The combination of bedside swallowing assessment and oxygen saturation monitoring of swallowing in acute stroke: a safe and humane screening tool

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Abstract

Background: dysphagia is common in acute stroke. Accurate detection of the presence or absence of aspiration by bedside swallowing assessment is difficult without objective methods, tending to over-diagnose aspiration. As a result, some patients suffer restricted oral intake unnecessarily.

Objective: we examined the predictive values of pulse oximetry and speech and language therapy bedside swallowing assessment in the detection of aspiration compared with videofluoroscopy.

Design: a double-blind observational study.

Setting: two university teaching hospitals.

Subjects: we studied 53 patients whose acute strokes were confirmed by computed tomography scan.

Methods: each subject had initial standard bedside swallowing assessment, closely followed by simultaneous and mutually blinded pulse oximetry, swallowing assessment and videofluoroscopy.

Results: 15 of 53 subjects aspirated. Bedside swallowing assessment and saturation assessment at ≥2% desaturation gave good sensitivity (80% and 87% respectively), but low positive predictive values (50% and 36% respectively). Both assessments mistook laryngeal penetration for aspiration. Re-analysis with aspiration ± penetration as a new endpoint improved bedside swallowing assessment positive predictive values to 83% ($\chi^2 = 3.59$, $P = 0.032$). Sensitivity of saturation assessment was maintained at 86%, positive predictive values of saturation assessment improved to 69% ($\chi^2 = 6.74$, $P = 0.009$). The combination of bedside swallowing assessment and saturation assessment versus aspiration ± penetration gave a positive predictive value of 95%.

Conclusions: screening by saturation assessments detects 86% of aspirators/penetrators and should be followed immediately by bedside swallowing assessment, as the combination of the two assessments gives the best positive predictive value. For patients with acute stroke, we advocate a 10 ml water-swallow screening test with simultaneous pulse oximetry by suitably trained medical and nursing staff. Use of this screening test would improve dysphagia detection whilst minimizing unnecessary restriction of oral intake in stroke patients.

Keywords: cerebrovascular disease, dysphagia, oxygen saturation

Introduction

The reported prevalence of dysphagia following stroke varies, depending on patient group sampled, clinical setting and sampling methodology. Figures of 29% [1] and 51% [2] have been reported. Most recovery occurs within 3 weeks. Aspiration (passage of material into the larynx below the true vocal cords) after swallowing, especially thin fluids, is common [1, 3, 4].

Bedside prediction of aspiration from clinical signs alone is inaccurate [5, 6]. Recent studies [7, 8] confirm low predictive values (especially positive predictive value;
PPV) in detection of aspiration compared with objective assessment by modified barium swallow or videofluoroscopy (VF). Smithard et al. report a PPV for speech and language therapists (SLTs) of 50% and a value for doctors of under 40% [8]. Linden et al. report a table of prediction from which we calculated a PPV of 58% [7]. Bedside swallowing assessment therefore tends to over diagnose aspiration.

Several factors, including stroke severity, conscious level, pre-morbid pulmonary function, ability to cough, mobility, oral hygiene and frequency of aspiration, contribute to the development of aspiration pneumonia. Early identification and confirmation of aspiration by objective methods (e.g. VF) is therefore important. Unfortunately, VF is not universally available nor suitable for all patients (e.g. those with poor sitting posture). It does not mimic normal feeding, may promote anxiety and exposes patients to radiation. Nonetheless, VF remains the standard assessment of aspiration. A reliable screening test for dysphagia is needed to complement, or replace bedside assessment.

We have previously shown [9] that 22–39% of acute stroke subjects develop arterial oxygen desaturation on swallowing 10 ml of water, and that desaturation is related to blinded SLT assessment of aspiration.

Aims

In this study we aimed to answer four questions:

1. Is arterial oxygen desaturation on swallowing in acute stroke patients associated with aspiration detected by VF?
2. What are the predictive values of arterial oxygen desaturation in detection of aspiration, compared with the standard of VF?
3. How do these predictive values compare with predictive values of SLT bedside assessment?
4. Does combining oxygen desaturation and bedside swallowing assessment indicators improve predictive values?

Methods

We considered for inclusion patients aged 18–90 years with acute haemorrhagic or infarctive stroke confirmed by computed tomography scan who were admitted consecutively to two Manchester hospitals between May 1995 and February 1997. Ethical committees of both Central Manchester Healthcare NHS Trust and South Manchester University Teaching Hospital approved the study. We obtained witnessed informed consent from all subjects.

Exclusions were: impaired conscious level; cognitive impairment or receptive dysphasia sufficient to prevent informed consent; inability to sit upright without minimal support (which precluded VF with our equipment—a Philips MD3 Digital Screening Unit); current lower respiratory tract infection; additional neurological condition; terminal illness; any other medical condition which, in the opinion of supervising consultant, precluded VF.

All acute stroke patients were visited by the research SLT within 24 h of admission (72 h at weekends). If a subject developed respiratory infection before the study, the procedure was postponed until clinical resolution was achieved. Bedside swallowing assessment comprised evaluation of each subject at rest and on swallowing a variety of quantities and consistencies. As well as assessing aspects of swallowing physiology, a subjective assessment of whether aspiration occurred on each swallow was made. Assessment was suspended if, in the researcher’s opinion, subjects were at risk of aspiration or in discomfort.

On the same day as bedside assessment, VF with simultaneous pulse oximetry (Minolta Pulsox 7) and further bedside assessment was performed (as per our routine clinical practice). The oximeter probe was attached to the index finger of the non-hemiplegic hand until baseline readings were stable. Subjects were then given varying amounts and consistencies of barium sulphate, starting with 3 ml and gradually increasing the aliquots. These comprised 5, 10 and 20 ml of thick liquid barium (e-z HD barium at 250% w/v), the same quantities of dilute liquid barium (125% w/v), then 5 ml yoghurt texture and finally 5 ml solid (bread plus barium). Oxygen saturation was measured during each swallow and for 2 min thereafter. VF was suspended if, in the opinion of the radiologist, subjects were at high risk of frank aspiration. Subjects were at liberty to suspend the procedure. VF was videotaped for later analysis. The three investigators (radiologist, SLT and physician monitoring saturation) were blinded to each other’s observations. Only the radiologist was able to view the television monitor during the study.

Subjects were studied in the lateral position during VF, allowing excellent views of penetration (entry of material into laryngeal inlet above the true vocal cords) or aspiration. One swallow was viewed in the anteroposterior plane to study symmetry of pharyngeal movements. The SLT conducted a further clinical evaluation (within the confines of the radiological procedure) and made a subjective assessment of whether subjects had aspirated for each swallow. All bedside assessment analyses refer to the blinded bedside swallowing assessment performed during VF.

Results

We studied 53 subjects (30 men) aged 51–90 (median 69) years. Two hundred and two subjects were excluded (Table 1). VF was performed between 3 and 31 days post-stroke (median day 10). Oxygen saturation and SLT bedside swallowing assessment data were analysed using
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SPSS for Windows on both a subject (hence referred to as ‘case’) and an individual swallow basis.

Analysis of VF revealed that 15 of 53 cases aspirated on one or more occasion. Forty-three aspirating swallows of 559 swallows were analysed. Predictive values by ‘case’ of bedside swallowing assessment and oxygen desaturation against VF as standard are given in Table 2.

Change in oxygen saturation ranged from a rise of 3% to a fall of 14%. A fall of ≥2% per case correctly identified 13 of the 15 aspirators (sensitivity 87%). However, there were 23 false-positives, giving a low PPV (36%) and a low specificity (39%). Different thresholds of oxygen desaturation gave inferior values (Table 2).

Because of the large number of false-positives in both SLT and saturation prediction of aspiration, we re-examined the relationship between VF data and bedside swallowing assessment and between VF data and oxygen saturation, for VF detection of penetration as well as aspiration. Therefore we re-analysed SLT and oxygen saturation data combining aspiration with penetration (detected by VF) as the new endpoint. This did not necessitate re-analysis of VF data as classification of penetration had been made by the radiologist during VF.

There were changes in all predictive values (Table 2) when comparing VF aspiration and/or penetration with bedside swallowing assessment predictions. PPV rose from 50 to 83% ($\chi^2 = 3.59$, $P=0.032$) and specificity rose (though not significantly) from 68 to 83% ($\chi^2 = 1.02$, $P=0.31$). There was no statistical change in sensitivity ($\chi^2 = 0.17$, $P=0.67$) or negative predictive value ($\chi^2 = 1.44$, $P=0.23$).

There were similar changes in predictive values when we re-analysed bedside swallowing assessment on a ‘by swallow basis’. PPV increased from 43 to 62.5% ($\chi^2 = 4.21; P=0.030$). There was no change in specificity ($\chi^2 = 1.13; P=0.29$). However, aspirating swallows undetected by bedside swallowing assessment increased, reducing sensitivity from 72 to 42% ($\chi^2 = 10.21; P=0.0014$). Negative predictive value fell from 97 to 87% ($\chi^2 = 3.6; P<0.001$).

We re-analysed all oxygen saturation data per case against penetration ± aspiration as detected by VF (Table 2). Best results were again obtained at a fall of ≥2% per case. PPV rose from 36 to 69% ($\chi^2 = 6.74; P=0.009$). Sensitivity was 86% (versus 87% for aspiration only, a non-significant change).

We analysed individual swallow characteristics to determine which, if any, were most predictive. None was as predictive as overall SLT bedside swallowing assessment.

Combining bedside swallowing assessment and oxygen saturation predictions improved PPV and specificity ($P \leq 0.05$ for both versus bedside swallowing assessment and versus oxygen desaturation in isolation; Table 2). Sensitivity and negative predictive value were not significantly different from their values pertaining to oxygen desaturation or SLT bedside swallowing assessment in isolation.

On $\chi^2$ analysis we found no differences in oxygen desaturation between penetration into the laryngeal vestibule only or to the level of the vocal cords. To assess whether independent variables (age, sex, current medication, time to VF, side, site and type of stroke) predicted oxygen desaturation, we performed multiple regression analysis. None was a significant predictor and <10% of the variability in desaturation was explained by variation in all other independent variables ($R^2 = 0.09$).

### Discussion

Stroke-related swallowing problems are common. Those who aspirate are 20 times more likely to develop pneumonia than non-aspirators [10], and aspiration of more

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**Table 1.** Exclusions from study

<table>
<thead>
<tr>
<th>Reason for exclusion</th>
<th>No. (%)</th>
</tr>
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<tbody>
<tr>
<td>Early discharge home or transfer</td>
<td>31 (15.3)</td>
</tr>
<tr>
<td>Died</td>
<td>29 (14.4)</td>
</tr>
<tr>
<td>Aphasic</td>
<td>28 (13.9)</td>
</tr>
<tr>
<td>Too ill for procedure</td>
<td>22 (10.9)</td>
</tr>
<tr>
<td>Decreased level of consciousness/poor positioning</td>
<td>21 (10.4)</td>
</tr>
<tr>
<td>Cognitively impaired</td>
<td>19 (9.0)</td>
</tr>
<tr>
<td>Other neurological cause</td>
<td>13 (6.4)</td>
</tr>
<tr>
<td>Refused consent</td>
<td>13 (6.4)</td>
</tr>
<tr>
<td>No computed tomography scan</td>
<td>13 (6.4)</td>
</tr>
<tr>
<td>Other (e.g. unable to schedule procedure)</td>
<td>8 (4.0)</td>
</tr>
<tr>
<td>Previous unresolved dysphagia</td>
<td>5 (2.5)</td>
</tr>
<tr>
<td>Total</td>
<td>202 (100)</td>
</tr>
</tbody>
</table>

**Table 2.** Predictive values (by case) of bedside swallow assessment and oxygen desaturation in acute stroke

<table>
<thead>
<tr>
<th>Observation</th>
<th>Endpoint (per case)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Positive (%)</th>
<th>Negative (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedside assessment</td>
<td>Asp</td>
<td>80</td>
<td>68</td>
<td>50</td>
<td>90</td>
</tr>
<tr>
<td>$O_2$ desaturation ≥ 2%</td>
<td>Asp</td>
<td>87</td>
<td>39</td>
<td>36</td>
<td>88</td>
</tr>
<tr>
<td>Bedside assessment</td>
<td>Asp ± pen</td>
<td>69</td>
<td>83</td>
<td>83</td>
<td>69</td>
</tr>
<tr>
<td>$O_2$ desaturation ≥ 2%</td>
<td>Asp ± pen</td>
<td>86</td>
<td>54</td>
<td>69</td>
<td>76</td>
</tr>
<tr>
<td>Bedside assessment + $O_2$ desaturation</td>
<td>Asp</td>
<td>73</td>
<td>76</td>
<td>55</td>
<td>88</td>
</tr>
<tr>
<td>Bedside assessment + $O_2$ desaturation</td>
<td>Asp ± pen</td>
<td>65</td>
<td>96</td>
<td>95</td>
<td>70</td>
</tr>
</tbody>
</table>

Asp, aspiration; pen, penetration.
than 10% of a bolus is associated with increased risk of pneumonia [11]. However, the ability of clinicians to predict which patients are at risk is poor. Previous research [7, 8] concentrating on bedside swallowing assessment has found poor PPV for aspiration, with the potential consequence that stroke patients without important swallowing problems may be given nil by mouth unnecessarily. Concerns have been expressed about the value of VF in predicting outcome variables in stroke [12]. Despite these concerns, and the suggestion that some normal older people have minor abnormalities of their swallowing mechanism detected on VF [13], the present standard test for swallowing abnormalities remains VF, although this is unsuitable for some patients.

In the present study we have demonstrated a simple, non-invasive, safe and accurate screening test that can be carried out in most clinical settings. Screening of stroke patients by oxygen saturation assessment fails to detect only 14% of aspirators/penetrators and should be followed immediately by bedside swallowing assessment, as combined assessment has a PPV of 95% (i.e. in our hands only 5% of patients would be unnecessarily given nil by mouth).

In the UK SLTs are not on-call round the clock. Patients with acute stroke admitted to hospital often remain ‘nil by mouth’ (in some cases unnecessarily) until a water-swallow test is performed. In this study we have shown that, for patients with acute stroke (whether dysphagic or not), oxygen desaturation alone accurately predicts 86% of aspirators and penetrators, with a false-positive rate of 30% (better than previously reported by bedside swallowing assessment alone [7, 8]).

We hypothesize that the low PPV of bedside swallowing assessment detected in this and previous studies is the result of SLTs misinterpreting signs of laryngeal penetration for aspiration. Penetration has been considered to be an abnormal physiological event and is often a prerequisite for aspiration [14]. The clinical significance, however, of isolated laryngeal penetration is uncertain. Further longitudinal research is needed to answer this question. No reliable bedside technique to detect laryngeal penetration exists. Confirmation requires objective techniques, usually VF [14, 15].

We have shown that some subjects who show laryngeal penetration of barium but not aspiration desaturate by 2% or more. The mechanism by which oxygen desaturation occurs when fluid is at the true vocal cords is unclear. During fibre-optic bronchoscopy, transient oxygen desaturation may occur during passage of the bronchoscope through the vocal cords [16–24], some unknown reflex mechanism being hypothesized [20]. It is questionable, however, whether this explanation could apply to the present study.

Three other studies have examined oxygen desaturation as a predictor of aspiration [25–27]. Study populations were selected (i.e. subjects with well-documented or suspected dysphagia). One study failed to find an association between aspiration and desaturation [26]. However, the numbers were small (n = 6), aetiologies were mixed and the degree of desaturation considered to be clinically significant was high (4%). Collins and Bakheit, in a larger study (n = 54), concluded that pulse oximetry was reliable for detection of aspiration in stroke patients [25]. There were, however, methodological differences between this and the present study which make us reluctant to cite it as evidence to support our own results: computed tomography confirmation of stroke was not sought; only four independent oxygen saturation measurements were taken (rather than continuous monitoring during and after each swallow) so that episodes of oxygen desaturation may have been missed; finally, a large quantity of barium (150 ml) was used, and thus the mechanism of oxygen desaturation may have been akin to that during bronchoscopy and lavage [16–24]. Recently, in a group of patients with suspected dysphagia of mixed aetiology, Sherman et al. found results very similar to our own in all respects [27].

A recent report by the Health Advisory Service 2000 [28] highlights the urgent need for “increased availability of staff who have received specific training to perform swallowing assessments across all days of the week”.

Our screening test may easily be taught to junior doctors and nurses and may avoid not only patients being unnecessarily placed ‘nil by mouth until assessed by SLT’, but also avoid the cost of intravenous hydration and additional nursing time spent in administering mouth care. Based on the results of the present study, we have produced clinical recommendations (Table 3) for a screening process which is humane and simple to use and interpret.

Table 3. Clinical recommendation

| A doctor or nurse gives the patient 10 ml of water to swallow and applies simultaneous pulse oximetry |

If patients desaturate by 2% or more, they should be placed ‘nil by mouth’ and be referred for speech and language therapist bedside swallowing assessment. If the therapist is available at the time of screening with pulse oximetry, bedside swallowing assessment should be done at the same time (positive predictive value for combined assessment = 95%) |

If patients do not desaturate and give no other outward sign of aspiration, they should be allowed to eat and drink but be observed carefully (specificity = 96%) |
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Key points
- Swallowing problems are common in acute stroke and are difficult to detect clinically.
- The use of oxygen desaturation assessment as a screening test has high sensitivity in detection of aspiration and laryngeal penetration on swallowing.
- When combined with bedside speech and language therapy assessment, oxygen desaturation assessment on swallowing has an extremely low false-positive rate.

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References

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