Training and Assessment in Pediatric Endoscopy

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KEYWORDS

• Endoscopy, gastrointestinal/education • Endoscopy, gastrointestinal/standards
• Endoscopy, pediatric • Clinical competence • Educational measurement
• Education, medical, graduate/standards • Patient simulation • Assessment

KEY POINTS

- Given its unique nature, training in pediatric gastrointestinal endoscopy requires an approach that is tailored to pediatric practice to ensure delivery of high-quality endoscopic care in children.
- There remains a need for a comprehensive pediatric-specific endoscopy curriculum that incorporates best evidence in procedural skills education and reflects the current competency-based model of training.
- Current evidence supports the use of endoscopy simulation–based training for novice endoscopists to help speed up the early learning curve and reduce patient burden, although pediatric-specific data are limited.
- Assessment is an essential component of pediatric endoscopy education that drives both teaching and learning.
- Structured direct observational assessment tools, such as the $\text{GiECAT}_{\text{KIDS}}$, provide a framework for teaching, facilitate feedback provision, and can be used to generate aggregate assessment data across training programs to help gauge trainees' progress toward specific competency-based milestones.

INTRODUCTION

A key aspect of pediatric gastroenterology practice is the ability to perform endoscopy procedures safely, effectively, and efficiently. Similar to adult endoscopy, performance of pediatric endoscopy requires the acquisition of related technical, cognitive, and integrative competencies to effectively diagnose and manage gastrointestinal disorders in children. However, the distinctive requirements of pediatric patients and their

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families and the differential spectrum of disease highlight the need for a pediatric-specific training curriculum and assessment framework to ensure endoscopic procedures are performed safely and successfully in children. This review outlines the current state of evidence as it pertains to pediatric endoscopy training and assessment.

TRAINING

Training in pediatric gastrointestinal endoscopy largely occurs during formalized pediatric gastroenterology training programs that generally last 2 to 3 years in duration. Duty-hour restrictions and an increasing focus on patient quality, safety, and accountability have resulted in a paradigm shift across postgraduate medical education toward a competency-based system that defines desired training outcomes.[1] Resultantly, there is increasing focus on the determination of when an individual is truly competent to perform a procedure independently, how much training is required to reach this skill level, and how to optimally train.

Any practitioner wishing to perform endoscopic procedures should receive formal training in the principles and practice of safe endoscopy. To date, training in endoscopy continues to be predominantly based on the apprenticeship model with trainees learning fundamental skills under the supervision of experienced endoscopists in the clinical setting. Although adult and pediatric endoscopic practice are similar in many regards, there are key dissimilarities, such as differing procedural indications, the need for ileal intubation, and the importance of routine tissue sampling.[2] The unique nature of pediatric endoscopy dictates the need for endoscopists who wish to perform procedures on children to train under the supervision of certified pediatric endoscopists, as there is a steep learning curve even for fully trained adult endoscopists.[2]

Pediatric endoscopy training programs are obliged to ensure learners are competent to deliver high-quality endoscopic care at completion of training. To help guide and enhance training, endoscopy skills curricula have been outlined for surgical[3,4] and adult gastroenterology[5] trainees. However, there remains a need for a comprehensive pediatric-specific endoscopy curriculum that has been designed from a background of scientific research to ensure it is valid, efficient, and reflects the current competency-based training model. This section discusses a framework of procedural skill acquisition, describes commonly available training aids designed to enhance endoscopy education, and outlines the value of trainer education.

Endoscopy Skill Acquisition

The road to acquiring competency, and potentially expertise, in performing endoscopic procedures requires a combination of innate ability, dedicated trainers, and many hours of deliberate practice. With regard to procedures, skill acquisition has been described by Fitts and Posner[6] as a sequential process involving 3 major phases: cognitive, associative, and autonomous. In the *cognitive* stage, learners begin to develop a mental understanding of the procedure through instructor explanation and demonstration. Performance during this stage is often erratic and error filled. Feedback during this phase should focus on explanation of how the procedure is performed correctly and identifying common errors to increase learners' understanding of the tasks. Subsequently, in the *associative* phase, learners begin to translate the knowledge acquired in the cognitive stage into appropriate motor behaviors so that tasks are gradually executed more efficiently, with fewer errors and interruptions. Feedback is essential for learning during this stage, as has been demonstrated by the study by Mahmood and Darzi,[7] which showed no performance improvement in learners who received no feedback despite substantial training on a virtual reality colonoscopy simulator. Feedback during the cognitive stage should aim to help learners identify errors and corresponding corrective actions, as this has been shown to enhance skills acquisition within the surgical domain.[8] Finally, with ongoing practice and feedback, learners transition to the *autonomous* stage in which motor performance becomes automated such that skills are performed without significant cognitive or conscious awareness devoted to performance. Ongoing lifelong learning and practice are then required to ensure maintenance of skills.[9]

Endoscopy Training Aids

The increased focus on quality of training and patient safety has prompted educators to seek alternative methods of teaching endoscopy. Novel instructional aids are increasingly being integrated into training curricula with the aim of speeding up the learning curve, facilitating instruction, and helping to ensure trainees attain some degree of proficiency before performing real-life procedures. The following section discusses 2 commonly used aids designed to enhance endoscopy education: magnetic endoscopic imagers and simulation.

Magnetic endoscopic imagers

Magnetic endoscopic imaging is a nonradiographic technique that provides real-time 3-dimensional views of the colonoscope shaft configuration and its position within the abdomen during a procedure.[10] Imagers have been shown to be safe and beneficial for removing loops during colonoscopy in the clinical setting.[11] A recent meta-analysis of 13 randomized studies found that use of magnetic endoscopic imaging during real-life colonoscopy is associated with lower risk of procedure failure, lower patient pain scores, and shorter time to cecum compared with conventional endoscopy.[12] Regarding training, research indicates that use of an imager may enhance learners' understanding of loop formation and loop-reduction maneuvers.[13] For novice endoscopists, there has been shown to be no detrimental effects with regard to performance or workload with use of an imager during clinical training.[14] Additionally, imagers potentially allow trainers to better guide learners without having to take over the procedure. They have also been shown to potentially enhance simulation-based colonoscopy training, although research is limited.[15] Magnetic endoscopic imaging is a promising new training aide for endoscopy; however, studies to date have largely been carried out within the adult clinical context. Further research is required to establish its efficacy for pediatric endoscopy and to determine how best to maximize its effectiveness during training.

Simulation-based endoscopy training

Several factors have contributed to the shift toward incorporation of simulation into pediatric endoscopy training curricula. First, recent guidelines have encouraged the use of simulation-based training, as it is now mandated by accreditation organizations in certain jurisdictions such as the United States.[16] Second, although the "ideal" platform for training has traditionally been considered the patient, endoscopy is uniquely challenging to teach in the clinical setting, as supervisors are required to relinquish complete control of the endoscope to allow trainees to gain adequate experience. Additionally, clinical demands can limit a trainers' capacity to provide detailed instruction and feedback, and training on patients occurs through chance encounters, which may limit exposure to particular pathologies. Finally, with regard to pediatric endoscopy specifically, parents and trainers are often very protective of children; a factor that can limit case availability and training exposure.

Simulation-based training is steadily gaining grounds as a means of teaching the cognitive, technical, and integrative competencies related to pediatric endoscopy in a safe setting. The simulated setting is an optimal learning environment in many ways, as learners can build a framework of basic techniques through sustained deliberate practice in a setting in which they can make mistakes without causing patient harm. Additionally, learners can rehearse key aspects of procedures at their own pace, training can be structured to maximize learning, and errors can be allowed to progress to allow trainees to learn from their mistakes.[17] The use of simulation also permits educators to systematically vary training tasks; an instructional design feature that enhances learning.[18] Furthermore, faculty do not have to juggle teaching and clinical demands, thus creating a learner-centered educational experience.

The reasons to integrate simulation into endoscopy training are many. Additionally, it has been shown to be efficacious as a means to supplement the apprenticeship model of training for novice adult endoscopy trainees.[19,20] A systematic review of 13 randomized controlled trials (278 participants) revealed that simulation-based training, before patient-based training, enhanced novice endoscopist performance within the clinical setting as compared with untrained controls as measured by independent procedure completion, time, insertion depth, overall rating of performance, error rate, and visualization.[19] Another systematic review of 39 studies (21 randomized controlled trials, 1181 participants) found that simulation-based training, as compared with no intervention, is associated with improved patient outcomes in the clinical environment (procedure completion and major complications).[20] With regard to pediatric endoscopy, computer-based simulators have been shown to have face validity even through most models do not have pediatric-specific training cases.[21] Additionally, simulation-based training has been shown to increase pediatric endoscopic trainees' confidence and technical skills as measured by self-report.[21]

Evidence suggests that simulation-based endoscopy training is effective and learning outcomes transfer to the clinical setting; however, simply providing trainees with access to simulators does not guarantee their effective use. Educators must decide how to apply simulation-based technology to achieve optimal learning. Reviews examining principles of effective instructional design and selection of simulation modalities broadly have identified a number of best practices in simulation-based education, including feedback, repetitive practice, distributed practice, mastery learning, interactivity, and range of difficulty.[18,22–24] As mentioned, feedback is a major motivator for leaners and one of the most crucial determinants in ensuring successful procedural mastery within both the clinical and simulated settings.[23,24] The simulated setting provides an optimal environment for feedback provision, as learners can work through errors independently and feedback can be structured to enhance learning without compromising patient safety. For example, our educational research team has found that the timing of feedback provision is an important factor influencing skill acquisition in novice endoscopists in the simulated setting.[25] Terminal feedback that is given at task completion is more effective as compared with feedback given during task performance, because constant feedback may lead to an overreliance on feedback and suboptimal learning.[25] Concerns for patient safety do not permit use of terminal feedback within the clinical setting, pointing to the idea that simulation technology allows educators to use strategies shown to enhance learning, such as terminal feedback, which are not possible to use when teaching in the clinical setting.

Recent research has begun to assess characteristics of curriculum design and instruction required to enhance acquisition of broader endoscopic competencies, such as cognitive and integrative skills. A recently published study by Grover and colleagues[26] provides validity evidence for a structured comprehensive curriculum consisting of 6 hours of didactic lectures interlaced with 8 hours of virtual reality simulation-based training with expert feedback.[26] The curriculum improved technical, cognitive, and integrative skill acquisition for novice endoscopists and skill transfer to the clinical environment, as compared with self-regulated learning on simulators.[26] Building on this work, Grover and colleagues[27] found that a simulation-based training curriculum of progressive fidelity and task complexity improves colonoscopy skill acquisition and transfer to the clinical setting as compared with a curriculum using high-fidelity simulation in isolation. This finding is commensurate with the challenge point framework, which postulates that learners must be appropriately challenged for optimal and efficient learning to occur.[28] Learning is postulated to be enhanced when task difficulty is matched to a trainees' skill level and progressively increased as the individual acquires new skills to continually challenge them in an optimal manner. Additionally, the results provide support for the idea that less expensive, part-task simulators may be more appropriate for teaching very basic skills, as the information content of virtual reality simulators may impede novice learning by overwhelming learners' cognitive capacities.[28]

Based on current evidence, endoscopy simulation has been shown to be useful in the early training phase in helping to speed up trainees' learning curve and reduce patient burden, although pediatric-specific data are limited. To date, simulation has primarily been examined as a means to train novice endoscopists. An evidence base needs to be further developed with respect to optimal use of simulation for nontechnical skills training and more advanced endoscopic skills. Specifically, studies are needed that assess the use of simulation to teach higher-level competencies, such as crisis management, that require the integration of both technical and nontechnical skills for successful management.

Training the Pediatric Endoscopy Trainer

Effective endoscopy instruction requires the skillful application of evidence-based educational principles. There is increasing recognition that training should be provided by individuals with the skills and behaviors required to teach endoscopy, including an awareness of principles of adult education, best practices in procedural skills education, and appropriate use of beneficial educational strategies (eg, feedback).[29] The ability to teach endoscopy is an important skill that can be improved with instruction. "Train the trainer" courses have been developed to heighten trainers' awareness with regard to educational approaches that can be used to enhance endoscopy teaching. These courses are now mandatory for adult gastroenterology endoscopy trainers in the United Kingdom and are increasingly being implemented across other jurisdictions, such as Canada. Pediatric gastroenterology societies should strongly consider adapting the content of "train the trainer" courses to pediatric endoscopy practice.

ASSESSMENT

Endoscopic procedures are an integral component of pediatric gastroenterology practice, and training programs strive to ensure learners are competent to perform procedures independently at completion of training. Assessment is required to support training and subsequent practice to optimize learners' and practitioners' capabilities through the provision of motivation and direction for future learning, to ensure competency before performing procedures independently (ie, certification), and to protect society from substandard care.[30] The unique nature of pediatric endoscopy highlights the need for an assessment approach tailored to pediatric endoscopy practice and the use of pediatric-specific assessment methods and measures. The subsequent section examines how endoscopic competence is conceptualized, outlines the importance of integrating assessment throughout the endoscopy learning cycle, and discusses currently available assessment methods and measures for pediatric endoscopy.

Endoscopic Competence

Endoscopic competence has been defined as the minimum level of skill, knowledge, and/or expertise, derived through training and experience, required to safely and proficiently perform a task or procedure.[31] Skills required to perform endoscopic procedures have traditionally been classified into 2 skill domains: technical and cognitive. Examples of technical or psychomotor skills include strategies for scope advancement (eg, torque steering) and loop-reduction techniques.[32,33] Cognitive competencies are reflective of knowledge and the application of endoscopically derived information to clinical practice. Examples include knowledge of procedural indications and contraindications, equipment selection, and pathology identification.[32,33]

In addition to technical and cognitive competencies, there are nontechnical skills that are required to perform endoscopic procedures safely and proficiently that are outlined explicitly within general competency-based frameworks from accreditation bodies such as the Accreditation Council of Graduate Medical Education in the United States[34] and the Royal College of Physicians and Surgeons of Canada.[35] Additionally, the importance of assessing nontechnical skills is recognized by pediatric gastroenterology-focused organizations such as the North American Society for Pediatric Gastroenterology, Hepatology, and Nutrition (NASPGHAN).[33] Although no studies have investigated the role of nontechnical skills within the pediatric context specifically, literature from adult practice suggests they play a central role in high-quality care. For example, the vast majority of recommendations stemming from a report by the National Confidential Enquiry into Patient Outcomes and Death,[36] which investigated deaths occurring within 30 days of therapeutic endoscopy procedures in the United Kingdom, highlight failings in nontechnical skills, such as communication and teamwork, as opposed to technical skills.

A well-defined understanding of the competencies required to carry out pediatric endoscopic procedures is fundamental to the development of an assessment framework. The literature highlights that technical and cognitive skills are necessary but not sufficient to ensure acquisition and maintenance of competency in gastrointestinal endoscopy. Nontechnical skills are an integral facet of competent endoscopic practice and an important contributor to patient safety and clinical outcomes. It has, therefore, been proposed that endoscopic competence should be conceptualized as encompassing 3 core competency domains: technical, cognitive, and integrative competencies (**Table 1**).[37] Integrative competencies are defined as higher-level competencies required to perform an endoscopic procedure that complement an individual's technical skills and clinical knowledge to facilitate effective delivery of safe and effective care in varied contexts.[38] Examples of integrative competencies include teamwork and professionalism. Reflective of this framework of endoscopic competence, assessment methods and measures should ideally reflect the full scope of technical, cognitive and integrative competencies required to perform pediatric endoscopic procedures.

Intent of Assessment: Formative Versus Summative

From an educational perspective, assessment can be broadly classified as formative or summative. Formative assessment is process focused. It aims to provide trainees with informative, timely feedback and benchmarks to enable leaners to reflect on their

Table 1
Examples of technical, cognitive, and integrative competencies required for performance of endoscopic procedures

Competency Domain	Example Skills
Technical	• Correct hand position to hold scope • Use of scope controls • Torque steering • Tip control • External pressure • Withdrawal • Visualization of mucosa
Cognitive	• Anatomy • Pathology identification • Principles for safe sedation and monitoring • Procedural indications and risks • Equipment selection
Integrative	• Communication • Team work • Situational awareness • Professionalism • Patient safety awareness • Interpretation and management of findings • Patient education

performance and guide future learning to foster their progress from novice to competent (and beyond).[30,39] Summative assessment, alternatively, is outcome focused. It aims to produce an overall judgment to determine competence, readiness for independent practice or qualification for advancement, and, therefore, must have sufficient psychometric rigor.[30] Although summative assessment provides professional self-regulation and accountability, it may not provide adequate feedback to direct learning.[30,40] Assessment must be an ongoing process throughout the endoscopy learning cycle, from training to accreditation to independent practice, and thoughtful integration of both formative and summative assessment is essential to simultaneously optimize the learning and certification functions of assessment (Table 2).

Table 2
Framework for the integration of assessment throughout the endoscopy learning cycle from training to independent practice

Stage of Learning	Assessment Goals	Assessment Type
Training or retraining	• Monitor progress • Provision of focused feedback • Optimize learning capabilities • Enhance motivation • Guide instruction	Formative
Accreditation (certification)	• Establish competence	Summative
Independent practice	• Quality improvement • Ensure maintenance of competence (recertification) • Ensure provision of high-quality patient care	Formative Summative

Assessment Aims

The Miller pyramid provides a framework that can be used to help guide selection of assessment methods to target specific facets of clinical competence, including "knows," "knows how," "shows how," and "does."[41] This framework, which moves from a focus on learner's cognition at the lower end of the pyramid and toward a focus on learner's behaviors, has heightened educators' awareness that competence can and should be evaluated at multiple levels. It also highlights the importance of assessments conducted in the authentic clinical environment. Table 3 outlines each of the 4 levels of the Miller pyramid matched to assessment methods of relevance to pediatric endoscopy.

Current State of Assessment of Pediatric Endoscopy

Over the past 2 decades, we have seen a profound shift in training as a result of several factors, including an increased focus on learner centeredness, quality, outcomes, and accountability. Postgraduate medical education has shifted from a process-based framework that delineates the time required to "learn" specified content (eg, 3-year gastroenterology fellowship) to a competency-based model that defines desired training outcomes (eg, perform upper and lower endoscopic evaluation of the luminal gastrointestinal tract for screening, diagnosis, and intervention[42]) that are organized around competencies derived from an analysis of societal and patient needs.[43–45] Assessment is an integral component of competency-based education, as it is required to monitor progression throughout training, document trainees' competence before entering unsupervised practice, and ensure maintenance of competence. Despite the shift toward competency-based assessment and training, procedural assessment in pediatric gastroenterology still focuses predominately on the number of procedures and a "gestalt" view of the supervising physician.[46] This type of informal global assessment is fraught with bias inherent to subjective assessment and is not designed to aid in the early identification of trainees requiring remediation. To support high-quality pediatric endoscopic care, assessment is required to monitor learners' progress, provide focused and informative feedback, document competency to practice, ensure practitioners maintain competence, and monitor

Table 3
Relationship between the Miller pyramid[41] and potential methods of assessment of pediatric endoscopy skills

Level of Miller Pyramid		Assessment Construct	Assessment Approach
Professional authenticity ↑	Does	Knowledge, skills, and attitudes integrated into context	Performance integrated into practice (eg, direct observation, practice portfolio, workplace-based assessments, narratives)
	Shows how	Integrated knowledge, skills, and attitudes	Demonstration of learning (eg, simulation, standardized patient-based tests, objective structured clinical examination)
	Knows how	Applied knowledge	Interpretation and/or application (eg, problem-based scenarios, extended matching, case-based multiple-choice questions)
	Knows	Knowledge	Fact gathering (eg, multiple-choice questions, short answers)

training quality. Assessment methods and measures that are commonly used in the context of pediatric colonoscopy and upper endoscopy procedures are reviewed later in this article.

Procedural numbers

Within the traditional apprenticeship model of training, the number of endoscopic procedures performed under supervision sufficed as a surrogate for demonstration of competent performance.[47–49] However, research on adult endoscopists has shown that there is wide variation in the rate at which trainees acquire skills.[50,51] Furthermore, in addition to procedural volume, there are many other factors that affect skill acquisition, including training intensity,[50] presence of disruptions in training,[52] use of training aids (eg, simulation[19,20]), quality of teaching and feedback received, and a trainees' innate ability.[53] Procedural number requirements, therefore, do not ensure competence. Additionally, the accuracy and objectivity of logbooks, which have been traditionally used by endoscopists to record their experience, has been questioned.[54,55] Logbooks also do not provide learners and educators with specific information about the nature of learning achieved.

Reflective of these concerns, current pediatric credentialing guidelines outline "competency thresholds," as opposed to absolute procedural number requirements that ensure attainment of competence. A "competence threshold" is the minimum recommended number of supervised procedures a trainee is required to perform before competence can be assessed.[56] As seen in **Table 4**, there is variability with regard to current credentialing guidelines that outline competence thresholds for pediatric upper endoscopy and colonoscopy. Guidelines for upper endoscopy are principally based on expert opinion due to the lack of high-quality data. Two adult studies have examined competency in upper endoscopy. Cass and colleagues[47] demonstrated an 80% success rate of esophageal intubation after 100 procedures, whereas Vassiliou and colleagues[57] concluded that 50 procedures are required to achieve a plateau in skills as measured using the Global Assessment of Gastrointestinal Endoscopic Skills tool.

There is a paucity of literature with regard to endoscopic skill learning curves among pediatric endoscopists; therefore, current guidelines for colonoscopy have largely been extrapolated from adult data. Current guidelines are principally based on the study by Cass and colleagues[58] that assessed 135 adult gastroenterology trainees from 14 programs and showed it took, on average, 140 colonoscopies to achieve a 90% cecal intubation rate. More recent studies that have attempted to validate adult procedural volume recommendations indicate that published requirements may significantly underestimate the amount of training required to achieve competence.[59] Two recent studies, involving 41 and 93 trainees, found that competency thresholds were achieved, on average, by 275 and 250 procedures when using criteria including cecal intubation rate, time to intubation, and competency benchmarks on the Mayo Colonoscopy Skills Assessment Tool[60] and the newer Assessment of Competency in Endoscopy[61] tool, respectively. However, it took upwards of 400 procedures for some trainees to achieve competence. The largest study to date that prospectively analyzed 297 trainees over 1 year in the United Kingdom found that it took, on average, 233 colonoscopies to achieve a 90% cecal intubation rate.[50] Additionally, a regression analysis of 10 adult studies, including 189 trainees, estimated 341 colonoscopies are required to achieve a 90% cecal intubation rate.[62]

Further research is required to help clearly delineate appropriate competence thresholds for both pediatric colonoscopy and upper endoscopy. However, as mentioned, pediatric endoscopy training guidelines (see **Table 4**) emphasize

Table 4
Training requirement recommendations from pediatric endoscopy professional organizations

		Colonoscopy		Upper Endoscopy	
Organization	**Country**	**Minimum No. of Cases**	**Other Training Requirements**	**Minimum No. of Cases**	**Other Training Requirements**
North American Society for Pediatric Gastroenterology, Hepatology, and Nutrition[33]	North America	120	• Cecal intubation rate: $\geq$90% • 10 snare polypectomies	100	• 10 foreign body removals • 15 with control of bleeding (variceal or nonvariceal) with various methods[b] and/or colonoscopy with control of bleeding
Joint Advisory Group Pediatric Certification (BSPGHAN Endoscopy Working Group)[64]	United Kingdom	100	• Terminal ileal intubation rate: >60% • Cecal intubation rate: >90% • Formative DOPS: >90% 3s and 4s (>10 DOPS assessments) • Serious complications: <0.5%[a] • Completed "Basic Skills Course Lower GI Endoscopy" • Summative assessment ($\geq$2 assessors, $\geq$2 procedures)	100	• D2 intubation rate: >95% • Retroflexion rate: >95% • Unassisted physically: >95% • Formative DOPS: >90% 3s and 4s (minimum 10 DOPS) • Completed "Basic Skills Course in Upper GI Endoscopy" • Summative assessment ($\geq$2 assessors, $\geq$2 procedures)
Conjoint Committee[119]	Australia	100	• To the cecum (ileum preferable) • Cecal intubation rate: >90% excluding patients with severe colitis (preferably ileum) • $\geq$75 in pediatric patients under supervision of recognized pediatric supervisor • Some polypectomy experience	200	• Unassisted, complete examination • $\geq$100 in pediatric patients under supervision of recognized pediatric supervisor • $\geq$10 therapeutic procedures of which $\geq$5 involve control of upper GI hemorrhage

Abbreviations: DOPS, Direct Observation of Procedure or Skills; GI, gastrointestinal.

[a] Serious complications defined as death, perforation, significant bleeding requiring a two or more unit transfusion, unplanned post-procedure hospital stay of over 24 hours (related to the procedure) or admission to hospital due to a complication of the procedure following discharge from the endoscopy Unit.

[b] Methods to control bleeding may include injection, band ligation, electrocautery (eg, heater probe, multipolar probe, argon plasma coagulator, loop application, hemostatic clips), or additional methods as they become available.

procedural numbers as “competence thresholds”; promoting the idea that numbers in isolation do not guarantee competence. The question still remains: how can we best assess learning and performance to determine when a trainee displays clinical performance commensurate with competent, independent practice?

Tools for Assessment

Assessment is reliant on the existence of tools and measures that are reliable and valid. Reliability is a measure of the consistency or reproducibility of assessment data or scores.[63] The validity of a test reflects the degree to which an assessment measures what it is purported to measure.[63] The following section outlines tools that can be used to aid in the assessment of endoscopic competence. Ultimately, competence is best assessed using objective criteria such as quality metrics and direct observation of performance, an idea supported by pediatric gastroenterology-focused organizations such as NASPGHAN[33] and the Joint Advisory Group on gastrointestinal endoscopy.[64]

Written knowledge tests

Knowledge relevant to endoscopy (eg, anatomy, scope selection) is essential to the development of clinical competence and should be tested alongside other competency domains. With regard to adult endoscopy, the Fundamentals of Endoscopic Surgery Program developed by Society for Endoscopic and Gastrointestinal Surgeons uses a multiple-choice examination to assess cognitive knowledge.[65] Additionally, in the United Kingdom, assessment of colonoscopy-specific knowledge is part of the accreditation process for the UK Bowel Cancer Screening Program.[66]

The core cognitive skills underpinning safe pediatric endoscopy practice have been outlined by organizations such as NASPGHAN[33]; however, corresponding assessments with good reliability and validity evidence have yet to be formally developed for pediatric endoscopy. There are many ways of assessing knowledge, such as multiple-choice or short-answer questions (see **Table 3**). However, for cognitive skills, educational best practice supports the use of assessments that test trainees’ ability to apply knowledge to problem solving or clinical reasoning in specific clinical contexts at the “knows how” level of the Miller pyramid.[41,67] For example, testing pathology recognition skills through the use of clinical vignettes linked with images or videos.

Simulation-based assessment

Simulation technology is increasingly being integrated into medical education as a means to assess performance across a variety of domains[68]; however, the validity evidence for simulation-based assessment of endoscopic skills remains limited.[68,69] Simulation-based assessments are attractive to educators, as they offer a proxy for clinical observations and are capable of providing objective, reproducible assessments at the “shows-how” level of the Miller pyramid.[41] Simulation allows for standardization of scenarios, anatomy, and pathology across trainees. The controlled nature of the simulated learning environment also permits assessment of trainees as they perform tasks independently in a risk-free environment, thus removing considerations of patient safety. Additionally, simulation enables assessment of integrative (nontechnical) competencies, such as situational awareness and teamwork. For example, through use of an endoscopy-based Integrated Procedural Performance Instrument[70] format assessment scenario, during which a learner is assessed performing a simulated endoscopy procedure while interacting with team members (eg, endoscopic assistant, anesthesiologist) and an actor portraying a patient in a naturalistic setting.

Although simulation-based assessment of endoscopic competence is an attractive idea, before widespread implementation, more research is required to ensure assessments can reliably distinguish individuals with a range of levels of endoscopic skill and can accurately predict performance within the clinical setting.[71] Simulator metrics, motion analysis, and direct observational assessment tools are commonly used to assess simulated endoscopy performance.[72] High-fidelity virtual reality simulators typically provide learners with objective computer-generated performance metrics, such as completion time and patient discomfort.[73] However, research assessing the validity evidence of these measures has yet to demonstrate that they are capable of meaningfully discriminating between endoscopists across skill levels.[74–86] Metrics generated from tasks performed on part-task endoscopy simulators that reflect speed and precision also are being studied as a potential tool to assess technical skills[87,88]; however, further validity evidence is required before widespread adoption. Assessments based on motion analysis aim to quantify performance using parameters produced by motion-tracking hardware and/or software that are extracted from movements of an endoscopists' hands and/or procedural instrument(s) (eg, path length).[89] Research to date is limited and further validity evidence of the technology as an assessment tool within the simulated and/or clinical setting must be gathered before implementation.[90–94] Direct observational assessment tools depend on an external rater who scores learners using predefined criteria that are built around an assessment framework (see the section "Direct observational assessment tools," later in this article). Such assessments are advantageous, as compared with simulator-generated metrics and motion analysis, because they are capable of providing trainees with informative feedback. To date, however, no studies have been carried out to examine reliability and validity evidence of a direct observational tool for simulated pediatric endoscopy.

Endoscopic simulation has recently been integrated into the board-certification process for general surgery in the United States through the Fundamentals of Endoscopic Surgery Program.[95] The performance-based manual skills assessment is composed of 5 individual tasks on a virtual reality simulator designed to assess fundamental technical skills.[95] The hands-on component has good test-retest reliability and scores have been shown to vary across skill levels (discriminative validity).[95] Scores also correlate moderately with clinical colonoscopy performance; however, assessors were not blinded to the endoscopists' skill level.[96] Although this is a promising first step in the application of simulation to the assessment of endoscopic skills, additional research is still required to determine whether passing scores are a reliable and valid marker of competency in performing endoscopy within the clinical setting. Reliability and validity evidence of the assessment in the context of pediatric endoscopy has not been assessed.

Quality metrics in pediatric endoscopy

In line with the current health care systems' focus on delivery of effective, safe, equitable, and high-quality care, current pediatric endoscopy credentialing guidelines emphasize the importance of using evidence-based endoscopy quality metrics to help determine competency. Endoscopy training programs are increasingly requiring learners to monitor quality measures, such as independent terminal ileal intubation rate and patient comfort, so that they can be used as part of a summative assessment of trainees. Additionally, quality metrics are being used by practicing endoscopists as a formative assessment tool to help promote improvement in care delivery. Although quality metrics reflect trainees' performance at the "does" level of the Miller pyramid[41] (see **Table 3**), they do not provide trainees with detailed feedback to help pinpoint deficiencies. Additionally, although there is evidence in adult practice to show that these metrics can be used to authenticate provision of high-quality endoscopic care,[97–99] research is required to provide validity evidence for their use as objective measures of competence in performing endoscopy during training.

In adult practice, the introduction of cancer screening programs has fostered the development and validation of evidenced-based quality and safety indicators.[98,99] However, given the unique nature of pediatric practice, quality and safety indicators derived from adult practice are not always directly applicable to the specific needs of children and their families.[2,100] Currently, there are limited data on the applicability of adult-derived quality metrics to pediatric practice and their impact on clinically relevant outcomes. For example, with regard to cecal intubation rate, the reported successful completion rate for pediatric endoscopists varies from 48% to 96%.[101–106] Terminal ileum intubation rate is a potential quality indicator specific to pediatric colonoscopy, given the differential indications for pediatric colonoscopy as compared with adults. The reported ileum intubation rate varies from 11.0% to 87.5%,[101,103–107] and the independent success rates of pediatric trainees at various stages of training have not been reported. Given the paucity of literature, additional research is required to further delineate and define pediatric-specific quality indicators that can be used for assessment and quality assurance purposes, and validate them in a longitudinal prospective fashion.[100]

Direct observational assessment tools

In recent years, accreditation bodies and endoscopy training and credentialing guidelines have been placing greater emphasis on the continuous assessment of trainees as they progress toward competence. Direct observational assessment tools are one such method to support ongoing skills assessment. Additionally, direct observational tools can be used to support a competency-based education model that defines desired training milestones and outcomes and necessitates the use of psychometrically sound assessment tools to document achievement. Typically, the acquisition of procedural proficiency in endoscopy has been based on an apprenticeship model, in which supervising staff make a subjective global judgment at the end of training as to whether a learner is prepared to perform procedures independently. However, without a structured schema on which to base such observations, these assessments are largely unreproducible and unreliable.[108,109] These global assessments also do not allow for the timely identification of learners in difficulty. Increasingly in medical education, it is recognized that the addition of structure to components of the assessment process makes it more objective, valid, and reliable.[110–112] Additionally, there has been an augmented focus on assessment of real-world events, such as procedures, through direct observation, as it allows for assessment of clinical competence at the "does" level of the Miller pyramid.[41,113]

Although a number of endoscopy assessment tools have been developed and validated within the adult setting, until recently there has been limited research outlining the development or validation of tools designed to assess competence in performing pediatric endoscopy. Key practice differences between adult and pediatric endoscopy emphasize the need for pediatric-specific procedural assessment tools. The NASPGHAN training guidelines[33] outline endoscopy scorecards; however, the psychometric properties of these instruments have not been evaluated. Additionally, although pediatric trainees were included in a study assessing validity evidence for the Global Assessment of Gastrointestinal Endoscopic Skills tools for upper endoscopy and colonoscopy, these tools were developed in the adult context, they focus on technical skills, and only a handful of procedures from one pediatric institution were included.[114]

The Gastrointestinal Endoscopy Competency Assessment Tool for pediatric colonoscopy (GiECAT$_{KIDS}$)

Our team recently developed the Gastrointestinal Endoscopy Competency Assessment Tool for pediatric colonoscopy (GiECAT$_{KIDS}$), a task-specific 7-item global rating scale that assesses holistic aspects of pediatric colonoscopy skill and a structured 18-item checklist that outlines key steps required to complete the procedure.[37] Using Delphi methodology, the GiECAT$_{KIDS}$ was developed by 41 pediatric endoscopy experts from 28 North American hospitals and thus is reflective of endoscopic practice across institutions. A recent prospective study that examined 116 colonoscopies performed by 56 pediatric endoscopists (25 novice, 21 intermediate, and 10 experienced) from 3 North American academic hospitals provides reliability and validity evidence of the GiECAT$_{KIDS}$ for use in the authentic clinical context in a formative manner throughout training, including evidence of strong interrater reliability; excellent test-retest reliability; evidence of content, response process, and internal structure validity; discriminative validity (ability to detect differences in skill level); validity evidence of associations with other variables thought to reflect endoscopic competence (eg, ileum intubation rate); and educational usefulness.[38] As an assessment measure, the GiECAT$_{KIDS}$ has a number of strengths. In particular, it has been designed to assess the broad array of competencies required to perform pediatric colonoscopy (including cognitive, integrative, and technical skill components) in an integrated manner that is known to facilitate learning.[115] Additionally, it addresses performance of all components of the procedure, including preprocedural, intraprocedural, and postprocedural aspects of care.

Assessment is an essential component of endoscopy education, as it drives both teaching and learning.[115,116] The GiECAT$_{KIDS}$ represents a critical step in the development of a robust pediatric-specific program of assessment to support pediatric endoscopy training and practice. The integration of rigorously developed assessment tools, such as the GiECAT$_{KIDS}$, with strong reliability and validity evidence throughout the training cycle, is essential because they can support trainees' learning through the provision of instructive feedback, allow program directors to monitor skill acquisition to ensure trainees are progressing, facilitate identification of skill deficits, and help ensure readiness for independent practice.[117] Looking to the future, the universal adoption of robust assessment tools, such as the GiECAT$_{KIDS}$, by pediatric gastroenterology training programs across jurisdictions would be useful, as it would generate aggregate data that could be used to develop average learning curves of pediatric endoscopists. These data could then be used to define milestones for pediatric endoscopists at different levels of training and to help to establish minimal performance-based benchmark criteria for competence in pediatric endoscopy procedures to support competency-based training.

SUMMARY

Endoscopy is an important diagnostic and therapeutic tool for gastrointestinal disorders in children. Differences between pediatric and adult practice highlight the need for pediatric-specific training and assessment approaches to ensure safe and effective endoscopy in pediatric populations. The ultimate goal of pediatric endoscopy training is to ensure trainees are competent to perform procedures independently. Over the past decade a lot of effort has been made to more clearly define the competencies required to carry out pediatric endoscopic procedures and develop tools to support the assessment of competency in performing pediatric endoscopy. In addition, novel methods of instruction, such as simulation, have been developed and introduced with the aim of accelerating the endoscopy learning curve and ensuring trainees attain some degree of proficiency before performing real-life procedures. Ultimately, assessment goals and goals for teaching and curriculum development should be fully intertwined, as assessment is known to drive learning.[118] Reflective of this, there remains a need for a comprehensive evidence-based pediatric endoscopy training curricula and a complementary assessment system that integrates multiple assessment methods to examine the technical, cognitive, and integrative domains of endoscopic competence longitudinally from training to independent practice to ensure achievement and maintenance of competence.

Although great strides have been made in recent years with regard to pediatric endoscopy training and assessment, looking to the future, additional research is required to examine best practices with regard to the use of novel instructional aids, such as simulation, that are designed to accelerate the endoscopy learning curve. In addition, studies are required to help further delineate instructional design features (eg, mastery learning, feedback) that optimize pediatric endoscopy skill acquisition. There also remains a need to systematically integrate common pediatric-specific gastrointestinal endoscopy competency assessment tools, such as the GiECAT$_{KIDS}$, across training programs to help systematically define milestones for pediatric endoscopists and subsequently, to monitor trainees' progress to support competency-based training.

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