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Early View

Review

Effects of high-flow nasal therapy on swallowing function: a scoping review

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Effects of High-flow Nasal Therapy on Swallowing function: A Scoping Review

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Take home message: The available evidence on the impact of High-Flow Nasal Therapy on swallowing function is insufficient and controversial.

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Abstract

Background: High-flow nasal therapy (HFNT) is widely used in patients with respiratory failure in different clinical settings, but the effect of HFNT on respiratory-swallow coordination is unknown. Understanding this relationship is crucial, considering the necessity for patients to maintain adequate nutrition during daytime HFNT.

Purpose: This scoping review aims to synthesise available data on the effects of HFNT flow rates on swallowing function and the possible risk of aspiration during treatment, focusing on knowledge and evidence gaps.

Methods: PubMed, Scopus, Web of Science and Google Scholar databases were searched from inception to May 30th, 2023, for studies reporting data on swallowing assessment in healthy adults or patients with acute or chronic respiratory failure receiving HFNT. Data on study design, patients' characteristics, and quality outcomes were extracted, and risk of bias was assessed.

Results: Eight studies were included, four including cohorts of healthy volunteers (n=148) and four including patients with acute or chronic respiratory failure (n=151). Study designs, patient populations, and quality outcome measures were heterogeneous. Two studies indicated improvement, while four articles showed impairment in swallowing function during HFNT; two studies showed that patients' overall clinical picture and underlying medical conditions influence swallowing-breathing coordination rather than HFNT *per se*. Risk of bias was judged low for all the included studies.

Conclusion: This scoping review found limited and controversial evidence of the impact of HFNT on swallowing function. Remarkably, methods for swallowing function assessment were quite heterogeneous. Additional research is required to test the effect of HFNT on respiratory-swallowing coordination.

Introduction

Both vital functions of breathing and swallowing pass through the upper airways, emphasising the critical need for coordinated interaction to protect the respiratory tract from aspiration [1]. This coordination can be impaired in individuals with respiratory diseases [2, 3] due to changes in patients' breathing pattern and modifications of the respiratory drive, which reduce the frequency of swallowing, shorten apnoeic periods and decrease glottis closure durations, ultimately increasing the likelihood of airway vulnerability [4, 5]. Indeed, signs of swallowing abnormalities are common in patients with acute respiratory failure without pre-existing dysphagia [5, 6]. Thus, weakness related to critical illness, including both pharyngeal and laryngeal muscles, has been demonstrated to impede a patient's ability to swallow [7, 8].

High-flow nasal therapy (HFNT) is a form of noninvasive respiratory support used as an alternative to conventional oxygen therapy (COT) and noninvasive ventilation in patients with acute and chronic respiratory failure [9-11]. It provides humidified gas at high flows (up to 60 Lpm) that assures a continuous washout of CO_2 from the anatomical dead space, generating a slight positive end-expiratory pressure effect that may reduce the inspiratory effort and dyspnea while improving oxygenation delivering a stable fraction of inspired oxygen (FiO2) [12, 13]. Moreover, HFNT improves secretion clearance, reduces the need for invasive mechanical ventilation in patients with *de novo* respiratory failure [14] and may be as comfortable as COT for patients and easy to use for clinicians [15]. HFNT has been widely used for treating patients with acute respiratory failure of different aetiologies [16-21], including viral infections [22] and COVID-19 pneumonia [15, 23, 24] and proposed for long-term domiciliary treatment in selected patients [25-27]. High-flow nasal therapy is generally well tolerated by patients, and its compact nasal interface potentially allows patients for unimpeded speaking, coughing, and oral feeding during its use [28]; however, HFNT increases pharyngeal pressures [29, 30] and as a result, it may impact airway protection

mechanisms. This scoping review aims to synthesise available data on the effects of HFNT on swallowing function and the possible risk of aspiration during treatment.

Methods

This scoping review was performed and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines [31] (Supplementary file S1 PRISMA-ScR Checklist).

Data sources and search strategy

A comprehensive search of PubMed, Scopus, Web of Science and Google Scholar was made for articles published from database inception to May 30th, 2023, for randomised and nonrandomised studies, with both retrospective and prospective designs. Case reports and case series were excluded. We restricted the search to studies published in the English language. The search strategy included the following Mesh terms or keywords (according to the specific vocabulary of the databases): "High-Frequency Ventilation" or "high-flow oxygen" or "high flow nasal cannula" or “high flow nasal therapy” or "Non-invasive ventilation" AND "Deglutition" and "dysphagia" OR "swallowing" OR "aspiration" OR "inhalation". The full search output is available as Supplementary Material (Supplementary file S2). We excluded conference proceedings, abstracts, book chapters or unpublished literature.

Article selection and eligibility criteria

According to the eligibility criteria and the following recommendations of the PRISMA-ScR [31] and the Population, Intervention, Comparison, Outcome, and Study Design (PICOS) criteria [32] (Table 1), the studies were included if (1) the participants were adults, healthy volunteers or patients affected by acute or chronic respiratory failure (P); (2) the intervention was based on the use of HFNT (I); (3) no comparators or other forms of respiratory support (C); (4) the outcomes of interest included the results of any type of

bedside swallowing assessment such as clinical symptoms evaluation, food/water swallow test, submental electromyography (EMG), fiberoptic endoscopic evaluation of swallowing (FEES), Blue Dye Test [33] (O).

Article Selection

After the independent inclusion/exclusion screening process by two reviewers (RC, CC), 35 papers were selected for full-text review to confirm eligibility. The articles excluded were 27 for the following reasons: 10 did not consider HFNT, 6 did not describe swallowing involvement, 10 did not have patients' data, but they were only descriptive or did not include respiratory disorders, 1 was the protocol of a randomised control trial (Figure 1). Discrepancies at any stage were solved by consensus between the two reviewers.

Data extraction, quality of evidence assessment and risk of bias

Two study team members (RC and CC) independently charted and extracted data from all the studies and performed the risk of bias assessment using the Revised Cochrane risk-of-bias tool for randomised trials (RoB_2) [34] and Risk Of Bias in Nonrandomised Studies of Interventions (ROBINS I) [35] tools. Disagreements were solved by consensus between the two reviewers.

The protocol of this review was registered on PROSPERO, registration ID: CRD42023421871. After performing the systematic search as indicated, we realized that a formal systematic review and meta-analysis would not have been possible due to the characteristics of available evidence. Thus, we decided to perform a scoping review as the best type of evidence synthesis in this case [36].

Results

Description of the articles

Identified articles were published in 2016 or later. From 2016 to 2023, the search strategy initially identified 250243 potentially relevant papers. After title screening and

duplicate removal, a total of 69510 citations remained. After abstract screening, a total of 35 studies met the inclusion criteria and were therefore selected for full text review. The final selection included eight [37-44] studies: 1 randomised crossover trial, 5 prospective cohort studies, 2 retrospective studies. The inclusion/exclusion process is presented as a PRISMA flow diagram, as shown in Figure 1. The main characteristics and design of the included study are reported in Table 1. The selected eight articles described the influence of HFNT on swallowing in 148 healthy adults and 151 patients affected by acute or chronic respiratory failure. A large variation among the studies was present concerning the general clinical characteristics, such as clinical presentation, severity of symptoms, duration of the disease (acute or chronic), methodology used to assess swallowing, time of starting oxygenation therapy, and duration of treatment (Table 1). This heterogeneity of the sample precluded the performance of a quantitative analysis of the data.

All the studies were judged at low risk of bias. Table 2 reports the quality of the included studies as assessed using the RoB2 and ROBINS I, respectively.

Characteristics of Included Studies

Involvement of swallowing during high-flow nasal cannula: studies on healthy volunteers

Sanuki et al. [42] showed that HFNT facilitated swallowing function during treatment with increasing flow rates by reducing the latency of the swallowing reflex, enabling a safe oral intake. The authors studied the swallowing latency time, which is the period between swallowing onset (when the patients were requested to swallow) and the start of the first wave in the surface EMG. Indeed, aspiration was linked to a longer latency time; therefore, the reduced latency time from high flow could cause a more effective and coordinated swallowing. The latency times of the swallowing reflex with high flow of 15, 30, and 45 L/min were significantly shorter than those under control conditions (at 0 L/min). Moreover, the fluctuation in airway pressure during HFNT activated receptors in the upper airway and

initiated the swallowing reflex, as opposed to what occurs with nasal continuous positive airway pressure (CPAP).

Arizono et al. [38] showed that a flow rate of 20 L/min or more resulted in a reduction in the number of swallows and an increase in swallowing effort. The authors described that, as the flow increased up to 40 L/min and above, it caused choking and coughing in a quarter of healthy volunteers (26.6%); flow rates of 50 L/min reduced the numbers of swallows from 10.7 at 0 L/min to 6.8 times at 50 L/min. Allen and coworkers [37] highlighted that another concept to consider was the duration of laryngeal vestibule closure (time for one swallow), which captured significant changes across airflow conditions. In particular, the modulation of the duration of laryngeal vestibule closure during swallowing in response to changes in bolus volumes and flow rate showed the ability of healthy individuals to adapt to swallowing conditions as needed to protect the airway from aspiration. However, higher flow rates were subjectively perceived by individuals as causing more difficulty swallowing [37].

Eng et al. [44] showed that changes in swallowing performance occur in healthy volunteers with increased HFNT flow rates. In particular, they observed an increase in the Modified Barium Swallow Impairment Profile scores during HFNT compared to baseline that was higher at flow rates of 60 L/min and that the increase in flow rate affects the oral phase of swallowing reducing lip closure and tongue control and increasing the oral residue.

Overall, in healthy volunteers, high flow rates seem to exert a significant influence on swallowing mechanics, making swallowing more difficult and increasing the risk of coughing and the chance of aspiration by prolonging the duration of laryngeal vestibular closure [37, 38, 44].

Involvement of swallowing during high-flow nasal cannula: studies on patients with respiratory diseases

In a retrospective cohort study [39], silent aspiration was reported in 5 (50%) out of 10 critically ill patients with respiratory distress who underwent a modified barium swallow

study (MBSS) while receiving HFNT during hospitalisation. Conversely, Leder et al. [40] showed that when considered appropriate from medical perspectives, adult patients admitted to the intensive care unit (ICU) requiring HFNT successfully restarted oral alimentation, highlighting that it is not the use of HFNT *per se* but rather patient-specific determinants of feeding readiness and underlying medical conditions that impact decisions for oral alimentation. Zerbib et al. [43] demonstrated that the administration of HFNT in ICU settings was associated with significant underfeeding so that, in order to reach the optimal caloric and protein intake, parenteral nutrition had to be considered in the presence of swallowing disorders associated with the use of higher flow rate. Additionally, Flores and coworkers [41] showed that the use of HFNT during the post-extubation period improved the coordination between swallowing and breathing, thanks to the increase in the likelihood of swallowing during the expiratory phase by lengthening the expiratory period and protecting the airways from aspiration. The potential positive and negative effects of HFNT on swallowing function are displayed in Figure 2.

Discussion

This scoping review showed conflicting results on the effects of HFNT on swallowing function and, therefore, its impact on oral feeding and risk of aspiration during treatment both in healthy subjects and in patients with respiratory disorders. In this regard, some of the included studies indicated improvement in swallowing function during HFNT [41, 42] while others showed a decrease in swallowing function during HFNT [37, 38, 43, 44]; one study showed no impact of HFNT on swallowing [40] and another highlighted the need for a deep investigation of swallowing physiology [39].

High-flow nasal therapy is frequently and widely used in clinical practice to manage patients with various types of acute respiratory failure in different clinical settings with varying nurse-to-patient ratio among facilities; therefore, careful consideration of the safety implications of concurrent oral feeding during treatment is required. Furthermore, recent

evidence showed that HFNT has beneficial effects even in chronic respiratory failure [10], boosting its use in long-term domiciliary settings and reinforcing the importance of obtaining safety data on concurrent oral intake while on treatment. To the best of our knowledge, this is the first scoping review examining the evidence on the impact of HFNT on swallowing function.

The majority of the studies included in our review were published within the past decade, indicating a growing interest in understanding, and addressing the problem of safety of swallowing during HFNT. Early reports in healthy subjects showed favourable airway protective adaptation during HFNT, including a decreased latency of swallow initiation with increased flow rates, a compensatory pharyngeal response during swallowing at HFNT rates of up to 60 L/min and a dose-dependent lengthening of the duration of the laryngeal vestibule closure and concurrent signs of airway protection on videofluoroscopic examination [37]. However, we are unable to determine if similar protection mechanisms are present also in patients with acute or acute on chronic lung diseases. Thus, in patients affected by acute respiratory failure, the breathing pattern, the presence of underlying chronic respiratory diseases, comorbidities, cognitive status, physical abilities, and performance status can influence the decision regarding the safety of oral intake while on treatment with any noninvasive oxygenation strategies [39]. Indeed, oropharyngeal dysphagia is more common in chronic respiratory diseases since swallowing more often occurs during the expiration-inspiration transition and not during expiration as it should be [6]. Moreover, COPD patients tend to assume a hunched posture, consequently reducing the coordination between the diaphragm and rectus abdominis, which is crucial to control physiological apnoea during swallowing [45]. Indeed, in chronic respiratory diseases, the coordination between swallowing and breathing can be impaired due to muscle dysfunction, changes in breathing pattern and lung capacity, and the presence of dyspnea, which may increase swallowing frequency and generate laryngeal irritation [4]. In addition, it has been shown that survivors

of severe acute respiratory failure present abnormalities of laryngeal structure, sensation, swallowing physiology, reduced pharyngeal squeeze/medialisation and upper airway edema that may increase the risk of developing dysphagia [5]. Nevertheless, a recent survey [46] on clinicians' feeding practices during HFNT showed great variability among different facilities without any specific protocol in this regard, with physicians and respiratory therapists considering oral intake during HFNT safe for stable patients with no need for swallowing evaluation and speech-language pathologists favouring a bedside clinical swallowing screening for patients on HFNT before eating or drinking.

HFNT at different flow rates (15, 30 and 45 L/min) seems to enhance swallowing function, reducing the latency times of the reflex in healthy subjects [42]. Similarly to HFNT, nasal CPAP at low pressure (5, 10, 15 cmH_2O) was shown to attenuate the swallowing reflex [6] (already compromised in chronic respiratory diseases with consequent increased latent time to trigger the reflex) due to the mechanical increment of the airway generated by the positive pressure, inhibition of the swallowing receptors and the reduction of peripheral sensation mechanisms [47]. However, unlike HFNT devices, CPAP reduces the inspiration after swallowing frequency, increases the swallowing-associated non-inspiratory flow occurrence, and normalises the timing of swallowing, alleviating the risk of aspiration in patients with COPD [48]. None of the included studies evaluated the association between different temperatures and FiO_2 as effect modifiers on swallowing function.

Based on our findings, the relationship between HFNT and swallowing function has not yet been clearly established, and the currently available literature offers conflicting evidence. However, oral feeding should not be withheld or delayed exclusively based on the ongoing treatment with HFNT. On the other hand, the potential impact of HFNT flow rates on swallowing physiology and aspiration-related concerns should be considered based on patient-specific factors, and swallowing bedside clinical or instrumental evaluation should be performed on selected clinical scenarios based on clinical judgment. Clinicians should

carefully evaluate starting, keeping, or stopping oral intake in patients on HFNT as in every noninvasive respiratory support, considering the underlying disease and comorbidities, cognitive status, cough effectiveness and ability to clear secretions, age, sedation and possible pharmacological interaction and obliged position. Considering the contradictory effects of HFNC on swallowing based on few heterogeneous short-term studies, it is reasonable to consider that the risk of unsafe swallowing may change over time in candidates for long-term intra-hospital or home-based treatment considering several confounding factors (i.e. physiologic adaptation to changes flow and pressure status in upper airways, changes in pulmonary gas exchange, impact on respiratory muscle's distress). Standardized protocols for the full clinical swallowing assessment or multidisciplinary teams, including speech and swallowing pathologists, should be considered for the optimal nutritional management and aspiration risk assessment of patients on noninvasive respiratory support in the acute settings and for the transition from hospital to home.

Knowledge gaps

The results of our scoping review suggest a limited amount of literature addressing the issue of swallowing function during HFNT and highlight important research gaps type, including 1) evidence gap due to low number of studies and included participants, reporting contradictory findings on different populations; 2) methodological gap due to lack of standardised methods to assess the interaction between HFNT and swallowing function and outcomes; 3) practical-knowledge gap since no studies evaluated the effect of HFNT on swallowing-breathing interaction with a practical focus on important patients outcome in a study with pragmatic design.

Implication for future research

Our findings support the need for additional research focused on assessing the impact and potential consequences of HFNT on swallowing function as well as investigating the possible

influence of different flow rates, temperature, FiO_2, bolus quantity and quality, breathing patterns, and the potential role of an adjuvant head posture, during treatment using appropriate standardised and homogeneous swallowing evaluation tests in order to fill important knowledge gaps. Future research should also aim to establish gold standard diagnostic criteria for swallowing evaluation during HFNT, enabling clinicians to better characterise patients at risk of aspiration during treatment.

Strengths and Limitations

This scoping review has been conducted according to the current methodological standards, in line with PRISMA-ScR requirements. The comprehensive search, including studies on both healthy volunteers and participants suffering from acute and chronic respiratory failure, led to the identification of knowledge gaps and implications for future research concerning the effects of HFNT on swallowing function. We also tried to provide a multidisciplinary, balanced interpretation of available data, helping the clinicians to navigate the uncertainty concerning this topic. The limitations are related to the characteristics of available evidence. First, the heterogeneity of patients' severity and underlying respiratory disease was evaluated in the included studies. Second, the different types of swallowing evaluation used for assessing swallowing function during HFNT across the included studies. Indeed, the clinical bedside evaluation of swallowing alone is not accurate enough in determining swallowing disorders, especially in the presence of silent aspiration; thus, some research findings should be considered carefully because they did not use appropriate instrumentation for swallowing evaluation, such as FEES or submental EMG. Third, it is unclear or even not investigated if the alterations in swallowing function were caused by the treatment with HFNT per se, promoted by the underlying respiratory disease, or both.

Conclusion

This scoping review clearly shows that there is insufficient data on the impact of HFNT on swallowing function, leading to inconsistent evidence in favour of or against the practice of

oral intake during HFNT use. Due to the lack of safety data from adequately designed clinical trials, clinicians should proceed with caution when making decisions about oral feeding in patients with acute respiratory failure on treatment with HFNT and consider patient-specific factors.

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Table 1 Effects of high-flow nasal cannula flow rates on swallowing function. Characteristics and outcomes of studies included in the systematic review, according to PICOS criteria for inclusion of studies.

Authors	Study design	Characteristics of subjects (n, age)	Status or comorbidities	Flow rates	Swallowing assessment	Statistical results	Conclusions
Allen 2021 [37]	Prospective study	n=29; < 60 y	Healthy volunteers	10, 20, 30, 40, 50, and 60 L/min	VFSS; Duration of laryngeal vestibule closure; PAS scores. -	The amount of airflow via HFNT significantly influenced the duration of laryngeal vestibule closure, F (1, 810) =19.056, p<.001. There was no association between normal/abnormal PAS score and no airflow/HFNT (p=.610).	There is a flow-dependent influence on the duration of laryngeal vestibule closure which increased with higher airflow. Modulation of duration of laryngeal vestibule closure in response to the amount of airflow highlights the ability of healthy adults to adapt to swallow conditions to protect the airways as needed.
Arizono 2021 [38]	Prospective cohort study	n=30; 30 y	Healthy volunteers	0, 10, 20, 30, 40, and 50 L/min, in random order	WST for aspiration; RSST for swallow frequency; 0-100 mm VAS for swallowing effort. -	Nine subjects (30.0%) choked at 10, 40 and 50 L/min during the WST (p<0.05). Swallowing effort was increased during flow rates ≥ 20 L/min *vs* 10 L/min (p<0.05). Flow rates ≥ 20 L/min resulted in a lower number of swallows during the RSST compared to 0 and 10 L/min (p<0.05) -	HFNT flow rates ≥ 40 L/min are associated with choking (increased risk of aspiration). Greater swallowing efforts during HFNT flow rates ≥ 20 L/min.
Sanuki 2016 [42]	Prospective study	n=9	Healthy volunteers	0, 15, 30 and 45 L/min	Submental EMG; Mean latency times of the swallowing reflex while swallowing 5 mL of	Mean latency times of the swallow reflex with 15 (9.8 ± 2.9 s), 30 (9.0 ± 2.7 s) and 45 (8.5 ± 3.0 s) L/min of HFNT were significantly shorter than	HFNT enhances swallowing function with increasing levels of flow by reducing the latency time of the swallow reflex.

					distilled water over 3 seconds.	those under control conditions (11.9 ± 3.7 s; P < 0.05)	HFNT allows the continuation of oral intake without aspiration during oxygen therapy
Eng 2019 [44]	Prospective, single-center, cohort study	n=80; 35–65 y	Healthy volunteers		MBSS; MBSImP scores; PAS score.	Total MBSImP scores were higher on HFNT 60 L/min (M = 10.1063, SE = 0.3923) *vs* baseline (M = 8.9257, SE = 0.3117), t(75) = −3.14, p = .0024, *vs* HFNT 20 L/min (M = 8.9029, SE = 0.3289), t(75) = −3.36, p = .0012, or HFNT 40 L/min (M = 9.2554, SE = 0.3393), t(75) = −2.16, p = .0342. Flow rate affects the oral phase of swallowing, reducing lip closure and tongue control and increasing the oral residue. No effects of flow rates on PAS score.	HFNT impacts the swallowing dynamics in the oral stage. There is an impairment in swallowing performance with the increase in HFNT flow rate.
Flores 2019 [39]	Retrospective study	n =9; 71 y	Respiratory failure; Atrial fibrillation, Tachycardia; COPD; Acute asthma exacerbation.	30, 35, 40, 50 L/min	MBSS; MBSImP scores; PAS score; Functional Oral Intake Scale scores. -	100% of patients remained nil per os after bedside evaluation due to aspiration risk. After MBSS, 8 of 9 patients were started on a complete oral diet, and 1 of 9 patients was started on a partial oral diet. 50% presented with silent aspiration on PAS scores	The decision regarding the safety of oral intake in patients using HFNT depends on cognitive status, physical abilities, and performance on MBSS.
Leder 2016 [40]	Prospective, single-center, cohort study	n =50; 70 y	Acute respiratory disease	10 L/min 5 s; 15 L/min 3 s; 20 L/min 14 s; 25 L/min 2 s;	FEES. - .	Deemed appropriate for oral feeding 78%; Oral feeding success 100%	The use of HFNT should not delay the introduction or resumption of oral feeding.

				30 L/min 17 s; 35 L/min 1 s; 40 L/min 4 s; 50 L/min 4 s			
Rattanajiajaroen 2021 [41]	Randomized crossover study	Group A: n=11 pts Group B: n=11 56 y	Pneumonia, congestive heart failure, alteration of consciousness, lactic acidosis, asthmatic attack, COPD	Group A: HFNT 50 L/min Group B: LFNO 5 L/min	Electrocardiography-derived respiratory signals; Submental EMG; Swallowing Frequency; Timing of swallows in relation to respiratory phases; Food intake. -	In the HFNT group, higher numbers of expiration swallow pattern (74.3% HFNT *vs* 67.6% LFNO; p=0.048) and lower numbers of inspiration swallow pattern (14.3% HFNT *vs* 23.1% LFNO; p=0.044).	HFNT may have some favourable effects on post-extubation patients' swallowing-breathing coordination.
Zerbib 2020 [43]	Observational retrospective study	n=40; 51.2 ± 18.7 y. (oral diet n=11; enteral nutrition n=21; parenteral nutrition n=4; enteral + parenteral nutrition n=2; no nutrition n=2. -	Respiratory distress due to infection, surgery, multiple trauma	45 L/min		The oral nutrition group had the highest calorie and protein intake, 600 (IQR 459-850) kCal/day and 22 (IQR 20-45) gm protein/ day.	The administration of HFNT was associated with significant underfeeding.

Modified barium swallow studies (MBSS); 30-mL water swallow test (WST); repetitive saliva swallowing Test (RSST); videofluoroscopic swallow studies (VFSS); modified water swallowing test (MWST); repeated saliva swallowing test (RSST); cervical chest auscultation method (CCA); 0 to 100mm visual analog scale (VAS); The modified barium swallow impairment profile (MBSImP); penetration-aspiration cale (PAS); chronic obstructive pulmonary disease (COPD); high flow nasal therapy (HFNT); low flow nasal oxygen (LFNO); electromyography (EMG); years old (y); kilocalories (kCal), interquartile range (IQR).

Table 2 Risk of bias summary for each included study and GRADE quality of evidence.

Studies, year			**Bias arising from the randomization process**	**Bias due to deviations from intended interventions**	**Bias due to missing outcome data**	**Bias in measuring outcomes**	**Bias in selection of reported results**	**Overall Risk of bias**
Rattanajiajaroen 2021[41]			+	-	+	+	+	Low
Studies, year	**Bias due to confounding**	**Bias in selection of participants**	**Bias in classification of interventions**	**Bias due to deviations from intended interventions**	**Bias due to missing data**	**Bias in measurement outcomes**	**Bias in selection of reported results**	**Overall Risk of bias**
Allen 2021[37]	+	+	+	+	+	+	+	Low
Arizono 2021[38]	+	+	-	-	+	+	+	Low
Flores 2019[39]	+	+	+	+	+	+	+	Low
Eng 2019[44]	+	+	+	+	+	+	+	Low
Leder 2016[40]	-	-	-	-	+	+	+	Low
Sanuki 2016[42]	+	+	-	-	+	+	+	Low
Zerbib 2020[43]	+	+	+	+	+	+	+	Low
Quality assessment					**Summary of findings**	**Quality of Evidence GRADE**		
N. of studies	**Limitations**	**Inconsistency**	**Indirectness**	**Publication bias**	**Sample characteristics**			
8 studies	No significant limitations	No serious inconsistency	No serious indirectness	Unlikely	*Population*: adults, healthy volunteers, or patients with acute or chronic respiratory failure *Intervention*: use of high-flow nasal therapy *Comparison:* no comparators or other forms of respiratory support	High		

					Outcomes: results of any type of bedside swallowing assessment	

+ indicates reporting in full with low risk of bias; / indicates partial reporting with unclear risk of bias; - indicates no reporting with high risk of bias.

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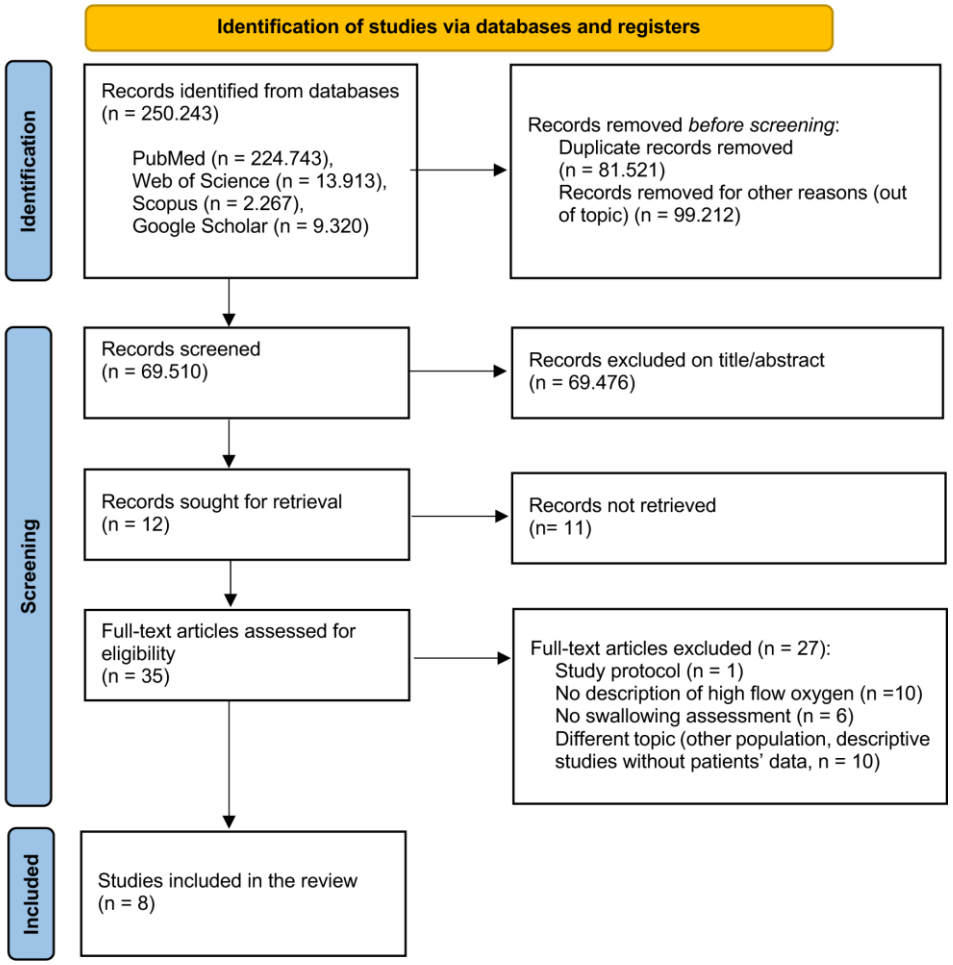
Identification of studies via databases and registers
Identification
Records identified from databases (n = 250.243)
PubMed (n = 224.743),
Web of Science (n = 13.913),
Scopus (n = 2.267),
Google Scholar (n = 9.320)
Records removed *before screening*:
Duplicate records removed (n = 81.521)
Records removed for other reasons (out of topic) (n = 99.212)
Screening
Records screened (n = 69.510)
Records excluded on title/abstract (n = 69.476)
Records sought for retrieval (n = 12)
Records not retrieved (n= 11)
Full-text articles assessed for eligibility (n = 35)
Full-text articles excluded (n = 27):
Study protocol (n = 1)
No description of high flow oxygen (n =10)
No swallowing assessment (n = 6)
Different topic (other population, descriptive studies without patients' data, n = 10)
Included
Studies included in the review (n = 8)

Figure 1

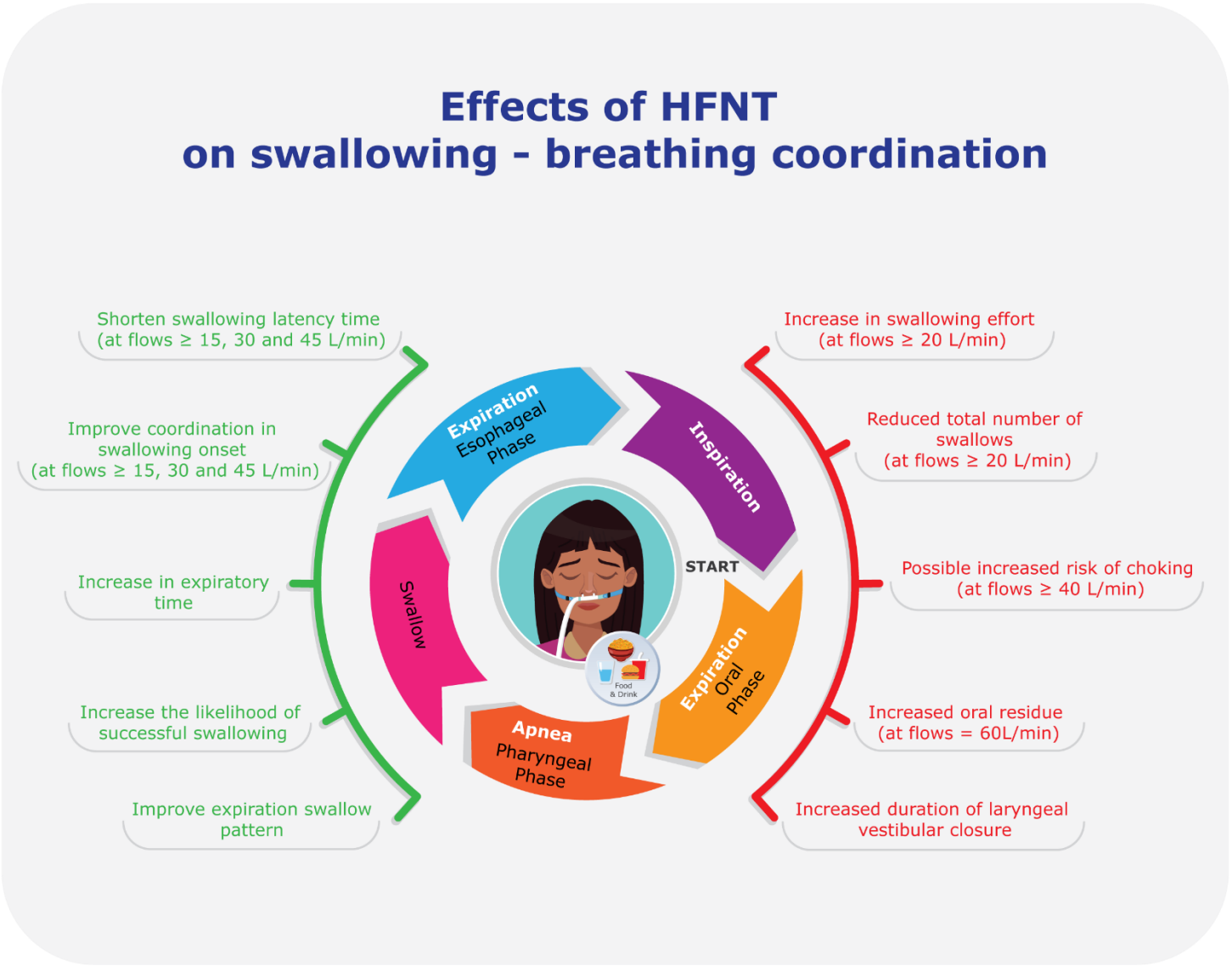
Effects of HFNT
on swallowing - breathing coordination
Shorten swallowing latency time
(at flows ≥ 15, 30 and 45 L/min)
Improve coordination in
swallowing onset
(at flows ≥ 15, 30 and 45 L/min)
Increase in expiratory
time
Increase the likelihood of
successful swallowing
Improve expiration swallow
pattern
Expiration
Esophageal
Phase
Inspiration
START
Swallow
Expiration
Oral
Phase
Apnea
Pharyngeal
Phase
Food
& Drink
Increase in swallowing effort
(at flows ≥ 20 L/min)
Reduced total number of
swallows
(at flows ≥ 20 L/min)
Possible increased risk of choking
(at flows ≥ 40 L/min)
Increased oral residue
(at flows = 60L/min)
Increased duration of laryngeal
vestibular closure

Figure 2

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	3
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	3-4
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	N/A
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	5
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	5
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	S2
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	5
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	6
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	5-6
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	N/A

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	5-6
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	5, Figure 1
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	6-8
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	N/A
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	6-8
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	7,8, 14-18
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	9-12
Limitations	20	Discuss the limitations of the scoping review process.	12-13
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	13
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	13

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.