Simulators and training models for diagnostic and therapeutic gastrointestinal endoscopy: European Society of Gastrointestinal Endoscopy (ESGE) Technical and Technology Review

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ABSTRACT

Gastrointestinal (GI) endoscopy comprises both diagnostic and therapeutic procedures involving the luminal GI tract as well as the biliary tree, liver, and pancreas. GI endoscopy is challenging to learn, requiring both cognitive (nontechnical) and technical skills, and requires extensive practice to attain proficiency. Simulation-based training has been shown to assist trainees and young endoscopists in acquiring new skills and accelerating the learning curve. Moreover, simulation-based training creates an ideal environment for trainees to initially learn and practice skills while making mistakes with no risk to patients.
This review, divided in two parts, offers a comprehensive summary of the different classes of simulators available for GI endoscopic training.
In Part I, only mechanical simulators are reported and described. In Part II, animal simulators (ex vivo/in vivo) and virtual reality models are detailed, together with prototypes that are currently not commercially available.

ABBREVIATIONS

3 D	three-dimensional
CBD	common bile duct
CT	computed tomography
EGD	esophagogastroduodenoscopy
EMR	endoscopic mucosal resection
ERCP	endoscopic retrograde cholangiopancreatography
ESD	endoscopic submucosal dissection
FNA	fine-needle aspiration
EUS	endoscopic ultrasonography
GI	gastrointestinal
PEG	percutaneous endoscopic gastrostomy
POEM	peroral endoscopic myotomy
RCT	randomized controlled trial
VR	virtual reality

SCOPE AND PURPOSE

Simulators represent a crucial part of the training phase for gastrointestinal endoscopy. Nowadays, several classes of simulators are available on the market and also as prototypes, with different characteristics and purposes. The aim of this paper is to provide a comprehensive review of the accessible simulators for training in various gastrointestinal endoscopic procedures, providing a practical guide for both trainers and trainees.

PART 1: MECHANICAL SIMULATORS

Background: Part 1

Gastrointestinal (GI) endoscopy is demanding, requiring integrative skills, both technical and nontechnical (cognitive). For these reasons, training in GI endoscopy is challenging. The increasing incorporation of simulators into the GI endoscopy training model represents an important step forward in the practice of complex procedures in a controlled environment avoiding the direct involvement of patients [1, 2]. This is especially true for GI endoscopy trainees and is recommended in the Position Statement of the European Society of Gastrointestinal Endoscopy (ESGE) on training in basic GI endoscopy procedures [3].

Since the 1960 s [4], GI endoscopy simulators have been designed to mimic real-life procedures with the purpose of allowing trainees to develop and improve their skills.

There are currently four classes of endoscopic simulators, each with its own advantages and disadvantages: (I) mechanical simulators, (II) ex vivo and (III) in vivo animal models, and (IV) computer-based (e. g. virtual reality [VR]) simulators. In addition, some noncommercially available prototypes are also presented here to raise awareness of the rapid progression of scientific research in this field.

The aim of this technical review is to provide an extensive and updated overview of the currently commercially available simulators for training in GI endoscopic procedures (both diagnostic and interventional), focusing on their technical features and applications, and to provide a practical and easily consultable guide for trainers and trainees.

Methodology and development process

The ESGE Research Committee Chair (L.F.) and the ESGE Executive Committee, appointed a leader (C.C.) for this technical review. They invited three more authors to be co-leaders (I.B., J.J., I.H.) and a list of co-authors among the ESGE Research Committee members to participate in this review. Two task forces were created to evaluate and report on the different classes of simulators: one for mechanical simulators (task force leaders, C.C. and I.B.) and one for in/ex vivo animal model simulators, VR, and prototypes (leaders J.J., and I.H.).

The authors performed a systematic literature search on PubMed/MEDLINE, Scopus, and the Cochrane Library to prepare an evidence-based, narrative review, identifying pertinent clinical studies on the topic, published up to September 2024 as full-text or abstracts, and restricted to English language. The following keywords were used for the search: "endoscopy simulator," "endoscopic simulator," "endoscopy and simulator," "colonoscopy and simulator," "gastroscopy and simulator," "ERCP and simulator," "endoscopic ultrasound and simulator," and "EUS and simulator," amongst others.

The literature search was focused on randomized controlled trials (RCTs) and meta-analyses of RCTs, but also encompassed observational studies, and case series. Pilot studies were included if they addressed topics not covered in the RCTs. A database was created, retrieving technical data from scientific publications and formal communications with pertinent vendors. A significant effort was made to contact all the companies producing the simulators in order to have additional and accurate information or to confirm the available simulators and provide consent for reproduction of the simulator images.

All task force members were required to disclose potential financial and intellectual conflicts of interest, which were addressed according to ESGE policies. Various online meetings were held between the Research Committee Chair and the task force leaders to discuss and resolve issues and finalize the draft by December 2024. The final draft was reviewed by the ESGE Governing Board and two external reviewers, and after agreement on a final version, the manuscript was submitted to the journal *Endoscopy* for publication in a two-part format: Part I on mechanical simulators and Part II on in vivo/ex vivo models, VR, and prototypes. All authors agreed on the final revised manuscript version.

Mechanical simulators: Overview

Mechanical simulators in GI endoscopy integrate synthetic soft (for the interior) and hard (for the exterior) materials to replicate an organ's anatomy. These mechanical models are the most commonly used for simulation-based training in GI endoscopy. Usually, insertion of a standard endoscope inside the simulator is enabled, which replicates the standard endoscopic maneuvers. Many favorable properties characterize this class of simulator: high fidelity in terms of haptic feedback, lower cost than other models, and effectiveness for the initial phase of apprentice training. On the other hand, as compared to animal models, mechanical models are generally less realistic, and every additional endoscopic scenario requires creation of a different physical reproduction [5]; however it should be highlighted that some recent and advanced mechanical simulators offer highly realistic designs.

In the following text, all the available simulators are briefly described along with the available evidence that supports their use. This is divided into three sections according to the intended procedures: (a) endoluminal diagnostics (▶ **Table 1**); (b) endoluminal interventions (▶ **Table 2**); (c) biliary diagnostics and interventions (▶ **Table 3**). For each simulator that is reviewed herein, and where available, a figure and two tables (one for technical characteristics and one for related literature) are included as Supplementary Material (available online-only).

Endoluminal diagnostics: Upper GI tract

Thompson Endoscopic Skill Trainer

The Thompson Endoscopic Skill Trainer (TEST) (EndoSim LLC, Hudson, Massachusetts, USA) is designed for practicing the five main skills required for the precise use of an endoscope: retroflexion, torque, knob control, loop reduction, and navigation, aiming to familiarize beginners with these maneuvers in both the upper and lower GI tracts. A module with a light bulb attached to a small ring or silicone cap is mounted inside the box. The model is easy to set up in any standard endoscopy suite, with reusable components and minimal supervision.

Ou et al. reported that endoscopist performance using the TEST correlated well with endoscopic metrics of performance (e. g., adenoma detection rate and cecal intubation time), indicating its effectiveness in demonstrating competency [6]. The content validity index (CVI) of all five modules was 0.88 for realism, 1.00 for relevance, and 0.88 for representativeness, yielding a composite CVI of 0.92. Moreover, when trainee performance was evaluated with two test administrators, the mean score for all participants with proctor 1 was 297.6 and 308.1 with proctor 2 ($P = 0.94$), suggesting reproducibility and minimal error associated with test administration [7] (**Fig. 1s; Tables 1 s** and **2 s**; available online-only in Supplementary Material).

Left-Hand Trainer

The Left-Hand Trainer (Glück Medical, South Korea) is designed to train therapeutic endoscopists to use their left hand for scope manipulation and control, so that the right hand can independently and simultaneously operate any accessory in use. This not only minimizes the need for an additional endoscopy assistant but also enhances procedural efficiency by eliminating the need to detach the right hand to assist the left. The model is designed to force trainees to only use their left hand to rotate the scope and/or control the wheels on the knob, while simultaneously using their right hand to control a biopsy forceps to perform a set of tasks (e. g., moving plastic buttons inside the model) (**Table 3 s**).

Esophagogastroduodenoscopy simulator

The EGD (EsophagoGastroDuodenoscopy) Simulator (Koken Co., Ltd., Tokyo, Japan) is a silicone frame resembling the upper GI tract (from the mouth to the duodenum), mounted on a plastic panel to perform either transoral or transnasal EGD. To train for detecting gastric lesions, a lesion resembling a gastric ulcer or early gastric cancer is placed on the lesser curvature of the stomach. There is also an area where different simulated polyps can be inserted. As a separately sold option, a polyp can be attached for practicing resection and hemostasis using clipping [8]. In addition, there is a second ulcer located in the duodenum. Moreover, the EGD simulator model also allows for endoscopic retrograde cholangiopancreatograhy (ERCP) through the opening of the ampulla of Vater in the second part of the duodenum.

One study evaluated the training effect of this simulator both in novice and non-novice endoscopists, and reported that 90.6 %

▶ **Table 1** Mechanical endoluminal diagnostics simulators.

Simulator	Manufacturer	Target	Interventional Modules	Material	Weblink
Thompson Endoscopic Skill Trainer	EndoSim, USA	EGD	No	Silicone	https://endosim.com/product-page/thompson-endoscopic-skills-trainer-test
Left-Hand Trainer	Glück, Korea	EGD	No	Plastic	https://gluckmedical.com
EsophagoGastro-Duodenoscopy (EGD) Simulator	Koken, Japan	EGD ERCP	No	Silicone	https://www.kokenmpc.co.jp/english/products/educational_medical_models/anatomical/lm-103.html
EGD Method Trainer (EGDS MT)	Anymedi, Korea	EGD	Yes; hemostasis and polypectomy	Silicone	https://www.anymedi.com/products/simulator
Upper GI Trainer	Chamberlain Group, USA	EGD	No	Silicone	https://www.thecgroup.com/product/upper-gi-trainer-2002/
Mikoto Gastrointestinal Endoscopy Model	R Zero (Fujifilm), Japan	EGD	No	Silicone	https://rzero.jp/mikoto/english.html
Medical Rising Star Ulcer-Type	Denka, Japan	Hemostasis	Yes; hemostasis	Plastic stomach with ulcer and vessels, connected to syringes	https://www.denka.co.jp/eng/pdf/corporate/thedenkaway/
Upper GI bleed Phantom	Nordic Phantoms, Denmark	Hemostasis	Yes; hemostasis	Plastic	https://nordic-phantoms.com/products/uppergi-bleed-phantom/
Colonoscope Training Simulator	Kyoto Kagaku Co., Japan	Colonosopy	No	Soft and hard resin	https://www.kyotokagaku.com/en/products_data/m40/
Colonoscopy Trainer	Chamberlain Group, USA	Colonosopy	No	Plastic, silicone	https://www.thecgroup.com/product/colonoscopy-trainer-2003/
Mikoto Colonoscopy Training Simulator	R Zero (Fujifilm-Olympus), Japan	Colonosopy	No	Silicone resin	https://rzero.jp/mikoto/english.html
Endoscopy Model System Trainer	Chamberlain Group, USA	EGD Colonosopy	Yes	Silicone	https://www.thecgroup.com/product/ems-trainer-2068/
NKS 3D colonoscopy simulator	Kyoto Kagaku, Japan	Colonosopy	No	Mechanical	https://www.kyotokagaku.com/en/products_data/mw24/
Colonoscopy Lower GI Endoscopy Simulator Type II	Koken, Japan	Colonosopy	Yes	Silicone	https://www.kokenmpc.co.jp/english/products/educational_medical_models/anatomical/lm-107.html
Colonoscopy-Trainer LS90	Samed, Germany	Colonosopy	Yes; polypectomy	Plastic, silicone, tissue imitation	https://samed.dresden.de/en/ls90_en.php

EGD, esophagogastroduodenoscopy; NA, not available.

of all participants, and specifically 92.9 % of novice endoscopists, rated the simulator as helpful [9] (**Tables 4 s** and **5 s**).

EsoGastroDuodenoscopy Method Trainer

The EsoGastroDuodenoscopy Method Trainer (EGD-MT; Anymedi Inc., Seoul, South Korea) is produced using tridimensional (3 D) printing based on images obtained during computed tomography (CT) scans, and silicone molding technologies; the printed elements are glued together to replicate a realistic upper GI tract. The EGD-MT consists of two training modules: one for basic endoscopy skills and a second called the Scope Handling Trainer (SHT) module, with magnetically attached polyps allowing for forceps and snare resection techniques. More recently, a modified version of this model was developed to simulate basic hemostasis techniques (e. g., injection, through-the-scope clipping), including the use of a waterjet pump.

▶ **Table 2** Mechanical endoluminal intervention simulators.

Simulator	Manufacturer	Target	Interventional modules	Material	Weblink
Endoscopic Variceal Ligation Simulator	Glück, Korea	EVL	Yes	Plastic frame, silicone varix module	https://gluckmedical.com/25
EndoGel Training Model for ESD/POEM	Sunarrow, Japan	ESD POEM	Yes	Polyvinyl alcohol hydrogel	https://www.sunarrow.co.jp/en/endogel/
ESD Training Model	Koken, Japan	ESD	Yes	Silicone, polyurethane resin	https://www.kokenmpc.co.jp/english/products/educational_medical_models/
G-Master	Kotobuki Medical, Japan	ESD	Yes	Metal	https://www.kotobuki-medical.com/
Percutaneous Endoscopic Gastrostomy Simulator	Glück, Korea	PEG	Yes	Silicone, plastic module	https://gluckmedical.com/26
Freka Phant	Fresenius Kabi, Bad Homburg, Germany	PEG	Yes	Silicone, plastic	https://www.fresenius-kabi.com/de/pressemitteilungen
SimStar Family Simulators	Dr. Henke, Germany	EGD Colonoscopy EUS ERCP ESD	Yes	Silicone, 3D-printed parts	https://www.drhenke.com

EGD, esophagogastroduodenoscopy; ESD, endoscopic submucosal dissection; EUS, endoscopic ultrasonography; EVL, endoscopic variceal ligation; PEG, percutaneous endoscopic gastrostomy; POEM, peroral endoscopic myotomy; NA, not available.

▶ **Table 3** Biliary diagnostics and intervention mechanical simulators.

Simulator	Manufacturer	Target	Interventional modules	Material	Weblink
Biliary Endoscopy Trainer	Chamberlain Group, USA	ERCP	Yes	Silicone	https://www.thecgroup.com/product/biliary-endoscopy-trainer-2061/
ERCP Trainer	Chamberlain Group, USA	ERCP	Yes	Silicone	https://www.thecgroup.com/product/ercp-trainer-2101/
Boskoski-Costamagna ERCP Trainer	Cook Medical, Limerick, Ireland	ERCP	Yes	Stainless steel, silicone, biological materials	https://www.cookmedical.com/endoscopy/focus-on-education-and-training/
CompactERCP Trainer	EndoSim, USA	ERCP	Yes	Artificial material	https://endosim.com/compact-ercp

ERCP, endoscopic retrograde cholangiopancreatography; NA, not available.

Although no formal validation studies are available, the EGD-MT was assessed in two studies, one for each model [10, 11]). In both, novice and expert operators were timed while performing standardized tasks and both models were graded using a 7-point Likert scale. The studies reported that the model was realistic and that procedural duration significantly decreased with repetition of the required endoscopic task, particularly in the novice operator group (**Tables 6 s** and **7 s**).

Upper GI Trainer

The Upper GI Trainer (Chamberlain Group LLC, Great Barrington, Massachusetts, USA) is designed only for diagnostic esophagogastroduodenoscopy (EGD), including a head and esophagus block, head cover, thorax cover, base, and stomach with an attached duodenum, allowing endoscope passage. The esophagus is stable and scopeable, the pliable stomach has rugae and a pylorus. Replaceable stomachs are available for repeated use. Currently, no validation studies are available for this model (**Table 8 s**).

Mikoto Gastrointestinal Endoscopy Model

The Mikoto Gastrointestinal Endoscopy Model (R Zero Inc, Japan, provided by Fujifilm, Tokyo, Japan) is designed for beginners to acquire basic gastroscopy skills, offering an innovative sensory experience enhanced by a specially developed navigation function. Four simulation modules are available, tailored to specific skill levels, and a voice guidance and LED lighting provide intuitive support. Additionally, the simulator offers immediate feedback and scoring to enhance skill acquisition. This simulator is currently not available on the market, but it is expected soon. To date, no validation studies have been conducted for this model (**Table 9 s**).

Medical Rising Star Ulcer-Type

Medical Rising Star Ulcer-Type (Denka, Tokyo, Japan) allows training in hemostasis using hemostatic clips and graspers. It features a plastic model of the upper GI tract with adjustable ulcer-like patches that simulate bleeding and allow for the use of electrocautery. The system is quick to set up, reusable, transportable, and offers variable complexity levels. However, it does not accurately simulate fibrotic ulcers and has limitations in fluid accumulation [12, 13]. A recent prospective study, including 50 gastroenterologists from Canada and Japan recruited to participate in a simulation-based training program, showed that the primary outcome, namely the hemostasis success rate of the trainees, significantly increased after instruction (64 % vs. 86 %, $P < 0.05$). This simulator was demonstrated to be a potentially valuable tool for improving technical skills and confidence [13] (**Table 10 s, 11 s**). Currently, no validation studies are available for this model.

UpperGI Bleed Phantom

The UpperGI Bleed Phantom (Nordic Phantoms, Odense, Denmark) model is designed to simulate treatment of upper GI bleeding (e. g., clipping, injection therapy, band ligation, and esophageal stent or balloon tamponade placement). Made from silicone, it closely mimics the texture and responsiveness of human tissue. It includes internal channels and an electrically driven fluid system that mimics active bleeding, with a custom blood solution replicating real blood's viscosity, color, and flow characteristics under pressure. The model features exchangeable inserts, allowing users to practice managing various bleeding sources such as ulcers, varices, or neoplasms. Due to its durable materials, the system is designed for easy cleaning and reuse, ensuring long-term functionality and maintaining hygiene standards (**Fig. 2s; Table 12 s**). No validation studies are currently available for this model.

Endoluminal diagnostics: Lower GI tract

Colonoscope Training Simulator

The Colonoscope Training Simulator (CTS; Kyoto Kagaku Co., Japan) features a 3D resin model of the colon based on CT images. The model simulates colonoscope insertion and manipulation using six different configurations mimicking different difficulty levels. The incorporation of an adjustable anal sphincter pump provides an airtight model configuration that allows for insufflation and suction techniques. The sigmoid colon can be preset to have any of three common anatomic morphologies (alpha, long alpha, or N loop), and three patient positions can be employed (supine, left lateral, and right lateral). The CTS also allows for the provision of manual abdominal compression training, using a membrane on top of the colon model to simulate the anterior abdominal wall. Furthermore, the model can be combined with other teaching tools such as the Scope Guide (Olympus), thus enhancing the training experience.

The construct validity of this model was evaluated [14], demonstrating that the CTS can discriminate among operators' expertise based on performance outcome measurements. Furthermore, a comparison study showed that the CTS was considered to be more realistic compared with the GI Mentor II (VR) model [15]. Despite these encouraging results [16], studies of trainee performance in real-life cases showed mixed results for the utility of the CTS [17, 18].

The more commonly sold version of this colonoscopy simulator is the CTS M40, made of mixed soft/hard resin, and used in different studies to evaluate parameters such as targeted biopsy [19], monitoring of endoscopic competence [20], and learning curve [21] (**Figs. 3As**, **3Bs**; **Tables 13 s**, **14 s**).

Colonoscopy Trainer

The Colonoscopy Trainer (Chamberlain Group LLC, Great Barrington, Massachusetts, USA) is designed for training novice endoscopists on basic colonoscopy insertion and intubation techniques. The interior of the model is designed to replicate the colorectal structure and allows the insertion of a single stricture and a fixed number of polyps. The plastic exterior model encapsulates the colon in a rigid foam material, thus supporting the colon anatomy [5]. It is reasonably priced and requires no significant preparation or setup. However, this model does not provide any interventional training modules or effects of suction/insufflation (**Table 15 s**).

Mikoto Colonoscopy Training Simulator

The Mikoto Colonoscopy Training Simulator (R Zero Inc, Japan, distributed by Fujifilm, Tokyo, Japan, and Olympus Corporation, Tokyo, Japan), is known for its anatomical realism and real-time haptic feedback, aiding in diagnostic procedures including polyp detection. The crafted organ is replaceable in the case of perforation, though at a high cost. External cameras monitor the endoscopist's position and movements, and recorded videos can be utilized for objective feedback. This model features motors for positional changes and high fidelity pressure and optical sensors, to simulate patient pain. Suitable for all skill levels (with options for different levels of difficulty), the model offers objective performance metrics with automatic scoring for self-learning. Its high cost is influenced by factors such as customization options, service packages, and regional pricing differences [22, 23] (**Fig. 4s; Table 16 s**).

Endoscopy Model System Trainer

The Endoscopy Model System (EMS) Trainer (Chamberlain Group LLC, Great Barrington, Massachusetts, USA) provides simulated access to the entire GI tract within a compact platform appropriate for multiple GI endoscopy procedures. Silicone models of the esophagus, stomach and colon are combined into one framework and, after each tissue element has been inserted into the model, many endoscopic techniques can be performed (e. g. biopsy, colonic polyp snaring, clipping for bleeding gastric ulcer or colonic post-polypectomy hemostasis or perforation, and stenting for esophageal, pyloric, and duodenal strictures).

This model is considered to be useful for teaching endoscopy trainees/novices specific endoscopic techniques (**Table 17 s**).

Noda–Kitada–Suzuki 3 D colonoscopy simulator

The Noda–Kitada–Suzuki (NKS) 3 D colonoscopy simulator (Kyoto Kagaku Co., Ltd, Japan), includes a skeleton body, abdominal membrane, colon–rectum tube, and other accessories. The device, based on CT colonography data, features a transparent tube with a silicone large intestine for visual inspection. It aids in cecal intubation and loop reduction, with adjustable colon anatomic morphologies (**Table 18 s**).

Colonoscopy Lower GI Endoscopy Simulator Type II

The Colonoscopy Lower GI Endoscopy Simulator Type II (Koken Co., Ltd, Japan) is made with a special silicone rubber that simulates a realistic feel. The model includes four colon tubes joined by three connectors and a virtual peritoneal membrane. It offers the following options: simulated polyps and laterally spreading tumors for observation or polypectomy, clipping technique for hemostasis practice, and an optional "small intestine" for enteroscopy training with adjustable difficulty. The small intestine is 120 cm long with internal scale markings (**Table 19 s**).

Colonoscopy-Trainer LS90

The Colonoscopy-Trainer LS90 (SAMED GmbH, Dresden, Germany) is a mechanical model consisting of a plastic phantom (body with bracket), a silicone colon, and an imitation of the buttocks. The model can be used to perform colonoscopy in the lateral or supine patient position, for both diagnostic and therapeutic exercises. There is the possibility to choose among three colon "tins," each replicating a colonic region with different scenarios: (i) a diagnostic model for detection of polyps and Crohn's disease (silicone); (ii) a diagnostic model for biopsy of carcinoma and polyps (silicone); and (iii) a therapeutic model for endoscopic resection of pediculated and flat polyps (tissue imitation, storable for 6 months) (**Fig. 5 s, Table 20 s**).

Endoluminal intervention simulators

Endoscopic Variceal Ligation Simulator

The Endoscopic Variceal Ligation (EVL) simulator (Glück Medical Co., South Korea) is made of a plastic esophagus-shaped frame and a silicone varix core containing three columns of varices. This allows for multiple attempts at band ligation or the simultaneous training of multiple endoscopists on the same module. The silicone core is intended to provide a degree of anatomic realism and feedback as it is designed to be ligated if the procedure is done correctly, and it also adapts to the degree of suction (i. e., failure of ligation if inadequate suction). The device does not contain the band ligation kit, which needs to be provided separately (**Table 21 s**).

EndoGel Training Model for endoscopic submucosal dissection (ESD) and peroral endoscopic myotomy (POEM)

The Endogel Training Model (ETM; Sunarrow Co., Ltd, Japan, provided by Fujifilm, Tokyo, Japan) consists of a stainless steel container filled with stacked, multilayer polyvinyl alcohol hydrogel plates that replicate the physical properties of each layer of the GI tract, allowing trainees to perform ESD or POEM procedures [8, 24]. The main advantages of the ETM include its reproducibility, realistic feedback and eco-friendliness (human-use endoscopes are used in nondedicated rooms without the risk of contamination with animal tissue).

A study of 28 trainees in endoscopy [25] reported a satisfaction and feasibility rate of 100 % and 96.4 %, respectively. Other studies have reported good reproducibility and a close simulation to real-life endoscopy experience [26, 27], as well as showing improvement in complete resection rates after three ESD training sessions and a decreased perforation rate after four training sessions [28]. A review article [29] described the ETM as most effective when combined with personalized one-on-one instruction, recommending approximately three training sessions to gain proficiency, after which it was advisable to proceed to live porcine ESD training (**Fig. 6s; Tables 22 s** and **23 s**).

ESD training model

The ESD Training Model (Koken Co., Ltd, Japan) combines a mechanical simulator with an attached dissected pig stomach. An aluminum outer case contains a stomach-shaped model made from silicone rubber and polyurethane resin, aiding in realism, and the esophagogastric junction is made of a soft resin material. The animal-based tissue can be fitted to different parts of the stomach using a stainless steel plate to which electrodes can be attached, allowing for the use of diathermy during ESD training.

This model gives the opportunity to simulate ESD in different anatomical parts of the stomach which pose distinctive technical challenges. However, ex vivo animal tissue preparation is required for this model, which is a limitation (**Table 24 s**).

G-Master

The G-Master (Kotobuki Medical Inc, Saitama, Japan) is designed for gastric ESD training and consists primarily of a konjac flour sheet that simulates the mucous membrane (composed of three layers: mucosal, submucosal, and muscular), supported by a complex metal chassis (width 635 mm × diameter 300 mm × height 310 mm). The model includes a plastic tube resembling the esophagus, ending in a cardiac-like section that is adjustable in three spatial directions, and transitioning into a plastic spatula to mimic the stomach's greater curvature. The flour sheet is fixed with adjustable tension to simulate different stomach distensions. The model has 9 adjustable components, allowing the mucous membrane to be positioned in 11 locations across anterior and posterior walls and lesser and greater curvatures.

A validation study involving 8 expert endoscopists performing ESD on 33 lesions in 3–5 locations [30] rated the simulator highly for realism, with no perforations recorded. A recent multicenter study compared ESD performed by 15 novice trainees, divided into G-Master-trained and nontrained groups [31]; the trained group showed faster ESD procedural speed and a trend towards fewer perforations and less intervention by experts. Kotobuki Medical recently launched a G-Master colorectal ESD version, with a colon-like tube and a dedicated traction sponge for practicing specific ESD techniques (**Table 25 s**).

Percutaneous Endoscopic Gastrostomy (PEG) Simulator

The PEG simulator (Glück Co., Korea) is made using 3 D printing, aiming to simulate PEG through the abdominal and gastric walls by placement of a silicone element, designed to mimic these structures, into the opening of a plastic stomach model. The model allows PEG training with both push and pull techniques and is reusable. Na et al. [32] reported that use of the PEG simulator reduced procedural time and mean procedure difficulty scores for beginners, while increasing the mean self-evaluation scores. The nonexpert group reported an improvement in skill score of 6.3. These results were subsequently confirmed by others [33], demonstrating a significant improvement in PEG technical skills and self-confidence for beginners (**Table 26 s**).

Freka Phant

The Freka Phant (Fresenius Kabi, Bad Homburg, Germany) is a mechanical simulator that allows the endoscopist to practice PEG by inserting an endoscope into a plastic box and puncturing skin patches. The model comprises latex and natural rubber-free materials and can be installed with two different skin diameter patches. Multiple tasks are available, such as pull or push technique, gastropexy, changing of exchange systems (balloon probes), measurement of stoma length (stoma length gauge), and wound care. This simulator can be useful for training novice endoscopists in the basic skills of PEG placement; however, other integrated technical skills of EGD cannot be simulated (**Table 27 s**).

SimStar Family Simulators

This group (Dr. Henke, Germany, Electronic Associates, Inc) of endoscopy simulators includes many simulators designed for upper and lower GI procedures, featuring realistic anatomy with different elements made of H-Flex material inserted for repeated use. The SimStar Gastro Upper GI simulator is designed for EGD, offering various diagnostic and interventional scenarios, and includes a blood perfusion system oriented to hemostasis techniques. The model supports several technical maneuvers including polypectomy, mucosal biopsy, variceal band ligation, stent placement (esophagus, stomach, duodenum), as well as the use of injection, clip, and loop systems for hemostasis. Medtronic Inc supports simulated bleeding in this model with a water-filled syringe; the "bleeding" has to be stopped using its topical hemostatic agent, Nexpowder.

This group of simulators also offers several options for training in colonoscopy (diagnostic and interventional), ERCP (basic and advanced maneuvers), and endoscopic ultrasound (EUS) with the facility to practice puncture technique. The simulator is reported to provide real-time feedback, good handling, and affordability (**Fig. 7s; Table 28 s**).

Biliary diagnostics and intervention simulators

Biliary Endoscopy Trainer and the ERCP Trainer

The Biliary Endoscopy Trainer (Chamberlain Group LLC, Great Barrington, Massachusetts, USA) reproduces the biliary and pancreatic system with insertion of replaceable strictures, to provide hands-on training for and tissue biopsy of the common bile duct (CBD). This simulator is made of silicone and does not reproduce the full anatomy of the upper GI tract; in fact to reach the biliary tree the scope is passed through a system of multiple straps to keep it stable. It allows only for the realistic deployment of devices inside the CBD.

The ERCP Trainer (Chamberlain Group LLC) represents a more advanced version in which the biliary tree is placed in a box, reachable through a long tube (simulating the passage of a scope through esophagus, stomach, and duodenum). The ERCP trainer can simulate both the lateral and prone positions. Also, two anatomical covers, one clear for direct visualization and one opaque for endoscopic viewing, are provided. Fluid injection is allowed through a dedicated port.

Katanuma et al. slightly modified this model to develop a dry model for endoscopic sphincterotomy and needle-knife precut sphincterotomy, creating a simulated papilla with a piece of rolled uncured ham. The investigators enrolled 21 endoscopists in a hands-on training study using this model; sphincterotomy was successful in 97 % and precut in 100 %, with questionnaire median scores for realism of 7 and 8, respectively, on a scale of 1 to 10 [34] (**Table 29 s**).

Boskoski-Costamagna ERCP trainer

The initial prototype of the Boskoski–Costamagna ERCP trainer (BCT; Cook Medical, Limerick, Ireland) was composed of a metal and plastic frame simulating the upper GI tract and a latex papilla connected to biliary and pancreatic ducts [35]. This initial model was validated for cannulation in various anatomical scenarios and also for biliary stenting and stone extraction [36, 37]. The model is not commercialized yet, but it can be accessed through Cook Medical representatives.

To increase its technical realism, a subsequent version was designed with a synthetic papilla model [38], and later with the option to use ex vivo chicken heart explants. This updated model was validated for teaching conventional sphincterotomy, precut, and ampullectomy [39]. Furthermore, this ERCP trainer was assessed in several studies. The first RCT, in a preclinical setting, demonstrated an improvement in cannulation times for endoscopy trainees using an innovative "motion-training" exercise on the BCT model. A subsequent international observational multicentric study demonstrated the improvement of early cannulation rates in trainees exposed to the BCT compared to those receiving standard ERCP training [40, 41]. Moreover, a large international RCT demonstrated that overall competence in ERCP (assessed by a validated tool) was significantly higher in the ERCP simulator-trained group compared to controls [42] (**Fig. 8s; Tables 30 s** and **31 s**).

CompactERCP Trainer

The CompactERCP Trainer (EndoSim LLC, Bolton, Massachusetts, USA) is designed for practicing ERCP techniques including cannulation of the bile and pancreatic ducts, sphincterotomy, stone extraction, biopsies, and stent placement and removal. The simulator features realistic duct anatomy and provides real-time feedback to improve precision and manipulation skills. Currently, no published validation data or additional detailed model information are available (**Table 32 s**).

Summary and Conclusions: Part 1

Mechanical simulators for GI endoscopic procedures (both diagnostic and therapeutic) provide a significant advantage in endoscopic training by offering a safe and controlled environment for practice. The simulator models offered on the market are extensive apart from for EUS, where availability is very limited with only one model offering this facility, and double-balloon enteroscopy for which there is no availability. Expensive models are often more realistic and complex in functionality, while other, more affordable, simulators may be simpler and less suitable for advanced endoscopy training. Despite the abundance of available mechanical simulators and their assumed favorable impact on endoscopic training, validation studies demonstrating effectiveness remain lacking for most of the models.

To the best of our knowledge, no comprehensive comparative studies have been conducted among the various endoscopic simulators; therefore, the choice of a specific simulator over another may be multifactorial, including personal preferences and available budget, and also ethical considerations, particularly in relation to in vivo models and the regulations set by relevant authorities.

PART 2: ANIMAL/VIRTUAL REALITY SIMULATORS AND PROTOTYPES

Background: Part 2

In this second and final part of the ESGE Technical and Technology Review dedicated to GI endoscopy simulators and training models, an updated overview of the available ex vivo, in vivo, and virtual reality (VR) simulators is provided. We also include a section dedicated to simulator prototypes currently under development but not yet commercially available. The aim of this review is to provide a practical, updated and easily consultable guide for trainers and trainees in GI endoscopy who wish to incorporate endoscopy simulators and training models into their daily practice.

Methodology and development process

The methodology and development process has already been reported in **Part 1** of this Technical Review. All authors agreed on the final revised versions.

Ex vivo simulators

Ex vivo models are a cornerstone of flexible GI endoscopy simulation. Their advantages include their widespread availability at reasonable prices via specialist companies or even directly through an organization with a regulated slaughterhouse. From a technical point of view, ex vivo models mimic the human anatomy, offer a layered structure identical to that of humans, provide good electrical conduction capacity and realistic haptic feedback. These models can be used as an attachment to plastic models offered by manufacturers or made by hand. Moreover, ex vivo models can be preserved frozen (requiring a dedicated storage freezer) for use on demand in simulation units after being thawed in water [43, 44].

The major limitation is the need for endoscopes dedicated to animal use only, to ensure compatibility and to minimize damage to the model and to prevent wear and tear of the clinical scopes. On the other hand, they are more suitable for repeated use without the stringent sterilization requirements of clinical instruments. Additional limitations to their use relate to anatomical differences compared to humans (see **In vivo simulators**) even if this is minimized by the use only of the desired lumen, an unpleasant odour after a few hours of training, and ethical concerns. The latter are slightly less significant than in the in vivo situation, as the GI samples are supposed to be obtained from abattoirs where the animals are killed for meat production.

There follows an outline of available ex vivo GI endoscopy simulators (▶ **Table 4**) along with brief technical descriptions.

Erlangen Active Simulator for Interventional Endoscopy (EASIE) series (Erlangen Endo-Trainer): Erlangen compactEASIE/EASIE-R (compact version) to EASIE-R4

The Erlangen team, pioneers in ex vivo simulator development since the 1990 s, introduced a range of models, notably the EASIE, commercially available as the Erlangen Endo-Trainer. Since 1997, EASIE [44, 45] and its updated versions (EASIE-R, EASIE-R1 to EASIE-R4; EndoSim LLC, Hudson, Massachusetts, USA) [5, 23] have utilized ex vivo porcine organs that provide realistic haptic feedback. These devices were subsequently developed with improved plastic frames to better mimic human anatomy, and were even endowed with ex vivo esophagus and stomach. EASIE was the first model to simulate arterial bleeding accurately, using a perfusion device equipped with an adaptable box and a stop-valve system. This regulates the blood circulation, thanks to an electric pump that simulates the heart rate of a patient, and the device is easily controlled by an assistant.

Over time, these models have expanded to allow a wide range of endoscopic procedures, from basic to advanced techniques, such as polypectomy, endoscopic mucosal resection (EMR), endoscopic submucosal dissection (ESD), double-

▶ **Table 4** Ex vivo simulator models.

Simulator	Manufacturer	Target	Material	Ease of use	Weblink
EASIE/EASIE-R Series	EndoSim Hudson, Massachusetts, USA ECE-Training, Erlangen, Germany	EGD Colonoscopy DBE EUS ERCP	Ex vivo pig tissues	Easy	https://endosim.com/product-page/easie-r4-simulator
Colo-EASIE/Colo-EASIE2	EndoSim	Colonoscopy	Ex vivo pig tissues	Easy	https://endosim.squarespace.com/
EUS RK Phantom	Dr. Koji Matsuda	EUS	Ex vivo pig tissues	Easy	NA
Neo-Papilla	EndoSim	ERCP	Ex vivo pig and chicken tissues	Intermediate	https://endosim.squarespace.com/
Endo X Trainer	Medical Innovations International, Rochester, Minnesota, USA	EGD Colonoscopy ERCP	Plastic/animal	Easy	https://www.medicalinnovations.com
DeLegge EndoExpert Tray	DeLegge Medical, Awendaw, South California	EGD Colonoscopy ERCP	Plastic/animal	Easy	https://www.organsbydesign.com

DBE, double-balloon enteroscopy; EGD, esophagogastroduodenoscopy; EMR, endoscopic mucosal resection; ERCP, endoscopic retrograde cholangiopancreatography; EUS, endoscopic ultrasonography; NA, not available.

balloon enteroscopy, and luminal stenting. The latest version, the EASIE-R4, focuses on upper GI tract training and features an improved torso-shaped tray for specimen support, allowing secure positioning. It includes new endoscopic retrograde cholangiopancreatography (ERCP) and endoscopic ultrasound (EUS) modules, such as an insert for biliary ducts that enables fluoroscopy simulation without the use of X-rays, and a model for EUS-guided direct biliary access using ultrasound to simulate access to an artificially dilated bile duct [23].

A new EASIE-R5 will soon be launched. This has a mannequin head, with the oropharyngeal section being ex vivo porcine tissue that allows the specimen to be submerged in water, and that can be heated to body temperature, improving the conductivity of electrocautery for ESD and peroral endoscopic myotomy (POEM).

The EASIE simulators have been extensively validated as effective tools for GI endoscopy training, significantly enhancing trainees' skills. Hochberger et al. conducted a RCT [46] comparing standard clinical training with intensive training using the compact EASIE model. Among 28 randomized GI trainees, compared to the control group, those trained with the simulator showed significant improvement in all evaluated endoscopic techniques. Similarly, Maiss et al. evaluated a 1-day training course using the compact EASIE, revealing significant skill enhancements among GI fellows [47]. Following a successful pilot project in the US, a similar program was implemented in France, confirming the better performance of simulator-trained fellows [48, 49]. Its usefulness has also been expanded to "train the trainer" sessions for endoscopists, resulting in newly trained tutors achieving outcomes comparable to those of expert-led training sessions [50].

Workshops using visceral organ packages also validated training for push-and-pull enteroscopy and small-bowel insertion measurement, showing accurate results [51].

In comparison with other ERCP teaching models, the Erlangen Endo-Trainer's pilot study demonstrated its feasibility for simulating ERCP [52], and found that porcine organ models offered greater realism and utility [53].

The latest EASIE-R simulator, developed for EUS, has shown effectiveness in improving GI fellows' abilities to recognize anatomical structures and perform fine-needle aspiration (FNA), validating the simulator's role in structured endoscopic training programs [54] (**Fig. 9 s, Fig. 10s; Tables 33 s**, **34 s**).

Colo-EASIE/Colo-EASIE2

Colo-EASIE and its updated version Colo-EASIE2 (Erlangen team; EndoSim LLC, Hudson, Massachusetts, USA) were developed for proctoscopy, sigmoidoscopy, and colonoscopy training. Utilizing a plastic platform and ex vivo bovine or porcine colon specimens, the model offers realistic training for procedures including polypectomy, EMR/ESD, and GI bleeding [23]. The platform can rotate to simulate patient positioning, though it has limitations in scope advancement methods. Despite positive feedback from early users, no formal validation or comparative studies have been conducted, limiting scientific support for its training effectiveness (**Fig. 11s; Table 35 s**).

EUS RK Phantom

The EUS RK Phantom (Dr. Koji Matsuda) is a modified EASIE model specifically for EUS training, using a pig stomach placed in a silicone case, surrounded by grapes (simulating lymph nodes or cystic lesions) and plastic tubes (mimicking the aorta and trachea) [55]. The setup is immersed in gelatin for acoustic coupling. Preparation is labor-intensive (about 6 hours), but the model can be stored for 2–3 days in a refrigerator. It offers a realistic environment for basic EUS training and was widely used in training sessions in the early 2000 s. Experts rated it favorably for visualization and manipulation, though it was considered intermediate in realism and ease of use [56] (**Table 36 s**).

Neo-Papilla

The Neo-Papilla (EndoSim LLC, Hudson, Massachusetts, USA), used in the EASIE simulator, offers a realistic alternative for ERCP training (sphincterotomy, post-sphincterotomy bleeding, and stent placement) by using modified porcine tissue and 15–20 chicken-heart simulated papillae per model, enabling performance of multiple procedures. Evaluated initially by 9 experts, the Neo-Papilla was rated highly for realism and usefulness, particularly for basic ERCP skills, with scores comparable or superior to VR and live animal models [57]. Despite its advantages, such as reduced costs and no need for fluoroscopy, this model requires time for preparation and tissue disposal (**Tables 37 s**, **38 s**).

Endo X Trainer

The Endo X Trainer (Medical Innovations International Inc., Rochester, Minnesota, US) is a plastic/ex vivo model for EGD, colonoscopy, and ERCP training [58], including therapeutic procedures (bleeding, polypectomy). Despite limited face validity, one study has reported its content, construct, and criterion validity [59, 60]. The model is lightweight and portable, characterized by a realistic mimicking of the endoscopic mucosal appearance, perception of scope movements, and evaluation of cecal intubation time (**Tables 39 s**, **40 s**).

DeLegge EndoExpert Tray

The DeLegge EndoExpert Tray (DeLegge Medical LLC, Awendaw, California, US) is a composite plastic/ex vivo simulator for training in EGD, colonoscopy, and ERCP (with interventional modules for bleeding and polypectomy), using ex vivo porcine organs in a portable tray. This model is available in the USA and Canada [58] (**Table 41 s**).

In vivo simulators

In vivo simulators for training in GI endoscopy involve the use of anesthetized live animals, primarily pigs due to their similarity to human GI tract anatomy, especially pigs weighing over 30 kg [61]. These models provide the most realistic simulation experience, replicating haptic feedback, secretions, respiratory movements, and peristalsis, which are nearly identical to those encountered in humans. This realism makes these in vivo animal models valuable for training in advanced endoscopic procedures and safely managing intraprocedural adverse events.

However, there are some anatomical differences between pigs and humans, such as the presence of a diverticulum in the gastric cardia, a large amount of submucosal fat in the colonic wall, and the lack of abdominal wall fixation of the proximal colon. This is particularly relevant for ERCP and EUS because the porcine pancreaticobiliary anatomy differs significantly (pancreatic duct and bile duct are separated), making bile duct cannulation more challenging [62, 63]. Despite these limitations, in vivo porcine models have proven effective for training in ESD, with studies showing improvement in resection skills and a decrease in adverse events through repeated practice [64, 65, 66].

The use of in vivo models is, however, limited by significant logistical, financial, and ethical challenges. Setting up these models requires substantial investment in infrastructure, animal lab facilities, and specialized equipment, including dedicated "animal-only" use endoscopes. The animals used require extensive preparation, such as dietary restrictions, fasting, and bowel cleansing before procedures. General anesthesia, endotracheal intubation, and mechanical ventilation are necessary during training, requiring the presence of a veterinarian. Furthermore, animals are usually euthanized post-training, raising ethical concerns.

Ethical committees must approve the use of live animals, with an emphasis on balancing animal welfare against the benefits of training. The increasing availability of ex vivo alternatives further intensifies these ethical concerns. Additionally, certain interventions such as sphincterotomy, cannot be repeated on the same animal, thereby limiting the practical utility of live models compared to reusable options. Finally, the cost of facilities authorized for animal experimentation is significant.

Given these constraints, the use of in vivo animal models remains restricted and is generally recommended for advanced stages of training (e. g. ESD or therapeutic EUS). Economic, ethical, and logistical demands mean that in vivo models are unlikely to become a widespread option for basic GI endoscopic training.

Virtual reality (VR) simulators

VR simulators (▶ **Table 5**) are contemporary systems using computer modeling to simulate the endoscopy experience. A three-dimensional (3 D) model of the GI tract, generated through a combination of hardware components and software functionalities, is investigated using a standard endoscope as controller. Upon entrance of the endoscope into the machine, the user is transferred to a virtual environment that responds to the user's endoscopic movements in real time for practicing multiple endoscopic scenarios. This is while receiving haptic, audio, and visual feedback regarding his/her performance according to objective indices that measure endoscopic competency [5, 67, 68].

Furthermore, unlike ex vivo animal models, these VR simulators do not require maintenance in the form of replacement tissue and have the potential to include built-in training software programs that could prove a cost-effective way to provide early training without requiring the time of an endoscopy trainer.

CAE EndoVR

The CAE Healthcare VR simulator (CAE Healthcare, Montreal, Quebec, Canada; previously called the AccuTouch Endoscopy Simulator, and redesigned in 2012) is a sophisticated platform with a specialized endoscope inserted into the simulator, a display monitor, and an endoscopic interface device [69]. The

▶ **Table 5** Virtual reality (VR) simulator models.

Simulator	Manufacturer	Target	Material	Ease of use	Link
CAE Endo VR	CAE Healthcare, Montreal, Quebec, Canada	EGD Colonoscopy ERCP Biopsy Polypectomy Bleeding	Silicone/2 monitors/cart/ Integrated keyboard	Easy	https://www.caehealth-care.com/media/files/User_Guides/EndoVR-User-Guide.pdf
Endo Suite GI Mentor	Simbionix, later acquired by Surgical Science	EGD Colonoscopy, ERCP EUS Bleeding EMR ESD	Silicone/1 monitor/cart/Integrated keyboard	Easy	https://surgicalscience.com/simulators/gi-mentor/
ViGaTu simulator	University Hospital Wurzburg, Open Source Project	Multiple	VR	Unclear	https://github.com/virtual-gastro-tutor/vigatu
EndoSim	Surgical Science, Sweden	EGD Colonoscopy ERCP	VR	Easy	https://surgicalscience.com/simulators/endosim/
EndoVision Standard	MedVision	EGD Colonoscopy Bronchoscopy	VR	Easy	https://www.medvisiongroup.com/endovision.html
CLA 4/5 – 5/4	Coburger Lehrmittelanstalt, CLA, Coburg, Germany	EGD Colonoscopy Bronchoscopy	VR	Unclear	NA

EGD, esophagogastroduodenoscopy; ERCP, endoscopic retrograde cholangiopancreatography; EMR, endoscopic mucosal resection; ESD, endoscopic submucosal dissection; NA, not available; VR virtual reality.

system mechanics enable haptic feedback to reproduce the sensation of endoscope looping and resistance, along with a computer-generated voice simulating patient discomfort. An additional multimedia function is available, where didactic video clips of experienced endoscopists or an anatomy–pathology atlas can be accessed. CAE allows performance of EGD, colonoscopy, and ERCP as well as polypectomy, biopsy, and hemostasis. This VR model offers an accurate replication of real-life endoscopy experience as the patient's parameters are virtually displayed (i. e., vital signs, electrocardiogram, oxygen saturation) and are subject to change according to the performed endoscopic maneuvers. Trainees are required to manage sedation during endoscopy without compromising the patient's oxygen saturation.

Preliminary studies [70] evaluated the construct validity of the sigmoidoscopy and colonoscopy simulator [71, 72], followed by results from RCT [73] and prospective studies [74, 75] which were less promising. Subsequently, additional RCTs reported a significant increase in completion rate (52 % vs. 19 %, $P = 0.001$) and reduction of both procedure time and patient discomfort among trainees who had already achieved a high level of performance in the simulator compared to controls [76]. This achievement was enhanced by the presence of a supervisor [77]; this role in a training program has been extensively underlined [77, 78, 79]. Finally, in a study examining the ERCP module, the performance of apprentice fellows and faculty members was compared, with the total procedure time being significantly shorter in the expert group (444 vs. 617 seconds, $P = 0.03$) [80] (**Tables 42 s**, **43 s**).

ENDO Suite-GI Mentor

The ENDO Suite-GI Mentor (Simbionix Corp., later acquired by Surgical Science, Sweden), which represents the newest version of GI Mentor II, offers the widest variety of GI endoscopy tasks available, allowing basic EGD and colonoscopy as well as advanced procedures (EMR/ESD, hemostasis), with the availability of modules for EUS and ERCP. This simulator features over 120 different tasks, a pain indicator and endoscope locator are available during the simulation, and the system guides the user step by step in learning the deconstructed skills (i. e., endoscopic navigation, mucosal inspection, and loop reduction). To enhance realism, the endoscope is inserted through an orifice into the model that is in the left lateral position and, while advancing, the system displays on the screen credible visual and audible feedback based on endoscope manipulation. Training in ERCP uses a split screen (endoscopic and fluoroscopic views), different patient cases with diverse anatomy, and performance of therapeutic procedures (sphincterotomy, stone extraction, stent placement, etc.). A portable edition, known as the GI Mentor Express, is also available, consisting of a box where the endoscope is inserted while a laptop computer can be used as a screen.

Data from RCTs suggest that, compared with nonsimulator-trained fellows, training with VR before conventional endoscopy provides benefit in procedure completion time (239 vs. 310 seconds, $P<0.0001$) and technical accuracy (85 % vs. 72 %, $P<0.01$) [81, 82]. There is strong evidence on its usefulness from RCT and prospective cohort studies, regarding colonoscopy [83, 84] and ERCP [85]. In a recent study assessing the construct validity of virtual ERCP using the GI Mentor II, the time to visualize the papilla and achieve deep cannulation was significantly shorter for experts (both $P<0.05$), especially in the management of cystic leakage [86]. Data regarding GI Mentor's EUS module remain scant, with evidence suggesting that it surpasses other types of simulators in terms of usefulness and realism, but there remain limitations regarding the VR EUS-FNA training mode [55] (**Fig. 12s; Tables 44 s**, **45 s**).

ViGaTu simulator

The Immersive Virtual Reality Endoscopy Suite (ViGaTu, University Hospital Wurzburg, Open Source Project, Germany) was developed as a collaborative venture between physicians and nurses specializing in endoscopy, media educators, and computer scientists. The Meta Quest 2 system (Meta Platforms Inc., Menlo Park, California, United States) was used to present the simulation which consists of a head-mounted display and two handheld manual controllers (not a dedicated endoscope). The virtual environment was created using Unity 3D (Unity Technologies, San Francisco, California, United States) with the 3D elements designed in collaboration with ThreeDee (ThreeDee GmbH, Munich, Germany). The framework of ViGaTu is open source and can be downloaded.

The ViGaTu project aims to enable both physicians and nonphysician specialists to gain training in peri-interventional tasks needed to carry out guideline-compliant screening colonoscopy, including: equipment setup, preparatory measures, sedation, colonoscopy, adverse event management, and physician–nurse communication. Participants can pick up equipment and place it in the correct position and freely move around the virtual endoscopy room by walking or by "teleporting" to a different place in the room using the handheld controllers.

A prospective multicenter study tested ViGaTu [87], including 43 nurses and 28 physicians taking part in VR training, to assess face, content, and construct validity of this model. In total, 75 % of the items for assessing face validity were rated as realistic and 60 % of items assessing content validity and usefulness were rated as useful. Experienced endoscopy staff were significantly faster than beginners in setting up the endoscope tower suggesting construct validity (**Fig. 13s; Tables 46 s**, **47 s**).

EndoSim simulator

The EndoSim Simulator (Surgical Science, Sweden) is designed for training in EGD, colonoscopy, and ERCP. The complete package includes a haptic feedback hardware platform that simulates forces during insertion and rotation of the endoscope. The system comes with one endoscope of choice, a full-length insertion tube, a working channel, computer, and monitor with a height-adjustable frame. The EndoSim "Cube" variant can also function as a portable desktop unit. This simulator features an oral orifice for endoscope insertion into a mannequin torso, after which a virtual replica of the GI tract is generated in real time, responding dynamically to the user's manipulation of the endoscope. This model also provides visual, auditory, and haptic feedback to the user. The EndoSim offers several training modules tailored to both basic and advanced endoscopic techniques. Moreover, this model allows photodocumentation in accordance with the ESGE guidelines, and biopsy sampling (with an assistant handling the biopsy forceps). The ERCP module has a split-screen display, showing both endoscopic and fluoroscopic views, and allows trainees to practice bile duct cannulation using a guidewire and sphincterotome (**Table 48 s**).

EndoVision Standard

The EndoVision Standard (MedVision, Tokyo, Japan) is designed for EGD, bronchoscopy, and colonoscopy. It is equipped with two full high definition displays, including one with a touchscreen interface that allows users to access real patient cases, virtual tips, videos, guidelines, and visual cues. The simulator is mounted on a transportable cart and includes a foot pedal for simulating coagulation and electric dissection. Integrated sensor technology tracks the endoscopist's movements upon endoscope insertion, delivering real-time visual, auditory, and haptic feedback to simulate realistic tissue resistance.

Biopsy, injection, balloon dilation, stenting, foreign body removal, and coagulation can be practiced using real patient case simulations. The colonoscopy module includes mucosal assessment in different clinical scenarios (i. e., polyps, inflammatory bowel disease, diverticulosis, and ischemic colitis) (**Table 49 s**).

CLA 4/5, CLA5/4

The CLA 4/5 (Coburger Lehrmittelanstalt, CLA, Coburg, Germany) is a basic phantom model made from plastic and is the size of an adult. This simulator is made for EGD, colonoscopy, and bronchoscopy (**Table 50s**). It is equipped with a flexible mounted head, nasopharyngeal zone, upper body with removable chest cover, and a lower body with a removable elastic abdominal cover (**Fig. 14 s**). There is the possibility to add many optional supplements according to the intended procedure, and some additional pathological changes (e. g. polyps) can be added through openings in the organs. The CLA 5/4 (**Table 50s**) is designed for colonoscopy and consists of lower body with a removable elastic abdominal wall.

Prototypes

Many companies and research institutions are continuously working on cutting-edge prototype endoscopy simulators that incorporate technologies such as haptic feedback. The introduction of 3D printing has allowed companies to develop prototypes for testing, refinement, and training of new endoscopic tools more rapidly than in the past. Some of these prototypes are currently used only in limited training programs by manufacturers of new accessories, but others await commercial approval, for example CE marking, to be prepared for sale and to be used on a larger scale in clinical training institutions. What follows is a summary of the currently known prototypes for endoscopic training (not yet commercially available) (▶ **Table 6**).

▶ **Table 6** Prototype simulator models.

Simulator	Manufacturer	Class	Target	Interventional module	Material	Weblink
Hot Axios Synthetic Trainer	Version3 D, Netherlands with Boston Scientific	Mechanical	Hot Axios LAMS indications	Collection & Lumen	3D-printed plastic	https://version3 d.com/
Hot Axios Artificial Trainer	Version3 D with Boston Scientific	Mechanical	Hot Axios LAMS indications	Drainage of PFC/ gallbladder/bile duct	3D-printed modules with artificial skin plates	https://version3 d.com/
CholangioBox	Version3 D with Boston Scientific	Mechanical	Cholangioscopy	Silicone ducts module	Silicone ducts module	https://version3 d.com/
Pentax C2 Cryoballoon Simulator	Lazarus 3 D, Philomath, Oregon, USA	Mechanical	EGD: Barrett's esophagus	Cryoablation	Silicone, thermochromic pigments	https://www.lazarus3 d.com/skill-sure
EndoCubot	Endorobotics	Virtual and Mechanical	EGD Colonoscopy	Gastro module: antrum, cardia, middle body Colon module: rectum, transverse and descending colon Interventional EGD and colonoscopy (EMR, ESD, suturing)	Plastic and metal Phantom tissue from Kotobuki Medical	https://www.endorobo.com/product/endo-cubot.php
Tübingen (Biliphant) model	University of Tübingen	Mechanical	ERCP	Guidewire placement, precut sphincterotomy, stone removal, stent placement and removal	3 D printing and latex	NA
Frimberger Simulators	Prof. Frimberger	Mechanical	ERCP Colonoscopy	Cannulation, lithotripsy, stenting	NA	NA
Satoshi Model	Olympus Corporation, Tokyo, Japan	Mechanical	ERCP	Cannulation capture, sphincterotomy, guidewire insertion	NA	NA
Colonoscopy Training Simulator Endonix	Olympus Corporation	Virtual	Colonoscopy	Yes	3D-printed	https://www.olympusprofed.com/gi/colonoscopy/39076 /
EUS Magic Box	Dhir group	Mixed Mechanical/ Ex vivo	EUS intervention	FNA, biliary or pancreatic duct drainage, pseudocyst drainage and gastroenterostomy	Pig esophagus and stomach, a silicon-based duodenum	NA

EGD, esophagogastroduodenoscopy; EMR, endoscopic mucosal resection; ERCP, endoscopic retrograde cholangiopancreatography; ESD, endoscopic submucosa dissection; LAMS, lumen-apposing metal stent; NA, not available.

Hot Axios Synthetic Trainer

The Synthetic 3D-printed trainer (Boston Scientific) is specifically intended for instruction in all steps of Hot Axios placement. This trainer includes two modules: one with a large pseudocyst to be drained, the second with a small lumen, to simulate stent deployment in a limited space (e. g. biliary duct), in which a red light is triggered if the opposite wall of the lumen is touched. The Synthetic training model can be used without any investment in capital equipment (**Fig. 15s; Table 51 s**).

Hot Axios Artificial Trainer

This training model, from Boston Scientific, is to instruct physicians in placing the Hot Axios in any situation where capital equipment, namely full endoscopy tower and EUS processor, is available. The EUS-guided image provides a simulation of all the steps in placing a Hot Axios device. Moreover, as with the abovementioned Synthetic Trainer, this device also has two modules with different sizes of lumen for drainage. It is a relatively simple model and not fully anatomically correct (**Fig. 16s; Table 52 s**).

CholangioBox

The CholangioBox, from Boston Scientific, consists of a hard plastic case with simulated silicone biliary ducts on the inside. This model provides the endoscopist with the ability to use all the Spyglass instruments, simulating performance in a real duct, without the need for a duodenoscope. Stone management with electrohydraulic lithotripsy and basket can be fully simulated, as can stricture management and acquistion of biopsies at different sites in the silicone model (**Fig. 17s; Table 53 s**).

Pentax C2 Cryoballoon Simulator

This simulator (Lazarus 3D, Philomath, Oregon, USA) permits training of cryoablation on an artificial esophagus. The model consists of an external acrylic box with suction feet for ease of use. Internal components include a heating element with external controls, insulation, and an esophagus. The esophagus features realistic anatomy including the lower esophageal sphincter and a portion of the upper stomach, and a red surface simulating Barrett's esophagus. Upon application of nitrous oxide to the red areas via the cryoballoon system, the tissue changes color to dark purple/grey. This color change is reversible, allowing multiple uses of the model. A full endoscopy tower and gastroscope are required (**Table 54 s**).

EndoCubot

The Endocubot (Endorobotics Co. Ltd, Seoul, South Korea) is a VR simulator box (gastric and colon models available) into which a standard endoscope can be inserted. Its robotic technology-based automated position control enables simulation of various anatomical positions that can be adjusted using the 8-inch touchscreen interface. In addition, this model is capable of simulating insufflation and desufflation features of the endoscope, and repetitive movements, such as respiration and heartbeats, as well as random events such as gagging and sneezing by the patient. Phantom tissue can be inserted to train in EMR or ESD, and electrocautery can be applied without the need for a grounding pad. The product weighs approximately 18 kg, making it relatively cumbersome to transport (**Fig. 18s; Table 55 s**).

Tübingen (Biliphant) Model

The Tübingen (Biliphant) model, developed at the University of Tübingen, is a sophisticated training simulator designed for ERCP, particularly in cases involving altered GI anatomy such as Billroth II or Roux-en-Y reconstructions, whose prevalence (also due to bariatric surgery) continues to rise. This model focuses on replicating key procedural steps, such as intubation, papilla identification, guidewire placement, and advanced interventions such as precut sphincterotomy, stone removal, and stent placement and removal.

Studies have highlighted its effectiveness in training endoscopists to manage postoperative anatomies. Participants in evaluation workshops reported realistic haptic feedback and visual impressions when navigating the model's artificial structures, with high ratings for its suitability as a teaching tool (average scores ranging from 1.36 to 1.73 on a scale of 1 to 5 where 1, the highest score, is "very good") [88].

This model is notable for its animal-free design, which uses advanced 3D printing and latex materials to recreate realistic organ textures, despite remaining limitations such as friction between surfaces and the absence of simulated peristalsis.

Although not yet commercially available, this simulator provides a practical, anatomically representative environment, making it a valuable tool for mastering both fundamental and advanced ERCP maneuvers.

Frimberger Simulators

Professor Frimberger (Germany) designed a group of mechanical simulators for ERCP, endowed with papillas in a duodenum that can be seen on the endoscopy monitor and with a unique window, that allows visualization of what is happening beyond the papilla in the pancreaticobiliary tract. There is a specific model for all relevant procedures (i. e., selective cannulation of the bile ducts and plastic stenting, papillotomy in Billroth 2 anatomy, and mechanical lithotripsy). All simulators can be equipped with a feature called the "intraduodenal observer," to see the duodenoscope and its actions in the duodenal space on a second monitor. There is also a group of simulators for diagnostic colonoscopy, aimed at developing motor and 3D orientation skills and for practice in straightening sigma loops, but also for therapeutic maneuvers such as hemostasis, or for polypectomy with stalks made of electrically conductive material and polyp heads made of silicone (**Fig. 19s; Table 56 s**).

Satoshi Model

This ERCP simulator (Olympus Corporation, Tokyo, Japan) is used for basic and advanced training. The endoscopist and assistant can practice ERCP with both the prone and supine patient position, with the same cannulation capture, sphincterotomy, and guidewire insertion, all with Olympus ERCP products (**Fig. 20 s**).

Colonoscopy Training Simulator Endonix

Endonix (Olympus Corporation,Tokyo, Japan) represents a 3D printed mock-up simulator for training in colonoscopy for both beginners and advanced endoscopists, offering practice in basic scope manipulation, and diagnostic and therapeutic endoscopy. It is very easy and quick to set up, requiring only a standard laptop. It is planned that literature on this model will be available soon (**Fig. 21 s**).

EUS Magic Box

Dhir et al. have reported on models for EUS training, namely on the Mumbai EUS I (Prototype) in 2015, a stereolithography 3D-printed bile duct prototype for EUS-guided biliary drainage [89], and on an updated version, the Mumbai EUS II in 2017 [90]. In 2022, this group designed the EUS Magic Box, consisting of an all-in-one hybrid model consisting of a pig esophagus and stomach, a silicon-based duodenum and pancreatoicobiliary system, a pseudocyst, and biopsy targets. This model is designed to provide simulation of multiple interventional EUS procedures (e. g., FNA, biliary or pancreatic duct drainage, pseudocyst drainage, and gastroenterostomy) and was graded as good or excellent by 30/36 trainees (83 %) [91].

Summary and Conclusions: Part 2

Animal and VR simulators offer a wide spectrum of diagnostic and therapeutic procedures, both in endoluminal and biliary tract procedures, often within the same model. Ex vivo simulators can provide more realistic haptic and visual feedback compared with other classes of simulators. Moreover, their financial burden is moderate, especially compared to VR. However, the tissue properties of explanted organs may differ from live tissue, making some endoscopy training maneuvers more difficult, and they require more preparation and appropriate disposal. Conversely, VR simulators do not require special preparation, they offer multiple training scenarios with varying levels of complexity and, above all, they provide objective measures of performance with a final summary that can be helpful for an endoscopy training program. Nevertheless, the high costs of VR simulators are actually the main obstacle that prevents the widespread incorporation of these modalities into everyday clinical practice. Numerous endoscopy simulator prototypes are currently being developed and tested, and hopefully these will be commercially available in the near future.

To the best of our knowledge, no comprehensive comparative studies among the various endoscopic simulators have been conducted. Therefore, the choice of a specific simulator over another may be multifactorial, including personal preferences, available budget, and also ethical considerations, particularly in relation to in vivo models and the regulations set by relevant authorities.

Disclaimer

The legal disclaimer for ESGE guidelines [92] applies to this Technical Review.

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Competing interests

I. Boskoski holds a patent for his endoscopy trainer (USA No.: US D740,361 S (Endoscopy Training Apparatus) Oct. 6, 2015). V. Bove is a consultant for Boston Scientific (from 2025 to 2027). C. Coluccio has lectured for Steris (from 2022 to 2025) and is a consultant for Medi-Globe (from 2024 to 2027). P.J.F. de Jonge has received a research fee from Fujifilm (from 2021 to 2025) and consultancy/speaker fees from Boston Scientific and Cook Medical. I. Gralnek declares collaboration with Olympus, Pentax, Medtronic, Motus GI, ERGO GI, and ERBE. I. Hritz has received consultancy and training fees from Olympus (from 2017, ongoing) and consultancy and speaker's fees from MicroTech (from 2023, ongoing). J. Jacques provides consultancy for Boston Scientific and for Fujifilm (from 2022, ongoing). R. Kalapala is a member of the Advisory Boards of the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) and the Association of Bariatric Endoscopy (ABE). M. Abdelrahim, B. Barbieri, J.A. Cunha Neves, G. Dell'Anna, X. Dray, G. Esposito, A. Facciorusso, L. Fuccio, R. Gincul, P. Giuffrida, C. Kapizioni, G. Longcroft-Wheaton, S. Nagl, G. Tziatzios, and T. Voiosu have no competing interests.

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Supplementary Material: Simulators and training models for diagnostic and therapeutic gastrointestinal endoscopy: ESGE Technical and Technology Review

Figures

Part 1: Mechanical simulators

Fig. 1s: Thompson Endoscopic Skills Trainer (TEST). Image courtesy of EndoSim LLC, Bolton, Massachusetts, USA.

Fig. 2s: UpperGI Bleed Phantom. Image courtesy of Nordic Phantoms.

Fig. 3As: Colonoscope Training Simulator; CTS. Image courtesy of Kyoto Kagaku Co., Japan.

Fig. 3Bs: CTS M40. Image courtesy of Kyoto Kagaku Co., Japan

Fig. 4s: Mikoto Colonoscopy Training Simulator. Image courtesy of R ZERO Inc, Japan (distributed by Fujifilm, Tokyo, Japan and Olympus Corporation, Tokyo, Japan).

Fig. 5s: Colonoscopy-Trainer LS90. Image courtesy of SAMED GmbH Dresden.

Fig. 6s: Endogel Training Model (ETM). Image courtesy of Sunarrow Co., Ltd, Japan (provided by Fujifilm, Tokyo, Japan).

Fig. 7s: SimStar family Simulators. Image courtesy of Dr. Henke, Germany - Electronic Associates, Inc.

Fig. 8s: Boskoski-Costamagna ERCP Trainer (BCT). Image courtesy Cook Medical, Limerick, Ireland

Fig. 9s: EASIE-R4 Simulator. Image courtesy of EndoSim LLC, Bolton, Massachusetts, USA.

Part 2: Animal/Virtual Reality simulators and Prototypes

Fig. 10s: Erlangen Active Simulator for Interventional Endoscopy Series (EASIE-R4). Image courtesy of EndoSim LLC, Bolton, Massachusetts, USA.

Fig. 11s: Colo-EASIE2. Image courtesy of EndoSim LLC, Bolton, Massachusetts, USA.

Fig. 12s: ENDO Suite-GI Mentor. Image courtesy of Surgical Science, Sweden.

Fig. 13s: Immersive Virtual Reality Endoscopy Suite (ViGaTu). Image courtesy of University Hospital Wurzburg, Open Source Project, Germany.

Fig. 14s: CLA 4/5. Image courtesy of Coburger Lehrmittelanstalt, CLA, Coburg, Germany.

Fig. 15s: Hot Axios Synthetic Trainer. Image courtesy of Boston Scientific.

Fig. 16s: Hot Axios Artificial Trainer. Image courtesy of Boston Scientific.

Fig. 17s: CholangioBox. Image courtesy of Boston Scientific.

Fig. 18s: EndoCubot. Image courtesy of Endorobotics Co. Ltd.

Fig. 19s: Frimberger Simulators, Image courtesy of Dr. Frimberger, Germany.

Fig. 20s: Satoshi Model. Image courtesy of Olympus Corporation, Tokyo, Japan.

Fig. 21s: Colonoscopy Training Simulator Endonix. Image courtesy of Olympus Corporation, Tokyo, Japan.

Fig. 1s: Thompson Endoscopic Skills Trainer (TEST). Image courtesy of EndoSim LLC, Bolton, Massachusetts, USA.

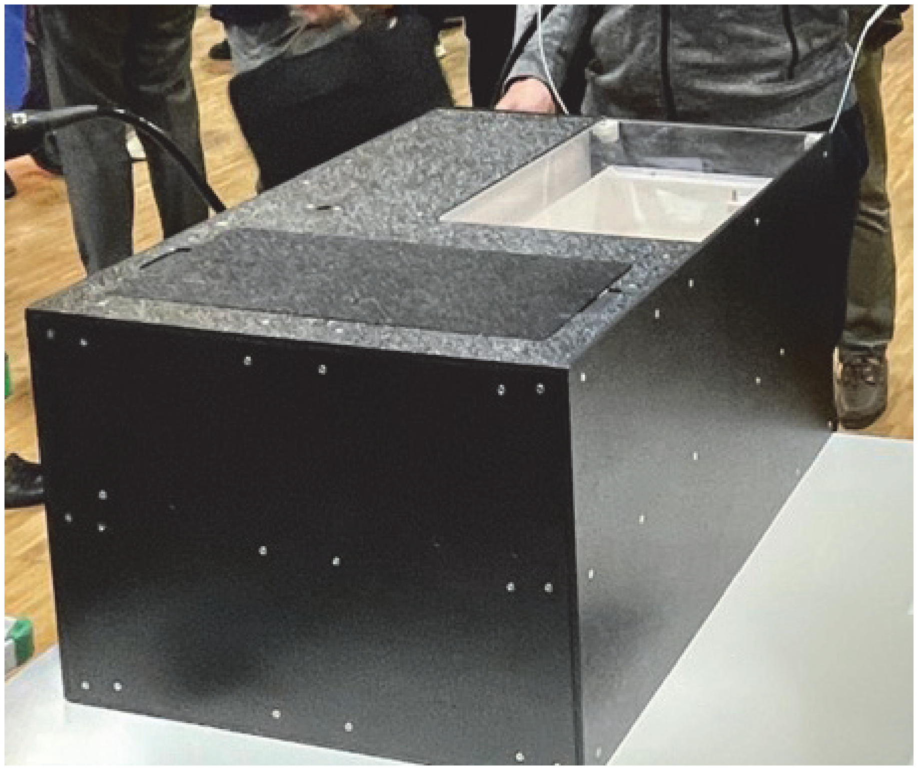


Fig. 2s: UpperGI Bleed Phantom. Image courtesy of Nordic Phantoms.

Endoscopy | DOI 10.1055/a-2569-7736 |

Fig. 3As: Colonoscope Training Simulator; CTS. Image courtesy of Kyoto Kagaku Co., Japan.

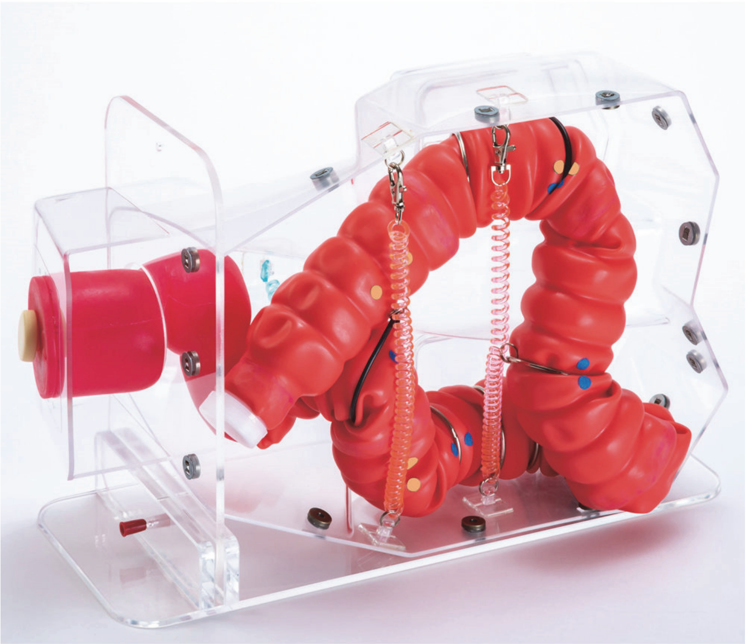


Fig. 3Bs: CTS M40. Image courtesy of Kyoto Kagaku Co., Japan

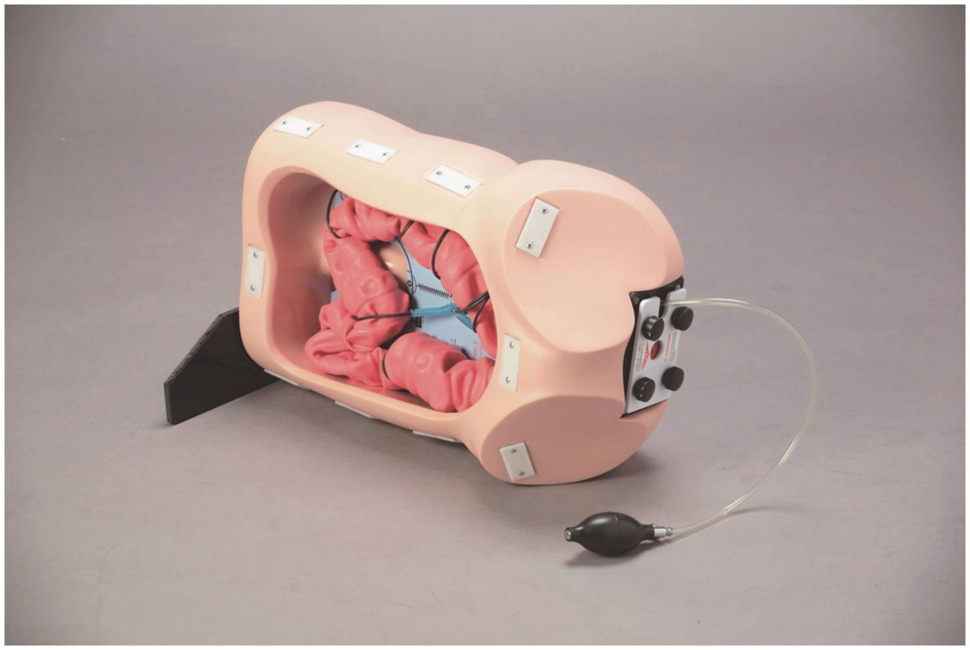


Fig. 4s: Mikoto Colonoscopy Training Simulator. Image courtesy of R ZERO Inc, Japan (distributed by Fujifilm, Tokyo, Japan and Olympus Corporation, Tokyo, Japan).

Fig. 5s: Colonoscopy-Trainer LS90. Image courtesy of SAMED GmbH Dresden.

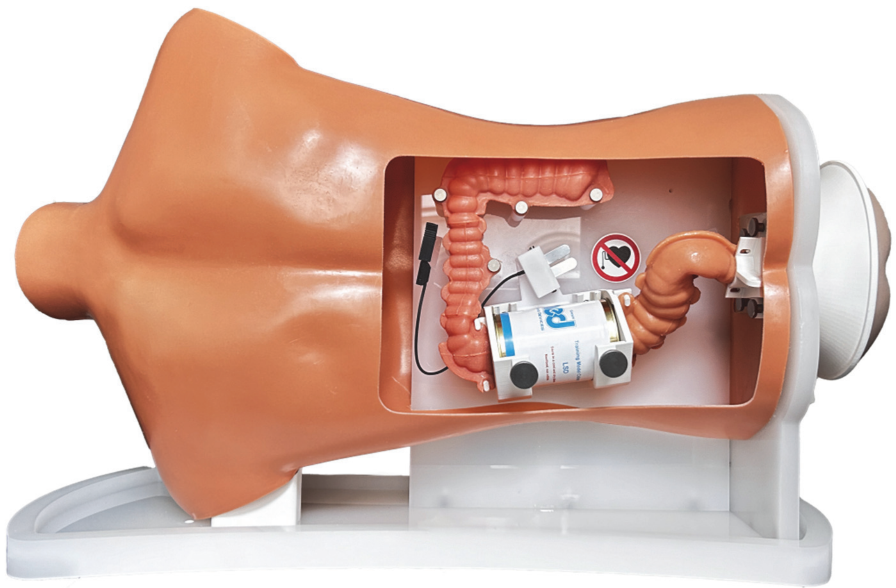


Fig. 6s: Endogel Training Model (ETM). Image courtesy of Sunarrow Co., Ltd, Japan (provided by Fujifilm, Tokyo, Japan).

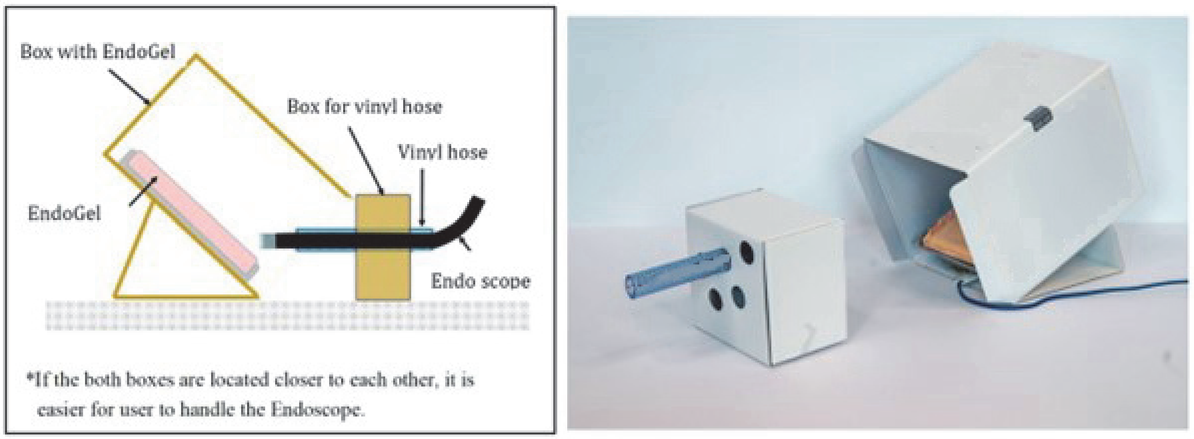
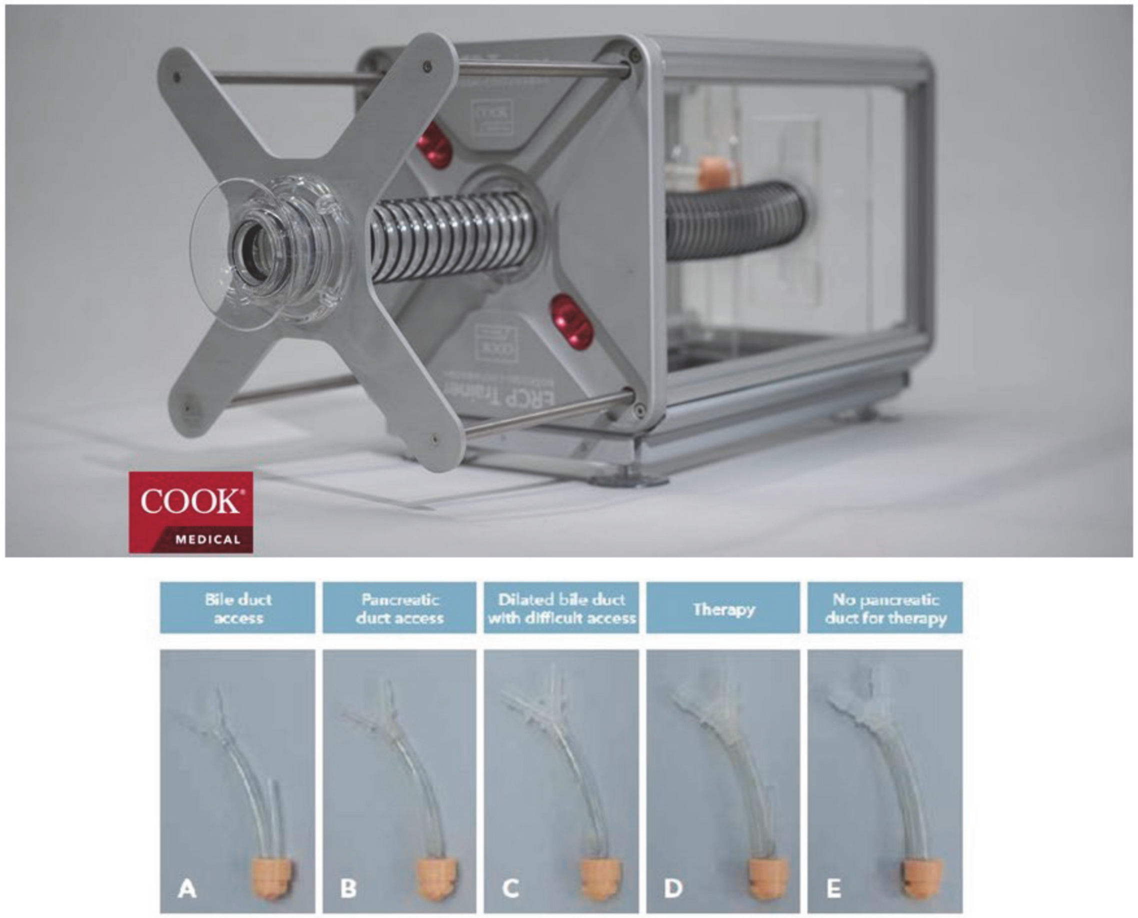


Fig. 7s: SimStar family Simulators. Image courtesy of Dr. Henke, Germany - Electronic Associates, Inc.

Fig. 8s: The Boškoski–Costamagna ERCP Trainer. Image courtesy of Cook Medical, Limerick, Ireland.



Part 2: Animal/Virtual realitysimulators and prototypes

Fig. 9s: EASIE-R4 Simulator. Image courtesy of EndoSim LLC, Bolton, Massachusetts, USA .

Fig. 10s: Erlangen Active Simulator for Interventional Endoscopy Series (EASIE-R4). Image courtesy of EndoSim LLC, Bolton, Massachusetts, USA.

Fig. 11s: Colo-EASIE2. Image courtesy of EndoSim LLC, Bolton, Massachusetts, USA.

Fig. 12s: ENDO Suite-GI Mentor. Image courtesy of Surgical Science, Sweden.

Fig. 13s: Immersive Virtual Reality Endoscopy Suite (ViGaTu). Image courtesy of University Hospital Wurzburg, Open Source Project, Germany.

Fig. 14s: CLA 4/5. Image courtesy of Coburger Lehrmittelanstalt, CLA, Coburg, Germany.

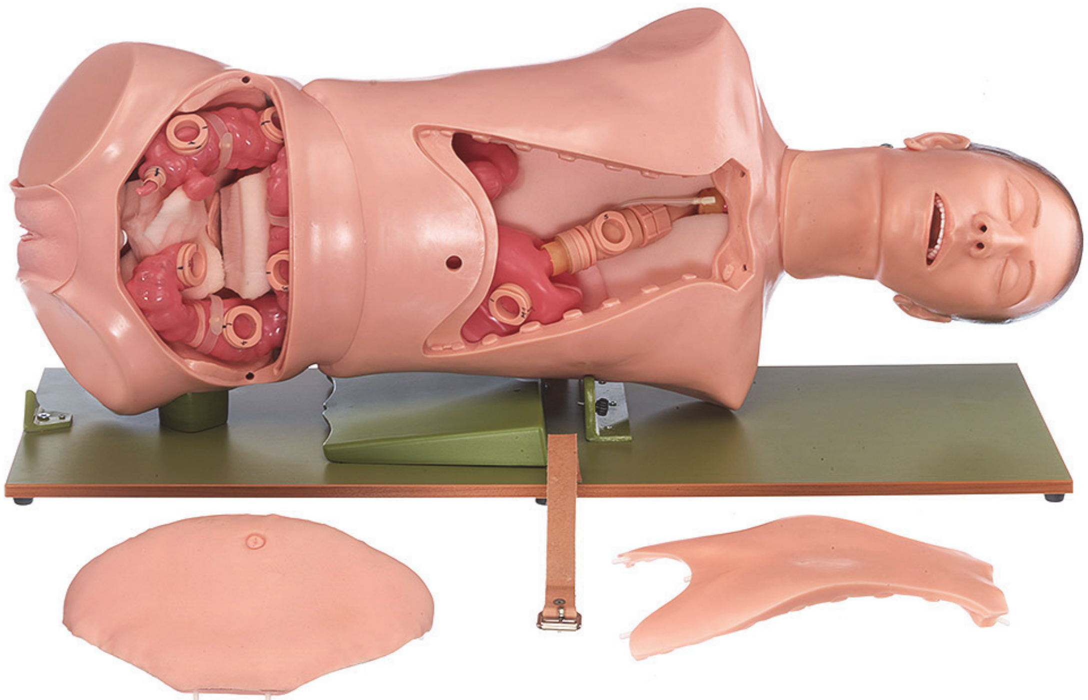


Fig. 15s: Hot Axios Synthetic Trainer. Image courtesy of Boston Scientific.

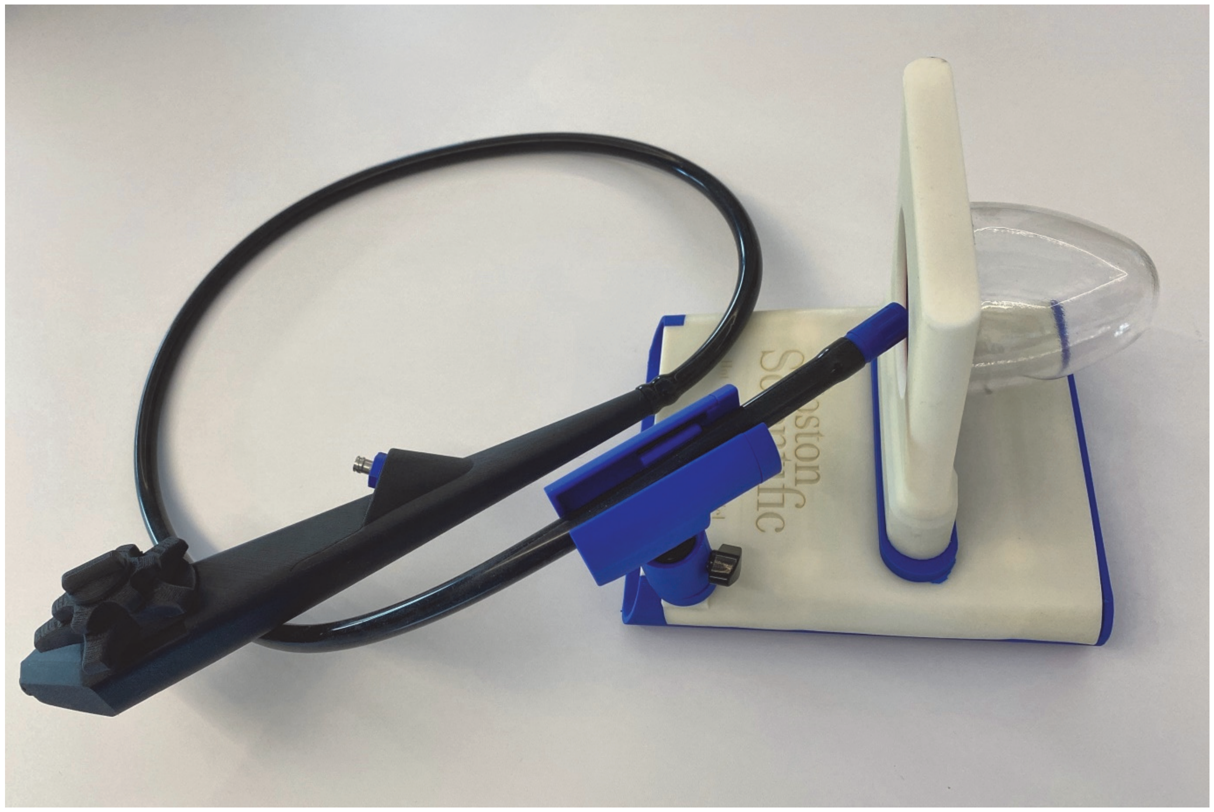


Fig. 16s: Hot Axios Artificial Trainer. Image courtesy of Boston Scientific.

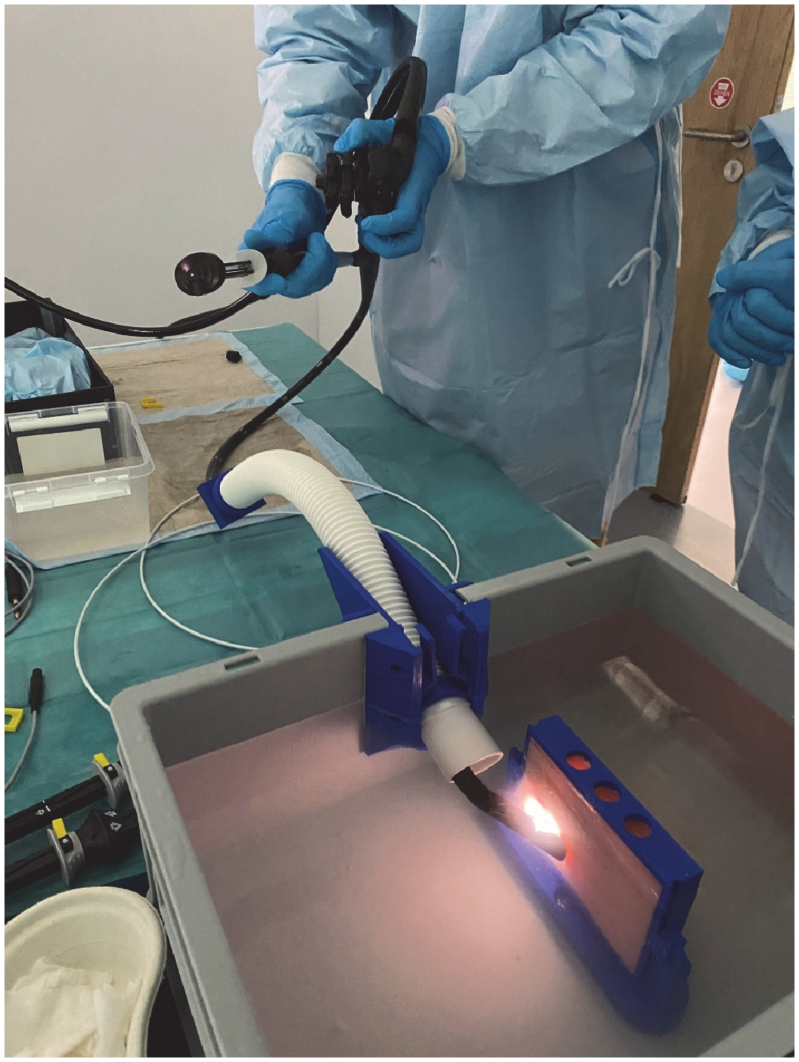


Fig. 17s: CholangioBox. Image courtesy of Boston Scientific.

Fig. 18s: EndoCubot. Image courtesy of Endorobotics Co. Ltd.

Fig. 19s: Frimberger Simulators, Image courtesy of Dr. Frimberger, Germany.

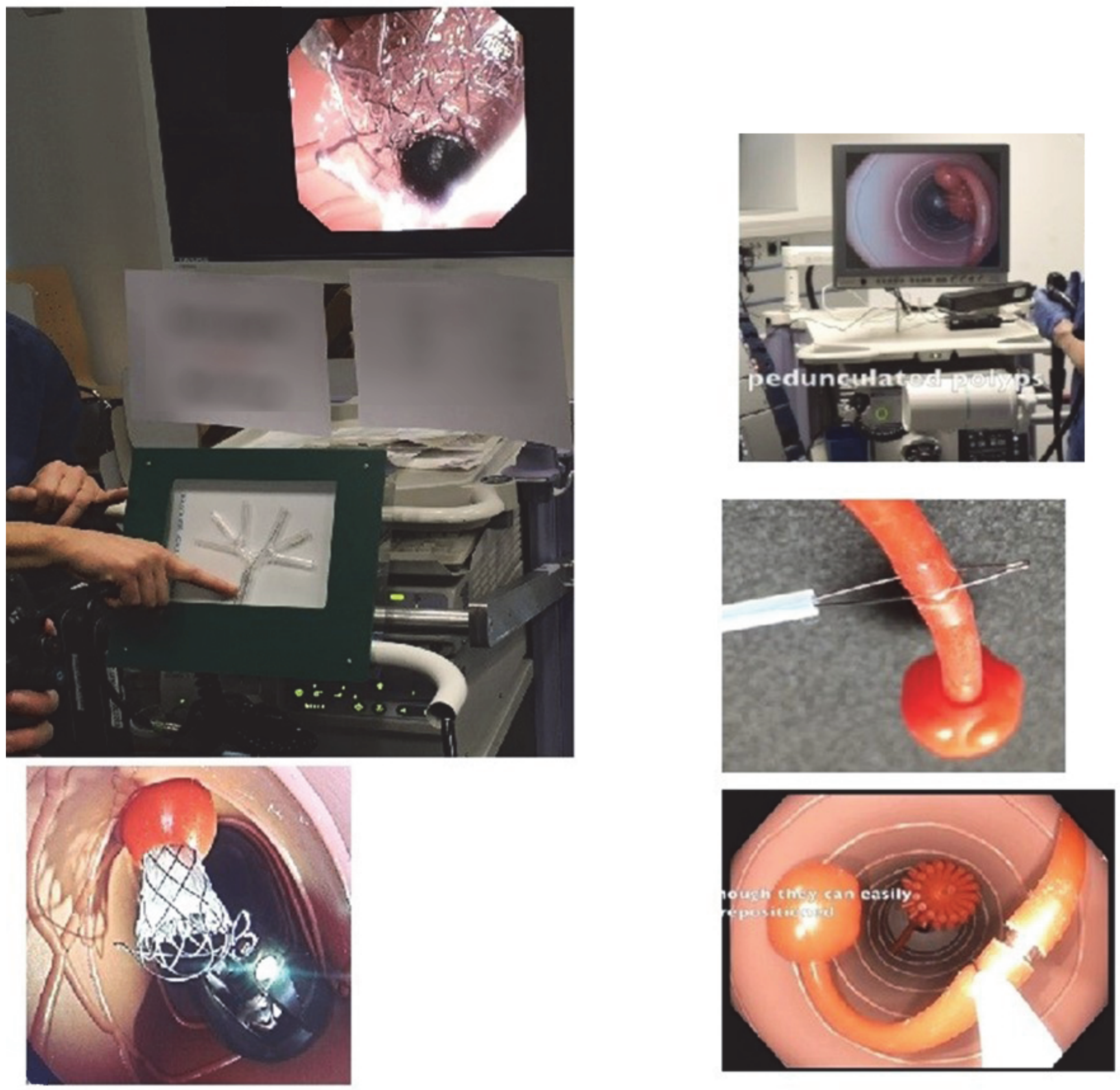


Fig. 20s: Satoshi Model. Image courtesy of Olympus Corporation, Tokyo, Japan.

Fig. 21s: Colonoscopy Training Simulator Endonix. Image courtesy of Olympus Corporation, Tokyo, Japan.

Supplementary Tables

Part 1: Mechanical simulators

Table 1s: Technical summary for TEST simulators.

Manufacturer	EndoSim LLC, Hudson, MA, USA
Class	Mechanical
Accessibility	International market
Country (Production/Use)	USA
Target	EGDS, colonoscopy
Interventional Modules	Yes
Validation Literature	Yes
Material	Silicone
Ease Of Use	Easy
Web Link	https://endosim.com/product-page/thompson-endoscopic-skills-trainer-test
Pro	Basic skills for both upper and lower GI endoscopy High reproducibility
Cons	Only deconstructed practice skills can be practiced without their integration

Table 2s: Studies for TEST simulator.

TEST				
First Author, Reference	**Study design**	**Outcome assessed**	**Key findings**	**Comments**
Thompson CC, et al. 24770972	Prospective	Scoring systems were developed to reflect the basic skills. Validity evidence for content, internal structure, and response process was evaluated.	Content validity index (CVI)-realism was 0.88, CVI-relevance was 1.00, and CVI-representativeness was 0.88, giving a composite CVI of 0.92. Overall, 82 % of participants considered the simulator to be capable of differentiating between ability levels, and 93 % thought the simulator should be used to assess ability prior to performing procedures in patients. Each module represented 16.0 %– 26.1 % of the total score, suggesting that no module contributed disproportionately to the composite score. Average score for all participants with proctor 1 was 297.6 and 308.1 with proctor 2 (P= 0.94), suggesting reproducibility and minimal error associated with test administration.	The simulator is useful and validated for practicing deconstructed basic skills for both upper and lower GI endoscopy, with high reproducibility.

Table 3s: Technical summary for Left Hand trainer simulator.

Manufacturer	Glück, Korea
Class	Mechanical
Accessibility	NA
Country (Production/Use)	South Korea
Target	EGD
Interventional Modules	No
Validation Literature	No
Material	Plastic
Ease Of Use	Easy
Web Link	EGD Simulator: LHT Performance (youtube.com)
Pro	Easy to use Provides measurement of performance.
Cons	Only for basic skills

Table 4s: Technical summary for EGD simulator.

Manufacturer	Koken Co., Ltd., Tokyo, Japan
Class	Mechanical
Accessibility	International market
Country (Production/Use)	Japan
Target	EGDS, Cannulation in ERCP
Interventional Modules	Yes
Validation Literature	Yes
Material	Silicone
Ease Of Use	Easy
Web Link	https://www.kokenmpc.co.jp/english/products/educational_medical_models/anatomical/lm-103.html
Pro	Basic skills Replicas of polyps, ulcers, bleeding
Cons	Only upper endoscopy reproduced Interventional components not included in the basic version of the model

Table 5s: studies for EGD simulator

EGD Simulator				
First Author, Reference	**Study design**	**Outcome assessed**	**Key findings**	**Comments**
Cha JM, et al. 22318817	Prospective, single centre	Score in a questionnaire regarding first impression and usefulness	The mean scores on the simulator's usefulness, features, and realistic movements before the training were between 1.5 and 2.0. There were no significant differences between the mean scores of novice vs non-novice users. After receiving training on the simulator, 90.6% of the participants considered the box simulator a generally useful tool for learning basic endoscopic techniques, and 90.6% agreed that the simulator was useful for improving hand-eye coordination.	EGD simulator may be useful for training novice endoscopists in basic gastrointestinal endoscopic techniques.

Table 6s: Technical summary for EGD Method Trainer (EGD MT).

Manufacturer	Anymedi Inc., Korea
Class	Mechanical
Accessibility	International
Country (production / use)	Korea
Interventional modules	Yes; haemostasis and polypectomy
Validation literature	No formal validation, 2 observational studies available
Material	Silicone
Ease of use	Easy to use
Web link	https://www.anymedi.com/products/simulator
Pro	Simple model, clear objectives for training in both basic diagnosis and therapy
Cons	Probably only useful in very early-stage training

Table 7s: Studies for EGD Method Trainer.

EGD Method trainer (EGD MT)				
First author, Reference	**Study design**	**Outcome assessed**	**Key findings**	**Comments**
Lee S, et al. 29069892	Pre-post study, expert control group available	Duration of the procedure	Realistic simulator	Biopsy model
Lee DS, et al. 30970441	Pre-post study, expert control group available	Duration of the procedure	Realistic simulator	Haemostasis model

Table 8s: Technical summary for Upper GI trainer

Manufacturer	Chamberlain Group LLC, Great Barrington, MA, USA
Class	Mechanical simulator
Accessibility	International
Country (production / use)	USA
Interventional modules	No
Validation literature	Not available
Material	Silicone
Ease of use	Unclear
Web link	https://www.thecgroup.com/product/upper-gi-trainer-2002/
Pro	Beneficial for apprentices just beginning endoscopy.
Cons	Cannot be used for therapeutic endoscopic training

Table 9s: Technical summary of Mikoto Gastrointestinal Endoscopy Model.

Manufacturer	R ZERO Inc. (FUJIFILM), Japan
Class	Mechanical
Accessibility	International market
Country (Production/Use)	Japan
Target	EGDS
Interventional Modules	No
Validation Literature	Not available
Material	Silicone
Ease Of Use	Easy
Web Link	https://rzero.jp/mikoto/english.html
Pro	Anatomical landmark practice
Cons	Limited to basic gastroscopy

Table 10s: Technical summary for Medical Rising Star Ulcer Type simulators.

Manufacturer	Denka, Japan
Class	Mechanical
Accessibility	International
Country (Production/Use)	Japan
Target	Haemostasis
Interventional Modules	Yes, Haemostasis
Validation Literature	Yes
Material	Plastic stomach with ulcer and vessels, connected to syringes
Ease Of Use	Easy
Web Link	https://www.denka.co.jp/eng/pdf/corporate/thedenkaway/
Pro	Basic skills Reusable Transportable Variable difficulty
Cons	Do not properly simulates fibrotic ulcers The model cannot accumulate simulated blood and clots

Table 11s: Studies for Medical Rising Star ulcer type simulator.

MEDICAL RISING STAR ULCER TYPE				
First author, Reference	**Study design**	**Outcome assessed**	**Key findings**	**Comments**
Kanno T, et al. 38420152	Prospective	Evaluate the reproducibility of the clinical difficulty of this model and the effectiveness of simulation-based training for clipping haemostasis.	The haemostasis success rate of the trainees significantly increased after instruction (64% vs. 86%, $P < 0.05$). The success rate for ulcers in the upper body of the stomach (59%), a high-difficulty site, was significantly lower than that for ulcers in the antrum, even after feedback and instruction. Trainee self-perceived proficiency and confidence significantly improved after simulation-based training ($P < 0.05$). Co-occurrence network analysis showed that trainees valued a structured learning approach, acknowledged simulator limitations, and recognized the need for continuous skill refinement.	The simulator is useful and validated as a valuable tool for improving technical skills and confidence in trainees learning to perform endoscopic haemostasis.

Table 12s: Technical summary of upper GI bleed Phantom.

Manufacturer	Nordic Phantoms
Class	Mechanical
Accessibility	International
Country (Production/Use)	Denmark
Target	Upper GI bleeding
Interventional Modules	Yes
Validation Literature	No
Material	Plastic
Ease Of Use	Easy
Web Link	https://nordic-phantoms.com/products/uppergi-bleed-phantom/
Pro	Realistic internal anatomy Invasive surgery Works with any endoscope Pulsatile blood flow Replaceable bleeding inserts
Cons	No validation studies

Table 13s: Technical summary of Colonscope training simulator (CTS).

Manufacturer	Kyoto Kagaku Co., Japan
Class	Mechanical
Accessibility	International (no CE mark)
Country (production / use)	Japan
Interventional modules	No
Validation literature	Yes
Material	Soft resin, hard resin (Latex free)
Ease of use	Easy to use and process
Web link	https://www.kyotokagaku.com/en/products_data/m40/; https://www.kyotokagaku.com/products_data/mw24_manual.pdf
Pro	Various scenarios for easy and difficult intubation of the colon
Cons	No possibility to perform basic manoeuvres (biopsy, polypectomy, injection)

Table 14s: Studies for CTS.

Colonoscope Training Simulator (CTS)				
First author, Reference	**Study design**	**Outcome assessed**	**Key findings**	**Comments**
Plooy AM, et al. 22726473	Pre-post study, expert control group available	Cecal intubation rates and time to cecum	Construct validity for the CTS model	
Hill A, et al. 22341108	Observational	Realism of the model	CTS and mechanical models superior to VR model	
Plooy AM, et al. 27995185	Pre-post study, expert control group	Cecal intubation rates and time to cecum	A structured training program using the model can significantly improve novice trainee performance ex-vivo	
Gomez PP, et al. 25239553	RCT	Global Assessment of Gastrointestinal Endoscopic Skills (GAGES)	Use of CTS in addition to a VR simulator improves colonoscopy skills compared to the CTS alone	Negative study for use of CTS as the sole training tool
Kaltenbach T, et al. 21409379	Pre-post study, no control	Cecal intubation rate and time; colonoscopy performance score	Improvement in all key parameters (intubation rate, time and technical performance)	Risk of bias because of concurrent performance of colonoscopy on patients

Tables 15s: Technical summary for Colonscopy Trainer

Manufacturer	Chamberlain Group LLC, Great Barrington, MA, USA
Class	Mechanical
Accessibility	International
Country (Production/Use)	USA
Target	Colonoscopy
Interventional Modules	No
Validation Literature	No
Material	Plastic frame, Foam support, silicone core (organ)
Ease of use	Cumbersome
Web Link	Colonoscopy Trainer (#2003) - The Chamberlain Group (thecgroup.com)
Pro	• Requires no preparation. • Replicate shape of the colon (one type). • Allows insertion of polyps and stricture.
Cons	• Lower degree of realism • No insufflation or suction • Does not provide online suggestion or measurement feedback • Only suitable for basic skills

Table 16s: Technical summary for Mikoto Colonoscopy simulator.

Manufacturer	R ZERO Inc. 2-218,kamo-cho,Yonago-shi,Tottori,Japan (OLY-FUJI)
Class	Mechanical simulator
Accessibility	International
Country (production / use)	North America, Europe, and parts of Asia.
Interventional modules	No
Validation literature	Not available
Material	Silicone resin
Ease of use	Easy to use
Web link	https://rzero.jp/mikoto/english.html
Pro	-High realism -Pre-programmed scenarios -Real-time feedback
Cons	-High cost -Specific to colonoscopy

Table 17s: Technical summary for Endoscopy model System (EMS) trainer.

Manufacturer	Chamberlain Group LLC, Great Barrington, MA, USA
Class	Mechanical stimulator
Accessibility	International
Country (production / use)	USA
Interventional modules	Multiple
Validation literature	No available
Material	Mechanical
Ease of use	Unclear
Web link	https://www.thecgroup.com/product/ems-trainer-2068/
Pro	Advanced therapeutic endoscopic techniques can be done Additionally, the colon frame can be outfitted with tissue elements for practicing procedures like polypectomies , colonic stentings
Cons	No clinical studies evaluating the effectiveness of this product

Table 18s: Technical summary for Noda–Kitada–Suzuki 3D (NKS) colonoscopy simulator

Manufacturer	Kyoto Kagaku Co., Japan
Class	Mechanical stimulator
Accessibility	International
Country (Production / Use)	Japan
Interventional Modules	No
Validation Literature	No available
Material	Mechanical
Ease Of Use	Unclear
Web Link	https://www.kyotokagaku.com/en/products_data/mw24/
Pro	Designed specifically for cecal intubation, a short- or long alpha loop and N-loop can be artificially set in the tortuous colon to aid in loop reduction during endoscopic insertion.
Cons	Cannot be used for therapeutic endoscopic training No evidence of value or benefit

Table 19s: Technical summary of Colonoscopy Lower GI Endoscopy Simulator Type II

Manufacturer	Koken Co., Ltd., Japan
Class	Mechanical simulator
Accessibility	International
Country (Production / Use)	Japan
Interventional Modules	Multiple
Validation Literature	Not available
Material	Mechanical
Ease Of Use	Unclear
Web Link	https://www.kokenmpc.co.jp/english/products/educational_medical_models/anatomical/lm-107.html
Pro	Attaching the optional small bowel makes it possible to use a shortening technique during balloon enteroscopy Various colonoscopy procedures including polypectomy , clipping techniques
Cons	No evidence of value and benefit

Table 20s: Technical summary for Colonscopy Trainer LS90.

Manufacturer	Samed, Dresden
Class	Mechanical
Accessibility	International
Country (Production/Use)	Germany
Target	CSPY
Interventional Modules	Yes
Validation Literature	No
Material	Silicone, Plastic
Ease Of Use	Easy
Web Link	https://samed-dresden.de/en/ls90_en.php
Pro	Availability of interventional and diagnostic models
Cons	No evidence of benefit

Table 21s: Technical summary for Endoscopic Variceal Ligation (EVL) simulator.

Manufacturer	Glück Co., Korea
Class	Mechanical
Accessibility	NA
Country (Production/Use)	South Korea
Target	EVL
Interventional Modules	Yes
Validation Literature	No
Material	Plastic frame, silicone varix module
Ease of use	Easy
Web Link	https://gluckmedical.com/25
Pro	• Degree of realism and feedback. • Cost effective. • Facilitate multiple attempts using the same varix module.
Cons	• Band and ligation kit not included.

Table 22s: Technical summary for EndoGel Training Model for ESD/POEM.

Manufacturer	Sunarrow Co., Japan (FUJI)
Class	Mechanical
Accessibility	International market
Country (Production/Use)	Japan
Target	ESD/POEM
Interventional Modules	Yes
Validation Literature	Yes
Material	Polyvinyl alcohol hydrogel
Ease Of Use	Easy
Web Link	https://www.sunarrow.co.jp/medical/en/products/endogel/
Pro	Reproducibility feedback Realism feedback Ecologically acceptable
Cons	Cost

Table 23s: Studies for EndoGel Training Model for ESD/POEM.

EndoGel Training Model for ESD/POEM				
First author, Reference	**Study design**	**Outcome assessed**	**Key findings**	**Comments**
Sato H, et al. 28616397	Pilot study	Satisfaction and feasibility rate	Endoscopic submucosal dissection (ESD), peroral endoscopic myotomy (POEM), hands-on, achalasia, endoscopy	In one study, 28 residents practiced ESD and POEM with EndoGel and completed a self-report questionnaire. The satisfaction rate was 100%, and the feasibility rate was 96.4%, indicating that EndoGel may be an effective endoscopy education tool.
Lee DS, et al. 37524564	Pilot study	(1) lifting of the submucosal layer; (2) cutting of the submucosal layer; (3) visibility by bubble; (4) thickness of the muscle layer; (5) combination of the three layers; (6) size of the ESD sheet; and (7) connectivity of the electrode.	-	Compared with the real human stomach, the new simulator showed similar performance in lifting of the submucosal layer (5.00 [4.00–6.00]), cutting of the submucosal layer (6.00 [5.00–6.00]), visibility by bubble (4.00 [4.00–6.00]), thickness of the muscle layer (4.00 [4.00–5.00]), combination of the three layers (6.00 (6.00–7.00)), size of the ESD sheet (6.00 [5.00–6.00]), and connectivity of the electrode (6.00 [6.00–7.00]). All participants agreed that the new PVA-H-based gastric ESD simulator provided reasonable human gastric ESD training results.
Kim SH, et al. 38467861	Review Article		Endoscopic submucosal dissection; Gastric cancer; Hands-on	Japanese text and English abstract
De Cristofaro E, et al. 37604439	E-video	-	-	The procedure was performed by experts who confirmed good reproducibility and analogy with real-life experience. We hypothesize that an ecologically acceptable dedicated model with no animal components could facilitate ESD training with adaptive traction strategies. The model allows human scopes to be used in nondedicated rooms without the risk of scope contamination with animal tissue.

Table 24s: Technical summary for ESD training model.

Manufacturer	Koken Co., Ltd., Japan
Class	Mixed Mechanical/ex-vivo
Accessibility	NA
Country (Production/Use)	Japan
Target	ESD
Interventional Modules	Yes
Validation Literature	No
Material	Aluminium (case), silicone rubber & polyurethane resin (stomach model), stainless steel (metal plates)
Ease Of Use	Cumbersome
Web Link	ESD (Endoscopic Submucosal Dissection) Training Model LM-083 | Koken Co., Ltd. (kokenmpc.co.jp)
Pro	Allows practicing ESD in different gastric locations.
Cons	Need animal tissue prepared seperately.

Table 25s: Technical summary of G-Master.

Manufacturer	KOTOBUKI Medical, Inc. Saitama, Japan
Class	Mechanical
Accessibility	International
Country (Production/Use)	Japan
Target	ESD
Interventional Modules	Yes
Validation Literature	Yes
Material	Metal, konjac flour sheet (mucous membrane), plastic
Ease Of Use	Intermediate
Web Link	https://www.thieme-connect.de/products/ejournals/html/10.1055/a-1845-5556#ME2668-1
Pro	- Several stomach locations - Realistic reproduction of gastric wall - Adjustable gastric wall tension
Cons	- Only one sheet model with predefined mucosa and submucosa thickness - No possibility to use traction devices - Change of mucosal tension only in longitudinal direction - No training for haemostasis - Need for dedicate gastroscopy

Table 26s: Technical summary for PEG simulator

Manufacturer	Glück Co., Korea
Class	Mechanical
Accessibility	NA
Country (Production/Use)	Korea
Target	PEG
Interventional Modules	Yes
Validation Literature	Yes
Material	The abdominal and gastric walls by inserting a silicone module shaped like the abdominal and gastric walls into the hole of a plastic stomach model.
Ease Of Use	
Web Link	https://www.youtube.com/watch?v=F24hX8eoq74)
Pro	Modules can be reused multiple times train with different types of PEG
Cons	Single scenario Cost

Table 27s: Technical summary for Freka Simulator.

Manufacturer	Fresenius Kabi
Class	Mechanical
Accessibility	Europe
Country (Production/Use)	Germany
Target	EGD
Interventional Modules	PEG
Validation Literature	NA
Material	Silicone, Plastic
Ease of use	Easy
Web Link	https://www.fresenius-kabi.com/de/pressemitteilungen
Pro	Multiple modules
Cons	Integrated technical skills of endoscopy cannot be practiced

Table 28s: Technical summary of Sim Star simulator.

Manufacturer	Dr Henke, Germany – electronic associates, Inc
Class	Mechanical
Accessibility	International
Country (Production/Use)	Germany
Target	EGD, colonoscopy, ESD, EUS, ERCP
Interventional Modules	Multiple
Validation Literature	NA
Material	Artificial material
Ease of use	Easy
Web Link	https://drhenke.de/en/product/simstar-gastro
Pro	Detailed anatomy, customizable scenario and different difficulty level, complete disinfectability
Cons	Specific to upper gastrointestinal endoscopy

Table 29s: Technical summary for ERCP trainer.

Manufacturer	Chamberlain Group LLC, Great Barrington, MA, USA
Class	Mechanical
Accessibility	International Market
Country (Production/Use)	USA
Target	ERCP
Interventional Modules	Yes
Validation Literature	No
Material	Silicone
Ease of use	Easy
Web Link	https://www.thecgroup.com/product/ercp-trainer-2101/
Pro	Basic skills for ERCP, including sphincterotomy and stenting
Cons	Not suitable for upper GI endoscopy, Modified version lacks of evidence

Table 30s: Technical summary for Boskoski Costamagna Trainer (BCT).

Manufacturer	Cook Medical, Limerick, Ireland
Class	Mechanical or Mixed Mechanical/ex-vivo
Accessibility	International
Country (production / use)	Ireland
Interventional modules	Yes – sphincterotomy, stent placement, stone extraction
Validation literature	Yes, validation of the model and of additional training modules
Material	Plastic, metal, latex with add-ons including biological material (chicken heart explants)
Ease of use	Basic model is easy to use, but the ex-vivo sphincterotomy model requires some degree of training to set up and reprocess
Web link	NA (not commercially available)
Pro	Versatile model, allowing training in various basic and advanced scenarios, including a very realistic sphincterotomy model; Abundant literature supporting its validity and utility
Cons	Not commercially available (procurement logistics can be cumbersome). The advanced training models are relatively more difficult to set up and process (some technical support might be required)

Table 31s: Studies for Boskoski Costamagna Trainer (BCT).

Reference	**Study design**	**Outcome assessed**	**Key findings**	**Comments**
Van der Wiel et al 29881768	Observational	Time to cannulation, successful stent placement and stone extraction	Face and construct validity demonstrated for the initial iteration	
Van der Wiel et al 31157293	Observational	Realism of the synthetic papilla model	Face validity for synthetic papilla demonstrated	
Teles de Campos S et al 37390863	Observational	Realism of the biological papilla model	Face and content validity demonstrated	
Voiosu T et al 33532551	RCT	Time to cannulation on the BCT	"motion training" on the BCT improves cannulation time for trainees	
Van der Wiel et al 37564331	Prospective cohort study	Cannulation rate	Simulator based training improves cannulation rates for early-stage trainees	Clinical data in support of BTC use
Teles de Campos S et al. **39542016**	RCT	Overall technical Competence in ERCP (TEESAT score); cannulation rates	Simulator-based training improves technical performance of ERCP	First RCT to show clinical benefit for simulator-based training on the BTC

Table 32s: Technical summary for Compact ERCP trainer.

Manufacturer	EndoSim LLC, USA
Class	Mechanical simulator
Accessibility	International
Country (production / use)	United States of America
Interventional modules	Multiple
Validation literature	Not available
Material	Artificial material
Ease of use	Unclear
Web link	https://endosim.com/compact-ercp
Pro	-Detailed bile and pancreatic ducts simulation -Therapeutic scenarios
Cons	-No validation literature; -Limited use: it is specific to ERCP, so it is not useful for other types of endoscopy.

Part 2: Animal/Virtual realitysimulators and prototypes

Table 33s: Technical summary for Erlangen Active Simulator for Interventional Endoscopy Series (EASIE) / Erlangen Endo-Trainer model; Erlangen compact EASIE/EASIE-R (compact version) - EASIE-R4

MANUFACTURER	EndoSim LLC, Hudson, MA, USA, ECE-Training GmbH, Erlangen, Germany
CLASS	Ex-vivo model
ACCESSIBILITY	International
COUNTRY (Production/Use)	USA/Europe
TARGET	EGD, CS, DBE, EUS, ERCP
INTERVENTIONAL MODULES	Yes (haemostasis, EMR, ESD, Dilatation, Stenting)
VALIDATION LITERATURE	Yes
MATERIAL	Ex-vivo pig tissues
Ease of use	Easy
WEB LINK	https://endosim.com/product-page/easie-r4-simulator
PRO	Realistic tactile feedback, wide range of techniques, flexible setup, repeatability, cost-effective
CONS	Need preparation and simulation area with animal scopes only

Table 34s: Literature for Erlangen Active Simulator for Interventional Endoscopy Series (EASIE) / Erlangen Endo-Trainer model; Erlangen compact EASIE/EASIE-R (compact version) - EASIE-R4

Reference (First author, PMID/doi)	Study design	Outcome assessed	Key findings	Comments
Yusuf E.T 10.1016/j.gie.2008.12.224	Proof of concept	good visual realis, pliability and atomical correlation	good overall realism of the simulator	just a proof of concept study
May A, et al. 15657861	Cross-sectional	Length of small bowel insertion	ability to learn DB enteroscopy	No solid conclusions, small pilot study, no relevant endpoints
Matthes K, et al. 16301038	Cross-sectional	haemostatic ability on model (Lickerdt Scale)	significant improvement of haemostatic skills thanks to one day intensive training	success of the model to train trainees and trainers, no control group
Maiss J, et al. 15933929	Cross-sectional	haemostatic ability on model (Lickerdt Scale)	significant improvement of haemostatic skills thanks to one day intensive training	intensive training with 32 physicians, objective evaluation scale, no control group
Maiss J, et al. 16942923	RCT	haemostatic ability on model (Lickerdt Scale)	Significant Efficiency on haemostatic skills of model based training compared to no training	randomized control trial but no sample size calculation
Kato M, et al. 22806508	Cross-sectional	learning curve, effect of location of the lesion on ESD outcomes, cost to overcome the learning curve	30 cases needed to reach competency, posterior wall more difficult, 8,410$ to overcome the learning curve	no results on human about efficiency of the training
Hochberger J, et al. 15729227	RCT	haemostatic ability on model (Lickerdt Scale) between clinical + model training vs clinical training only	significant improvement of all haemostatic techniques in the model based training vs significant improvement only for variceal band ligation for the clinical training only group	well-designed RCT
Gromski MA, et al. 28281126	Cross-sectional	Evaluation of colorectal ESD learning curve	learning curve overcome after 9 procedures	previous experience in gastric ESD influenced the results
Gonzalez JM, et al. 27995190	Cross-sectional	Ability to perform EUS FNA	Significant improvement after 15 EUS FNA (procedure time, accuracy of the FNA)	lack correlation with sensitivity of EUS FNA in human lesions
Ende A, et al. 22153875	RCT	skill score for gastroscopy, comparison of model + clinical training vs clinical training alone vs model training alone, evaluation on model and on clinical EGD	No difference of the 3 strategies of training on model evaluation , no superiority on clinical evaluation of adding simulator to clinical training, model training alone is the less good option	one of the only study with clinical evaluation without significant adding of the model training but small sample size.
Kanno T, et al. 38420152	RCT	haemostatic ability on model (Lickerdt Scale) between clinical + model training vs clinical training only	significant Improvement of all skills in simulation + clinical training group vs only in 2 skills in clinical training group only , quantitative superiority of simulation + clinical training vs clinical training only	blinded RCT with objective evaluation and great sample size (35 fellow)

Table 35s: Technical summary for Colo EASIE 2.

MANUFACTURER	EndoSim LLC, Hudson, MA, USA
CLASS	Ex-vivo model
ACCESSIBILITY	International
COUNTRY (Production/Use)	USA/Europe
TARGET	CS
INTERVENTIONAL MODULES	Yes (Polypectomy, EMR, ESD, GI bleeding)
VALIDATION LITERATURE	No
MATERIAL	Ex-vivo pig tissues
Ease of use	Easy

WEB LINK	https://endosim.squarespace.com/
PRO	Real tissue feedback Multiple procedures
CONS	Need simulation area with animal scopes only, no efficiency for colonoscopy intubation learning, Very limited evidence of value or benefit

Table 36s: Technical summary EUS RK Phantom.

MANUFACTURER	Dr. Koji Matsuda
CLASS	Ex-vivo
ACCESSIBILITY	International Market
COUNTRY (Production/Use)	Japan, Asia, Europe, USA
TARGET	EUS
INTERVENTIONAL MODULES	YES, EUS FNA
VALIDATION LITERATURE	YES
MATERIAL	Ex vivo pig, upper GI tract
Ease of use	Laborious
WEB LINK	https://endosim.squarespace.com/
PRO	Real tissue feedback Multiple procedures
CONS	Need simulation area with animal scopes only, no efficiency for colonoscopy intubation learning, Very limited evidence of value or benefit

Table 37s: Technical summary for Neo-papilla ERCP.

MANUFACTURER	EndoSim LLC, Hudson, MA, USA
CLASS	Ex-vivo model
ACCESSIBILITY	International
COUNTRY (Production/Use)	USA/Europe
TARGET	ERCP
INTERVENTIONAL MODULES	Yes (Sphincterotomy, biliary stenting)
VALIDATION LITERATURE	Yes
MATERIAL	Ex-vivo pig and chicken tissues
Ease of use	Intermediate
WEB LINK	https://endosim.squarespace.com/
PRO	Real tissue feedback ; Multiple sphincterotomies in one specimen
CONS	Lack of realism for scope intubation, only for basic ERCP teaching, Limited evidence of value or benefit

Table 38s: Literature for Neo Papilla ERCP.

Reference (First author, PMID/doi)	**Study design**	**Outcome assessed**	**Key findings**	**Comments**	
Matthes, et al 16996352	Observational pilot study	9 ERCP experts used and assessed 3 different domains on a 7 or 4 point Likert scale	1. Realism 2. Basic vs advanced skills use 3. Performance vs other models	higher than the other models in usefulness as an educational tool, ease of use, and ease of incorporation into fellowship training	No solid conclusions, small pilot study Prospective validation studies needed

Table 39s: Technical summary of EndoX trainer.

MANUFACTURER	Medical Innovations International Inc., Rochester, Minnesota
CLASS	Mixed Mechanical/Ex-vivo
ACCESSIBILITY	International
COUNTRY (Production/Use)	USA
TARGET	EGD, CS, ERCP
INTERVENTIONAL MODULES	Yes (Polypectomy, Hemostasis)
VALIDATION LITERATURE	Yes
MATERIAL	Plastic/Animal
Ease of use	Easy
WEB LINK	https://pdf.medicalexpo.com/pdf/medical-x-112986.html
PRO	Lightweight Portable Allows simulation of therapeutic procedures Positive rating of realism of the endoscopic mucosal appearance, extent of paradoxical motion and cecal intubation time
CONS	No face validation

Table 40s literature for EndoX trainer

Reference	Outcome assessed	Key findings	Comments	Reference
17100968	Cross-sectional	1. Simulated cecal intubation rates and times. 2. Subjective assessments of mucosal visualization.	high fidelity in mucosal realism, endoscopic views, and paradoxical motion. effectively distinguishes users by experience level, Correlates well with patient-based performance	Content, construct and criterion validity. Lack of face validity.

Table 41s: Technical summary of DeLegge EndoExpert Tray.

MANUFACTURER	DeLegge Medical LLC, Awendaw, South California
CLASS	Mixed Mechanical/Ex-vivo
ACCESSIBILITY	USA, Canada
COUNTRY (Production/Use)	USA, Canada
TARGET	EGD, CS, ERCP
INTERVENTIONAL MODULES	Yes (Polypectomy, Hemostasis)
VALIDATION LITERATURE	Yes
MATERIAL	Plastic/Animal
Ease of use	Easy
WEB LINK	https://www.organsbydesign.com
PRO	Lightweight Portable
CONS	No validation

Table 42s: Technical summary of CAE EndoVR.

Manufacturer	CAE Healthcare, Montreal, Quebec, Canada
Class	Computerized (virtual reality)
Accessibility	International market
Country (production / use)	Canada
Target	EGD, CS, ERCP, biopsy, polypectomy, bleeding
Interventional modules	Yes
Validation literature	Yes
Material	Silicone/ 2 monitors/ cart / Integrated keyboard
Ease of use	Easy
Web link	https://www.caehealthcare.com/media/files/User_Guides/EndoVR-User-Guide.pdf
Pro	Basic skills Force feedback Combination of endoscopy procedure with medical history of a virtual patient Sedation management
Cons	Cost

Table 43s: Literature for CAE EndoVR.

Reference	Study design	Procedure/groups	Outcome assessed	Key findings	Comments
MacDonald *et al*. 12632138]	Prospective cohort	Sigmoidoscopy Clerical group Residents group Expert group	Total procedure time Insertion length Percentage of time patient had no pain	1033 vs. 952 vs, 450 No differences in all other parameters	Small study size
Ahlberg *et al*. 16329017	RCT	Colonoscopy Simulator group Control group	Cecum reached during the first 10 colonoscopies Time (min) to reach cecum Patient discomfort (estimated probability group 2)	52% vs 19% (P = 0.0011) 30 vs 40 (P = 0.037) 2.27 (95%CI: 1.14-4.76)	Small numbers of residents
Gerson *et al.* 12822091	RCT	Sigmoidoscopy Virtual simulator training (without on-patient training) On patient training group	Time (min) to complete live case Live cases trainees completed independently	24 vs 24 (P = NS) 29% vs 72% (P < 0.001)	
Kruglikova I, *et al.* 19828469	RCT	Simulator group - received structured feedback No feedback	The proficiency levels	0 vs. 7 perforations in control group (median 0, range 0e3),	No blinding Simulator based outcomes
Grover SC *et al.* 26007221	RCT	Colonoscopy Simulation-based structured comprehensive curriculum (SCC) group Self-regulated learning (SRL) group	Joint Advisory Group Direct Observation of Procedural Skills (JAG DOPS) scale Procedural knowledge, immediate post-training simulation performance, and delayed post-training (4-6 w)	67 vs. 54 (P < 0.01) CC, 35.5% ± 14.2%; SRL, 34.1% ± 9.8%	Impact on clinical performance unknown
Sedlack *et al.* 15067632	Prospective cohort	Sigmoidoscopy Simulator group Control group	Patient discomfort score (1-10) Competence score to perform endoscopy independently (1-10)	1.3 vs. 4 (P < 0.01) 2.8 vs. 8 (P = NS)	Small numbers of residents in each group
McConnell RA *et al* 22968094	Prospective cohort	Gastroscopy Colonoscopy novice first-year gastroenterology fellows and experts	57 objective performance parameters measured by the endoscopy simulator	Differences only in 19 of 57 (33%) performance metrics. 8/19 (42%) were time-related metrics	
Sahakian AB *et al.* 26572779	Prospective cohort	ERCP Simulator group	Total time to complete the ERCP procedure	444.0 vs. 616.9, p = 0.026 for experts vs. Novices No difference experts vs. novices in difference of total procedure time between session 1 and 2 (-200.3 vs. -164.4; p = 0.402).	Small study size

Table 44s: ENDO Suite-GI Mentor.

Manufacturer	3D Systems, Littleton, Colorado, US
Class	Computerized (virtual reality)
Accessibility	International market
Country (production / use)	USA
Target	EGD, CS, ERCP, EUS, bleeding, EMR, ESD
Interventional modules	Yes
Validation literature	Yes
Material	Silicone/ 1 monitor / cart / Integrated keyboard
Ease of use	Easy
Web link	https://surgicalscience.com/simulators/gi-mentor/
Pro	Basic skills Advanced skills Force feedback
Cons	Cost

Table 45s Literature for Endosuite-GI mentor

Reference	Study design	Procedure/groups	Outcome assessed	Key findings	Comments
Ende *et al.* 22153875	RCT	Gastroscopy Clinical plus simulator training Clinical training only Simulator training only	Skills evaluation score Time (s) to pass pylorus	Median score: 7 vs 6 vs 5 (P = NS) 183 ± 65 vs 207 ± 61 vs 247 ± 66 (P = NS)	
Silva Mendes S *et al*. 36545187	Prospective cohort	EGD, Colonoscopy Simulator group Control group	Time (s) to reach duodenum Time to reach caecum	Time to D2 significantly lower (193 vs. 63 s; p < 0.001), efficiency of screening better (64 vs. 91%; p < 0.001); in colonoscopy, time to reach the cecum significantly lower (599 vs. 294 s; p = 0.001), the time patient in pain significantly lower (27 vs. 10%; p = 0.005), efficiency of screening had a tendency towards improvement (50 vs. 68%; p = 0.062)	
Ferlitsch *et al*. 20972956	RCT	Gastroscopy Simulator training before conventional training	Time (s) to reach duodenum Percentage of unaided examinations (after 10 endoscopies)	239 vs 310 (P < 0.000) 85% vs 72% (P < 0.01)	Small numbers of residents
Di Giulio *et al*. 15278044	RCT	Gastroscopy Simulator group Control group	EGDs no. 1-20 assessed for independent completion (benchmarks), need for assistance, time, and graded by a nonblinded expert	Complete procedures (87.8% vs. 70.0%; p < 0.0001), Less assistance (41.3% vs. 97.9%; p < 0.0001), "positive" performance (86.8% vs. 56.7%; p < 0.0001)	
Shirai *et al*. 18554236	RCT	Gastroscopy Simulator group Control group	Performance evaluation	Significantly higher score in the simulator group regarding insertion, passing the EGJ into	Small numbers of residents

				the antrum, passing through the pyloric ring, and examination of the duodenal bulb and the forn, total procedure time (14:40 [12:15 – 16:07] min vs 14:05 [13:30 – 16:00] min	
Cohen *et al*. 16923483	RCT	Colonoscopy Simulator group Control group	Competency after 100 cases Number of cases for reaching competency	Higher in group 1 (P < 0.0001) 160 in both groups (P = NS)	
Eversbusch A *et al*. 15791380	RCT	Colonoscopy Simulator group Control group	To analyse the learning curve Experienced surgeons (group 1, > 200 endoscopic procedures, (n = 8)) Residents (group 2, < 50 endoscopic procedures, (n = 10)), medical students (group 3, never GI endoscopy, (n = 10))	Learning curve for time expended reached a plateau after the second repetition for group 1 (Friedman's test, p < 0.05), after fifth repetition for group 2 (p < 0.05), and after seventh repetition for group 3 (p < 0.05)	Single-centre study, no formal sample size calculation
Morato R *et al*. 36545182	RCT	Colonoscopy Simulator group Control group	To analyse the impact of 3 virtual exercises in simulated colonoscopy skills	Cecum faster (278 vs. 356 s, p = 0.035) higher screening efficiency (83% vs. 75%, p = 0.019), longer to reach the cecum (241 vs. 292 s, p = 0.021) and higher percentage of time patient in pain (6% vs. 9%, p = 0.021)	
Matsuda K, *et al*. 16802228	RCT	EUS Simulator group Control group	The experience of each tool by eight EUS experts		Small numbers of trainees
Buzink SN *et al*. 17484004	Prospective cohort	Colonoscopy Simulator group Control group	Cecal intubation time, time patient in excessive pain	Novices progressed significantly, particularly in the time (p < 0.05), experts did not improve significantly, except in the percentage of time the patient was in excessive pain	Single-centre study, no formal sample size calculation

Koch *et al.* 25475901	Prospective cohort	Colonoscopy Simulator group Control group	Cecal intubation time, colonic insertion depth, and cecal intubation rate	Cecal intubation time 9.50 minutes vs. 2.20 minutes, P = .002 Colonic insertion depth 29.4 cm to 63.7 cm (P < .001)	Single-centre study, no formal sample size calculation
Van Sickle KR *et al*. 21487880	Prospective cohort	Colonoscopy Simulator group Control group	Mean number of trials to proficiency Cecal intubation time total time	Mean number of trials to proficiency 13 ± 10 vs. cecal intubation time (229 ± 97 vs. 150 ± 57 s; p <0.001), total time (454 ± 147 vs. 320 ± 115 s; p < 0.001	Small numbers of residents
Grantcharov TP *et al*. 15984697	Prospective cohort	All GI endoscopy Simulator group Control group	To analyse the learning curve Experienced (group 1, > 200 endoscopic procedures, (n = 8)) Residents (group 2, < 50 endoscopic procedures, (n = 10)), medical students (group 3, never GI endoscopy, (n = 10))	Differences in time (Kruskal-Wallis test, P<0.001), percentage of mucosa surface examined (P=0.001), efficiency of screening (P=0.001), time with a clear view (P=0.001), pain experienced (P=0.004), time with pain (P=0.012), loop formation (P<0.001), time with a loop (P<0.001), pressure (P=0.001)	Small numbers of residents
Fayez R *et al*. 19911225	Prospective cohort	Colonoscopy Evaluate metrics gastrointestinal endoscopists with varying clinical experience a novice group (<5 scope experiences, n = 12) and an experienced group (>50 scope experiences, n = 8)Simulator group Control group	Time taken to reach the cecum	(1.6 min; IQR, 1.2-1.9 min) versus novice group (3.2 min; IQR, 2.4-4 min) (p < 0.01) Efficiency (experienced group: 94%; IQR, 94-96% vs novice group: 88%, IQR, 69-92%) (p < 0.01) Module 3 (most difficult), reached the cecum faster (5.7 min; IQR, 3.6-6.6 min vs. 14 min; IQR, 9-16 min; p < 0.01), fewer occasions of lost view (0.5; IQR, 0-1 vs. 2; IQR, 2-3; p < 0.01), fewer episodes of excessive pressure (2; IQR, 1-2 vs. 4.5; IQR, 2.5-6; p < 0.01), greater overall efficiency (87%; IQR, 82-89% vs. 29%; IQR, 23-55%; p < 0.01).	
Kim S *et al.*	Prospective	EGD, colonoscopy	Time spent on the	52% vs 19% (P = 0.0011)	

20464425	cohort	experienced vs. novice	procedure	30 vs 40 (P = 0.037) 2.27 (95%CI: 1.14-4.76)	
Phitayakorn R *et al*. 18813977	Prospective cohort	Colonoscopy Simulator group	Time spent on the procedure	Total time the colon was looped was 22 +/- 35 s (range 0-133 s) Overall efficiency of screening was 70.33 +/- 23.45% (range 20-94%)	
Bittner JG *et al*. 19922914	Prospective cohort	ERCP Simulator group Control group	Times to complete the procedure, reach the papilla, use fluoroscopy; attempts to cannulate the papilla, pancreatic duct, common bile duct; number of contrast injections, complications	547 (164) vs. 330 (73) p=,.001 105 (67) vs. 61 (28) p=.048 2.27 (95%CI: 1.14-4.76)	Small sample size, single institution
Georgiou *et al*. 38125582	Prospective cohort	ERCP Simulator group Control group	Cannulation of the BD, correct diagnosis, sphincterotomy, and time to complete intervention	Time required to visualize the papilla and to cannulate deeply when removing the BD stone was significantly shorter for the experts (both p < 0.05). The time to visualize the papilla, cannulate deeply, reach a diagnosis, complete sphincterotomy, and complete the intervention was significantly shorter for experts when managing cystic leakage (all p < 0.05)	Few parameters of the intraprocedural procedure
Mahmood T, Darzi A. 15457382	Cohort study	26 postgraduate doctors who each perform 5 virtual colonoscopies on the simulator, acting as their own control. No structured feedback was given between	To investigate the learning curve for the HT Immersion Medical Colonoscopy Simulator without any structured feedback. Change in performance between virtual colonoscopies	There was no improvement in performance on the simulator from first attempt to the fifth in the absence of feedback. If there was any initial gain in any measurable outcome, this was lost in subsequent attempts indicating lack of learning. outcomes measured:	In the absence of feedback, it is not possible to improve performance on the HT Immersion Medical Colonoscopy Simulator. Independent of

		virtual colonoscopies		1. time taken to complete test 2. percentage of the mucosa visualized 3. depth of the instrument inserted, 4. path length used.	level of experience of the doctor Demonstrates importance of feedback. I question however whether 5 procedures is anywhere near enough to demonstrate a learning curve. Also does not answer whether feedback through the simulator could provide good learning
Mahmood T, Darzi A. 12915972	Cohort study	25 postgraduate doctors were recruited and divided into three groups according to their level of colonoscopy experience. Novice (10 colons) Intermediate (11-100 colons) Experienced (>100 colons) Candidates performed colonoscopy on module 3 or 4 (complex loops) A time result of 3,600 s (1 h) was	The performance of novice, intermediate, and experienced operators is different on simulators, just as it is on real patients.	The experienced group were shown to perform better than the intermediate group, which in turn performed better than the novice group. (P<0.000)1. 1. time taken to complete the test, 2.percentage of the colonic mucosa visualized, 3. incidence of colonic perforations, 4. path length used.	This study demonstrated that operators who differ in terms of their clinical experience and technical ability also differ in their performance of simulated colonoscopy. None of the study endoscopists sounded particularly experienced (>100 colons is

		used to denote perforation.			not experienced)
Sedlack RE, Kolars JC. 12114172	Process description	A tutorial and six cases of varying complexity Performance variables measured by the simulator 1. time to complete the procedure 2. the distance that the scope was advanced, 3. degree to which the mucosa was adequately visualized 4. possible complications such as colonic perforation, and the level of pain experienced by the simulated patient. Established ideal performance standards by measuring the above variables for ten "expert" faculty colonscopists who completed two cases Next, CBCS performance standards for five partially trained colonoscopists	To describe a process by which a CBCS curriculum and CBCS-based performance criteria were established for first-year gastroenterology fellows	The curriculum developed consisted of viewing a one-hour multimedia tutorial, describing the procedure and various colonoscopy techniques 9h of hands-on CBCS experience, during which time the trainee completes approximately 25 CBCS colonoscopies. Trainee must meet certain performance standards on specific CBCS cases before going onto live patient colonoscopy	Early validation work

		was measured Finally, two non-physician gastrointestinal assistants, without prior endoscopic training, were asked to practice on the simulator By calculating average performance standards within each of these three groups the number of CBCS cases and minimal performance standards for new trainees set			

Table 46s: Technical summary ViGaTu Immersive virtual reality endoscopy suite.

Manufacturer	Ulm University Open source project
Class	Virtual reality simulator
Accessibility	Open source
Country (production / use)	Germany
Target	CS
Interventional modules	Multiple
Validation literature	Limited
Material	VR
Ease of use	Unclear
Web link	GitHub - virtual-gastro-tutor/vigatu
Pro	Huge potential with massive flexibility. Unique in simulating the whole endoscopy suite set up.
Cons	Difficult to see how colonoscopy can be learnt without an endoscope controller. The room dynamics might be simulated easier and cheaper through roleplay.

Table 47s: Literature for ViGaTu Immersive virtual reality endoscopy suite.

Reference	Study design	Procedure/groups	Outcome assessed	Key findings	Comments
Henniger D *et al*. 38944875	Prospective multicentre single-arm study	43 nurses and 28 physicians taking part in VR training	To assess the face, content, and construct validity of the ViGaTu (Virtual Gastro Tutor) immersive virtual reality (VR) simulator in teaching Peri-interventional tasks checking patient data filling out forms patient monitoring performing sedation	75% of the items for assessing face validity were rated as realistic and 60% of items assessing content validity and usefulness were rated as useful Experienced endoscopy staff were significantly faster than beginners in setting up the endoscope tower suggesting construct validity	This is a simulator designed to model the entire endoscopy department process rather than just the procedure itself

Table 48s: Technical summary for Endosim Simulator.

Manufacturer	Surgical Science Sweden
Class	Virtual reality simulator
Accessibility	International
Country (production / use)	Sweden
Target	EGD, CS, ERCP
Interventional modules	Multiple
Validation literature	Limited
Material	VR
Ease of use	Easy
Web link	https://surgicalscience.com/simulators/endosim/
Pro	Multiple modules for upper and lower GI and ERCP Haptic feedback Potential for future software updates
Cons	Limited evidence of value or benefit

Table 49s: Technical summary for Endovision Standard.

Manufacturer	MedVision, Tokyo, Japan
Class	Virtual reality simulator
Accessibility	International
Country (production / use)	Japan
Target	EGD, CS, bronchoscopy
Interventional modules	Multiple
Validation literature	Limited
Material	VR
Ease of use	Easy
Web link	https://www.medvisiongroup.com/endovision.html
Pro	Multiple modules for upper and lower GI and bronchoscopy Haptic feedback Broad range of diagnostic and therapeutic procedures Potential for future software updates
Cons	Limited evidence of value or benefit

Table 50s: Technical summary for CLA 4/5 -5/4 simulator.

Manufacturer	Coburger Lehrmittelanstalt, CLA, Coburg
Class	Virtual reality
Accessibility	International
Country (production / use)	Germany
Target	EGDS, CS and bronchoscopy
Interventional modules	Multiple
Validation literature	No
Material	VR
Ease of use	Unclear
Web link	NA
Pro	Multiple modules
Cons	Limited evidence of value or benefit

Table 51s: Technical summary of Hot Axios Synthetic Trainer.

MANUFACTURER	Version3D /NL in close collaboration with Boston Scientific
CLASS	Mechanical
ACCESSIBILITY	Europe
COUNTRY (Production/Use)	Europe
TARGET	Hot Axios LAMS indications
INTERVENTIONAL MODULES	Module for Collection & Lumen. BD module with feedback function (Red light)
VALIDATION LITERATURE	None
MATERIAL	3D printed plastic
Ease of use	Easy
WEB LINK	https://version3d.com/
PRO	Simulating Basic & Advanced Hot Axios steps without capital equipment. Very Effective. Easy to set up and use. BD module with feedback function
CONS	Simple model. Not anatomical correct. Only simulating the technical steps of placing a Hot Axios

Table 52s: Technical summary of Hot Axios Artificial Trainer.

MANUFACTURER	Version3D /NL in close collaboration with Boston Scientific
CLASS	Mechanical
ACCESSIBILITY	Europe
COUNTRY (Production/Use)	Europe
TARGET	Hot Axios LAMS indications
INTERVENTIONAL MODULES	Work in progress: Module for drainage of PFC/ GB / BD
VALIDATION LITERATURE	None
MATERIAL	3D printed modules with artificial skin plates
Ease of use	Easy
WEB LINK	https://version3d.com/
PRO	EUS guided simulator for both Basic & Advanced skills placing Hot Axios. All Hot Axios indications.
CONS	Simple model. Not anatomical correct. Only simulating the technical steps of placing a Hot Axios.

Table 53s: Technical summary of CholangioBox.

MANUFACTURER	Version3D /NL in close collaboration with Boston Scientific
CLASS	Mechanical
ACCESSIBILITY	Europe
COUNTRY (Production/Use)	Europe
TARGET	Cholangioscopy therapy
INTERVENTIONAL MODULES	Silicone ducts Module
VALIDATION LITERATURE	None
MATERIAL	Silicone
Ease of use	Easy
WEB LINK	https://version3d.com/
PRO	Easy but effective Basic trainer for Spyglass SOC instruments. Training the use of EHL, Biopsy, Basket and snare usage. No ERCP scope needed only Spyglass SOC.
CONS	Not anatomical correct. No use of ERCP scope handling possible.

Table 54s: Technical summary of Pentax C2 Cryoballoon Simulator.

MANUFACTURER	Lazarus 3D, Inc.
CLASS	Mechanical
ACCESSIBILITY	Global
COUNTRY (Production/Use)	USA
TARGET	Gastroscopy: Barrett's oesophagus
INTERVENTIONAL MODULES	Cryo ablation
VALIDATION LITERATURE	None
MATERIAL	Silicone, Thermochromic pigments
Ease of use	Easy
WEB LINK	https://www.lazarus3d.com/skill-sure
PRO	Easy to use. Reversibly changes colour in response to cryoablation (temp < -10C). Heating element keeps model at physiological temperatures. Reusable and affordable.
CONS	Only one scenario. Must be plugged into an outlet. Does not simulate mouth/larynx

Table 55s: Technical summary of Endocubot.

MANUFACTURER	Endorobotics Co. Ltd
CLASS	Virtual and Mechanical
ACCESSIBILITY	Awaiting CE, KC, FCC approval
COUNTRY (Production/Use)	Republic of Korea
TARGET	EGD and Colonoscopy
INTERVENTIONAL MODULES	Gastro module: antrum, cardia, middle body Colon module: rectum transverse and descending colon Interventional EGD and Colonoscopy (EMR, ESD, Suturing)
VALIDATION LITERATURE	None
MATERIAL	Plastic, metal parts Phantom tissue from KOTOBUKI Medical (Japan)
Ease of use	Easy
WEB LINK	https://www.endorobo.com/product/endocubot.php
PRO	Capable of simulating the inflation and deflation features of endoscope Providing a lifelike environment with features simulating respiration and random events such as gagging and sneezing Selectable lesion location in both the stomach and colon via Touchscreen based interface Wireless battery-powered device with at least 4 hours of operation
CONS	Not yet oesophagus module available Need for an endoscope Large and heavy simulator (660 mm wide and 18 kg resp.)

Table 56s: Technical summary for Frimberger Simulators.

NAME OF THE SIMULATOR	Frimberger Simulator
MANUFACTURER	Dr. Frimberger
CLASS	Mechanical
ACCESSIBILITY	Not available
COUNTRY (Production/Use)	Germany
TARGET	CSPY, ERCP
INTERVENTIONAL MODULES	Yes
VALIDATION LITERATURE	No
MATERIAL	Not clear
Ease of use	Easy
WEB LINK	NA
PRO	Multiple modules for basic and advanced procedures, Many scenarios
CONS	Lack of evidence