**Cough reflex testing in acute stroke: a survey of current UK service provision and speech and language therapist perceptions**

**Abstract**

*Background:* Silent aspiration (SA); airway entry of food, drink or other material without a cough response, is common post-stroke. Clinical swallowing examination misses up to 40% of dysphagic patients with SA. This may put these patients at risk of aspiration pneumonia, prolonged length of hospital stay and increased healthcare costs.

After stroke, the laryngeal cough reflex is frequently impaired with significant relationships between pneumonia rates and reduced cough strength and sensitivity.

There has been a significant amount of recent interest in cough reflex testing (CRT) as a potential means to improve clinical identification of patients at risk of SA. However, there is a lack of consensus regarding methodology and protocols for use of CRT with widely varying outcomes reported in the literature.

*Aims:* To provide an overview of current practice in the UK with regards to clinical use of CRT by speech and language therapists (SLTs) in acute stroke settings and explore perceptions regarding its potential application in clinical dysphagia management and barriers and facilitators associated with adopting CRT in clinical practice.

*Methods and procedures:* A cross-sectional web-based survey was developed, piloted and delivered. The survey targeted all UK-based SLTs working in acute stroke settings.

*Outcomes and Results:* 129 SLTs with varying levels of experience of CRT from all regions of the UK responded. Only 4 SLT services in the UK were reported to be currently using CRT clinically with acute stroke patients. 29% of respondents who were not using CRT were considering introducing CRT into their service’s dysphagia protocol. Variation was reported in procedures and protocols. Overall, users reported improved confidence in clinical detection of silent aspiration and felt that introduction of CRT had improved their patient-related outcomes. Issues included difficulties procuring citric acid, implications for SLT time (including service set-up and delivery of CRT) and restricted access to instrumental assessments.

*Conclusions and Implications:* This survey gives valuable insight into current practice and perceptions of SLTs in the UK working in acute stroke settings in relation to CRT. It highlights discrepancies between reported approaches and recommendations from existing guidelines and validation studies. The variation in responses indicates a need to develop a consensus statement and further research to guide practice.

**What this study adds**

*What is already known on the subject?*

Cough reflex testing (CRT) is gaining popularity as a screening tool for clinical identification of silent aspiration with acute stroke patients. However, there is a lack of consensus in the literature regarding methodology and protocols with widely varying outcomes. Further work needs to be done to standardise its use especially if it is to be incorporated into dysphagia protocols for use in the acute stroke setting.

*What this study adds*

This survey of SLTs working in acute stroke settings highlights variability in practice in CRT service-delivery in the UK, reflecting findings from the existing CRT literature.

*Clinical implications of this study*

Findings of this study support the need for further research relating to clinical screening tests for silent aspiration and standardisation of methodology and protocols for CRT use if it is to continue to be used clinically.

**Introduction**

*Post-stroke dysphagia and its consequences*

Dysphagia is a common side-effect of stroke, affecting between 64-78% of acute stroke patients (confirmed with videofluoroscopic swallowing study (VFSS), Martino *et al.* 2005). Up to 52% of patients are at risk of aspiration, the entry of food or fluid into the airway, in the first week post-stroke (Lim *et al* 2001). Silent aspiration, where material enters the airway in the absence of a protective cough response, affects up to 25% of patients within the first 5 days post-stroke and of those who aspirate, up to 67% do so silently (Daniels *et al.* 1998).

Aspiration is a significant risk factor for developing pneumonia. Up to a third of acute stroke patients develop pneumonia (Sellars *et al.* 2007) with pneumonia resulting in a 2.2- to 3-fold increase in mortality in the first month post stroke (Finlayson *et al.* 2011, Katzan *et al.* 2003, respectively). Patients who silently aspirate are approximately 13 times more likely to develop pneumonia than those with normal swallowing (Pikus *et al.* 2003). Aside from increased mortality secondary to pneumonia, which is associated with increased hospitalization costs (Wilson *et al.* 2012) and dependency at discharge (Finlayson *et al.* 2011), other consequences of post-stroke dysphagia include increased length of hospital stay (Altman *et al.* 2010) and adverse effects on nutrition, hydration and quality of life (Martino *et al.* 2010).

Sensory and motor control of airway protective mechanisms are mediated by activation of brainstem and/or cortical regions of the brain (Mazzone *et al.* 2011). Damage to these neural pathways which commonly occur as a result of stroke can cause laryngeal sensory and/or motor loss which increases silent aspiration risk as a consequence of reduced effectiveness or absence of airway protection in response to airway penetration or aspiration.

*Swallow screening*

In view of the health and psychosocial risks associated with unsafe swallowing, early identification of dysphagia and detection of those at highest risk of aspiration is of great importance. This facilitates timely and appropriate referrals for more comprehensive specialist swallowing assessment. It can also facilitate safe and appropriate administration of nutrition, hydration and medications. Early management has potential to reduce morbidity, rates of pneumonia, length of hospitalisation and medical costs (Perry *et al.* 2019).

Swallow screening has been found to reduce stroke associated pneumonia (Yeh *et al*. 2011). This is likely to be a consequence of improved awareness and earlier identification of dysphagia and subsequent implementation of management strategies to reduce risk of aspiration. National Institute for Health and Care Excellence guidelinesrecommend that all patients with stroke should be screened for dysphagia by appropriately trained healthcare professionals on admission and referred on for specialist swallowing assessment preferably within 24 hours and no longer than 72 hours following admission if difficulties are identified. If dysphagia persists 3 days following admission, instrumental swallow assessment should be considered (NICE 2019).

Despite advice for early swallow screening of stroke patients, swallow screening tests vary significantly locally, nationally and internationally with a lack of consensus regarding the most appropriate screening test or components.

*Instrumental swallow assessment: the gold standard for identification of aspiration*

Instrumental swallow assessments i.e. flexible endoscopic evaluation of swallowing (FEES) and VFSS are widely acknowledged to be the gold standards for identifying aspiration (Rao *et al.* 2003). As well as allowing visualisation and quantification of aspiration, they provide valuable information regarding the anatomy and physiology of the swallow which can help inform strategies to assist with management of dysphagia such as postural changes and/or consistency modifications which may reduce the risk of aspiration.

It is not practical or appropriate to carry out instrumental assessment of all patients with suspected dysphagia. FEES is an invasive procedure requiring complex specialist equipment which is poorly tolerated by some patients and does not allow direct observation of the oral or cervical-oesophageal function, while VFSS carries the risk of radiation exposure and aspiration of barium, requires provision of transport, only allows examination of function over a very brief period of time due to use of radiation, utilises idealised positioning and requires a radiographer/radiologist and x-ray suite. Both assessments are often not readily available, require specialist training and are significantly more time-consuming than clinical swallowing evaluation. Numbers and availability of appropriately trained staff can also impact on the ability of services to complete instrumental assessments.

Daniels *et al.* (1998) posit that improving sensitivity and specificity in the clinical examination should help to more accurately identify those patients who require instrumental swallow assessments and thereby reduce the amount of unnecessary instrumental swallow assessments with potential implications for sparing facilities, ensuring effective use of clinical time, reducing cost, avoiding unnecessary travel and radiation exposure.

*Clinical swallowing examination and the role of the cough*

Clinical identification of aspiration is unreliable using traditional clinical swallowing evaluation (CSE). Although a number of validated tools show good sensitivity (Martino *et al.* 2009, Suiter *et al.* 2014, Daniels *et al.* 2016), specificity of these tests is low suggesting that they over-estimate aspiration risk. Inter- and intra-rater reliability is frequently not evaluated and in the limited number of studies where it is, reliability problems are evident (McCullough *et al.* 2005). While case histories, cranial nerve examinations and observations of oral diet and fluids provide useful information regarding the patient’s swallowing function specifically relating to oral motor and feeding abilities, there is a significant risk of under-identifying patients who are at risk of silent aspiration as many of the available published dysphagia screening tools rely on the presence of a cough to indicate aspiration. This is particularly problematic for stroke patients as after stroke, the laryngeal cough reflex may be impaired for up to a month or longer and, in some cases, it may remain impaired indefinitely (Kobayashi *et al.* 1994). Significant relationships have been found in stroke patients between pneumonia rates and reduced voluntary cough strength and sensitivity (Nakajoh *et al.* 2000). Horner and Massey (1988) found that more than 60% of acute stroke patients in their study who silently aspirated showed weakened cough response.

It has been reported that CSE misses up to 40% of dysphagic patients with silent aspiration (Lim *et al.* 2001). Splaingard *et al.* (1988) compared CSE and VFSS using various volumes and consistencies. They found that CSE identified only 42% of patients who aspirated on VFSS. 20% of those who didn’t show symptoms of aspiration on CSE aspirated during VFSS. Indeed, 70% of patients with profound aspiration on VFSS in their study were not identified as aspirating during CSE. This is an issue which potentially puts dysphagic patients who are assessed via CSE at risk of aspiration pneumonia with subsequent prolonged length of hospital stay, reduced quality of life and associated costs to the healthcare provider.

*Cough reflex testing: a potential aid to identifying silent aspirators on CSE?*

There has been a significant amount of recent interest in use of cough reflex testing (CRT) as a means of identifying patients at risk of aspiration during swallowing. One of the first studies to look at use of CRT with the dysphagic population reported CRT as a safe, reliable and cost-effective procedure for testing the laryngeal cough reflex and detecting silent aspiration risk at the bedside among patients with acute stroke(Addington *et al.* 1999).

The test involves inhalation of a tussigenic (i.e. cough-provoking) agent delivered via nebulised air which triggers both mechano- (mechanical) and chemo- (chemical) receptors in the larynx and tracheobronchial tree and recording the behavioural response. A variety of tussigenic agents have been used in the literature, the two most commonly used being capsaicin and citric acid. Unlike capsaicin, citric acid is known to activate mechano-receptors as well as chemo-receptors (Mazzone 2005). Citric acid is known to stimulate cough at the laryngeal level (Morice 1997) which lends further weight to its use for identifying risk of aspiration.

Absent or weak cough in response to CRT suggests an impairment of laryngeal sensorimotor function. Studies have posited that a failed cough reflex test (variably measured by absent and/or weak cough on a specified number of administrations of CRT or during a set time period) indicates that a patient will be at significantly higher risk of either silently aspirating in response to food or fluids and/or that their cough will be ineffective in clearing penetrated or aspirated material which may exacerbate pulmonary consequences resulting from penetration or aspiration (Fontana and Widdicombe 2007). There is no way to test the status of the airway protection mechanism other than by stimulating the reflex.

However, there has been a lack of consensus regarding methodology and protocols for use of CRT including methods of administration, concentration of citric acid solution and criteria for pass/fail. Both Sato *et al.* (2012) and Lee *et al.* (2014) utilised the mouth piece method with 0.05mmmol/L citric acid solution and classified a failed CRT as less than 1 cough within 1 minute or approximately 30 seconds respectively, whereas Miles *et al.* (2013*b*) favoured the face mask method with 0.6mmol/L and classified a fail as less than 2 coughs on 2 of 3 15 second inhalations. As such, widely varying outcomes have been reported in the literature, with CRT often over-identifying patients at risk of aspiration although Miles *et al.* (2013*b*) found that, in isolation, CRT provides better diagnostic accuracy for identifying silent aspirators than many other isolated components of a bedside swallow assessment.

CRT is increasingly being utilised in dysphagia research and clinical practice. It has been used across all New Zealand district health boards as part of a structured protocol for diagnosis and management of swallowing impairment following stroke since 2011 and is increasingly being used in Australia. The European Respiratory Society (ERS) task force on cough methodology called for standardisation of all CRT methods (Morice *et al.* 2007) but this has not yet been achieved. A recent systematic review of citric acid CRT (Wallace *et al.* 2019) highlighted the continued lack of consistency between studies, with sub-standard reporting, a wide range of different instrumentation and protocols and omission of methodological components resulting in reduced ability to replicate studies or compare findings across studies. Despite evidence regarding use of CRT to screen for silent aspiration risk and its adoption in other countries, little is known at present about its use in the UK.

*Aim*

The aim of the current study was to determine the practice patterns of UK speech and language therapists (SLTs) working in acute stroke settings with respect to CRT methods and perceptions of barriers and facilitators to its implementation.

**Methods**

*Study design*

A cross-sectional self-administered UK web-based survey. Approval for the study was obtained from the Newcastle upon Tyne Hospitals NHS Foundation Trust (Reference No. 10051).

*Selection of participants*

Inclusion criteria were SLTs currently working in acute stroke settings in the UK. Exclusion criteria were SLTs working in other countries or with other clinical caseloads or stroke settings where patients were no longer classified as acute stroke (e.g. rehabilitation units or community settings).

*Survey development, content and administration*

A self-complete survey was designed and administered by the author with reference to published survey design guidance (Dillman *et al.* 2014). It was piloted with 5 SLTs working within the author’s SLT service and revised following feedback. The final survey consisted of 6 items relating to demographic information intended for completion by all participants with 27 additional questions for current and previous users of CRT and 5 for SLTs who had never used CRT. Specific questions for current and previous users were designed to elicit information regarding CRT protocols, procedures, availability of instrumental assessments (VFSS and/or FEES) and perceived barriers and facilitators to adoption of CRT. Questions for SLTs who had never used CRT probed whether their service was considering use of CRT and reasons for/against adopting this as part of their dysphagia protocol. The survey included a combination of open and closed questions and multiple choice questions and utilised skip logic (automatic redirection to questions relevant to the individual participant) in order to ensure that participants were only answering the questions that were relevant to them, thus reducing the time and effort involved for completion. Question content was guided by knowledge of clinical practice from discussions with current CRT users, literature review and feedback from the survey pilot.

The survey was administered via an online survey tool (<http://www.surveymonkey.com>) to enable ease of access for SLTs throughout the UK. As personalised contact has been shown to boost response rates (Dillman *et al.* 2014), the invitation email was designed to provide additional information regarding the survey author as well as a summary of the purpose and anticipated benefits of the study. Anonymity of responses was emphasised and the researcher’s contact details were provided in case of queries. The survey remained open for 3 months from 27th January 2020.

*Recruitment/Dissemination*

The survey was advertised via a research newsletter distributed by the Royal College of Speech and Language Therapists (RCSLT) (the professional body for SLTs in the UK). An email invitation was also sent to UK-based Clinical Excellence Networks (CENs) listed on the RCSLT website with a remit to dysphagia and/or neurological disorders. Those who received the email were invited to forward the invitation to group members working in acute stroke.

*Data analysis*

Quantitative data generated by closed and multiple choice questions were analysed using descriptive statistics via the built in data analysis function on Survey Monkey. The first and second authors independently coded open text responses and organised them into themes. Both authors met to discuss the analysis to reach consensus on themes. Data was analysed by grouping responses from current users, previous users and SLTs who had never used CRT.

**Results**

Responses were initially received from 133 SLTs. 4 responses were ineligible therefore 129 responses were included in the final analysis from a total of 507 qualified SLTs reported to be working in acute stroke units in the UK (Sentinel Stroke National Audit Programme (SSNAP) 2019) i.e. responses were received from a quarter of the total number of eligible SLTs. 71% of respondents completed all questions.

*Demographic information*

Responses were received from all regions of the UK (figure 1), with those who provided information on their location representing the acute stroke unit from 45 hospitals and/or NHS (National Health Service) trusts from a total of 182 acute stroke units (SSNAP 2019) i.e. a quarter of the total number of stroke units in the UK.

Figure 1. Geographical distribution of respondents who provided information regarding location (n = 100)



Figure 2. Pathways for survey responses

The majority of respondents (88%) had never used CRT, with significantly fewer (8%) currently using CRT and still fewer (4%) having previously used then stopped using CRT on their acute stroke units (figure 2). Only 4 hospital trusts in the UK were identified by this survey as currently using CRT as part of their acute stroke unit dysphagia protocol.

*SLTs who had never used CRT*

88 respondents had never used CRT. Of this number, 13% (n =13) reported that they had not heard of CRT and/or its application in dysphagia assessment. Of those who were aware of CRT, 34% (n = 29) reported they were considering using it on their acute stroke units and 66% (n = 56) reported that they were not.

Reasons reported for considering use of CRT are shown in figure 3, with all respondents reporting the aim of increasing clinical identification of silent aspirators.

Figure 3. Reasons given by SLTs for considering inclusion of CRT in acute stroke settings in the UK (n = 29)

Of those who were not currently considering use of CRT on their acute stroke unit, the most common reason was lack of time to consider its use, with over half of respondents reporting this (56%; n = 29). Figure 4 shows reasons reported by respondents for not considering use of CRT.

Figure 4. Reasons given by SLTs for not considering inclusion of CRT in acute stroke settings in the UK (n = 52)

*Current CRT users*

*Duration and nature of use*

A third of current CRT users (n = 3) reported using the test clinically for less than a year, a further third for 1-2 years and the remaining third for greater than 3 years. A third of respondents were also using CRT for research purposes.

*Staff characteristics and training received*

CRT is primarily carried out by SLTs (all 9 respondents), with a third of respondents (n = 3) reporting that nursing staff also carry out the test. All staff administering CRT receive in-house training of up to a full day (mean 2-4 hours training).

*Point and timing of administration*

Four of six respondents reported that CRT was completed during the nurse swallow screen within 4 hours of stroke patients being admitted to hospital. The remainder of respondents indicated that CRT was carried out when patients had failed the nurse swallow screen. All respondents reported that CRT was completed within 48 hours of hospital admission.

Two respondents reported that they would never repeat CRT. Of the 6 respondents who felt that it was acceptable to repeat CRT, the majority (n = 5) said they would consider repeating CRT if a patient showed significant improvement following their initial CRT and two thirds if a patient significantly deteriorated (n = 4). 1 respondent indicated that they would repeat it 24 hours after the initial CRT and an additional 2 respondents stated that they would repeat CRT if there was a significant delay while the patient was awaiting instrumental swallow assessment having failed their initial CRT.

*CRT protocols*

*Citric acid solution concentration*

The majority of respondents reported that their service used 0.6mmol/L citric acid solution diluted in 0.9% sodium chloride (n = 7 of 8 respondents). Only 1 reported that they used an alternative concentration (3mmol/L).

*Nebuliser/compressor used*

Most respondents were unsure of the make/model of nebuliser and/or compressor used by their service (n =5 and 3 of 8 respondents respectively). One respondent reported that their service was using the Hudson Respiratory Care Micro Mist Small Volume Nebuliser (jet nebuliser) but were about to change to the Salter 8900 Series Small Volume Nebuliser. The 2 respondents who reported on their compressor were using the Devilbiss Pulmo-Aide Compressor Nebuliser System (model numbers 4650D and 4650F respectively).

*Duration of exposure to citric acid solution*

All respondents reported administering 2-3 separate trials of citric acid solution for each patient. The majority of respondents (n = 7 of 8) reported that they administered citric acid solution to patients for 45 seconds or less with the remaining 2 reporting 45-90 seconds of exposure.

*Measurement and classification of cough*

All respondents used the C2 method of recording presence or absence of cough (i.e. 2 or more coughs in given time period required for a cough to be classed as present). The majority of respondents (n = 5 of 7) recorded natural cough, 1 recorded suppressed cough and 1 recorded both types of cough. Instructions varied slightly between services. For suppressed cough the instruction was given to ‘breathe through your mouth and try not to cough’. All respondents who recorded natural cough gave instructions relating to breathing (e.g. ‘breathe through your mouth’, ‘I’m going to have a look at your breathing’, ‘breathe normally’). 2 also made reference to cough (e.g. ‘cough if you need to’ or ‘it might/might not make you want to cough’).

There was also variation among respondents in terms of whether a perceptually weak cough was considered a pass or fail and management options for patients who presented with a weak cough. Just over half of respondents (n = 4 of 7) reported that they recorded cough strength but classed a weak cough as a pass, 2 reported that they would class a weak cough as a fail and 1 reported that they did not include judgements on cough strength.

In the case of the respondent who classed a weak cough as a fail, this resulted in such patients remaining nil by mouth until instrumental assessment. Where weak cough was considered a pass, patients were assessed clinically with oral diet and fluids. Only one respondent reported that use of clinical judgement allowed them to deviate from a set protocol of pass or fail.

*Instrumental assessment*

Survey responses indicated variation in waiting times for instrumental assessment following a failed CRT, types of assessment used and those available. Waiting times were comparable between types of assessment, with a tendency for FEES (where available) to be more rapidly accessible. No respondents reported an average wait time of over 3 days for FEES where it was available, whereas 3 (of 7) of respondents reported an average wait time of over 3 days for VFSS with 1 reporting an average wait time of 5 or more days between failed CRT and VFSS. 3 respondents reported that their service only had access to VFSS.

*Previous users*

Five previous users reported using the test for less than a year. All were using it clinically, with one also using CRT for research purposes. Three previous users reported that SLTs administered CRT with one service training nursing staff to deliver CRT. Amount of training varied from under 2 hours (n = 2) to a full day of training (n = 1). Delivery of training was evenly split between in-house (n= 2) and external training delivered by SLTs from another service (n =2).

CRT was variably administered during the initial nurse swallow screen (n = 1) or after a failed swallow screen (n =2). A comment from another respondent was ambiguous so it was not possible to determine whether CRT was administered as part of the initial swallow screen or, if it was, whether food or fluids were given before or after patients received CRT.

All respondents (n = 4) reported that CRT was administered within 72 hours of admission to hospital (within 24 hours when delivered by nursing staff as part of initial swallow screen), with only one quarter (n = 1) finding it acceptable for CRT to be repeated by SLT (in the instance of significant clinical improvement). All respondents reported use of 0.6mmol/L citric acid solution. Only one respondent specified the nebuliser and compressor make/model that they had used (Lifecare Microneb III nebuliser used with Clement Clarke Medix AC2000 compressor). Two respondents commented on the type of cough that was assessed with one recording only natural cough and the other recording both natural and suppressed cough.

One respondent reported that only strong coughs were classed by their service as a pass, with anther reporting that a weak cough would also be classed as a pass.

Instructions were reported by only one respondent, which consisted of advising the patient that the test would assess their sensation and asking them to continue to breathe normally.

Both respondents who commented on instrumental assessment reported that their service only had access to VFSS. While one service had capacity to provide VFSS within 72 hours of CRT, the other service cited a waiting time of up to 1 month.

Two respondents commented on why their service had stopped using CRT. One cited a prolonged lack of access to citric acid (over a year) coupled with lack of time and motivation from SLTs in the service to pursue use of CRT and remain up to date with the evidence base relating to CRT. The other service, which only had access to one VFSS clinic per month and no access to FEES, stated that lack of access to instrumental assessment was their service’s primary reason for discontinuing use of CRT.

*Barriers/issues*

Six key themes emerged when current and previous CRT users were asked about perceived barriers. These related to implementation/administration, storage, instrumental assessment, pharmacy, staff attitudes and efficacy (figure 5).

Implementation/administration issues were reported by three quarters of respondents (n = 6). These were largely related to time and resources; set up of CRT service including obtaining an appropriate nebuliser, delivery of training and maintenance of competencies, seeking medical consent and gathering required materials for each assessment and administration. One respondent reported that CRT added approximately 30 minutes to a clinical swallowing assessment.

Two current users reported finding storage space for CRT equipment and citric acid solution was a barrier to use.

Almost a third of respondents reported issues with instrumental assessment (n = 3). One reported that they increased their service’s access to VFSS clinics prior to implementing CRT, while the other respondents reported no increase (one held once-weekly, the other once-monthly). It was acknowledged that introduction of CRT led to a significant increase in demand for instrumental assessments (at least double). If the FEES equipment was not working in one of the services where there was no increase in VFSS availability, instrumental assessment was therefore delayed. For one previous user, lack of a FEES service resulted in reduced access to instrumental assessment.

The unlicensed status of citric acid solution proved problematic for several respondents (n = 3). Respondents reported that the need for obtaining approval to add this to their individual Trusts’ formularies made it difficult to set up CRT services. Procurement and availability of the appropriate concentration were also reported as issues. Lack of access to citric acid was a significant issue for one respondent with their service being unable to produce the required concentration in-house.

Two thirds of respondents (n = 4) expressed concerns regarding staff attitudes, including SLT, nursing and medical staff. Responses included concerns that SLTs may become over-reliant on the outcome of instrumental assessments to inform dysphagia management. Concerns relating to nursing staff involved negative attitudes towards and understanding of CRT. Respondents indicated that medical staff were inappropriately requesting CRT to assess level of risk for risk feeding (i.e. allowing oral diet and/or fluids to be given with the acknowledged risk of aspiration), to assess palliative patients despite the fact that it would not change management resulting in unnecessary testing.

One current user reported that their recent audit of CRT use found low levels of sensitivity and specificity for detection of silent aspiration. Similarly, one previous user commented that ‘the sensitivity and specificity is not much greater than bedside assessments’ and suggested the need to compare outcomes from bedside assessment alone with bedside assessment combined with CRT.

Figure 5. Perceived barriers to use of CRT from current and previous users (n = 30 comments)

*Facilitators/Benefits*

Current and previous CRT users reported benefits which were classified into three key themes: impact on patients, SLTs and intra-/inter-professional relations (figure 6).

A quarter of comments from CRT users (n = 5 of 20) reported faster access to instrumental assessment, shorter duration of nil by mouth status, decreased use of thickener, fewer patients requiring modified diet and fluids, and earlier discharge from their caseload.

CRT had a positive impact on SLTs, with users describing increased confidence in referring for instrumental swallow assessment appropriately, a clear division of roles and freeing up of SLT time. The only comment from a previous user in response to this question was that CRT was relatively cheap and quick to use.

CRT users reported the introduction of the test had led to support from the multidisciplinary team, senior colleagues, consultants and innovations panel and improving information sharing between SLT services. One respondent whose nursing staff administered CRT on their acute stroke unit referred to potential benefits for nursing staff with reported improvements in provision of dysphagia-specific education and training and awareness of responsibilities relating to dysphagia management; specifically, recognising swallow screening as part of their role.

Figure 6. Perceived benefits to use of CRT from current and previous users (n = 21 comments)

*Other components of dysphagia protocols*

Responses from current and previous CRT users indicated that CRT was not used as a standalone tool by their acute stroke services. The majority of respondents utilised a number of methods to gather information regarding degree of dysphagia and/or aspiration risk. All respondents (n = 11) reported that their service’s dysphagia protocol included trials of oral diet and fluids, most (n = 10) involved taking a case history and completing a cranial nerve or oro-motor examination. Just under half (n = 5) used a water swallow test and cervical auscultation. 4 respondents reported use of pulse oximetry and one reported use of the Dysphagia Trained Nurse assessment which enables nursing staff to assess patients with modified diet and fluid consistencies.

**Discussion**

This is the first survey-based study of CRT use by UK-based SLTs in acute stroke settings, providing a valuable record against which clinicians can compare their practice. Survey responses indicate that despite CRT being adopted in other countries, the majority of respondents (88%) did not use it in their practice. CRT is currently being used clinically in only a small number of acute stroke units in the UK although 34% of respondents reported that they were considering incorporating it into their dysphagia protocol in this setting. The majority of services have been using CRT for fewer than 2 years, with only one having used it for more than 3 years. Services which discontinued use all used CRT for less than 1 year.

Responses from current and previous CRT users demonstrated variation between services using CRT with regard to amount of training received, whether nursing and/or SLT staff delivered CRT, point of administration in terms of time post-admission and whether CRT was carried out as part of or following the initial swallow screen. Variation was also reported in protocols; including duration of exposure to and concentration of citric acid solution, criteria for pass/fail and subsequent management of patients dependent on their performance on CRT, including variation in wait times for and access to instrumental assessment.

Such variation in protocols and procedures is likely to impact on efficacy and validity of CRT in identifying patients at risk of silent aspiration. For instance, by administering CRT on only those patients who have failed their initial nurse-led swallow screen, a number of silent aspirators may already have been missed and by increasing the duration of exposure, sensitivity may be improved but specificity is likely to be adversely affected.

Amount of training received with regards to interpreting results of CRT is an important consideration for reliability. One study (Miles and Huckabee 2013) demonstrated untrained SLTs achieved only fair to moderate intra- and inter-rater reliability for judging reflexive cough strength on CRT video examples. Other studies have found high levels of inter-rater reliability (McCullough *et al.* 2005) when using experienced judges and trained raters. Further studies are required to determine the optimal amount of training required to improve accuracy of cough judgement. It is of note that services in this study which discontinued use of CRT delivered the least training to staff.

Similarly, variations in citric acid concentration and type of instrumental assessment used will affect the sensitivity and specificity of detecting silent aspiration. A validation study comparing CRT using a range of citric acid concentrations with findings of aspiration on instrumental assessment (Miles *et al.* 2013*a*) showed that sensitivity and specificity was optimised for FEES at 0.4mmol/L and VFSS at 0.6mmol/L. Sensitivity was improved when coughs that were subjectively rated as weak were classed as a fail but this reduced specificity. However, sensitivities and specificities were still unremarkable (67 and 85 respectively for FEES with use of 0.6mmol/L citric acid solution when trace aspirators were excluded, 50 and 85 when trace aspirators were included and 71 and 60 for VFSS). This suggests that a significant proportion of silent aspirators will be missed while those who are not silently aspirating will frequently be wrongly identified, thereby potentially allowing those who are at risk of silent aspiration to commence oral intake and keeping those who are not at risk unnecessarily nil by mouth pending instrumental assessment. This finding was consistent with one respondent who had conducted an audit of their SLT service. Furthermore, the validation study was conducted on mixed dysphagia groups, less than half of whom were stroke patients. Further validation studies are needed to determine the optimal concentration of citric acid solution for CRT with stroke patients.

The majority of respondents reported current or previous use of 0.6mmol/L. Citric acid solution is classed as an unlicensed medicine and issues with procurement and availability of alternative concentrations may have led to the widespread use of this concentration, despite more recent studies demonstrating potential for improved patient outcomes (lower aspiration pneumonia rates, readmissions, shorter hospital stays and return to normal diet) at higher concentrations (Perry *et al.* 2019) although it should be acknowledged that the changes in patient outcomes in this study were felt to be due to use of a standardised dysphagia management protocol that guided clinical interpretation of CRT results rather than as a result of inclusion of CRT per se.

The majority of survey respondents were unsure of the type of nebuliser and compressor used by their service and when reported, variation was noted between services. The literature suggests that aerosol particle size plays an important role in where the aerosol is deposited which may be of significance to citric acid cough thresholds although this is an area which requires further investigation. Several researchers have suggested that it is important to match the nebuliser and compressor to ensure optimal flow rate and particle size/percentage of particles in respirable range as choice of nebuliser and compressor have been found to alter the performance characteristics of nebuliser/compressor combinations (Reisner *et al.* 2001).

Respondents differed in the types of cough they assessed; some assessing natural cough, others suppressed cough and still others, both types of cough. Earlier studies involving use of CRT to aid identification of patients at risk of aspiration have examined voluntary cough (VC). VC is cortically-controlled whereas involuntary or RC is brainstem-generated though able to be cortically-mediated (Mazzone *et al.* 2011); both are impaired after acute hemispheric infarction (Ward *et al.* 2010).

VC is thought to be important for clearing aspirated material from the airway (Fontana and Widdicombe 2007) with impairment correlating with increased incidence of aspiration and chest infections (Addington *et al.* 1999, Smith Hammond *et al.* 2001). RC is felt to be of particular importance in protecting the airway from immediate threat and clearing the upper airway of laryngeal-penetrated material (Smith Hammond *et al.* 2001) and therefore may be considered more clinically significant than VC in terms of identifying those at risk of developing pneumonia.

Suppressed cough has recently been more widely used in dysphagia research using CRT with the hypothesis that cortical inhibition will allow for a true sensory reflex cough as the individual can no longer voluntarily control their cough response (Mills *et al.* 2017). This method of testing enables the assessor to determine whether an individual’s cortical cough centres have been affected by their stroke; the ability to suppress a cough response indicates that the cortical regions responsible for cough are intact, whereas an inability to suppress coughing may suggest stroke-related injury to these areas. Instructions for testing suppressed cough should relate to advising an individual to ‘try not to cough’ during the procedure.

A study relating to objective cough strength measures in healthy individuals which recorded peak airflow during cough (Mills *et al.* 2017), found that whether a VC was strong or weak it was still stronger than an RC. A priming or placebo effect relating to instructions given for CRT has been speculated (Monroe 2010), suggesting instructions such as ‘cough if you feel the need to’ (as per the protocol from Miles *et al.* 2013*a*) or ‘it might/might not make you want to cough’ may be more likely to elicit a VC than an RC. This theory needs further research but it may be appropriate to choose wording of instructions carefully to minimise the likelihood of priming patients and more accurately elicit an RC. This may avoid the need to assess both VC and RC separately and allow for inclusion of patients with apraxia, cognitive or communication impairment (common issues post-stroke) who cannot carry out volitional movements or adequately follow instructions for the voluntary cough test.

However, inclusion of assessment of VC where this is considered possible (based on patients’ relative levels of cognitive and/or communication function) with instructions such as ‘allow yourself to cough if you need to, and as much as you need to’ as per Morice *et al.* (2007), has the potential to determine the relative integrity of cortical control of cough to facilitate airway clearance.

The time period between CRT and instrumental assessment is also likely to be of significance, as in the acute phase post stroke it is well known that patients’ neurological conditions can significantly fluctuate with deterioration or spontaneous recovery of function both possible. It is therefore important to have as minimal a time lag between CRT and VFSS or FEES as possible to minimise the likelihood of a mis-match between patient’s functional presentation on one test compared with the other due to neurological variability especially if findings are to be used for research purposes. Respondents considered access to instrumental assessment one of the main barriers to implementation of CRT and reported that referrals for instrumental assessment increased at least two-fold following its introduction into their dysphagia protocols. This increase in demand for instrumental assessment is similar to findings from Perry *et al.* (2019) who reported an increase in VFSS referrals from 18% to 31% following introduction of their dysphagia protocol incorporating CRT although Field *et al.* (2018) report a more modest 6.7% increase in referrals for VFSS following implantation of CRT in their study published in the same year. This suggests that increase in demand for instrumental assessment following introduction of CRT is likely but may vary between regions and services. Findings from the current study suggest that improvement in clinical identification of patients who require instrumental assessment is not consistently supported by availability of the required resources. Delays in access to instrumental assessment have the potential to skew the validity of CRT findings and result in patients being kept (perhaps unnecessarily) nil by mouth for longer periods of time. Services should therefore be aware of demand and capacity issues for instrumental assessment if considering incorporating CRT into their dysphagia protocol.

As well as methodological considerations relating to CRT, it is important to recognise the limitations on resources imposed by service restrictions. These are highlighted by survey respondents and the issues raised in this study are likely to be familiar to SLTs working clinically. Access to instrumental assessment and procurement of citric acid solution have already been discussed above. Further restrictions include time for set-up and maintenance of a CRT service including obtaining approval for use of citric acid solution, establishment of a clinical protocol, provision of training, storage of equipment, delivering CRT and maintenance of competencies. For those who are not currently using CRT, many of the reasons cited for not pursuing its adoption related to lack of time. In terms of the delivery of CRT, if the respondent who reported that CRT adds approximately 30 minutes to a clinical swallowing assessment is correct in their estimation of time required to set up, complete and score CRT, then it is essential given the potential resource limitations to ensure that this is an appropriate use of clinical time. However, readers may want to interpret this claim with caution as the test itself should only take approximately 3 minutes to administer (Field *et al.* 2018) although it is acknowledged that issues related to prescribing of citric acid solution, set-up and consent may take longer than the test itself.

From a patient and service perspective, survey responses suggest that introduction of CRT has potential to result in faster access to instrumental assessment, shorter duration of nil by mouth status, decreased use of thickener, fewer patients on modified diet, upgrades of recommended diet and/or fluid consistencies and discharge from SLT caseload occurring sooner than they previously would have. Many of these perceived benefits are corroborated in recent literature with reduced waiting times for VFSS, fewer days on acute stroke ward, fewer days in hospital, improved return to normal diet and reduced rates of pneumonia reported following inclusion of CRT in a structured dysphagia protocol (Perry *et al.* 2019). Patient outcomes following introduction of CRT certainly should be explored further and, if these confirm the opinions of survey respondents and recent published studies, could result in improved quality of life for patients and increased efficacy of SLT service provision. Efficiency in service delivery and improved delineation of nursing and SLT roles and responsibilities may also be improved if CRT were administered by nursing staff rather than SLTs. However, these perceived benefits would also need to be tempered with comparisons with health-related outcomes such as calculating the accuracy for detection of silent aspiration as compared with instrumental assessment and development of aspiration pneumonia.

From a psychosocial perspective, findings of this study suggest that introduction of CRT has the potential to increase clinicians’ confidence in identifying patients who require instrumental swallow assessments and those whose dysphagia can be managed clinically. This is consistent with findings from recent studies (Holmes 2016, Field *et al.* 2018). Findings also suggest potential for improved intra- and inter-professional relations and information sharing. Several respondents who had never used CRT reported that one of the reasons they have not considered it is due to concerns regarding the evidence base for its use. Certainly, respondents indicated that they were not relying on CRT as a standalone tool but had incorporated it in to their services’ dysphagia protocols as an additional component to improve identification of patients requiring instrumental swallow assessments. Further research should carefully weigh up whether the confidence and support expressed by clinicians in this study in relation to CRT is justified or would be better redirected to other methods for screening for silent aspiration.

*Limitations*

This study was carried out with the intention of providing preliminary exploratory data on CRT use by SLTs in acute stroke settings within the UK. Few services in the UK currently use CRT, and although this is itself is a novel finding, as such, survey findings on implementation are based on a small number of CRT users and therefore it is possible that opinions expressed by respondents are not necessarily representative of the wider population and should be interpreted with caution. A larger sample of SLTs may have been more representative of the SLT population and would have given more statistical power to the findings. There was a wide range of geographical distribution from participants which suggests a lack of regional or selection bias in the method of recruitment.

The survey was intended to be as brief as possible with a view to encouraging participation and optimising completion rate. Therefore, issues such as inclusion and exclusion criteria, method of delivery, qualification of cough strength and presence or absence of cough, were not covered in this study. These topics may be of interest in future studies with a view to developing more robust standardised clinical protocols for CRT use.

**Conclusions**

Findings from the literature suggest that there is a lack of consensus regarding methodology and protocols for use of CRT with validity frequently being no better than other isolated components of standard bedside screening tests and clinical swallow examinations. This variation in use is reflected in the findings of this survey.

Despite current CRT users reporting perceived improvement in their clinical detection of silent aspirators, there are still concerns regarding the test’s accuracy for silent aspiration identification. Furthermore, it is widely acknowledged that variation in procedures and protocols makes it difficult to replicate or compare across studies and between services.

This study aims to lay the foundations for potential areas for improvement, further research and consideration of whether standardisation of citric acid CRT may be possible for SLT services in the UK and further afield.

Creation of a UK-wide and/or international forum should be considered to allow for continuing discussion and dissemination of existing evidence alongside further research comparing CRT with other methods of clinically screening for silent aspiration both in acute stroke and other patient populations. This would support clinicians to determine whether CRT is an appropriate tool to include in their dysphagia protocols and if so, make further steps towards standardising its use.

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**Addendum**

Further to the above, this survey was conducted prior to the COVID-19 pandemic and it is imperative to consider CRT in light of the possible health and safety implications. Public Health England (PHE 2020) report that the highest risk of transmission of respiratory viruses is known to be during aerosol generating procedures (AGPs) of the respiratory tract. Although they have not explicitly listed CRT as an AGP, they classify procedures involving sputum induction as infectious AGPs. CRT could therefore be considered as a procedure which is likely to generate an aerosol from patient secretions in instances where it elicits a cough response in patients. PHE advise that for patients with possible or confirmed COVID-19, potentially infectious AGPs should only be carried out when essential. This is an issue which will no doubt generate further debate and discussion and may influence methods involved in standard dysphagia practice.

**Appendix A**

*Cough Reflex Testing (CRT) in Acute Stroke Survey*

*Questions for all respondents*

1. Are you currently using or have you previously used CRT in your acute stroke service?
2. In which region within the UK do you work?
3. Name of SLT completing survey (optional)
4. Email address of SLT completing survey (optional)
5. Name of hospital and trust (optional)
6. Would you like to be contacted in the future with any other information regarding CRT?

*Section A: Questions for current users of CRT*

1. How many years has your service been using CRT?

0-1 1-2 2-3 3-5 More than 5

1. How is CRT being used?

Clinically only For research purposes only Both clinically and for research purposes

1. Who administers CRT? (Please select all that apply)

SLT Nursing staff Other (please specify)

1. How many hours of training do staff receive regarding cough/use of CRT prior to using (including observed administration of CRT)?

None 0-2 2-4 4-6 6-8 More than 8

1. Who delivers CRT training to staff? (Please select all that apply)

SLTs from the service I work in SLTs from a different SLT service Nursing staff Other (please specify)

1. When is CRT administered?

After failed nurse swallow screen As part of initial swallow screen Other (please specify)

1. On average, how many hours after admission to hospital is CRT administered?

Within 4 4-24 24-48 48-72 More than 72

1. Is CRT ever repeated?

No Yes

1. When is CRT repeated? (Please select all that apply)

24 hours after failed CRT If the patient’s condition significantly improves

If the patient’s condition significantly deteriorates Other (please specify)

1. What concentration(s) of citric acid solution is used by your service (mmol/L)?

0.4 0.6 0.8 1.2 Other (please specify)

1. What is the make and model of nebuliser used by your service (i.e. the nebuliser chamber used)?

Unsure Please specify (if known)

1. What is the make and model of compressor used by your service?

Unsure Compressor not used Please specify (if known)

1. If compressor not used, please specify air source for nebuliser
2. What is the total duration of exposure to citric acid by patients during CRT (in seconds)?

45 or less 45-90 90-120 Greater than 120 (please specify)

1. How many citric acid trials are administered to each patient?

1 2-3 More than 3

1. What type of cough is being assessed?

Natural Suppressed Both Not sure

1. What instructions are given to patients for CRT? (Please specify if different instructions are given for natural vs suppressed if both are being assessed)
2. What is the cough threshold criteria? (i.e. how many coughs need to be elicited to pass)

2 or more (C2) 5 or more (C5) Other (please specify)

1. Does your service include judgements on cough strength and how does this impact on the outcomes of CRT? (please select all that apply)

No - record presence/absence of cough only and do not make a judgement on cough strength

Yes - patients need to produce strong cough to pass

Yes - but patients still pass if the cough is judged as weak

1. What is your service's protocol for patients who pass/fail? (please select all that apply)

Pass - proceed to oral trials

Pass with caution - proceed to oral trials

Pass with caution - NBM + proceed to instrumental assessment

Fail - NBM + proceed to instrumental assessment

Other (please specify)

1. What other components are included in your service's dysphagia protocol? (Please select all that apply even if they are not used by all SLTs in your service).

Water swallow test Trials of oral diet and fluids Pulse oximetry

Cervical auscultation Cranial nerve/oro-motor examination Case history

Other(s) (please specify)

1. What is the average waiting time between CRT and instrumental swallow assessment (i.e. videofluoroscopic swallowing study (VFSS) or flexible endoscopic evaluation of swallowing (FEES))?

VFSS

Significantly limited or no access Within 24 hours Within 48 hours

Within 72 hours 3-5 days after 5 or more days after

FEES

Significantly limited or no access Within 24 hours Within 48 hours

Within 72 hours 3-5 days after 5 or more days after

1. Does your service typically use VFSS or FEES more frequently?

Only have access to VFSS Only have access to FEES

Similar number of VFSS and FEES VFSS more frequently than FEES

FEES more frequently than VFSS

1. What have you found to be barriers to use of/potential issues with CRT (if any)?  Please list as many as you can think of.
2. What have you found to be facilitators to use of/potential benefits to use of CRT (if any)? Please list as many as you can think of
3. Any other comments:

*Section B: Questions for previous users of CRT*

1. How many years did your service use CRT?
	1. 1-2 2-3 3-5 More than 5
2. How was CRT used?

Clinically only For research purposes only Both clinically and for research purposes

1. Who administered CRT? (Please select all that apply)

SLT Nursing staff Other (please specify)

1. How many hours of training did staff receive regarding cough/use of CRT prior to using (including observed administration of CRT)?

None 0-2 2-4 4-6 6-8 More than 8

1. Who delivered CRT training to staff? (Please select all that apply)

SLTs from the service I work in SLTs from a different SLT service Nursing staff Other (please specify)

1. When was CRT administered?

After failed nurse swallow screen As part of initial swallow screen Other (please specify)

1. On average, how many hours after admission to hospital was CRT administered?

Within 4 4-24 24-48 48-72 More than 72

1. Was CRT ever repeated?

No Yes

1. When was CRT repeated? (Please select all that apply)

24 hours after failed CRT If the patient’s condition significantly improved

If the patient’s condition significantly deteriorated Other (please specify)

1. What concentration(s) of citric acid solution were used by your service (mmol/L)?

0.4 0.6 0.8 1.2 Other (please specify)

1. What was the make and model of nebuliser used by your service (i.e. the nebuliser chamber used)?

Unsure Please specify (if known)

1. What was the make and model of compressor used by your service?

Unsure Compressor not used Please specify (if known)

1. If compressor was not used, please specify air source for nebuliser
2. What was the total duration of exposure to citric acid by patients during CRT (in seconds)?

45 or less 45-90 90-120 Greater than 120 (please specify)

1. How many citric acid trials were administered to each patient?

1 2-3 More than 3

1. What type of cough was being assessed?

Natural Suppressed Both Not sure

1. What instructions were given to patients for CRT? (Please specify if different instructions were given for natural vs suppressed if both were assessed)
2. What was the cough threshold criteria (i.e. how many coughs needed to be elicited to pass)?

2 or more (C2) 5 or more (C5) Other (please specify)

1. Did your service include judgements on cough strength and how did this impact on the outcomes of CRT (please select all that apply)

No - recorded presence/absence of cough only and did not make a judgement on cough strength

Yes - patients needed to produce strong cough to pass

Yes - but patients still passed if the cough was judged as weak

1. What was your service's protocol for patients who passed/failed? (please select all that apply)

Passed - proceeded to oral trials

Passed with caution - proceeded to oral trials

Passed with caution - NBM + proceeded to instrumental assessment

Failed - NBM + proceeded to instrumental assessment

Other (please specify)

1. What other components were included in your service's dysphagia protocol? (Please select all that apply even if they are not used by all SLTs in your service).

Water swallow test Trials of oral diet and fluids Pulse oximetry

Cervical auscultation Cranial nerve/oro-motor examination Case history

Other(s) (please specify)

1. What was the average waiting time between CRT and instrumental swallow assessment (i.e. videofluoroscopic swallowing study (VFSS) or flexible endoscopic evaluation of swallowing (FEES))?

VFSS

Significantly limited or no access Within 24 hours Within 48 hours

Within 72 hours 3-5 days after 5 or more days after

FEES

Significantly limited or no access Within 24 hours Within 48 hours

Within 72 hours 3-5 days after 5 or more days after

1. Did your service typically use VFSS or FEES more frequently?

Only had access to VFSS Only had access to FEES

Similar number of VFSS and FEES VFSS more frequently than FEES

FEES more frequently than VFSS

1. What did you find to be barriers to use of/potential issues with CRT (if any)?  Please list as many as you can think of.
2. What did you find to be facilitators to use of/potential benefits to use of CRT (if any)? Please list as many as you can think of
3. Why did your service stop using CRT? Please provide as much information as possible
4. Any other comments:

*Section C: Services who do not currently use/have not previously used CRT*

1. Has your service heard of cough reflex testing and are you aware of its use in dysphagia assessment?

Yes No

1. Is your service considering using CRT on its acute stroke unit?

Yes No

1. Why is your service considering using CRT? (Please select as many of the following options as appropriate and list others if they are not included below).

To aim to increase identification of potential silent aspirators

Faster decision-making regarding swallowing management plans

To aim to reduce length of hospital stay

To aim to reduce rates of pneumonia

Other(s) (please specify)

1. Why is your service not considering using CRT? (Please select as many of the following options as appropriate and list any others if they are not included below).

Haven't had time to consider it

Don't think the evidence base is good enough

Think implementation of CRT service would be too time-consuming

Concerned about obtaining pharmacy approval

Concerned about amount of SLT time needed to do CRT

Concerned about potential for increased demand for instrumental assessments (i.e. VFSS and FEES)

Concerned about cost

Concerned about training of staff in use of/interpretation of CRT

Don't think the stroke MDT would be keen

Other(s) (please specify)

1. Any other comments:

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