

RESEARCH ARTICLE



Screening for silent penetration and/or aspiration in older adults: assessment of different cough reflex test modalities

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ABSTRACT

Objectives: Reduced laryngeal sensitivity increases the risk of silent penetration and/or aspiration (SPA) and reduces the effectiveness of dysphagia screening tests. The aim of this study was to evaluate the diagnostic value of several Cough Reflex test (CRT) modalities for screening SPA in patients over 75 years of age.

Methods: This prospective study included 37 patients over the age of 75 who were hospitalised for acute conditions. Fiberoptic Endoscopic Evaluation of Swallowing (FEES) was used to compare the presence of SPA with the results of CRT obtained using citric acid at concentrations of 0.1 mol/L, 0.2 mol/L and 0.4 mol/L. During CRT, the presence of C2 (2 or more coughs) and C5 (5 or more coughs) were noted.

Results and discussion: Only the 0.1 mol/L concentration proved to be discriminatory: absence of C2 distinguished patients with SPA from healthy individuals ($p=0.009$; Se: 81.25%; Sp: 71.43%). Absence of C5 discriminated patients with SPA from those with detected penetrations and/or aspirations (DPA) (i.e. aspiration triggering cough) ($p=0.026$; Se: 81.25%; Sp: 71.43%). This test does not require specific expertise in dysphagia management, is non-invasive and is sensitive for detecting SPA.

Conclusion: The CRT using citric acid at 0.1 mol/L is a clinically valuable, non-invasive and sensitive tool for detecting SPA in an acute-care geriatric population.

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Dysphagia; geriatrics; silent penetration; silent aspiration; cough reflex test; screening

Introduction

Oropharyngeal dysphagia is a swallowing disorder characterized by difficulty in transferring a bolus (food, liquids, saliva, or mucus) from the mouth to the oesophagus. This condition can compromise swallowing safety, leading to aspiration of pharyngeal secretions, food, or liquids that pass below the vocal folds into the trachea and lower airways. Normally, aspiration is detected and triggers a cough reflex, which expels the inhaled material from the airway. However, silent penetration and/or aspiration (SPA) occur when the cough reflex is absent, allowing material to enter the airway without eliciting a cough. Silent aspiration is the most severe manifestation of dysphagia, as its presence increases the risk of pneumonia by thirteenfold [1].

Oropharyngeal dysphagia affects up to 47% of older adults admitted to hospital in acute care settings [2]. Early screening for dysphagia is crucial, as timely treatment can improve quality of life, reduce the risk of complications and ensure adequate nutrition [3]. Upon admission, screening tests are used to identify patients at risk of dysphagia. The De Pippo water swallow test is particularly useful in the geriatric population [4] and shows good sensitivity and specificity for detecting aspiration [5]. However, this test does not rule out penetration or aspiration when it is silent, as clinical observation alone is insufficient for detection [6]. Instrumental assessments, such as flexible endoscopic evaluation of swallowing (FEES) or videofluoroscopic swallowing study (VFS) are currently considered the reference standards for diagnosing dysphagia and detecting potential SPA, but these methods are not suitable for or available to all patients.

The cough reflex test (CRT) is an increasingly used method for assessing the risk of SPA [7–16]. Coughing is essential for airway protection, but this reflex tends to decline with age [6]. This decline, combined with swallowing dysfunction, increases the risk of aspiration [7,13]. The CRT involves the administration of a cough-inducing agent. When inhaled, this agent triggers an immediate series of vigorous coughs [17].

The aim of this study was to evaluate whether the cough reflex test (CRT) can be used to detect SPA in patients over 75 years of age and to assess its diagnostic performance. Its ability to distinguish between SPA and detected penetrations and/or aspirations (DPA) could help clinicians make more informed decisions regarding patient management and the need for additional instrumental assessments.

Method

In accordance with applicable regulations, this study was approved by the local ethics committee (No. B7072022000038).

Participants were recruited between 9 January and 24 April 2023 in the acute geriatric unit of a university hospital. Inclusion criteria were: age ≥ 75 years, hospital stay < 10 days and provision of written informed consent.

Patients were excluded for ethical reasons if they had contraindications to oral feeding (i.e. enteral or parenteral nutrition), severe respiratory insufficiency ($FEV_1 < 30\%$), or severe cognitive impairment precluding informed consent (Mini Mental State Examination score $< 10/30$ [18]); or for practical reasons if they had tracheostomy.

The cough reflex test (CRT) was used to assess laryngeal sensitivity through inhalation of a cough-inducing agent, citric acid, prepared by the hospital pharmacy at a concentration of 0.4 mol/L, was used. This solution was either administered at this concentration or diluted in 0.9% saline to obtain concentrations of 0.2 and 0.1 mol/L. Patients were blinded to the concentrations administered. The test was performed at the bedside using a disposable nebuliser. Airflow rate was set at 6 L/min *via* the room's medical air, and patients were seated. To familiarise patients with the procedure, a one-minute acclimatisation period with 0.9% saline was performed. Patients were instructed to “breathe normally and cough if needed.” The test was then conducted using the different concentrations in random order, with a 15-minute rest period between exposures. The mask and nebulizer chamber were rinsed with sterile water and dried during this interval. Each concentration was administered for a maximum of one minute. The number of coughs and duration of inhalation were recorded. As detailed in Table 1, at least two coughs (C2) were expected within the first 15 s, and at least five coughs (C5) during the remainder of the inhalation period.

All fiberoptic endoscopic evaluations of swallowing (FEES) were performed by a senior laryngologist, either before or after the CRT, in random order. When the CRT was performed first, the examiner was blinded to its results. Only the speech and language therapist, who administered the test, was aware of the concentrations used. A minimum interval of 3 h and a maximum of 20 h was maintained between FEES and CRT to avoid any influence of CRT on laryngeal sensitivity.

The following consistencies were tested: five spoonful of jelly (IDDSI 3) stained with methylene blue, solids (IDDSI 6 and 7) including salted crackers and piece of Madeleine cake (depending on prior test results); and finally, water (IDDSI 0) also stained with methylene blue. Aspiration events were recorded and classified according to the Penetration-Aspiration Scale (PAS) [19]. For each patient, the highest PAS score across all the tested consistencies was retained.

An initial analysis classified patients according to PAS scores: “Normal” = PAS 1–2, “Penetration” = PAS 3–5, “Aspiration” = PAS 6–8 and “Silent Aspiration” = PAS 8 only [19].

Table 1. Summary of scoring criteria for the cough reflex test.

		Assessment criteria	
		15 sec—C2	1 min—C5
Cough Reflex Test	Normal	2 coughs or more	5 coughs or more
	Pathological	Less than 2 coughs or no cough at all	Less than 5 coughs or no cough at all

A second analysis focused on airway clearance efficiency during penetration or aspiration events. “Silent penetration and/or aspiration” (SPA) referred to events that did not elicit a cough and were not effectively cleared (PAS 3, 5, 8), whereas “detected penetration and/or aspiration” (DPA) referred to overt events triggering a cough (PAS 2, 4, 6, 7) [20–22]. “Pathological” referred to SPA or DPA.

Statistical analysis was performed using Jamovi software (The Jamovi project (2024), Jamovi version 2.5)). C2 and C5 responses at each citric acid concentration were compared with FEES findings. Given that expected cell counts were < 5 , Fisher’s exact test was used. The significance threshold was set at $p < 0.05$. Sensitivity (Se)—and specificity (Sp) were calculated, along with positive predictive value (PPV), and negative predictive value (NPV). When significant associations were identified, their strength was assessed using univariate binary logistic regression with CRT results (normal vs pathological) as the dependent variable and FEES findings as the explanatory variable.

To account for potential confounders, a multivariable binomial logistic regression model was also developed. FEES results were used as the dependent variable, and CRT as the main independent variable. Sex and primary reason for hospitalisation were included as categorical variables, with pulmonary pathology as the reference category. Results are reported as odds ratios (ORs) with 95% confidence intervals (95% CI).

Results

Population

Patients characteristics are summarised in Table 2, and main reasons for hospitalisation in Table 3. Some patients had multiple diagnoses. For analysis purposes, each patient was assigned a single primary diagnosis corresponding to the main reason for admission. Secondary diagnoses were recorded but not used for classification.

Patient distribution by airway invasion severity are shown in Table 4, and by detection status (silent vs detected) in Table 5.

Table 2. General characteristics of the population.

Total number of patients	37
Sex	Females : 17, Males : 20
Age range	75 to 97 years
Mean age (X)	84 years
Standard deviation (σ)	5.40

Table 3. Summary of hospitalisation reasons.

Medical Category	Number of Patients
Pulmonology ($n = 14$)	Bronchopneumonia ($n = 12$) Dyspnoea with oxygen desaturation ($n = 1$) Lung malignancy ($n = 1$)
Neurology ($n = 9$)	Parkinson’s disease - related decompensation ($n = 5$) Stroke / Transient ischemic attack ($n = 2$) Acute cognitive disorder (confusion, cognitive assessment without respiratory cause) ($n = 2$)
Geriatrics / Functional ($n = 9$)	Falls ($n = 4$) Functional decline ($n = 3$) General condition deterioration ($n = 2$)
Cardiology ($n = 3$)	Acute decompensated heart failure ($n = 2$) Cardiac arrest ($n = 1$)
Digestive / Metabolic ($n = 1$)	Acute pancreatitis ($n = 1$)
Nephrology ($n = 1$)	Acute renal failure ($n = 1$)

Table 4. Swallowing safety: first analysis in ascending order of PAS score.

Swallowing safety status	Number of Patients	Percentage of Sample
Aspirations PAS 6–8	16	43.2%
Penetrations PAS 3–5	5	13.5%
Normal / Healthy Swallowing PAS 1–2	16	43.2%

Tolerance

One patient reported dizziness following inhalation and withdrew from the study. No significant adverse effects were reported by the remaining participants, aside from transient throat discomfort.

First analysis: evaluation of criterion C2

No significant association was found between CRT results at 0.4 mol/L and FEES findings. Significant associations were observed at 0.2 mol/L ($p=0.035$) and 0.1 mol/L ($p=0.003$) for distinguishing pathological from normal patients. At 0.1 mol/L, the CRT discriminated healthy individuals from patients with aspirations ($p<0.001$) and silent aspirations ($p=0.006$), as shown in Tables 6 and 7.

First analysis: evaluation of criterion C5

No significant association was found at 0.4 mol/L. At 0.2 mol/L, the CRT distinguished healthy individuals from patients with aspiration ($p=0.024$). At 0.1 mol/L, significant associations were observed for aspiration ($p=0.018$) and silent aspiration ($p=0.007$) (Tables 8 and 9).

Table 5. Swallowing safety: second analysis, focused on laryngeal sensitivity.

Swallowing safety status	Number of patients	Percentage of sample
Silent penetration/aspirations (SPA) PAS 3–5–8	16	43%
Detected penetration/aspirations (DPA) PAS 2–4–6–7	7	19%
Normal/healthy swallowing PAS 1	14	38%

Table 6. Results of cough reflex test (C2 criterion) according to the three concentrations of citric acid (0.4, 0.2 and 0.1 mol/L) and FEES results (swallowing safety: Normal, Penetration, aspiration, silent aspiration).

		FEES			
		Normal PAS 1–2	Penetration PAS 3–5	Aspiration PAS 6–8	Silent aspiration PAS 8
CRT C2 normal	0.4 mol/L	15	4	11	9
	0.2 mol/L	14	3	8	7
	0.1 mol/L	12	3	2	2
CRT C2 pathological	0.4 mol/L	1	1	5	5
	0.2 mol/L	2	2	8	7
	0.1 mol/L	4	2	14	12

Table 7. Relationships between cough reflex test (C2 criterion) at three concentrations (0.4 mol/L; 0.2 mol/L and 0.1 mol/L) and FEES results (swallowing safety: Normal, Penetration, aspiration, silent aspiration).

	Normal PAS 1–2	Penetration PAS 3–5	Aspiration PAS 6–8	Silent Aspiration PAS 8
CRT C2 0.4 mol/L	$p=0.113$	$p=1.000$	$p=0.202$	$p=0.080$
CRT C2 0.2 mol/L	$p=0.035$	$p=1.000$	$p=0.077$	$p=0.146$
CRT C2 0.1 mol/L	$p=0.003$	$p=0.644$	$p<0.001$	$p=0.006$

Values shown in bold are statistically significant ($p < 0.05$).

Table 8. Results of cough reflex test (C5 criterion) according to the three concentrations of citric acid (0.4, 0.2 and 0.1 mol/L) and FEES results (swallowing safety: Normal, Penetration, aspiration, silent aspiration).

		FEES			
		Normal PAS 1–2	Penetration PAS 3–5	Aspiration PAS 6–8	Silent aspiration PAS 8
CRT C5 normal	0.4 mol/L	15	4	14	12
	0.2 mol/L	15	4	9	8
	0.1 mol/L	10	3	3	2
CRT C5 pathological	0.4 mol/L	1	1	2	2
	0.2 mol/L	1	1	7	6
	0.1 mol/L	6	2	13	12

Table 9. Relationships between the cough reflex test (C5 criterion) at three concentrations (0.4 mol/L; 0.2 mol/L and 0.1 mol/L) and FEES results (swallowing safety: Normal, Penetration, aspiration, silent aspiration).

	Normal PAS 1–2	Penetration PAS 3–5	Aspiration PAS 6–8	Silent Aspiration PAS 8
CRT C5 0.4 mol/L	$p=0.618$	$p=0.456$	$p=1.000$	$p=0.625$
CRT C5 0.2 mol/L	$p=0.050$	$p=1.000$	$p=0.024$	$p=0.057$
CRT C5 0.1 mol/L	$p=0.052$	$p=0.634$	$p=0.018$	$p=0.007$

Values shown in bold are statistically significant ($p < 0.05$).

Table 10. Results of cough reflex test (C2 criterion) according to the three concentrations of citric acid (0.4, 0.2 and 0.1 mol/L) and FEES results (normal, detected penetrations and/or aspiration-DPAs, silent penetrations and/or aspirations-SPA).

		FEES		
		Normal (PAS 1)	DPA (PAS 2,4,6,7)	SPA (PAS 3,5,8)
CRT C2 normal	0.4 mol/L	13	6	11
	0.2 mol/L	12	5	8
	0.1 mol/L	10	4	3
CRT C2 pathological	0.4 mol/L	1	1	5
	0.2 mol/L	2	2	8
	0.1 mol/L	4	3	13

Table 11. Association between FEES results and CRT C2 results at three concentrations (0.4, 0.2 and 0.1 mol/L).

	DPA vs normal	SPA vs normal	SPA vs DPA	Pathological (DPA+ SPA) vs normal
CRT C2 0.4 mol/L	$p=1$	$p=0.175$ Se : 31.25% Sp : 92.86%	$p=0.621$ Se : 31.25% Sp : 85.71%	$p=0.217$ Se : 73.91% Sp : 92.86%
CRT C2 0.2 mol/L	$p=0.574$	$p=0.058$ Se : 50% Sp : 85.71%	$p=0.405$ Se : 50 % Sp : 71.43 %	$p=0.084$ Se : 43.48% Sp : 85.71%
CRT C2 0.1 mol/L	$p=0.638$	$p=0.009$ Se : 81.25% Sp : 71.43%	$p=0.137$ Se : 81.25% Sp : 57.14 %	$p=0.021$ Se : 69.57% Sp : 71.43%

Values shown in bold are statistically significant ($p < 0.05$).

Table 12. Odds ratio of presenting a pathological CRT (DPA vs SPA).

	p	OR (95% CI)
DPA—healthy	0.515	1.875 (0.282–12.45)
SPA—healthy	0.006	10.8333 (1.961–59.83)

Table 13. Multivariable logistic regression for FEES results (normal versus silent penetrations and/or aspirations).

Variable	p	OR (95 CI)
CRT C2 0.1 mol/L	0.47	1.93 (0.32–11.66)
Sex	0.40	0.50 (0.10–2.58)
Hospitalisation reason: Neurological vs pulmonary	0.28	0.29 (0.03–2.71)
Hospitalisation reason: Geriatric vs pulmonary	0.21	0.25 (0.03–2.18)

Second analysis: evaluation of criterion C2

No significant relationship was found at 0.4 ($p=0.303$) or 0.2 mol/L ($p=0.127$). At 0.1 mol/L, a significant association was observed between the CRT and the FEES ($p=0.013$), including with SPA specifically ($p=0.009$).

CRT at 0.1 mol/L distinguished SPA from healthy individuals (Se: 81.25%; Sp: 71.43%; PPV: 76.47%; NPV: 76.92%). Additionally, a significant association was observed between CRT results at 0.1 mol/L and pathological examination in the FEES ($p=0.021$). The CRT was able to differentiate dysphagic patients from healthy individuals (Se: 69.57%; Sp: 71.43%; PPV: 80%; NPV: 58.82%) (Tables 10 and 11).

The regression analyses (see Table 12) indicates that patients with SPA on FEES are 10.8 times more likely to have a pathological CRT than those with normal FEES findings, corresponding to an approximately 983% increase in odds. In multivariable analysis (see Table 13), no variables remained significantly associated with FEES findings.

Second analysis: evaluation of criterion C5

No significant association was found between the CRT and the FEES at 0.4 or 0.2 mol/L. At 0.1 mol/L, a significant association was observed ($p=0.03$), including between SPA and DPA ($p=0.026$; Se: 81.25%; Sp: 71.43%; PPV: 86.67%; NPV: 62.5%, as shown in Tables 14 and 15).

Table 14. Results of cough reflex test (C5 criterion) according to the three concentrations of citric acid (0.4, 0.2 and 0.1 mol/L) and FEES results (normal, detected penetrations and/or aspirations-DPA, silent penetrations and/or aspirations-SPA).

		FEES		
		Normal (PAS 1)	DPA (PAS 2,4,6,7)	SPA (PAS 3,5,8)
CRT C5 normal	0.4 mol/L	13	6	14
	0.2 mol/L	13	5	10
	0.1 mol/L	8	5	3
CRT C5 pathological	0.4 mol/L	1	1	2
	0.2 mol/L	1	2	6
	0.1 mol/L	6	12	13

Table 15. Association between FEES results and CRT C5 results at three concentrations (0.4, 0.2 and 0.1 mol/L).

	DPA vs normal	SPA vs normal	SPA vs DPA	Pathological vs normal
CRT C5 0.4 mol/L	$p=1$	$p=1$ Se : 12.5% Sp : 92.86%	$p=1$ Se : 12.5% Sp : 85.71%	$p=1$ Se : 13.04% Sp : 92.86 %
CRT C5 0.2 mol/L	$p=0.247$	$p=0.086$ Se : 37.5% Sp : 92.86%	$p=1$ Se : 37.5% Sp : 71.43%	$p=0.112$ Se : 34.78% Sp : 92.86%
CRT C5 0.1 mol/L	$p=0.656$	$p=0.057$ Se : 81.25 % Sp : 57.14 %	$p=0.026$ Se : 81.25% Sp : 71.43%	$p=0.305$ Se : 65.22% Sp : 61.90%

Values shown in bold are statistically significant ($p < 0.05$).

Discussion

The use of the cough reflex test (CRT) for detecting silent aspiration has mainly been studied in neurologic populations [7,8,12,15] and across various conditions [9,12,13,15,16] but rarely in geriatric patients. Methodologies vary widely in both test administration and interpretation criteria. Some studies use the C2 criterion, defined as the production of at least two coughs to consider the reflex non-pathological [11,13, 15,16] while others rely on C5, or adopt perceptual approaches based on cough presence or strength [8,10,12]. Test parameters, including inhalation duration, airflow, instructions and tussive agents, also differ considerably [23]. These inconsistencies highlight the need for standardisation [22].

This study aimed to define optimal CRT parameters for screening silent aspiration in geriatric patients. Our findings indicate that a concentration of 0.1 mol/L and the C2 criterion provide the most informative results. This is particularly relevant given the high prevalence of impaired swallowing safety in this population, reaching 62% in our sample, with 70% of those cases involving silent penetration and/or aspiration.

To the best of our knowledge, there was no consensus in the literature and published methods vary regarding how to perform the CRT [23]. A recent meta-analysis concludes that the use of a tussive agent such as citric acid in cough reflex testing represents the safest and most prudent approach [22]. In 2013, Miles et al. suggested the use of a low concentration of citric acid (0.4 mol/L) for high-risk populations [11]. Given that presbyphagia in geriatric wards is associated with a high risk of decompensation, we selected this dosage, along with a lower concentration of 0.1 mol/L as proposed by Battel et al. in 2016 [15]. These authors recommended a concentration of 0.1 mol/L, but their study lacked instrumental assessment of swallowing to support their recommendations. Lower concentrations likely improve diagnostic accuracy, as higher concentrations may trigger coughing even in patients with reduced sensitivity, leading to false-negative results. (i.e. PAS = 8 in the first analysis, and SPA in the second). Regardless of the criteria (C2 or C5), significant associations were demonstrated as long as patients presented with reduced laryngeal sensitivity.

The scoring criteria used in the literature also vary. The two most commonly employed criteria are C2 and C5, both of which were used in this study. Criterion C2 was successful in distinguishing between healthy individuals and those with silent aspiration. Criterion C5 was able to differentiate between patients with detected aspiration and those with silent aspiration. Both C2 and C5 showed similar sensitivity and specificity (81.25% and 71.43%, respectively). Given the positive predictive values of 76.47% for C2 and 86.67% for C5, the results of this study are consistent with those of

previous authors [7–13,15,16,23], supporting the relevance of the CRT for identifying silent aspirators. C2 appears more suitable for screening due to its shorter administration time.

The CRT results showed high sensitivity for criteria C2 and C5 at 0.1 mol/L, and regression analysis confirmed that SPA significantly increases the likelihood of a pathological CRT result by 983%. However, this association did not persist after adjustment for sex and primary diagnosis, likely due to limited sample size.

In routine clinical practice, the CRT is quick, non-invasive, and easy to administer, requiring no specialised training. Consequently, it may serve as a first-line screening tool, and be combined with other clinical or instrumental assessments to optimize screening strategies [22].

However, a normal CRT does not exclude aspiration, since the test's sensitivity is not 100%. There are several potential mechanisms that could explain this observation. Firstly, CRT with citric acid evaluates the response to a chemical irritant. Aspiration of food or liquid may activate different sensory pathways, such as mechanical receptors. Secondly, some patients may have partial sensory impairment and only cough in response to strong irritants, rather than to specific volumes or consistencies. Another reason is impaired timing and coordination, since an intact cough reflex is insufficient if the coordination between breathing and swallowing is altered, or if laryngeal closure is delayed.

The present study is subject to several limitations, including the limited size of our sample. This may have reduced the statistical power in the multivariate analysis, explaining the wide confidence interval observed (95% CI 1.96–59.83) for the odds ratio. Secondly, we investigated the population of patients in acute geriatric care. As the cough reflex response and swallowing physiology may differ in other populations, generalisation of these conclusions beyond the cohort studied is restricted.

Further exploration of the CRT in at-risk populations is recommended for its validation in clinical practice. We expect the test to be appropriate in populations at risk of SPA, as explored in previous studies [7–13,15,16,23]. Exclusion criteria remain to be clearly defined, particularly for patients with severe emphysema. Although the CRT is generally well tolerated and no major adverse events have been reported in the literature, it would be relevant to investigate tolerance in population with increased vulnerability.

Conclusions

A pathological CRT result at 0.1 mol/L citric acid using the C2 criterion was associated with silent aspiration (SPA) on FEES, increasing the likelihood approximately tenfold. These findings support the use of CRT as a bedside screening tool for assessing laryngeal sensory function and identifying patients at risk of silent aspiration, who may benefit from further instrumental evaluation. However, it should not replace instrumental swallowing assessment.

Author contributions

CRedit: **M-C. Le Beller:** Conceptualization, Data curation, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing; **M Poncelet:** Conceptualization, Data curation, Investigation, Methodology, Project administration, Supervision, Writing – review & editing; **F Depierreux:** Writing – review & editing; **S Gillain:** Writing – review & editing; **V Defaweux:** Writing – review & editing; **A. Lagier:** Conceptualization, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing.

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Data availability statement

The data supporting this study cannot be shared openly due to the need to protect participant privacy and confidentiality. Access to the data may be granted upon reasonable request and subject to ethical and legal restrictions.

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