was not possible to do multi-variate analysis to isolate the different effects. This is an important limitation of this study and warrants a larger study. Although we may not have found weak associations between variables because of the small sample, the associations that were significant emerged despite this small sample of patients.

We propose two cognitive tests, which are simple, fast, and inexpensive to administer. Speech therapists who specialize in surgical voice rehabilitation should be able to administer these tests with some additional psychological training. This gives us hope that pre-laryngectomy assessment using the Digit Symbol Substitution Test and assessment of categorical fluency would help plan postoperative speech rehabilitation.

Acknowledgments. We thank Dr. Desmond Watson, Prof. Janet Wilson, and Prof. Paul Carding for their encouragement and support in this project.

REFERENCES