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A timed test of swallowing capacity for neurological patients

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Abstract

A timed test of swallowing capacity has been designed for use in patients with neurogenic dysphagia. Swallowing speed (ml/s) has been demonstrated to have high intra- and inter- rater and test- retest reliability, and to be essentially independent of flavour or temperature. "Guideline" normal values were established in individuals without a swallowing disorder: swallowing speed was less in females than males and declined in both groups with age. The validity of a swallowing speed <10 ml/s as an index of abnormal swallowing was tested by comparison with the complaint of abnormal swallowing in a group of 81 neurological patients. Swallowing speed had a sensitivity of 96% and specificity of 69%: some apparent false positive responses were found in patients with disordered swallowing, mainly due to multiple sclerosis. Using a standard questionnaire and examination a similar pattern of symptoms and signs were statistically associated with both the clinical complaint of abnormal swallowing and swallowing speed. It is concluded that swallowing speed is a reliable and valid index for assessing disordered swallowing in neurological patients and may be of value in monitoring response to therapy.

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Previous studies of patients with neuromuscular diseases monitored using quantitative strength measurements highlighted the need for some equivalent measure of swallowing capacity.[1] We empirically introduced a simple timed test into the routine assessment of neuromuscular patients and subsequently have made preliminary reports on reliability[2] and validity.[3]

Methods

1) The technique for the swallowing test

The nature of the test is explained to the subject who should be seated upright, preferably on a chair at a table. The subject is given 150 ml of cold tap water to drink from a standard glass: in patients predicted to have difficulty with this volume a lesser (measured) volume is given. The subject is asked to drink the water as quickly as possible but to take care and to stop if difficulty arises. The glass is held at the lips, until the "go" signal is given. The observer is seated at the side of the subject to obtain an adequate view of laryngeal movement during each swallow so that the number of swallows can be counted. The time and number of swallows taken from the "go" signal to the last swallow recognised by return of the larynx to the rest position (as seen exteriorly by the movement of the thyroid cartilage) are noted. Any coughing during or after the test and the quality of the voice after the test is noted. The residual volume is measured in those in whom the test is abandoned so that in all cases speed (ml/s), and average volume/swallow (ml) are calculated. Such a test is clearly inappropriate in patients with major dysphagia who are obviously aspirating.

2) Reliability studies

Intra-rater reliability was assessed by one examiner timing twice the videotaped record of the swallows undertaken by six normal subjects or patients in random order and with the stopwatch face obscured. Inter-rater reliability was examined by 6 observers observing videos of swallowing tests on five normal subjects or patients. The possibility of a learning effect was tested in 24 normal subjects by repeating the test in each subject 4 times over a 48 hour period: at the same time the effect of flavouring the drink was assessed by randomising the order of the 4 drinks—2 of which were water and two a flavoured drink. The effect of temperature on swallowing speed was studied by presenting water at three different temperatures (9°C, 19°C, 39°C) in random order to 6 normal subjects. Finally, swallowing speed was measured twice, at an interval of 1 to 37 days, in 38 neurological patients, of whom 24 had abnormal swallowing speeds (see below).

3) Guideline normal ranges

A swallowing test was undertaken in 101 "normal" subjects to establish a guideline range for swallowing speed. Individuals with clinically relevant medical or swallowing disorders were excluded.

4) Validity studies

The validity of the swallowing test was assessed by administering a questionnaire concerning symptoms related to impaired swallowing or aspiration, a standardised examination of the lower cranial nerves (V-XII), and the swallowing test (Table 3). Patients were initially categorised according to whether they perceived that they did or did not have a swallowing problem. As we had no reference test, the patients' perception ("yes" or "no") of a swallowing problem was taken as one variable

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in a series of cross-tabulations, using the answers to the questionnaire, scored physical examination and swallowing speeds. The sensitivity, specificity, and the positive predictive value of each feature were calculated. Secondly, similar calculations were performed using swallowing speeds of less or more than or equal to 10 ml/s (see below) as the index of abnormal or normal swallowing. The validity study included 81 inpatients with neurological diseases being investigated at a regional unit. There were 44 males, mean (SD) age 50·0 (13·9) years, and 37 females, mean (SD) age 50·4 (17·6) years.

5) Ethical approval

The studies were approved by the Ethics Committee at the National Hospital for Neurology and Neurosurgery and the Joint Ethics Committee of the University of Wales College of Medicine/South Glamorgan Health Authority. All patients gave consent for the studies.

Results

Reliability

The differences between two measurements of swallowing speed by a single rater on each of six video-records of a 150 ml swallowing test varied between 0·0 and 0·5 seconds, the difference on average being 2·4% of the mean time for the two swallows (paired t test, $p = 0·32$). An analysis of variance of the inter-rater results showed that >99% of the variance was attributable to between patient differences ($F = 10035$, $p < 0·0001$) and almost none due to order ($F = 0·97$, $p = 0·47$) or inter-rater effects ($F = 2·88$, $p > 0·05$). There was no significant difference in the swallowing speed from the first to the fourth test over a 48 hour period in 24 normal subjects (paired t test, $p = 0·194$), nor any significant effect of flavour or temperature. When 38 patients were retested between one and 37 days later, the mean (SD) difference in swallowing speed was −0·17 (1·98) ml/s and there was no systematic difference between the two occasions or with swallowing speed (range of speeds 1–37 ml/s).

Guideline values for swallowing speed (Table 1)

Swallowing speed declined with age in males ($r = 0·70$, $p < 0·001$) and females ($r = 0·58$, $p < 0·001$) (figure). Although several elderly subjects had rather low speeds, for subjects under 70 years age accounted for 32% and 16% of the variation (R^2 values) in speed in males and females respectively. The variances of swallowing speed for males and females were similar (variance ratio test, $p > 0·1$): the mean swallowing speed for all females ($n = 56$) and for females under 70 years old ($n = 41$) was less than for all males ($n = 45$) or males under 70 years old ($n = 40$) respectively (unpaired t test, $t = 4·476$ and $4·117$, $p < 0·001$). None of 81 subjects (male or female) under the age of 70 years drank more slowly than 10·7 ml/s.

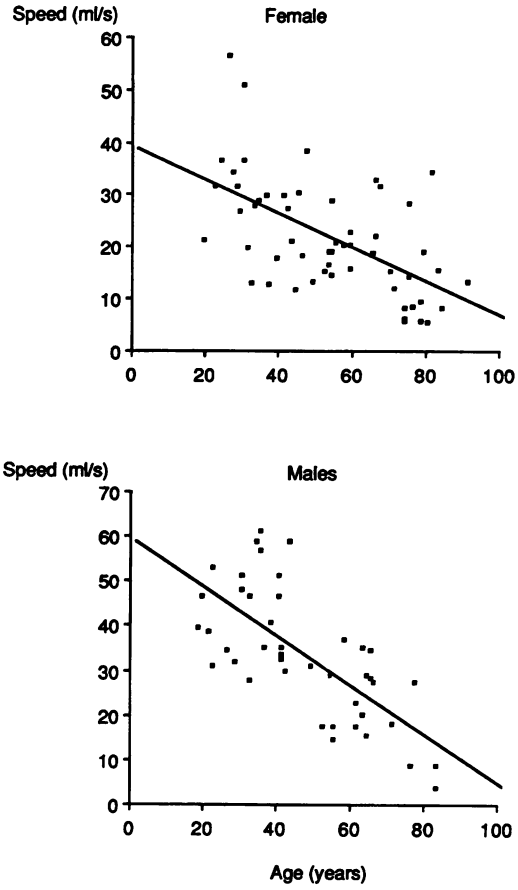

Figure Swallowing speed (y axis) and age (x axis) in 56 female and 45 male subjects without swallowing disorder. For females, $y = -0·324x + 37·84$, $r = 0·58$, $p < 0·001$, corrected $\hat{R2} = 0·33$. For males, $y = -0·548x + 57·553$, $r = 0·70$, $p < 0·001$, corrected $\hat{R2} = 0·48$.

Validity

A total of 81 neurological inpatients were classified according to whether they did (27) or did not (54) perceive a swallowing problem. Compared with both controls and those who denied a problem (table 1), the group which perceived a swallowing problem was slower (unpaired t tests, $p < 0·001$). Most who complained of a swallowing problem drank at less than 10 ml/s, that is, less than the minimum value for all normal subjects under 70 years

Table 1

Group	Variable	Normal All subjects	Subjects < 70 years	Neurological inpatients "no" problem	"yes" problem
Female	number	56	41	22	15
	mean (SD) age in years	52 (19·7)	43 (14·2)	49 (17·0)	53 (18·9)
	mean (SD) speed in ml/s	20·90 (10·98)	24·2 (9·96)	11·8 (7·87)	3·0 (2·57)
Male	number	45	40	32	12
	mean (SD) age in years	47 (18·1)	43 (15·2)	47 (12·9)	58 (13·9)
	mean (SD) speed in ml/s	32·07 (14·01)	34·6 (12·6)	20·8 (14·4)	4·8 (4·5)

Table 2 Swallowing Problem (questionnaire response)

Speed (ml/s)	*No*	*Yes*	*Total*
> 10 ml/s	37	1	38
< 10 ml/s	17	26	43
Total	54	27	81

old. When swallowing was classified as fast (=/> 10 ml/s) or slow (< 10 ml/s), a strong relationship between swallowing speed and a perceived problem was evident (Chi squared 30·4, p < 0·000) (table 2). The sensitivity of a "slow" swallowing speed as an indicator of a stated swallowing problem was 96% and the specificity 69%: there was one false negative result in a patient with hiatus hernia. The positive predictive value of a swallowing speed < 10 ml/s was 60% and thus the false positive rate was 40%. This latter group consisted of 17 patients therefore who drank slowly (< 10 ml/s) but perceived no problem: 12 clearly had abnormal swallowing on other clinical criteria of whom seven had multiple sclerosis. Of the 18 patients with MS tested 11 had speeds < 10 ml/s of whom 7 denied a swallowing problem: on the basis of other elements in the questionnaire or on clinical examination, however, the latter had significant swallowing difficulties. Thus the clinical complaint of abnormal swallowing was less reliable than the timed test in multiple sclerosis patients.

Symptoms and signs in the questionnaire and examination were analysed by cross tabulation against "abnormal swallowing" judged either by the patients perception ("yes" or "no") or whether swallowing speed was =/> or < 10 ml/s. Symptoms and signs showed similar statistically significant associations with each criterion of abnormal swallowing (Chi squared test with continuity correction) (Table 3): for instance the symptom of having to be "careful" when eating or drinking was strongly associated with abnormal swallowing judged either by the patient's perception or a slow swallowing speed (Chi squared 43·72 and 31·70, respectively p < 0·001). By contrast dentures, cigarette smoking, previous ENT problems, a jaw jerk and tongue fasciculations showed no or only very weak associations. A number of symptoms and signs (indicated by stars in Table 3) including control of substances in the mouth, nasal regurgitation, chest infections in the previous year, palatal movement on vocalisation and pharyngeal sensation were abnormal on too few occasions to draw reliable statistical conclusions and thus were insensitive indices of abnormal swallowing by either cri-

Table 3 Symptoms and signs

	Reference test (Yes/no or Slow/fast)					
Questions and pysical signs Significant (= < p 0·01) associations in descending order of significance	*Yes/no Sensitivity (%)*	*Slow/fast Sensitivity (%)*	*Yes/no Specificity (%)*	*Slow/fast Specificity (%)*	*Yes/no Pos Pred Val (%)*	*Slow/fast Pos Pred Val (%)*
Careful when eating or drinking (yes/no)	93	70	85	92	76	91
Food needing special preparation (yes/no)	74	51	98	100	91	100
Cough during swallowing test (yes/no)	67	44	98	100	95	100
Avoids some foods because difficult (yes/no)	78	58	91	97	81	96
Coughing when eating or drinking (0–1, 2–4)	70	49	91	92	79	88
Swallowing speed—(slow/fast)	96		69		60	
Food or drink the wrong way (0–1, 2–4)	63	42	93	92	81	86
Food getting stuck in the throat (0–1, 2–4)	62	41	94	95	84	90
Clear throat (yes/no)	48	30	87	97	93	93
Subjective feeling of voice change (yes/no)	93	77	67	74	58	77
Speech (0, 1–3)	93	79	67	76	58	79
Cough (abnormal/normal)	67	47	87	87	72	80
Tongue movements (normal/slow)	59	44	91	95	76	91
Waking up at night coughing (0–1, 2–4)	48	30	96	95	87	87
Facial weakness (present/absent)	56	37	93	92	79	84
Food left in the mouth after swallowing (0–1, 2–4)	46	31	96	97	87	93
Rt. palatal reflex (present, slight to absent)	67	49	78	76	60	70
Lft. palatal reflex (present, slight to absent)	67	51	77	78	60	73
Lft. pharyngeal reflex (present, slight to absent)	63	47	83	84	65	77
Rt. pharyngeal reflex (present, slight to absent)	56	44	80	82	58	73
Jaw weakness (present/absent)	26	21	96	100	76	100
Non significant associations (p > 0·05)						
Previous ENT problems (yes/no)	39	29	61	79	50	60
Tongue fasciculations (present/absent)	26	19	91	89	58	67
Jaw jerk (present/absent)	44	42	73	31	46	69
Dentures (yes/no)	50	49	70	79	45	71
Cigarettes smoking (yes/no)	33	28	75	74	41	55
Insufficient abnormal data						
Difficulty keeping substances in the mouth (0–1, 2–4)						
Liquids coming back through the nose (0–1, 2–4)						
Chest infection in the last year (0–1, 2–3)						
Right pharyngeal sensation (present/absent)						
Left pharyngeal sensation (present/absent)						
Palate on vocalisation (up/down)						
Palate deviates (no, left, right)						

2 × 2 tables were constructed for symptoms and signs (according to the categories shown in brackets after each) against both reference tests. The clinical features in the right hand column are ranked from above down for association according to the significance values of chi-squared tests (with continuity correction). Thus for Careful when eating . . . Chi squared (yes/no) = 43·72, Chi squared (slow/fast) = 31·7 (p < 0·001): for Jaw weakness Chi squared (yes/no) = 6·89, Chi squared (slow/fast) = 6·95 (p = 0·009).

terion. The sensitivity, specificity and positive predictive value of each clinical feature for a "swallowing problem" defined by each of the two criteria are shown in table 3. Finally the questionnaire and examination together with ward observation including assessment by a speech therapist formed the basis of an overall judgement as to whether the patient did or did not have a swallowing problem (excluding the criterion of the swallowing test). A swallowing speed of < 10 ml/s was strongly associated with abnormal swallowing so defined (Chi square 56·02, $p < 0·001$) with a sensitivity of 97%, specificity 88%, and a false positive rate of 12%.

Discussion

A timed test of swallowing capacity is rapid, requires minimal equipment and could potentially be incorporated into the routine neurological examination. The data in normal subjects indicates that the test can be reliably carried out with minimal specific training. Repetition, flavour, and temperature had no systematic effect but data on this is inadequate for the elderly and children. There is evidence from the "guideline" normal data of slowing with age. The specific reason is unclear but natural caution, local factors including dentures, oral or pharyngeal dysfunction,[4] cervical spondylosis (anterior osteophytes), chest disease and breathlessness, medication and occult disease of the CNS (for example, cerebrovascular disease, Parkinsonism) could all be factors which help to explain the high prevalence[5] of swallowing problems in the elderly.[6 7]

It appeared important in testing neurological patients to ensure a comfortable posture, preferably seated at a table rather than in bed. Posture of the head and neck are potentially important influences on the capacity to swallow and carrying out such a test semi-recumbent or in an uncomfortable position can be anticipated to reduce reliability. Impairment of conscious level or comprehension and lack of explanation also mitigate against reliable testing. The swallowing test itself will be potentially hazardous where the patient has overt aspiration or is strongly suspected of "silent aspiration" which may be difficult to confirm clinically[8–10] and has pulmonary problems. The use of a swallowing speed (volume/time) rather than the time of a fixed volume as the index in the test was chosen to allow the use of small volumes as dictated by clinical context. In some situations it will obviously be inappropriate to administer any fluid bolus by mouth and then the swallowing speed will be rated as zero.

Swallowing speed (< 10 ml/s) was a sensitive indicator of a swallowing problem in this series of neurological inpatients. The validity of this measure was suggested by its high sensitivity and the similar pattern and degree of association with clinical consequences of dysphagia compared with the patient's perception of a swallowing problem. The specificity of 69% can be partly attributed to apparent false positive tests in patients (notably with multiple sclerosis) who did not perceive that they had a swallowing problem but had one on overall clinical evaluation.

A slow swallowing speed cannot of itself indicate the cause of abnormal swallowing, although observation of the patient drinking, the volume of each swallow, the presence of drooling, coughing during the test and the voice quality after the test together with the presence of any coughing may shed light on the underlying mechanisms. The test cannot, however, supplant radiological/manometric investigation or formal assessment by a speech therapist. Nevertheless, slow swallowing speed alone may usefully alert the clinician to neurogenic dysphagia as a potential problem and cause of respiratory complications.

In conclusion we find that a timed test of swallow capacity is a reliable and valid indicator of perceived swallowing problems in neurological patients. The test is simple and only briefly extends the neurological examination but may detect unexpected cases of abnormal swallowing and provides a convenient interval measure (speed in ml/s) with which to quantitate changes in swallowing. Routine use of such a test may help to shift the neurological assessment of the integrity of swallowing away from specific but insensitive signs of bulbar dysfunction to a more functional approach especially relevant when considering the respiratory consequences of neurological disease.

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