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REVIEW ARTICLE

An optimal curriculum for training in endoscopic ultrasound: a summarized evidence-based literature systematic review

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Abstract

Background and Objectives Endoscopic ultrasound (EUS) training is strongly correlated with procedure quality and improved patient outcomes. However, EUS fellowship curricula and the environment in which training should take place are not well defined. A well-structured training curriculum should aim to establish a universally accepted competence framework before endosonographers are allowed to start independent practice. This systematic review seeks to identify the essential components of an EUS training curriculum, determine the optimal environment for this training, and highlight gaps and inconsistencies in current guidelines.

Material and Methods A comprehensive literature review was performed using different databases (PubMed, Science Direct, Cochrane library, Directory of Open Access Journals, and Google Scholar) using Mesh methodology for keyword search in the field of EUS training and following PRISMA guidelines. Inclusion criteria were review articles, original research articles, international societal guidelines, book chapters, and expert consensus addressing EUS educational aspects published in the last two decades (January 2002–August 2023) in peer-reviewed journals in English.

Results A total of 49 papers were included according to the inclusion criteria in the 20-year period range, from which 31 assessed diagnostic EUS curricula content and 19 any aspect of the therapeutic EUS curricula. The requisites, duration, and/or competence demonstration strategies were addressed in 28 publications, whereas 15 referred to the adequate environment for EUS training. Overall, there was a consensus on the need for a structured, formal EUS curriculum along with standardized and properly supervised training and assessment to ensure competence.

Conclusion The establishment of a structured EUS fellowship curricula should aim to produce competent practitioners, thereby ensuring safe and effective patient-care, uniformly and at the international level. While there is general agreement in the literature on the major aspects of a training curriculum, which we synthesize here, the ideal EUS training context deserves further study and better definition.

Keywords Endoscopic ultrasonography · Training · Education · Curriculum

Endoscopic Ultrasound (EUS) is a valuable diagnostic and minimally invasive therapeutic tool with a wide range of applications, ranging from assessment and treatment of the pancreato-biliary system, characterization of subepithelial lesions, and locoregional tumour staging [1–3]. Increasingly it is becoming a tool for endoluminal surgery with its availability to create anastomoses and perform ablations [4, 5]. Despite its current and developing implementations, EUS is considered to be underutilized, and its performance quality and outcomes are very heterogeneous and frequently poor [6, 7].

Quality in endoscopy is highly dependent on the quality of training [8, 9]. However, there is a great variability in the training periods undergone by current EUS operators worldwide, with a significant proportion being self-trained or trained only for short periods [10–13]. Furthermore, a European survey revealed that the majority of EUS fellows are not confident in their performance at the end of their training period, and wish to significantly improve competence, indicating room for improvement in training [14].

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Although the EUS learning curve is known to be flat and long, it is equally recognized that formal learning opportunities lead to a consistent improvement of knowledge and skills [6, 15]. However, an "ideal" curricula content for EUS fellowship and the environment in which it should take place are not well described or consistently applied. [7, 10, 16]. This exposes patients to the risk of sub-optimally performed procedures with potentially devastating clinical outcomes.

This systematic review aims to determine the essential components of an EUS training curriculum and the optimal environment in which this training should occur, as well as to identify gaps and inconsistencies in current guidelines. By synthesizing the literature, we seek to highlight universally supported aspects of training and pinpoint areas requiring further standardization, ultimately guiding towards an international consensus.

Methods

Search strategy

A systematic review of medical literature was conducted in August 2023 using the MeSH methodology for keyword searches across PubMed, ScienceDirect, the Cochrane Library, the Directory of Open Access Journals (DOAJ), and Google Scholar. Detailed search terms and databases are listed in Supplementary Table S1.

Eligibility criteria

All articles reporting aspects of EUS education were considered. Inclusion criteria were review articles, original research articles, international societal guidelines, book chapters, and expert consensus published in the last two decades (January 2002–August 2023) in peer-reviewed journals in English. Exclusion criteria included conference abstracts, letter to editors, articles focused exclusively on the development of specific EUS simulator/model without providing broader educational insights, and articles assessing training in trans-oesophageal or transrectal EUS in pulmonologists and colorectal surgeons, respectively. The systematic review was completed following the Preferred Reporting items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [17]. The PRISMA Checklist is shown in Supplementary Table S4.

Study selection

Two authors (JM, AHHL) independently assessed article eligibility, as shown in the PRISMA flowchart (Fig. 1). Discrepancies in title and abstract screening were resolved by consensus following full-text review.

Data extraction

The pertinent information concerning the key points of this review was extracted and organized into tables to facilitate comparison among the studies (Tables 1, 2, 3). As there are two specific EUS training periods currently determined (diagnostic EUS (DEUS), including fine needle aspiration (EUS-FNA) and fine needle biopsy (FNB), and therapeutic EUS (TEUS)), the curricula content was considered separately for each of them [18, 19].

Data synthesis

In line with the main objective of this review, included studies were grouped into two main categories: *EUS training curricula* and *Environment for EUS training*. For the first category, data were synthesized around key subtopics: *Need for a formal curriculum*, *Requirements before commencing training*, *Fellowship duration*, and *Curriculum elements*—for both DEUS and TEUS. Additional topics included *Tissue acquisition*, *Competence acquisition*, and *Ergonomics*. The second category, pertaining to the *Optimal training environment*, was addressed under a dedicated subheading. This structure guided the organization of the Results section.

Risk of bias assessment

The risk of bias was assessed by an adapted version of QUADAS-2 tool [20]. The first domain, adapted to "Trainee selection", was considered as "low risk" when the publication presented clear selection criteria and/or systematic methodology, whereas "high risk" was considered for narrative reviews and expert recommendations without systematic methodology. Applicability of this domain was not assessed since all included studies were inherently applicable due to their focus on health professions learners. The second domain, "Clarity and consistency of training aspects assessed", was pondered as "low risk" when learning objectives were clearly defined, and "high risk" when insufficiently explained. The third domain, "Clarity and quality of training aspect outcomes measurement", was classified as "low risk" if objective evaluation of training outcomes. Applicability for these domains related to reproducibility in a daily clinical setting. The fourth domain, "Flow and timing", considered data completeness and the report of the assessment timing. "Low risk" was applied when the moment of the outcomes assessment was reported and, if applicable, when all trainees who began the educational intervention were accounted for in the results. "High risk" was stated if the assessment time was not described, or trainee follow-up was lost. In addition to the QUADAS-2

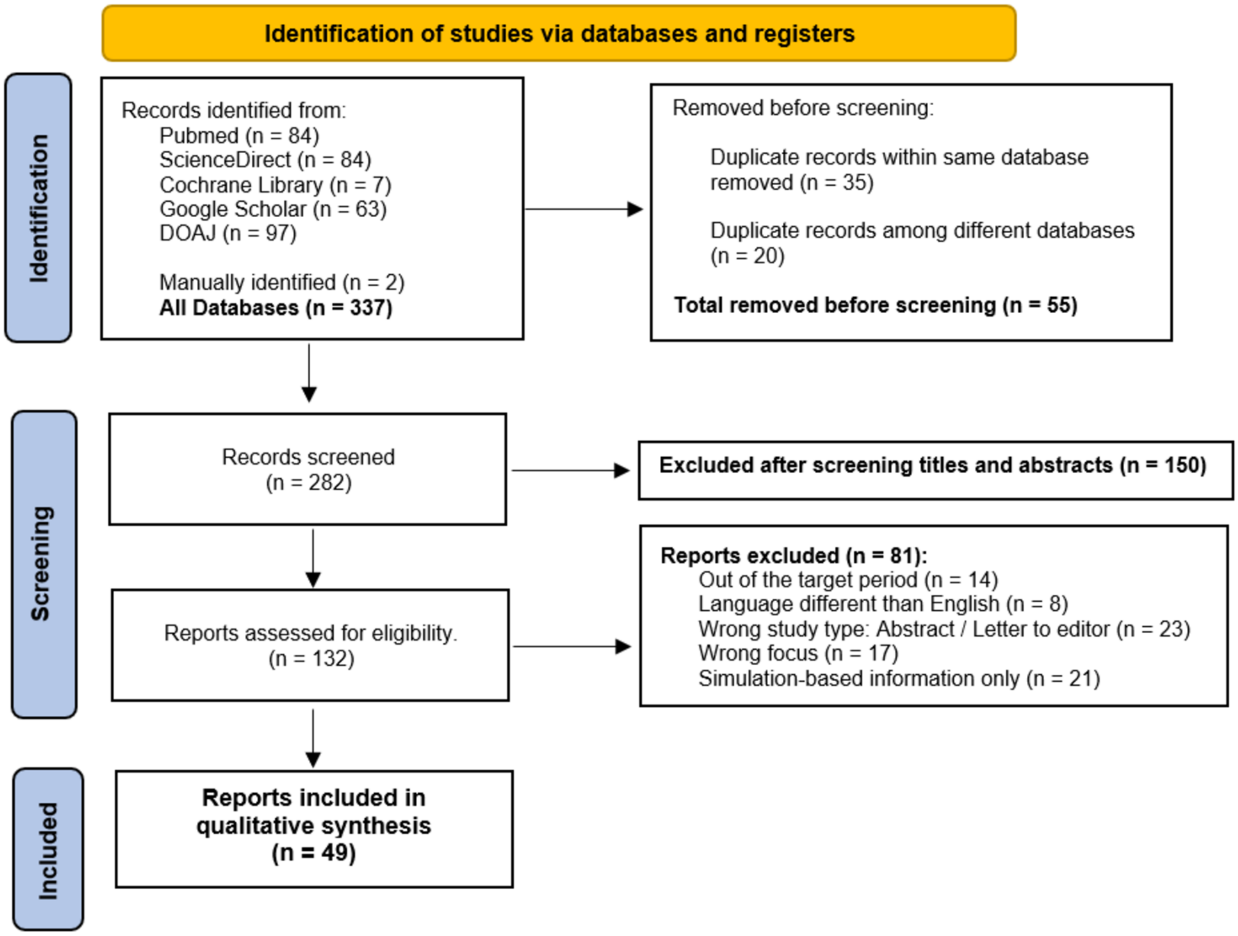

Fig. 1 PRISMA flowchart

tool, the included studies were also assessed according to the Centre for Evidence-Based Medicine (CEBM) levels of evidence to further evaluate their methodological rigor [21]. Details of these analysis are shown in Supplementary Table S3.

Results

Out of 337 publications retrieved, 132 underwent full-text review to determine eligibility. After a critical reading of the articles for relevance to this study, 49 articles were included. The PRISMA flowchart of the study selection process is presented in Fig. 1. The selected references are listed in Supplementary Table S2.

EUS training curricula

From the identified articles, 31 assessed a DEUS fellowship curricula content (Table 1), with another 28 addressing the requisites, duration and/or competence demonstration strategies (Table 2). TEUS curriculum aspects were addressed in 19 publications. However, due to the heterogeneous, non-comparable content of these articles covering different TEUS techniques, they were not included in a specific table and are instead analysed within the body of the discussion.

Environment for EUS training

There were 15 articles referring to the optimal environment for EUS training, including training center and mentor's characteristics, as outlined in Table 3.

Need for a formal EUS training curriculum

We found a general agreement on the need for a structured, formal EUS curriculum -currently lacking-, which would allow a standardized and adequately supervised training [7, 19, 23, 25, 26, 28, 29, 31–40, 43, 44].

Table 1 DEUS curricula content

		Jenssen 2009 [22]	Heller 2011 [43]	Meenan 2011 [23]	DiMaio 2012 [24]	Wani 2013 [69]	Paquin 2014 [25]	Park 2014 [70]	Wang 2015 [71]	Wani 2015 [68]	Xu 2015 [49]
Cognitive skills knowledge	EUS stations	–	–	–	–	✓	✓	✓	✓	✓	–
	Landmarks	–	–	–	–	✓	Ns	Ns	Ns	✓	–
	Luminal structures	–	✓	✓	✓	✓				✓	–
	Extraluminal structures	–	✓	✓	✓	✓				✓	–
	Surgical altered anatomy	–	–	–	✓	–				–	–
Technical skills know-ledge	Safe scope passage	–	✓	–	✓	✓	–	✓	✓	✓	–
	Image generation	–	Ns	–	✓	✓	–	Ns	Ns	✓	–
	Target measuring/ marking	–		–	✓	✓	–			✓	–
Communicative skills knowledge	Indications	–	–	✓	✓	–	✓	–	✓	–	–
	Contra-indications	–	–	✓	✓	–	✓	–	✓	–	–
	Patient selection	–	–	✓	✓	–	✓	–	✓	–	–
	Report creation	–	–	–	✓	–	–	–	–	–	–
	US principles	–	✓	✓	✓	–	–	–	✓	–	–
	Doppler principles	–	–	–	✓	–	–	–	–	–	–
	Processor setup	–	–	–	✓	–	–	–	✓	–	–
	Findings communication	–	–	–	✓	–	–	–	–	–	–
	Team communication	✓	–	✓	✓	–	–	–	–	–	–
Radial		–	–		✓	–	–	–	–	–	
Tissue acquisition (FNA/FNB)	Time of introduction	–	✓ Ns	–	✓	–	–	–	–	–	–
	Needle's mechanical aspects knowl-edge	–		–	✓	–	✓	–	–	–	–
	Needle's choice	–		–	✓	–	–	–	–	–	–
	Safe performance	–		✓	✓	–	✓	–	–	–	–
	Specimen handling	–		–	✓	–	✓	–	–	–	–
	Diagnostic rate	✓		–	–	–	–	–	–	–	–
	Complications management	–		–	✓	–	–	–	–	–	–
Complementary techniques	Mini probes	–	–	✓	✓	–	–	–	–	–	–
	Doppler	–	–	–	✓	–	✓	–	–	–	–
	CE-EUS	–	–	–	✓	–	–	–	–	–	–
	Elastography	–	–	–	✓	–	–	–	–	–	–
Supplementary learning	Self-learning through books, atlas, workshop, lectures, seminars	–	–	✓	✓	–	✓	–	✓	–	–
	Observation period	–	–	✓	–	–	✓	–	✓	–	–

Table 1 (continued)

		Early 2017 [26]	Faulx 2017 [27]	Cho 2017 [28]	Mukewar 2018 [72]	Saumoy 2017 [18]	Shahidi 2017 [29]	Wong 2017 [30]	Paquin 2018 [31]	Wani 2018 [32]
Cognitive skills knowledge	EUS stations	–	–	✓ Ns	–	–	–	–	✓	✓
	Landmarks	–	–		–	–	–	–	✓	✓
	Luminal structures	✓	–		–	✓	✓	✓	✓	✓
	Extraluminal structures	✓	–		–	✓	✓	✓	✓	✓
	Surgical altered anatomy	–	–		–	–	–	–	–	–
Technical skills know-ledge	Safe scope passage	✓	–	✓ Ns	–	✓ Ns	–	✓	✓	✓
	Image generation	✓	–		–		–	✓	–	✓
	Target measuring/ marking	✓	–		–		–	✓	✓	✓
Communicative skills knowledge	Indications	✓	✓	✓	–	✓	–	✓	✓	✓
	Contra-indications	✓	✓	✓	–	✓	–	✓	✓	✓
	Patient selection	–	✓	–	–	✓	–	✓	✓	✓
	Report creation	✓	–	–	–	–	–	–	–	–
	US principles	✓	–	✓	–	–	–	✓	✓	–
	Doppler principles	–	–	–	–	–	–	–	✓	–
	Processor setup	✓	–	–	–	–	–	–	✓	–
	Findings communication	✓	–	–	–	–	–	–	–	✓
	Team communication	✓	–	–	–	–	–	–	–	✓
Radial		✓	–	–	–	–	–	✓	✓	✓
Tissue acquisition (FNA/FNB)	Time of introduction	✓	–	–	✓ Ns	–	–	–	✓	–
	Needle's mechanical aspects knowledge	–	–	–		✓	–	–	–	–
	Needle's choice	–	–	–		✓	–	–	–	–
	Safe performance	–	–	–		✓	–	–	✓	✓
	Specimen handling	✓	–	–		✓	–	–	–	–
	Diagnostic rate	✓	–	–		–	✓	–	–	–
	Complications management	–	–	–		✓	–	–	✓	✓
Complementary techniques	Mini probes	–	–	–	–	–	–	–	✓	–
	Doppler	✓	–	–	–	–	–	–	✓	–
	CE-EUS	–	–	–	–	–	–	–	✓	–
	Elastography	–	–	–	–	–	–	–	✓	–
Supplementary learning	Self-learning through books, atlas, workshop, lectures, seminars	✓	–	✓	–	–	–	✓	✓	–
	Observation period	✓	–	–	–	–	–	–	✓	–

Table 1 (continued)

		Wani 2018 [33]	Waschke 2018 [34]	Chung 2021 [73]	Heden-ström 2021 [35]	Johnson 2021 [19]	Koo 2021 [36]	Mena-bawey 2023 [44]	Karstensen 2022 [37]	Raz-potnik 2023 [74]	Schutz 2022 [75]	Chavan Rajput 2023 [76]	De Cam-pos 2023 [38]
Cognitive skills knowledge	EUS stations	–	–	–	–	✓	✓ Ns	✓	✓	–	–	✓	–
	Landmarks	✓	–	–	✓	✓		✓	✓	–	–	✓	✓
	Luminal structures	✓	–	–	✓	✓		✓	–	–	–	✓	✓
	Extraluminal struc-tures	✓	–	–	✓	✓		✓	–	–	–	✓	✓
	Surgical altered anatomy	–	–	–	–	–	–	–	–	–	–	–	–
Technical skills know-ledge	Safe scope passage	✓	–	–	✓	✓	✓ Ns	✓	✓	–	–	✓	✓ Ns
	Image generation	–	–	–	✓	–		–	✓	–	–	✓	
	Target measuring/ marking	✓	–	–	✓	–		✓	✓	–	–	✓	
Communicative skills knowledge	Indications	–	–	–	✓	✓	✓	✓	–	–	–	–	✓
	Contra-indications	–	–	–	✓	✓	✓	✓	–	–	–	–	✓
	Patient selection	–	–	–	✓	✓	✓	✓	–	–	–	–	✓
	Report creation	–	–	–	–	✓	–	✓	–	–	–	✓	–
	US principles	–	–	–	–	–	–	✓	–	–	–	–	–
	Doppler principles	–	–	–	–	–	–	–	–	–	–	–	–
	Processor setup	–	–	–	✓	✓	–	✓	✓	–	–	✓	–
	Findings communi-cation	✓	–	–	✓	✓	✓	✓	–	–	–	–	✓
	Team communica-tion	✓	–	–	✓	✓	✓	✓	–	–	–	–	✓
Radial		–	–	–	–	–	–	–	–	–	–	–	–
Tissue acquisition (FNA/FNB)	Time of introduc-tion	–	–	✓ Ns	✓	✓	–	✓	–	✓ Ns	✓ Ns	–	–
	Needle's mechani-cal aspects knowledge	–	–		–	✓	–	✓	–			–	–
	Needle's choice	–	–		✓	✓	–	✓	–			–	–
	Safe performance	✓	–		✓	✓	–	✓	–			✓	–
	Specimen handling	✓	–		–	✓	–	–	–			–	–
	Diagnostic rate	✓	–		✓	✓	–	✓	–			✓	–
	Complications management	✓	–		✓	✓	–	✓	–			–	–

Table 1 (continued)

		Wani 2018 [33]	Waschke 2018 [34]	Chung 2021 [73]	Hedenström 2021 [35]	Johnson 2021 [19]	Koo 2021 [36]	Menabawey 2023 [44]	Karstensen 2022 [37]	Razpotnik 2023 [74]	Schutz 2022 [75]	Chavan Rajput 2023 [76]	De Campos 2023 [38]
Complementary techniques	Mini probes	–	–	–	–	–	–	–	–	–	–	–	–
	Doppler	–	–	–	–	✓	–	✓	✓	–	–	✓	–
	CE-EUS	–	–	–	–	✓	–	✓	–	–	–	–	–
	Elastography	–	–	–	–	✓	–	✓	–	–	–	–	–
Supplementary learning	Self-learning through books, atlas, workshop, lectures, seminars	✓	✓	–	–	✓	✓	✓	✓	–	–	–	✓
	Observation period	–	–	–	–	✓	✓	✓	✓	–	–	–	✓

DEUS: requirements before commencing training

There is general agreement that trainees should complete at least 18 months of formal gastrointestinal (GI) fellowship program to quality for entry-level DEUS training, implying competence in upper GI endoscopy [18, 19, 23, 24, 26, 28, 32–35, 40, 43] and diagnostic/therapeutic colonoscopy/sigmoidoscopy for those interested in rectal EUS training [26]. Ideally, this preceding period should include an exposure to EUS, enabling a foundational understanding of the procedure's significance [24].

Knowledge of abdominal imaging modalities is beneficial but not mandatory. Even though it has been shown that understanding ultrasound (US) principles speeds up EUS proficiency, there is no current evidence to document an advantage of transabdominal US competence prior to commencing EUS [23, 28]. However, some authors did stress the importance of US exposure before and during DEUS learning [15, 19, 43, 44].

Competence in ERCP is not mandatory before starting DEUS training. In early training, no advantage regarding DEUS aptitudes acquisition has been demonstrated for those practicing ERCP. However, for those interested in learning TEUS, a period of ERCP education is generally suggested in conjunction with DEUS [18, 19, 41, 42, 44].

The prior conditions that trainees should meet before starting DEUS training are listed in Table 2.

DEUS: fellowship duration

A dedicated training period outside the standard GI fellowship is considered necessary for EUS training. For DEUS, at least one year of hands-on experience is proposed by most authors [19, 23, 25, 26, 30–33, 36, 40, 43]. This time period is based on clinical hands-on exposure in real patients cases [45].

DEUS: curricula elements

It is uniformly recommended that DEUS should follow a stepwise training, starting with an observation period, followed by simulation-based training and finally, hands-on clinical practice [30]. Simulation-based training in this context includes the use of mechanical simulators, animal models (in vivo and ex vivo) and computer-based/virtual reality simulators. Training with simulators should be performed under supervision, progressing from less to more complex procedures and ideally starting with virtual reality and mechanical simulators during early training, followed by hands-on endoscopy in animal models [19].

Although absolute numbers are no longer considered a valid competence surrogate, procedure-thresholds remain useful in guiding training programmes as to the minimum

Table 2 Entry-level requirements and duration of EUS training

	Authors	Prior recquirements						Duration		Competence evaluation	Competence maintainance
		Before commencing DEUS			Before commencing TEUS			DEUS	TEUS		
		GI fellow	Images interpretation	ERCP	DEUS	ERCP	ATE				
1	Heller et al. [43]	Yes	Not specified, but remarks its importance for EUS	N/A	N/A	N/A	N/A	12 months	N/A	Yes	N/A
2	Meenan et al. 2011 [23]	DOPS pass for UGI and sigmoidoscopy	No demonstrated advantage	No (Parallel learning during DEUS training)	N/A	N/A	N/A	18 months		Yes, through DOPS for the second half of the required cases	Yes Annual report to JAG ≥ 15 h of EUS CPD
3	DiMaio et al. 2012 [24]	Yes ≥ 18 months	N/A	N/A	Yes	N/A	N/A	N/A	N/A	Yes	N/A
4	Omoto et al. 2022 [63]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes	N/A
5	Wani et al. 2013 [69]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes	N/A
6	Paquin et al. 2014 [25]	N/A	N/A	N/A	N/A	N/A	N/A	6–24 months	N/A	N/A	N/A
7	Wani et al. 2015 [71]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes	N/A
8	James et al. 2016 [39]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes, through objective tools	N/A
9	Cho et al. 2017 [28]	Yes, ≥ 24 months	N/A	N/A	N/A	N/A	N/A	6–12 months	N/A	Yes	Yes
10	Early et al. 2017 [26]	Yes, ≥ 24 months	N/A	N/A	N/A	N/A	N/A	12 months	N/A	Yes	Yes
11	Faulx et al. 2017 [27]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes, after 225 EUS performed	Yes
12	Moutinho et al. 2018 [77]	Yes	N/A	No (Parallel learning during DEUS training)	N/A	N/A	N/A	N/A	N/A	Yes	N/A
13	Saumoy et al. 2017 [18]	Yes, ≥ 18 months	N/A	N/A	Yes	Yes	Yes	N/A	12 – 14 months	Yes	N/A
14	Shahidi et al. 2017 [29]	Yes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes	N/A
15	Wani et al. 2017 [40]	Yes	N/A	No (Parallel learning during DEUS training)	N/A	N/A	N/A	12 months	N/A	Yes, through TEESAT regularly after #25 Record in a centralized database	Yes
16	Wong et al. 2017 [30]	N/A	N/A	N/A	N/A	N/A	N/A	Up to 12 months	N/A	N/A	N/A

Table 2 (continued)

	Authors	Prior recquirements						Duration		Competence evaluation	Competence maintainance
		Before commencing DEUS			Before commencing TEUS			DEUS	TEUS		
		GI fellow	Images interpretation	ERCP	DEUS	ERCP	ATE				
17	Paquin et al. 2018 [31]	Yes	N/A	N/A	N/A	N/A	N/A	6–24 months	N/A	Yes, after #250 performed, ideally through objective assessment tools	N/A
18	Saumoy et al. 2018 [41]	Yes	N/A	N/A	Yes ≥ 200–300 annually for ≥ 4 years		N/A	12–24 months		N/A	N/A
19	Wani et al. 2018 [32]	Yes	N/A	No (Parallel learning during DEUS training)	N/A	N/A	N/A	N/A	N/A	Yes, through TEESAT regularly after #25	Yes
20	Wani et al. 2018 [33]	Yes	N/A	No (Parallel learning during DEUS training)	N/A	N/A	N/A	12 months	N/A	Yes, through TEESAT every 5th after #25	Yes
21	Waschke et al. 2018 [34]	Yes	N/A	N/A	N/A	N/A	N/A	Milestone -based	N/A	Yes, regularly validated tools (e.g., TEESAT)	Yes
22	Hedenström et al. 2021 [35]	Yes, ≥ 24 months	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Yes, through GAPS-EUS	N/A
23	Johnson et al. 2021 [19]	Yes	N/A Should be part of DEUS curricula	Not specified	Yes	Yes	Advantageous	≥ 12 months	≥ 12 months	Yes, regularly through formal assessment tools (e.g., TEESAT, DOPS)	Period of mentored practice with experienced colleague (≥ 6 months)
24	Koo et al. 2021 [36]	N/A	N/A	N/A	N/A	N/A	N/A	12 months	N/A	Yes, continuously through validated tools (e.g., TEESAT)	N/A
25	Menabawey et al. 2021 [44]	Desirable but not mandated	Not specified, but US knowledge is expected	Not specified	N/A	Desirable	N/A	N/A	Additional period	Yes, through EUS DOPS, at least each 10 EUS	- 1 year mentorship period - 100 EUS/year (case mix + FNA) - Regularly performance audit -Morbidity and mortality meetings and MDT participation
26	Chavan Rajput 2023	N/A	Before and during	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 2 (continued)

	Authors	Prior requirements						Duration		Competence evaluation	Competence maintainance
		Before commencing DEUS			Before commencing TEUS			DEUS	TEUS		
		GI fellow	Images interpretation	ERCP	DEUS	ERCP	ATE				
27	De Campos et al. 2023 [38]	Yes	N/A	N/A	N/A	N/A	N/A	12–24 months	N/A	Yes, through a formal strategy (e.g. DOPS)	Yes
28	Rai et al. 2023 [42]	N/A	N/A	N/A	Yes	Yes	Advantageous	N/A	N/A	N/A	N/A

Competence evaluation and maintenance

If the training aspect is reported in detail, the textual recommendation is provided in the table; if the training aspect is simply mentioned with no further details, it is shown as "Yes" in the table; if the training aspect is not assessed, it is shown in the table as "N/A"

ATE Advanced therapeutic endoscopy, *CPD* Continuing professional development, *DEUS* Diagnostic Endoscopic Ultrasound, *DOPS* Direct observation of procedural skills, *ERCP* Endoscopic retrograde cholangiopancreatography, *FNA* Fine needle-aspiration, *GAPS-EUS* Global Assessment of Performance and Skills in EUS assessment tool, *MDT* Multidisciplinary teams, *N/A* not assessed, *TEESAT* EUS and ERCP Skills Assessment Tool, *TEUS* Therapeutic endoscopic ultrasound, *UGI* upper gastrointestinal endoscopy, *US* Ultrasound

number of cases they should offer [32]. There is currently a general agreement among most societies to require the performance of at least 225–250 EUS procedures during DEUS training (75–150 pancreatic, 80–150 upper GI luminal cancers, 10–25 rectal tumours, 20–40 subepithelial lesions). Considering the procedure mix, 50–75 should include the performance of EUS-FNA/EUS-FNB; and around 75 of these should be devoted specifically to the evaluation of the pancreas and biliary tract [27, 46]. Most of these pancreatic biopsies should correspond to pancreatic cancer cases [19, 23, 25, 31, 32, 36, 44, 47].

As for case variability, hands-on cases should cover GI tumour staging (oesophageal, gastric, rectal), evaluation of benign and malignant pancreato-biliary diseases and subepithelial lesions [19, 24, 26, 31, 33, 36, 43, 44]. In one article, the authors recommended assigning a tutor for each of the abovementioned major areas as subspecialisation is common in high-volume centres [23].

Regarding EUS skills, they can be grouped into cognitive, technical, and communicative skills. Among the cognitive ones, recognizing EUS stations and associated landmarks, as well as the various wall layers to characterize lesions is deemed crucial in DEUS curricula [15, 19, 32, 33, 35–37, 44]. The inclusion of technical and communicative skills in the EUS curricula have been consistently recognized as important over the two decades reviewed [7, 15, 18, 19, 22–28, 30–33, 35–38, 43, 44, 48]. Table 1 describes in detail the skills to be covered in DEUS training curricula.

Mastery of radial EUS is uniformly no longer universally required in EUS training. While older studies advocated its inclusion in training [23, 24, 26, 32], the latest guidelines do not consider it essential [19, 31, 49]. A randomized controlled trial found no improvement in linear EUS performance with prior radial EUS training [49].

EUS fellows are recommended to use additional learning tools, such as books, atlases, lectures, and seminars, so their inclusion in EUS curricula should be considered [15, 19, 23–26, 28, 31, 33, 34, 44]. Observation periods of experienced operators are recommended [15, 19, 23, 25, 26, 31, 44]. The addition of transabdominal, anorectal, and endobronchial ultrasound observation periods is also suggested by some authors [23].

Tissue acquisition

EUS-FNA/FNB should only be learned in a structured training context [28]. The first 20–30 EUS-FNA/FNB should ideally be performed using simulation-based tools [28]. Training can start as soon as a stable endoscopic position can be maintained to maximize exposure [14, 26, 29, 40]. Older recommendations claimed that linear EUS competence was needed before EUS-FNA/FNB, but one study showed no

Table 3 Environment for EUS training

	First Author—Year	Training centre			Expert presence	Trainer	
		Centre type	Volume/year	MDT		Hands-on experience	Didactic background
1	Heller et al. [43]	Tertiary referral	N/A	N/A	N/A	N/A	N/A
2	Meenan 2011 [23]	Single/ regional coordinated scheme (including cancer network)	N/A	Yes	N/A	Perform or supervise: $\geq$ 50 E–G cancer/ $\geq$ 120 P-B / $\geq$ 50 pancreatic FNA/ year	Yes (JAG compliant Training the trainer's course)
3	DiMaio 2012 [24]	Hospital-based/ambulatory	N/A	Yes	$\geq$ 1 (DEUS, FNA)	"Sufficient"	Yes
4	Early 2017 [26]	High-volume centres better outcomes for TNM staging	"Sufficient"	Yes	$\geq$ 1 (DEUS, radial, FNA)	N/A	N/A
5	Faulx 2017 [27]	N/A	N/A	N/A	N/A	Yes, credentialed and with sufficient expertise	N/A
6	Moutinho et al. 2018 [77]	Tertiary referrral	N/A	N/A	N/A	N/A	N/A
7	Saumoy 2017 [18]	High-volume (for TEUS) with sufficient clinical experience	N/A	Yes, especially for TEUS	Yes	N/A	N/A
8	Wong 2017 [30]	N/A	N/A		$\geq$ 1	N/A	N/A
9	Paquin 2018 [31]	N/A	"Sufficient"	Yes	$\geq$ 1 (DEUS, FNA)	"Sufficient"	N/A
10	Saumoy 2018 [41]	TEUS: With interventional radiology $\pm$ pancreatic-biliary surgery back-up	TEUS: High-volume, number not specified	Yes	Yes (TEUS)	N/A	N/A
11	Waschke 2018 [34]	N/A	N/A	N/A	N/A	N/A	Yes, with formal training (e.g., "Train the trainer courses")
12	Johnson 2021 [19]	High-volume	High-volume	Yes	In formal courses/ workshops	> 3 years independent experience Adequate annual volume to demonstrate competence maintenance	Yes, with "Train the trainer courses"
13	Koo 2021 [36]	N/A	Sufficient case volume	Yes	N/A	N/A	Yes, with "Train the trainer courses"
14	Menabawey 2021	JAG accredited unit	N/A	Yes	N/A	Yes	Yes, with "Train the trainer courses", ideally EUS dedicated
15	Rai 2023 [42]	Centers with expertise in interventional endoscopy, interventional radiology, and surgery (TEUS)	N/A	Yes (for TEUS)	N/A	N/A	N/A

If the training aspect is reported in detail, the textual recommendation is provided in the table; if the training aspect is simply mentioned with no further details, it is shown as "Yes" in the table; if the training aspect is not assessed, it is shown in the table as "N/A"

DEUS Diagnostic Endoscopic Ultrasound, *E–G* Esophageal-gastric, *FNA* Fine needle aspiration, *JAG* Joint Advisory Group on GI endoscopy, *MDT* Multidisciplinary teams, *P-B* Pancreato-biliary difference in sample sensitivity between those trained with and without prior linear EUS [26, 32].

The learning curve for EUS-FNA biopsies with rapid on-site evaluation (ROSE) is reported to be 30 cases for pancreatic solid lesions and 20 for the other solid lesions [28]. However, beyond these thresholds, the sensitivity for cytopathological diagnosis of cancer increases to 80% and the learning curves continue much after this (reduction of passes after 100, decrease of complications after 200) [29].

Regarding biopsy accuracy, most authors agree on ≥ 85% as the minimal threshold [19, 33, 44], although some are more lenient for malignant pancreatic lesions. The main factors associated to lower diagnostic accuracy include the trans-duodenal approach, lesions located in the pancreatic head lesions and malignant pathology [33].

Incorporating on-site cytopathology assessment in EUS curricula has been associated to higher diagnostic accuracy and lower number of passes needed to reach diagnosis [22, 50–52].

TEUS: requirements before commencing training

Autonomy in DEUS is essential before embarking on TEUS training [18, 19, 24, 42]. Similarly, competence in ERCP is deemed necessary before/during TEUS training [18, 19, 42]. Several authors emphasise the importance of a regular pancreato-biliary EUS practice to achieve high-quality results, including FNA. This "regularity" should be supported by 4–5 years of hands-on experience, the performance of ≥ 200–300 EUS and ERCP annually, and a 95–98% success rate in ERCP with normal anatomy [41].

Skills in therapeutic endoluminal endoscopy are advantageous considering that complications occur more frequently when performing TEUS procedures [18, 19, 34, 42].

TEUS: fellowship duration

While not explicitly addressed in most studies, some authors recommend at least one dedicated year of TEUS training beyond the years required for DEUS [18, 19]. However, this may still provide limited exposure, even within tertiary centers [53]. Given the ongoing expansion and increasing complexity of TEUS, some authors report that achieving competence may require more than 24 months of practical experience [15].

TEUS: curricula elements

A stepwise approach is recommended, starting with less complex cases (e.g., large targets, as with drainage of pancreatic pseudocysts) and more commonly encountered procedures [18, 19, 41, 42]. Simulation-based training is also encouraged for experienced endoscopists to gain/maintain competence in new, challenging, or unusual TEUS procedures [19, 34, 37, 42, 54]. Incorporating new technologies and live models can further enhance effectiveness in training [34, 55]. As with DEUS, expert observation is indicated for TEUS learning [56]. After clinical practice begins, a piecemeal approach (hands-on participation in specific steps of the procedure) can help trainees gain confidence while ensuring patient safety [18].

Most publications looking at learning curves for TEUS procedures report cases done by highly experienced operators (> 300 TEUS/year), but there is little or no data for operators who have only just reached DEUS competence [53, 57, 58]. Unlike DEUS, there are no current recommendations regarding an advocated threshold for TEUS performance. As these interventional procedures have been suggested as requiring at least 20–30 procedures to reach proficiency for experts, this has become the minimal suggested threshold to be performed under mentorship supervision [18, 19, 59–61]. For certain techniques such as EUS-guided pancreatic duct drainage, a significant reduction in mortality and a better efficacy has been shown to be achieved after 50 cases, demonstrating the impact of learning periods on patient outcomes, even for experienced endoscopists [62].

Competence acquisition

Competence, defined as the minimum level of skill, knowledge and expertise required for safe task performance, is typically influenced by the duration of training [46]. However, in EUS, assessing competence before granting credentials for independent practice is not as standardized as it is in upper and lower endoscopy.

Current guidelines support achieving competence thresholds instead of depending solely on procedure volume. Competence metrics include specific skills assessments using standardised tools, as detailed in Table 2 [6, 19, 23, 26, 27, 31, 32, 32–36, 39, 40, 43, 44, 63]. As there is no universal metric in EUS to assess performance and there is high interobserver variability even among expert evaluators [6], the use of a standardized, reproducible, and task-specific tool is advocated [34]. Structured evaluation with formal feedback from trainers and trainees has pedagogic benefits and should occur regularly throughout training, preferably after performing 225–250 procedures, before autonomous practice credentials are awarded [6, 19, 27, 46]. Validated assessment tools in EUS include the EUS and ERCP Skills Assessment Tool (TEESAT), the Global Assessment of Performance and Skills in EUS (GAPS-EUS) and the Direct observation of procedural skills (DOPS) [19, 23, 32, 35].

Rapid advancements in endoscopy have created a need for postgraduate training that extends beyond the formal training period to include practicing physicians; however, specific training characteristics are unclear in the literature

[34]. After accreditation, newly independent endoscopists should engage in mentored practice for at least six months [19, 44]. Keeping detailed records of procedures, complications, and outcomes is advised to facilitate the development of tailored training programs and assess the need for supervision in specific cases [23, 26, 32, 33, 40, 44]. Further details of competence maintenance are outlined in Table 2.

Ergonomics

Guidelines for EUS training lack specific recommendations on ergonomic education, despite evidence showing that teaching these principles early in general endoscopy training helps reduce musculoskeletal disorders and poor posture habits [64, 65]. However, formal evaluation and documentation by trainers are often missing in both general endoscopy and EUS training, leading to oversight of detrimental effects such as excessive torquing and high pinching forces, which are more prevalent among trainees during their initial practice [64, 66].

Optimal environment for training

High-volume EUS centres are the most appropriate for comprehensive EUS training, as they are more likely to ensure adequate volumes, cases variability and multidisciplinary meetings [19, 23, 24]. Active participation in case-management discussions help for trainees to enhance their understanding of EUS's current role in patient care [24].

It is recommended that EUS programs include at least one expert faculty member experienced in DEUS and FNA [24]. To be considered "sufficiently trained" overall, mentors must have at least 3 years of independent practice and perform a "vast, broad and adequate" volume to demonstrate proficiency maintenance [19, 24]. No further specifications have been made regarding the definition of an "adequate volume" in the assessed studies.

Discussion

High quality, structured EUS training is associated with better patient outcomes post-graduation [8, 9]. While access to EUS fellowships has increased over the last decade thanks to initiatives like the ASGE's Fellowship Matching Program and ESGE Fellowship opportunities, formal EUS-specific curricula remain limited and inconsistently implemented. Establishing such curricula would likely result in better-trained endosonographers and improved overall EUS quality, making the development of a formal training framework a key priority. This systematic review reveals that, although many core competencies are well defined, several training aspects remain to be clarified and elucidated. In an effort to contribute to the development of an international gold standard, we synthesized the existing literature to identify the essential content that EUS fellowship curricula should include, as well as the conditions necessary to ensure an optimal training environment. To the best of our knowledge, this is the first systematic review addressing these issues from an evidence-based perspective.

One important area requiring further definition is the integration of EUS training within or after the standard GI fellowship period. While some programs offer EUS exposure during general GI training, a more structured and standardized approach is needed to ensure competence without significantly prolonging training duration. Additionally, implementing a structured EUS curriculum may influence perceptions of training duration, and concerns about extended training could discourage potential candidates from pursuing advanced EUS. Therefore, striking a balance between ensuring competence and maintaining training feasibility is essential. Moreover, some candidates may gain competence faster than others (e.g., those with prior extensive ERCP extensive, or surgeons with a background on three-dimensional tissue manipulation and image directed therapies). Addressing these concerns requires optimizing training efficiency through competence-based models rather than fixed time requirements, allowing skill acquisition at an individualized pace.

Another major challenge is the practical feasibility of implementing standardized EUS training globally. Currently, training requirements vary significantly based on healthcare system resources, case volume and available mentorship. While high-volume centers are best suited for a comprehensive training, current recommendations do not specify the minimum annual case volume or the complexity of TEUS procedures that qualify a tertiary center to offer advanced training. For training centers with lower patient volumes, structured mentorship programs and regional collaborations could help bridge the gap. Future guidelines should offer adaptable models that contemplate different training environments, ensuring accessibility without comprising quality. Also, while the importance of strong mentorship is widely acknowledged, current recommendations lack sufficient detail on the essential characteristics required for this role. A more detailed description of these aspects is needed to define the number of fellows to be trained according to the availability of adequately equipped centers, both in terms of material and human resources. This alignment would help prevent informal advanced training pathways in centers lacking the necessary complexity to ensure appropriate training.

Simulation-based training has been widely recommended in the revised literature [15, 18, 19, 25, 26, 28, 31, 34, 36, 43, 59], but a clear framework regarding frequency, minimum exposure time and progression criteria remains absent. The integration of simulation is particularly relevant for low-resource settings and institutions with fewer cases. Developing phased curricula incorporating increasing hands-on exposure may facilitate democratize training.

The role of ergonomics in EUS training has not been thoroughly addressed in the existing literature. The use of a second monitor and the need to maintain stable postures for prolonged periods introduce unique challenges for endosonographers. Given the well-documented impact of poor ergonomics in general endoscopy, EUS training curricula should include formal instruction on ergonomics best practices to prevent long-term musculoskeletal injuries.

Procedural volume is no longer considered a reliable indicator of competence, as EUS trainees show wide variability in their learning curves depending on their background, prior skills, and learning ability. Competence-based assessment is therefore preferred. This is perhaps particularly relevant for TEUS, where early procedures (e.g., pseudocyst drainage) may support progression to more complex interventions. TEUS fixed volume thresholds are further challenged by the fact that existing learning curve data often derive from highly experienced endosonographers with extensive interventional backgrounds. Although procedure volume is not enough to determine competence, maintaining a record detailing trainee's specific steps involvement, degree of independence during the procedure, outcomes, etc.) remains essential for tracking progress and ensuring quality.

Concerning competence evaluation, current recommendations favor standardized assessment, yet their actual use in EUS training centres remain underreported. A survey of US Accreditation Council for Graduate Medical Education-accredited programs found that, although most directors value objective metrics, they still rely on procedure volume and subjective evaluations [67]. This results in high interobserver variability, which remains a significant issue in trainees' evaluation. Integrating validated tools into standardized assessments can help mitigate this variability, facilitate program comparisons and enhance result generalizability. Future guidelines should therefore outline clear strategies for their effective integration. Additionally, further studies comparing these tools' reliability, ease of implementation and validation are needed to provide better recommendations on their use.

Post-training supervision and continuing medical education are essential for maintaining and enhancing EUS competence. Newly certified EUS practitioners should engage in a flexible mentored practice period, tailored to their individual needs and specific procedural challenges. However, recommendations on the duration and structure of this post-graduate mentorship are scarce. Establishing clearer expectations for post-training supervision can ensure a smoother transition to independent practice. Additionally, timelapses for re-assessment intervals have not been described in the EUS training framework and will need better definition from major societies.

This study has some limitations that should be considered when interpreting the findings. A significant proportion of included studies were rated as "high risk" in the domain of trainee selection and in the applicability domain related to the clarity and quality of training outcomes measurement. This reflects ongoing challenges in standardizing trainee recruitment and in developing objective, universally accepted metrics for EUS training. Additionally, the majority of studies corresponded to lower levels of evidence (CEBM Levels 4 or 5), which is consistent with the predominance of observational studies and expert opinion currently available in this field. Although articles with the highest levels of evidence were given more weight in the literature synthesis, the predominance of observational data and expert opinion in the current literature on EUS training remains evident. While this may influence the strength of conclusions, it also highlights the evolving nature of EUS education and underscores the need for more rigorous, higher-quality, prospective studies in the field.

Concerning articles eligibility, studies on learning curves for trans-oesophageal/transrectal EUS in non-GI fellows were excluded, which may be also considered a limitation. However, this decision was made in line with current recommendations recognizing EUS as a post-GI fellowship subspecialty. Similarly, studies exclusively reporting the development of in-house simulation tools were excluded as beyond the scope of this review. Nevertheless, if the reports assessed more general training aspects (e.g., optimal timing for simulation-based training, areas where simulation has proven to be useful), these records were included and their recommendations reported in the corresponding Table. Additionally, while the inclusion of studies from the past two decades may be seen as too long, it was necessary given the limited and evolving literature since the first training recommendations in 2001. Specific comments were included to contextualize major paradigm shifts (e.g., radial EUS, tissue acquisition). Notably, only 4 of the included studies (8%) were from the first decade of the inclusion period, with the oldest dating to 2009—indicating a minimal impact from the extended timeframe.

In conclusion, EUS training should occur within standardized frameworks that define clear curricula while remaining adaptable to different training environments. Although supervised clinical experience is irreplaceable, many competencies may be reached outside the clinical setting. With the advancements of simulators and reduced acceptance of first-time hands-on directly on patients, further research on preclinical training conditions is indicated. We hope this review will serve as a foundation for structuring and specifying EUS curricula aspects within an evidence-based framework. To advance on this, collaboration among major

Gastroenterology Societies is essential. Joint initiatives, such as consensus statements and shared curricula, can harmonize training protocols and establish universally accepted competence benchmarks. Policymakers, training institutions, and professional societies must work collectively to define clear expectations for EUS training. A possible roadmap for international standardization could involve the establishment of core competencies, the development of a unified curriculum, the implementation of homogeneous assessment methods and the foundation of international collaborations. If more effective, consistent, and accessible learning opportunities are implemented, the efficiency of expert teaching time will be optimized, and progress towards proficiency will be assured which, in the end, will improve patient care.

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