Fiberoptic endoscopic evaluation of swallowing (FEES) in pediatrics: A systematic review

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ABSTRACT

Objectives: The systematic review aimed to provide an overview of the state-of-art regarding the use of fiberoptic endoscopic evaluation of swallowing (FEES) in pediatrics, specifically investigating FEES feasibility, safety, diagnostic accuracy, and protocols.

Methods: Four electronic databases were searched for original studies on the pediatric population that instrumentally assessed swallowing function using FEES. A hand-search of the references of included studies was performed. Data on the population, feasibility of endoscope insertion and bolus trials, adverse events, sensitivity and specificity, and FEES equipment and protocol were extracted. The quality of the studies was assessed using the checklists of the Johanna Briggs Institute. Selection of the studies, data extraction, and quality appraisal were conducted by two independent researchers.

Results: Eighty-two reports from 81 studies were included. The mean overall quality of the studies was 80 % (17–100 %). The feasibility of endoscope insertion was high (89%–100 %), while the feasibility of bolus trials varied from 40 % to 100 %. Adverse events were excessive crying (8 studies), irritability or agitation (4 studies), transitory oxygen desaturations (3 studies, 1.2–6.7 % of the patients), epistaxis (3 studies, 0.8–3.3 % of the patients), increased heart rate (1 study, 1 patient), vomiting (1 study, 1 patient), hypertonia (1 study), and hypersalivation (1 study). No major complications were reported. Using VFSS as the reference standard, FEES was generally found to be less sensitive (25–94 %) but more specific (75–100 %) for aspiration, whereas the reverse was true for penetration (sensitivity 76–100 %, specificity 44–83 %). FEES protocols were highly heterogeneous with poor reporting.

Conclusion: FEES is a safe, accurate, and generally feasible examination in the pediatric population with suspected dysphagia. However, a consensus on the best FEES protocol for clinical practice and research is currently lacking.

1. Introduction

First introduced in the late 1980s [1], fiberoptic endoscopic evaluation of swallowing (FEES) is now considered one of the two "gold standards" for the diagnosis of oropharyngeal dysphagia together with videofluoroscopic swallowing study (VFSS). Over the last decades, FEES has been increasingly used in the pediatric population [2], thanks to several factors. Firstly, advancements in neonatal care have led to an increasing prevalence of oropharyngeal dysphagia in infants and children [3]. Secondly, the clinical swallowing and feeding examination, although a fundamental step in the pathway of the assessment of pediatric dysphagia, lacks evidence of its accuracy in detecting oropharyngeal aspiration [4]. Finally, the advantages of FEES over VFSS make it more suitable for the assessment of infants and children by avoiding radiation exposure, providing a more detailed assessment of anatomical structures, being portable to neonatal intensive care units, and allowing the evaluation of secretion management, breastfeeding, and commonly consumed foods and liquids.

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In adults, FEES has been demonstrated to be a safe procedure [5] and to provide comparable sensitivity and specificity to VFSS for detecting the presence of penetration, aspiration, and pharyngeal residues [6–9]. Nevertheless, the differences between children and adults, concerning the size and position of the anatomical structures, the physiology of deglutition, the posture used during feeding, and collaboration, may significantly impact the feasibility, safety, and diagnostic accuracy of the procedure. Thus, there is a need to summarize evidence of the use of FEES in pediatrics. Recently, two systematic reviews have been published on this topic [10,11]. However, in the review by Christovam and colleagues only 3 studies using FEES were included [10], whereas the review by Zhang and colleagues only focused on FEES protocols reported in the literature [11].

This systematic review aims to provide an overview of the state-of-art in the use of FEES in the pediatric population. Specifically, we aimed to answer four research questions:

1. Is FEES feasible in the pediatric population?
2. Are there adverse events related to FEES examination in the pediatric population?
3. What is the diagnostic accuracy of FEES in the pediatric population?
4. What equipment, protocols, and metrics are routinely used to perform FEES in the pediatric population?

2. Methods

The scoping review was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Checklist [12]. An operative protocol for conducting the review was agreed upon and shared by all team members and registered on the Open Science Framework (doi: https://doi.org/10.17605/OSF.IO/Z6YTF). The research team included phoniatricians, ear, nose, and throat (ENT) specialists, and speech and language pathologists (SLPs).

2.1. Search strategy

The search was performed on four electronic bibliographic databases, PubMed, Embase, CINHAL, and the Cochrane Database of Systematic Reviews, from January 1, 2000, up to September 15, 2023, with no language restrictions. Our search strategy was adapted as necessary for each database and complete details of each search are described in Supplementary Material S1. Text words and database subject headings were used that were synonymous with the population ("Pediatric"), the intervention ("Fiberoptic endoscopic evaluation of swallowing"), and the outcome ("Deglutition disorders") of interest. The terms related to the population, the intervention, and the outcome were combined with the Boolean operator "AND". Additionally, the reference lists of the included studies and relevant reviews were checked for other potentially relevant studies.

2.2. Eligibility criteria

Study eligibility was based on inclusion and exclusion criteria regarding population, intervention, and publication type. More specifically, inclusion criteria were original studies on the pediatric population (<18 years) that instrumentally assessed swallowing function using FEES, full-texts in English, Italian, Spanish, French, or German. We excluded studies on esophageal dysphagia, studies with participants of mixed ages in case it was not possible to extract the data about the age group <18, abstracts in conference proceedings, theses, editorials, protocols, and full-texts not available (after two attempts of contacting the authors).

2.3. Study selection

The records identified from the electronic search were imported into the software Rayyan [13]. Following duplicate deletion, double independent screening of titles and abstracts for potentially eligible studies was conducted by two independent researchers (AE and MM). Potentially relevant studies were retrieved in full text and assessed for eligibility based on our prespecified inclusion criteria by two independent researchers (AE and MM). Reasons for the exclusion of full texts were recorded. Any discrepancies were resolved through consultation with a third researcher (NP).

2.4. Data extraction and synthesis

Two independent researchers (SR and SR) extracted the data from the included studies using a pre-specified form in Microsoft Excel (Microsoft Corporation). Disagreements were resolved through arbitration of a third rater (NP). For each included study, the following data were extracted: first author, year of publication, journal, study design, setting, sample size, population characteristics (age; diagnosis), number of FEES, FEES equipment and protocol (position, anesthesia, consistencies, volumes, number of trials, use of dye, feeding modality), examiner characteristics, signs of dysphagia investigated, metrics to assess swallowing function, percentage of patients who tolerated the endoscope insertion, percentage of patients who completed FEES examination, type and frequency of adverse events, reference test, sensitivity, specificity, inter-rater agreement, changes to feeding type or modality following FEES, mean duration. We did not contact the authors for missing data. The data was tabulated and discussed in a narrative synthesis reporting on the characteristics and the outcomes of included studies.

2.5. Quality assessment

Two review authors (NP and SR) independently assessed the methodological quality of all included studies. The Joanna Briggs Institute's (JBI) critical appraisal tools for cross-sectional studies or case reports, according to the study design, were used [14]. Disagreements were resolved through discussion and, if necessary, consensus agreement within the review team. Critical appraisal was not considered an exclusion criterion; rather it informed the interpretation of results, highlighting potential flaws and the need for further investigation. According to Vinas et al. [15], a percentage of quality was calculated for each included study by assigning a score to each item on the JBI checklist. Specifically, the total number of items was rated as "yes (1 point)", "unclear (0.5 points)" and "no (0 points)" and then divided by the total number of applicable items. This total score is presented as a percentage in which a higher score represents a lower risk of bias. Rates were defined as insufficient [0–33 %], sufficient (33–66 %), and high (66–100 %] quality [15].

3. Results

3.1. Studies' selection

The study selection and screening process are presented in the PRISMA flowchart (Fig. 1). The electronic search identified 8233 records. After duplicate removal, 6797 records were screened. In total, 275 full-text articles were assessed for eligibility. Ultimately, 82 reports on 81 studies met the eligibility criteria and were included in the review (a reference list is supplied as Supplementary Material S2).

3.2. Studies' characteristics and quality appraisal

Characteristics of the included studies are summarized in Table S3 (Supplementary Material S3). An increasing trend of publications on the use of FEES in the pediatric population was observed over the last two decades, with 14 (17 %) reports published in 2000–2009, 39 (47.6 %) reports published in 2010–2019, and 29 (35.4 %) reports published in
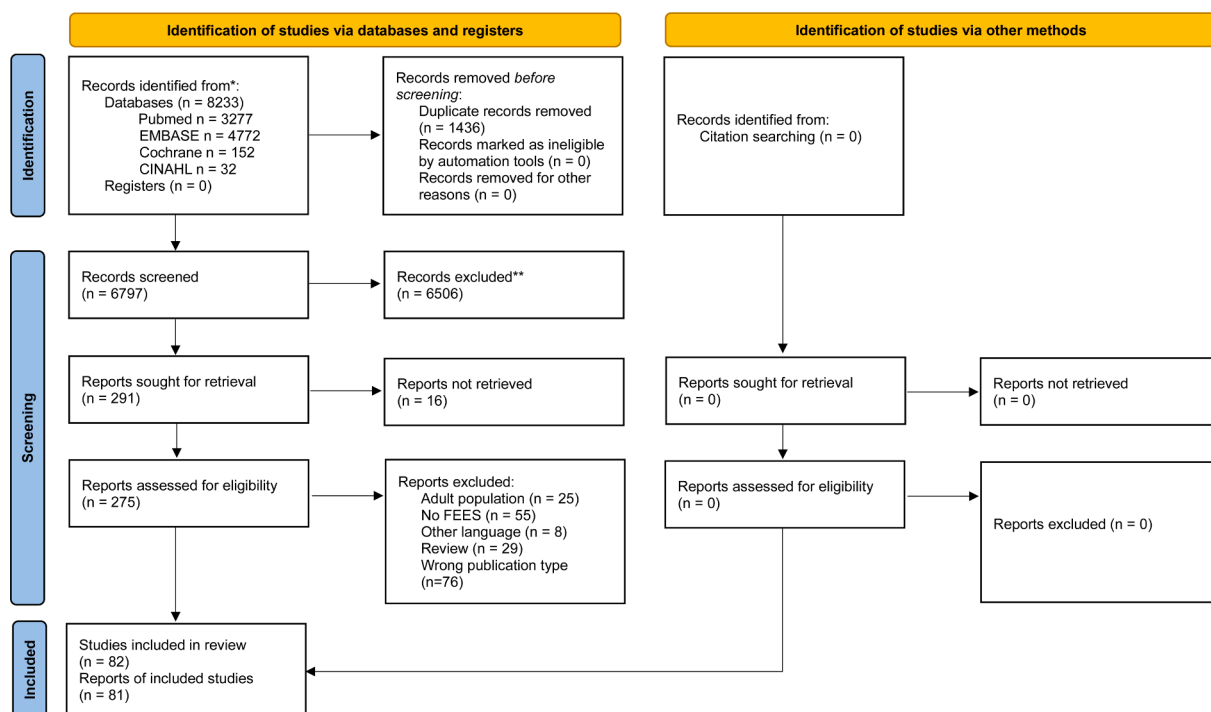
Fig. 1. PRISMA2020 Flow diagram.

2020–2023 (Fig. 2). Nine (11 %) studies were case reports, 37 (45.1 %) studies were retrospective case series, 17 (20.7 %) studies were prospective case series, 5 (6.1 %) studies were retrospective cross-sectional studies, 13 (15.9 %) studies were prospective cross-sectional studies, and 1 (1.2 %) study was an RCT. FEES were performed in children's hospitals in 37 (45.1 %) studies, in tertiary care hospitals in 22 (26.8 %) studies, in neonatal/pediatric intensive care units (NICU/PICUs) in 8 (9.8 %) studies, in outpatient clinics in 7 (8.5 %) studies, and in rehabilitation units in 6 (7.3 %) studies. Overall, the included publications reported data on 5061 FEES performed on 4437 pediatric patients. Patients were infants (≤12 months) in 16 (19.5 %) studies, toddlers (≤4 years) in 17 (20.7 %) studies, children (≤10 years) in 12 (14.6 %) studies, and both children and adolescents (≤18 years) in 29 (35.4 %) studies. The diagnosis of recruited patients was structural abnormalities of the upper aerodigestive tract in 19 (23.2 %) studies, genetic diseases in 13 (15.9 %) studies, neurological diseases in 10 (12.2 %) studies, prematurity in 5 (6.1 %) studies, cardiac diseases in 4 (4.9 %) studies, respiratory diseases in 3 (3.7 %) studies, gastrointestinal diseases in 2 (2.4 %) studies, feeding disorders in 1 (1.2 %) study, and mixed in 24 (29.3 %) studies.
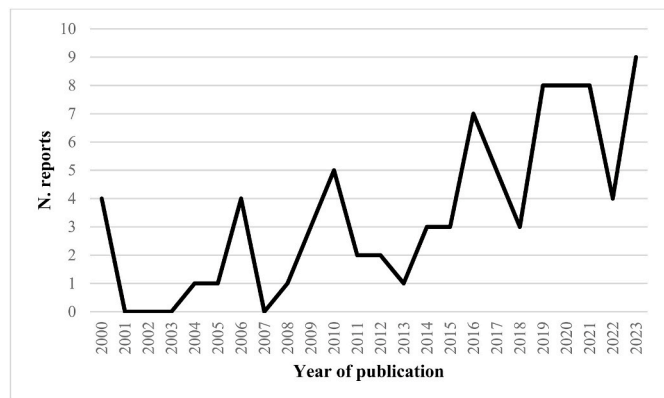

Fig. 2. Trend of publications on FEES in pediatrics from 2000 to 2023.

Quality appraisal results according to the JBI checklists are reported in Tables S4 and S5 (Supplementary Materials S4 and S5). Mean overall quality was 80 % (17–100 %) with 3 (3.7 %) reports judged as insufficient quality, 9 (11 %) reports judged as sufficient quality, and 70 (85.3 %) reports judged as high quality.

3.3. Feasibility

Thirty-four (41 %) studies reported on feasibility (Table 1). Apart from the single case report by Brooks and colleagues [16], the feasibility of endoscope insertion was high (89%–100 %). The success in assessing swallowing function using bolus trials varied from 40 % to 100 %. The lowest value (40 %) was reported by Armstrong et al. [17] studying breastfeeding on 5 newborns aged 38–42 weeks postmenstrual age in NICU. However, the low success of completing FEES was mainly related to difficulties in breastfeeding (i.e. ineffective latch to the breast or milk extraction) rather than to FEES itself. Overall, the reasons for incomplete FEES procedure were: hypertonia, lack of compliance, increased heart rate, physical resistance, excessive crying, food refusal, ineffective bolus extraction, excess of pharyngeal secretions, and anatomical restrictions. One study highlighted that some of the patients who did not tolerate FEES had prior FEES exams, suggesting that the tolerance to the exam may change according to the disposition of the child daily or the memory of previous exams [18].

When considering the influence of age, the feasibility of bolus trials was highly heterogeneous, ranging from 66 % [19] to 100 % [20–22] in the studies including infants aged ≤12 months and from 52.4 % [23] to 100 % [24] in the studies including both children and adolescents (0–18 years). Two studies investigated the factors associated with tolerance and cooperation during FEES [25,26]. Both studies reported no influence of the underlying diagnosis. Concerning age, Meister and colleagues found no difference in the median age between tolerant and intolerant children [26]. Conversely, in the study by Haller et al. median age was significantly higher in children that cooperated during FEES (3 years) than in those who did not (1.2 years), with around half of the patients in the latter group being aged less than 1 year [25].

Table 1
FEES feasibility and adverse events.

First author year	Feasibility of endoscope insertion (%)	Feasibility of bolus trials (%)	Adverse events
Armstrong 2019[a] Suterwala 2017[a]	–	92 %	One (4 %) infant's oxygen saturation level was as low as 52 % following a 10-min FEES assessment using honey consistency with multiple instances of penetration. Minimal irritability, 2 (8 %) infants were unable to calm after placement of the scope to initiate feeding.
Armstrong 2020	–	40 %	None
Aguirregomezcorta 2021	100 %	–	–
Averin 2012	100 %	–	–
Bader & Niemman 2008	98.8 %	52.4 %	Hypersalivation (3 %), epistaxis (1.8 %), desaturation (1.2 %)
Bader & Niemman 2010	–	53 %	–
Beer 2014	100 %	73.3 %	2 patients (6.7 %) had short dips of oxygenation (<85 %) with spontaneous recovery
Böcker 2016	89 %	66 %	–
Boseley 2006 (a)	100 %	100 %	–
Boseley 2006 (b)	100 %	100 %	–
Brooks 2021	100 % (n = 1)	0 % (n = 1)	Agitation
Celtik 2022	–	96.3 %	None
da Silva 2010	–	–	Crying
Haller 2020	–	87 %	Excessive crying (27 %), vomiting (0.8 %), epistaxis (0.8 %)
Givens 2018	100 %	100 %	None
Kwa 2022	–	88.7 %	Crying
Krug 2023	100 %	93.7 %	None
Leal 2017	100 %	100 %	Crying and irritability
Leder 2010	–	–	Crying
Link 2000	92.6 %	88.9 %	Excessive crying (5.6 %)
Meister 2020	100 %	69.4 %	None
Miller 2016	100 %	100 %	None
Mills 2021	100 %	100 %	None
Mizogami 2021	100 %	100 %	None
Morgan 2004	100 %	100 %	–
Partida-Justo 2017	–	–	Epistaxis in 2 patients (3.3 %)
Schroeder 2023	100 %	97.1 %	–
Suiter 2009	–	100 %	–
Tanaka 2019	96.6 %	96.6 %	Excessive crying or hypertonia (3.4 %)
Thottam 2015	100 %	100 %	–
Van Gelder 2012	100 %	66.7 %	–
Vaquero-Sosa 2015	100 %	100 %	–
Vetter-Laracy 2018	100 %	100 %	Poor cooperation
Willette 2016	100 %	92.3 %	Agitation with crying
Yan 2021	100 %	100 %	–
Zang 2021	–	96.7 %	None
Zang 2023	100 %	83.3 %	Increased heart rate (195bpm) in 1 patient (10 %)

Legend: , Information not available.
[a] Different reports from the same study.

3.4. Safety

Data on the safety of FEES were reported in 23 (28 %) studies (Table 1). Nine studies reported no complications. The most frequent complications were excessive crying (8 studies) and irritability or agitation (4 studies), followed by transitory oxygen desaturations <85 % (3 studies, 1.2–6.7 % of the patients), epistaxis (3 studies, 0.8–3.3 % of the patients), increased heart rate (1 study, 1 patient), vomiting (1 study, 1 patient), hypertonia (1 study), and hypersalivation (1 study).

Seven studies that included safety information were performed in NICU [17,21,22,27–30] and reported no major complications, except for one infant who exhibited oxygen desaturation as low as 52 % following a 10-min FEES assessment [21,28]. In one study, the infants' respiratory rate, heart rate, and oxygen saturation level were compared before and after FEES with no significant differences [17].

3.5. Diagnostic accuracy and inter-rater agreement

Eight (9.9 %) studies reported the diagnostic accuracy of FEES (Table 2). Additionally, the agreement between signs of dysphagia detected in FEES and the results of other swallowing evaluations were reported in 9 (11.1 %) studies against VFSS, 1 (1.2 %) study against laryngeal ultrasound, 4 (4.9 %) studies against clinical swallowing examination (CSE), and 1 (1.2 %) study against a parent-reported questionnaire (Table 2).

Agreement between FEES and VFSS in the pediatric population was extremely heterogeneous among the studies, ranging from 10 % to 100 % [27,31–35]. The reason for this heterogeneity may be attributed to the differences in the populations investigated and the protocols used, but also to the fact that, except for one study [33], the two instrumental assessments were not performed simultaneously, thus, capturing different swallows. Concerning the diagnostic accuracy, using VFSS as the reference standard, FEES was generally found to be less sensitive but more specific for aspiration (sensitivity 25–94 %, specificity 75–100 %) and pharyngeal residues (sensitivity 40–67 %, specificity 70–94 %), whereas the reverse was true for penetration (sensitivity 76–100 %, specificity 44–83 %) [21,28,32–34,36].

Compared to laryngeal ultrasound, Abdelrahman et al. [37] reported an agreement of >95 % between the presence of signs of pharyngeal dysphagia detected in FEES and the reduction of at least 40 % of the laryngeal excursion evaluated with ultrasound in 25 children with neurological disorders.

When coupling the results of FEES and CSE, general agreement between the suspicion of the presence of oropharyngeal dysphagia in CSE and the signs detected during FEES was reported [38–41]. Only in a minority of cases (5.5–6.3 %) did CSE findings strongly diverge from FEES [40,41]. Wet voice and gagging were found to be the most accurate clinical markers of signs of dysphagia at FEES in a study on 79 infants aged less than 2 years [41].

Concerning the accordance with parent-reported outcomes, Adel et al. [42] found that the Pediatric Eating Assessment Tool 10 [43] discriminated between children with and without aspiration and pharyngeal residue detected during FEES and significant correlations (r = 0.63–0.80) were found between the results of the severity of these signs.

Four (4.9 %) studies investigated inter-rater agreement in identifying the presence of signs of dysphagia during FEES and reported high rates of agreement between the assessors, ranging from 66.7 % to 100 % depending on the consistency and the sign investigated (Table 2) [21,27, 28,31,32].

3.6. Clinical utility and duration

Based on the results of seven (8.6 %) studies, changes to feeding type or modalities were recommended following FEES in 13.6–71 % of the children (Table 3). The recommendations included: consistency modifications, position changes, bottle-feeding, nipple changes, enteral feeding, express breastmilk before initiating breastfeeding to reduce milk flow rate during the letdown phase of breastfeeding, and external pacing.

Additionally, in one study on patients assessed with FEES before airway reconstructive surgery, FEES changed the type or the timing of

Table 2

FEES diagnostic accuracy, inter-rater agreement, and agreement with other swallowing evaluations.

First author year FEES vs. VFSS	Reference test	Timing between assessments	Sensitivity	Specificity	Predictive values	Main results
Alexander 2021	VFSS	–	–	–	–	***FEES vs. VFSS agreement*** Among 17 patients that had both FEES and VFSS, 4 patients had abnormal VFSS and normal FEES, whereas no patients had abnormal FEES and normal VFSS.
Armstrong 2019[a] Suterwala 2017[a]	VFSS	<24 h	Penetration: 76 % Aspiration: 25 %	Penetration: 45 % Aspiration: 98 %	Penetration: PPV 42 %, NPV 79 % Aspiration: PPV 50 %, NPV 94 %	***Inter-rater agreement in FEES*** High inter-rater agreement was obtained for penetration (80 %) and aspiration (80 %). ***FEES vs. VFSS agreement*** Comparing FEES and VFSS findings, there was a 56 % overall agreement for penetration and a 92 % agreement for aspiration. There were many more instances of penetration detected using FEES compared to VFSS. Considering the composite score of the presence of signs of dysphagia at either FEES or VFSS: - <u>for penetration</u>: FEES showed higher sensitivity (89 vs. 49 %) and higher negative predictive value (79 vs. 45 %) than VFSS - <u>for aspiration</u>: both assessments had high negative predictive values for aspiration (FEES 94 % vs. VFSS 98 %), whereas FEES showed lower sensitivity than VFSS (40 % vs 80 %).
da Silva 2010	VFSS	–	11.1–83.3 % (depending on the sign and the consistency)	52.4–100 % (depending on the sign and the consistency)	–	***Inter-rater agreement in FEES*** Inter-rater agreement ranged from 66.7 to 100 % depending on the sign investigated and the consistency. ***FEES vs. VFSS agreement*** Agreement between FEES and VFSS was 60–70 % for spillage, 63.3–80 % for residue, 53.3–83.3 % for penetration, and 10–53.3 % for aspiration.
Kamity 2020	VFSS	Simultaneous	Penetration: 100 % Aspiration: 75 %	Aspiration: 100 %	–	***FEES vs. VFSS agreement*** FEES identified laryngeal penetration on 55.1 % of all swallows compared to 23.6 % with VFSS (p < 0.01). FEES identified tracheal aspiration in 3.7 % of all swallows compared to 8.3 % with VFSS (p = 0.12). For penetration, the analysis of linked swallows showed 73 % agreement (either negative or positive). Simultaneous VFSS–FEES improved the ability to detect penetration compared to each test done separately.
Leder & Karas 2000	VFSS	Same day	100 %	100 %	–	***Inter-rater agreement in FEES*** Inter-rater agreement was 100 % for all signs of dysphagia. ***FEES vs. VFSS agreement*** There was 100 % agreement for detecting signs of dysphagia and dysphagia recommendation between FEES and VFSS.
Leder 2010	VFSS	–	100 %	100 %	–	***Intra-rater agreement in FEES*** Intra-rater agreement was 100 % for aspiration.
Meister 2020	VFSS	–	SEES 80 % (CI95 % 58.4–91.9 %)	SEES 85.7 % (CI95 % 60.1–97.5 %)	SEES PPV 88.9 % (67.2–98.0 %) SEES NPV 75.0 % (50.5–89.8 %)	–
Partida-Justo 2017	VFSS	–	Penetration: 98 % (CI95 % 95–100 %) Aspiration: 94 % (CI95 % 87–100 %) Pharyngeal residue: 63 % (CI95 % 43–82 %) Spillage: 86 % (CI95 % 71–100 %)	Penetration: 83 % (CI95 % 54–100 %) Aspiration: 75 % (CI95 % 51–100 %) Pharyngeal residue: 94 % (CI95 % 87–100 %) Spillage: 95 % (CI95 % 88–100 %)	**PPV** Penetration: 83 % (CI95 % 54–100 %) Aspiration: 75 % (CI95 % 51–100 %) Pharyngeal residue: 88 % (CI95 % 73–100 %) Spillage: 90 % (CI95 % 77–100 %) **NPV** Penetration: 98 % (CI95 % 95–100 %) Aspiration: 94 %	***FEES vs. VFSS agreement*** In FEES, more frequent spillage, residue, aspiration, penetration, and esophageal reflux were observed compared to VFSS. The concordance between FEES and VFSS was greatest for spillage (k = 0.815) and penetration (k = 0.815), while lower for aspiration (k = 0.688) and residue (k = 0.638).

Table 2 (*continued*)

				(CI95 % 87–100 %) Pharyngeal residue: 79 % (CI95 % 67–91 %) Spillage: 93 % (CI95 % 84–100 %)	–	
Pavithran 2020	VFSS	24–48 h	Penetration: 81 % Aspiration: 50 % Pharyngeal residue: 62 % Spillage: 75 %	Penetration: 44 % Aspiration: 82 %, Pharyngeal residue: 70 % Spillage: 35 %	–	**FEES vs. VFSS agreement** The frequency of pharyngeal dysphagia was 68 % in FEES compared to 45 % in VFSS. The overall accuracy of FEES compared to VFSS was 77 % for aspiration and 59 % for penetration. The agreement between FEES and VFSS on all parameters was low (k = 0.061–0.302). FEES findings such as glottic secretions (p = 0.02), weak or diminished laryngeal adductor reflex (p = 0.001), and penetration (p = 0.01) were significantly associated with aspiration in VFSS.
FEES vs. Ultrasound						
Abdelrahman 2019	Laryngeal ultrasound	Same day	–	–	–	**FEES vs. ultrasound agreement** The agreement between the reduced relative laryngeal movement and FEES for diagnosing abnormalities of swallowing pharyngeal phase was 96 % for a reduction of ≥40 % and 100 % for a reduction of ≥45 %.
FEES vs. CSE						
Beer 2014	CSE	CSE before FEES	–	–	–	**FEES vs. CSE agreement** The CSE correctly identified aspiration (either true positive or true negative) of: saliva in 70 % of the patients, pureed food in 55 % of the patients, and thin liquids in 67 % of the patients.
Freitag 2021	CSE	CSE before FEES	–	–	–	**FEES vs. CSE agreement** The overall correlation between CSE and FEES results was strong; only 6/110 patients (5.5 %) showed differing results in the two examinations
Krug 2023	CSE	CSE before FEES	–	–	–	**FEES vs. CSE agreement** 5/79 (6.3 %) findings of CSE and FEES could be identified as strongly divergent. Wet voice reported by caregivers or seen during CSE correlated significantly with premature spillage, and gagging reported by caregivers or seen during CSE correlated significantly with penetration.
Streppel 2019	CSE	–	–	–	–	**FEES vs. CSE agreement** FEES confirmed all findings from CSE.
FEES vs. parent-reported outcomes						
Adel 2022	Pedi-EAT-10	–	–	–	–	**FEES vs. PRO agreement** A significant strong positive correlation was found between the Pedi-EAT-10 and the PAS (r = 0.80) and the presence of pharyngeal residue (r = 0.63). The Pedi-EAT-10 was significantly different in patients with and without aspiration or residue.

Legend: , Information not available; CSE, Clinical swallowing examination; NPV, Negative predictive value; Pedi-EAT-10, Pediatric Eating Assessment Tool 10; PPV, Positive predictive value; VFSS, Videofluoroscopic swallowing study.

[a] Different reports from the same study.

the reconstruction in 13 % of the patients and the post-operative course in 33.8 % of the patients, whereas gastrostomy was recommended in 2.6 % of the patients [44].

Mean FEES duration was reported in only 2 (2.5 %) studies, ranging from 5 min in a study on children with spinal muscular atrophy type 1 aged 0–25 months [45] to 20 min in a study assessing bottle-feeding in NICU on infants aged 0–12 months [29].

3.7. Protocol

Table 4 depicts the summary of FEES equipment, procedure, and protocols used in the included studies; individual information from each study is available in Table S6 (Supplementary material S6). Many studies failed to report all data of interest. Specifically, information on the technical procedure (equipment, position, anesthesia, personnel) was missing in 39.5–60.5 % of the studies, information on the bolus trials (consistency or type of food and liquids, volumes, number of trials, utensils) was missing in 23.5–92.6 %, while information on the signs of dysphagia investigated and the outcome measures used to rate them were reported in nearly all the studies (missing data in 4.9–11.1 % of the studies).

A multi-professional team assisted during FEES in 35 (43.2 %) studies. Five studies implemented a breastfeeding protocol during FEES [17,20,46–48]. In one study [26] a Static Endoscopic Evaluation of Swallowing (SEES) was performed as an alternative to FEES in children who do not cooperate. Before SEES the children are given one or more boluses of a consistency, determined based on the patient's feeding history and the CSE. Afterward, the endoscope is inserted and the post-swallows signs of dysphagia (i.e. pharyngeal residue, traces of penetration, and aspiration) are assessed.

With regard to the protocol of bolus trials, two main approaches were observed: an ecological protocol and a standard protocol. The ecological

Table 3
Changes to feeding type or modality following FEES.

First author year	Recommendations
Krug 2023	50.6 % diet modifications[a]
Leder & Karas 2000	60 % diet modifications
Mills 2021	70 % breastfeeding position
Schroeder 2023	13.6 % from breastfeeding to bottle-feeding or NGT
Sitton 2011	19 % diet modifications (restricted or advanced)
Vetter-Laracy 2018	54.8 % thickened milk
	9.6 % GERD treatment (omeprazole and changes in body posture)
	6.5 % gastrostomy
Willette 2016	27 % express breastmilk prior to breastfeeding
	15 % position changes
	15 % external pacing
	19 % slow flow nipple for bottle-feeding
	35 % thickened liquids
	35 % alternative method for nutrition

[a] Combining the results from FEES and clinical swallowing examination.

protocol, described in 18 (22.2 %) studies, included a wide variety of consistencies and types of liquids and foods, sometimes even brought from home, whose selection was individually based on the developmental stage and the preferences of the children. Conversely, a standard protocol was adopted in 38 (46.9 %) studies and consisted of testing the same consistencies and types of food and liquids in all patients. Only one study [49] described the consistencies used according to the terminology of the International Dysphagia Diet Standardisation Initiative (IDDSI) [50].

Penetration and aspiration (86.4 %) and pharyngeal residue (44.4 %) were the most commonly investigated signs of dysphagia and were usually rated as present or absent, whereas a severity rating through ordinal scales (e.g. the Penetration-Aspiration scale [51]) was provided in ≤16 % of the studies.

4. Discussion

The present systematic review aimed to provide a general overview of the state-of-art in the use of FEES for diagnosing oropharyngeal dysphagia in the pediatric population, particularly its feasibility, safety, diagnostic accuracy, clinical utility, and the protocols used.

FEES feasibility including bolus trials varied from 40 % to 100 % for the bolus trials. Although feasibility may be expected to increase with age, this review failed to highlight a relationship between age and FEES feasibility as results from the literature were controversial [17,19–21, 23,25,26]. Failing to complete bolus trials was not only related to FEES itself, such as excessive crying or agitation due to tube insertion, but also food refusal or ineffective bolus extraction, suggesting the importance of carefully selecting children to be referred for an instrumental examination. Several strategies were suggested to improve FEES feasibility, including swaddling, containment hold, non-nutritive suckling (eventually with glucose solution), breastfeeding, toys, and environmental modifications by reducing sound and light sources [45,52]. Time is a critical factor for the success of FEES. Indeed, studies reported that excessive crying and agitation were generally transitory and resolved in a short time, often as soon as the feeding was started, therefore the exam should be performed without a time constrain [20,25]. When bolus trials cannot be carried out despite these precautions, a SEES can be successfully performed in nearly all pediatric patients with a suspicion of dysphagia as scope insertion was found to be feasible in over 90 % of the participants in the studies. SEES provides information on pharyngeal and laryngeal anatomy, motility, and sensitivity, secretion management, and post-swallow residue in the pharynx, larynx, and trachea [26].

Although invasive, FEES was found to be a safe procedure, even in NICUs if the infant is sufficiently medically stable [33]. Monitoring vital parameters (oxygen saturation, respiratory and heart rates) is generally

not required but is recommended in clinically complex children, patients requiring oxygen therapy, and newborns [52]. Resuscitation equipment should be available in pediatric FEES clinics not many for the risks associated with the procedure itself, but for the medical complexity of pediatric patients referred for FEES. The training and high skills of the multi-disciplinary team are of particular importance to ensure the safety of the procedure in pediatrics [17].

The results on diagnostic accuracy of FEES using VFSS as a reference standard showed on average satisfactory results, with higher specificity than sensitivity for aspiration and higher sensitivity than specificity for penetration [21,28,32–34,36]. These results suggest that FEES has good performance in ruling out the presence of penetration (i.e. no penetration in FEES is likely to correspond to no penetration also in VFSS) and ruling in aspiration (i.e. aspiration identified in FEES is likely to be identified also in VFSS) [34]. Thus, in case of a FEES negative for aspiration, the risk for aspiration should be appraised by taking into account other FEES findings, such as penetration, weak or absent laryngeal sensitivity or glottic secretions, and risk factors from the CSE and the medical history and, eventually, consider referral to VFSS. Results on the sensitivity and specificity of FEES identified in the present review are lower than those reported in the adult population [8]. These differences may be attributed to the smaller anatomy that limits the visualization of the structures and the low collaboration of pediatric patients that enables them to test only a few boluses during the exam.

FEES was found to be clinically relevant to revise recommendations on the type of diet and the route of nutrition [20,29,31,41,47,48,53]. However, it should be underlined that, unlike for the adult population, FEES, and more in general instrumental assessment, is not the first-choice examination in the evaluation pathway of pediatric patients with dysphagia and feeding disorders. The choice to refer a child to instrumental assessment is secondary to the CSE and the meal observation, which allow to differentiate the suspicion of oropharyngeal dysphagia from the presence of feeding disorders. Furthermore, clinicians should consider the child's readiness to participate in the instrumental assessment and the expectations that the findings from FEES would make a difference in the care of the patients [54].

Finally, a wide heterogeneity in FEES protocols was pointed out, confirming the lack of standardization of FEES protocols following previous reviews on both pediatric and adult populations [11,55]. Additionally, the reporting of the protocols was generally poor, lacking information and limiting the reproducibility of the results and the comparisons among studies. Reaching a consensus on standard age- and developmental-appropriate FEES protocols is desirable for research and can ease communication among clinicians and the monitoring of the development of swallowing function over time in clinical practice. By contrast, the use of ecological protocols tailored for each patient can better reflect the real-life swallowing performance during meals and improve the feasibility of bolus trials by considering individual preferences in the selection of foods and liquids to test. Regardless of the choice to adopt a standard or ecological protocol, the standardized terminology from the IDDSI framework [50] is encouraged in the description of the protocol for clinical practice and research.

The systematic review has several limitations. Concerning the included studies, many data were missing and the heterogeneity in the patients' age and diagnosis, setting, and protocols limits the possibility to draw general conclusions. Regarding the review protocol, the inclusion of case reports, although providing a complete overview of the state-of-art on the use of FEES in pediatrics, decreases the overall quality of included studies.

5. Conclusions

In the pediatric population, FEES is a safe, reliable, and generally feasible examination that provides useful information for clinical decision-making on feeding indications for children with suspected dysphagia. Nevertheless, careful selection of appropriate candidates for

Table 4
Summary of FEES equipment, procedure, and protocol (N = 81 studies).

Technical procedure

	Endoscope/Fiberscope diameter		Position		Anesthesia		Vital parameters		Who perform FEES		Who attend FEES	
N. of studies (%)	<2 mm	2 (2.5)	Breastfeeding position	3 (3.7)	No	14 (17.3)	Pulse oximeter	2 (2.5)	ENT	35 (43.2)	SLP	25 (30.9)
	2.00–3.00 mm	20 (24.7)	Bedside	2 (2.5)	Yes	18 (22.2)			SLP	4 (4.9)	Nurse	10 (12.3)
	>3.00 mm	23 (28.4)	Upright position	17 (21)					Phoniatrician	4 (4.9)	Occupational Therapist	3 (3.7)
			Supine	2 (2.5)					Pediatrician	2 (2.5)	ENT	2 (2.5)
									Neurologist	1 (1.2)	Neonatologist	2 (2.5)
											Pediatrician	2 (2.5)
											Physiatrician	1 (1.2)
											Pediatric radiologist	1 (1.2)
											Lactation consultant	1 (1.2)
											Dentist	1 (1.2)
											Dental Hygienist	1 (1.2)
											Physical therapist	1 (1.2)

Bolus trials

	Bolus consistency		Bolus volumes		Number of boluses per volume		Use of dye		Mode of feeding	
N. Of studies (%)	Liquids	35 (42)	5 ml	5 (6.2)	1	6 (7.4)	Yes	33 (40.7)	Bottle	10 (12.3)
	Semisolids	14 (17.3)	3 ml	4 (4.9)	1–3	4 (4.9)	No	1 (1.2)	Syringe	5 (6.2)
	Solids	8 (9.8)	1 ml	2 (2.5)	5	1 (1.2)			Breastfeeding	5 (6.2)
	Nectar or half nectar or honey	5 (6.2)	10 ml	3 (3.7)					Spoon	3 (3.7)
			30 ml	1 (1.2)					Cup	2 (2.5)
			2 gr (solids)	2 (2.5)					Regularly used utensilis	2 (2.5)
									Dropper	1 (1.2)

Dysphagia signs and outcome measures

	Pharyngeal residue	Penetration/Aspiration	Premature spillage		Pooling of secretions		Delay in initiation of swallowing		Dysphagia severity		Other signs	
N. Of studies (%)	36 (44.4)	71 (86.4)	20 (24.7)		9 (11.1)		7 (8.6)		7 (8.6)		Piecemeal deglutition	1 (1.2)
											Nasal regurgitation	1 (1.2)
N. Of studies (%)	Present/absent	30 (37)	Present/absent	52 (64.2)	Present/absent	11 (13.6)	Present/absent	4 (4.4)	Present/absent	3 (3.7)	DOSS [57]	2 (2.5)
	YPRSRS [56]	4 (4.9)	PAS [51]	13 (16)	Scale from 0 (bolus behind the tongue) to 4 (falls into the laryngeal vestibule)	1 (1.2)	Degree of pooling	2 (2.4)			Warnecke et al. scale [58]	2 (2.5)
							Murray Scale [59]	1 (1.2)			Degree of dyaphagia	1 (1.2)
											Present/absent	1 (1.2)

Legend: DOSS Dysphagia Outcome and Severity Scale; ENT, otorhinolaryngologists; PAS, Penetration Aspiration Scale; SLP, speech and language pathologist; YPRSRS, Yale Pharyngeal Residue Severity Rating Scale.
Note. The data was missing from the remaining studies.

FEES and adequate training of the personnel, time, and setting to perform the procedure are critical factors for the success of the examination. FEES provides high sensitivity for detecting the presence of penetration and high specificity in detecting the presence of aspiration. However, a consensus on the best FEES protocol for clinical practice and research is currently lacking.

CRediT authorship contribution statement

Nicole Pizzorni: Writing – review & editing, Writing – original draft, Visualization, Supervision, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Sara Rocca:** Writing – original draft, Visualization, Investigation, Formal analysis, Data curation. **Angelo Eplite:** Investigation. **Marta Monticelli:** Investigation. **Sibora Rama:** Investigation. **Francesco Mozzanica:** Writing – review & editing, Supervision, Conceptualization. **Letizia Scarponi:** Supervision, Methodology, Data curation, Conceptualization. **Antonio Schindler:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Conceptualization.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijporl.2024.111983.

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