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Simulation-Based Mastery Learning in Gastrointestinal Endoscopy Training

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Abstract

Simulation-based mastery learning (SBML) is an emerging form of competency-based training that has been proposed as the next standard method for procedural task training, including that in gastrointestinal endoscopy. Current basic gastrointestinal endoscopy training relies on the number of procedures performed, and it has been criticized for its lack of objective standards that result in variable skills among trainees and its association with patient safety risk. Thus, incorporating simulators into a competency-based curriculum seems ideal for gastrointestinal endoscopy training. The curriculum for SBML in gastrointestinal endoscopy is currently being developed and has promising potential to translate into the clinical performance. Unlike the present apprenticeship model of "see one, do one, teach one," SBML integrates a competency-based curriculum with specific learning objectives alongside simulation-based training. This allows trainees to practice essential skills repeatedly, receive feedback from experts, and gradually develop their abilities to achieve mastery. Additionally, trainees and trainers need to understand the learning targets of the program so that trainees can focus their learning on the necessary skills and trainers can provide structured feedback based on the expected outcomes. In addition to learning targets, an assessment plan is essential to provide trainees with future directions for their improvement and ensure patient safety by issuing a passing standard. Finally, the SBML program should be planned and managed by a specific team and conducted within a developed and tested curriculum. This review aims to discuss the current state of gastrointestinal endoscopy training and the role of SBML in that field.

Key Words: Simulation training; Education; Endoscopy; Mastery learning; Competency-based education; Curriculum

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Core Tip: The traditional apprenticeship model for gastrointestinal training has been widely criticized for its lack of standards and patient safety risks. Thus, the basic gastrointestinal endoscopy training method needs to be revised from the apprenticeship model to a simulation-based mastery learning (SBML) model, which relies on specific learning objectives with the integration of simulators. SBML is a competency-based training method aimed at creating highly competent trainees and reducing differences in skills among them. The present review discusses the current state of gastrointestinal endoscopy training, the role of SBML in that field, and recent experiences and future prospects of SBML.

INTRODUCTION

Endoscopy is the gold standard technique for the diagnosis of various gastrointestinal tract diseases and also allows examiners to directly provide therapeutic interventions if needed. This procedure is performed by a trained gastroenterologist or endoscopic surgeon. The need for endoscopic procedures is projected to increase every year owing to the growing prevalence of gastrointestinal diseases and technical improvements in gastrointestinal endoscopy[1]. Most gastrointestinal endoscopy training still follows the traditional apprenticeship model of "see one, do one, teach one." This model relies on the number of exposures to procedural caseloads, which causes varying results among trainees[2]. This lack of a standardized curriculum has recently come under intense scrutiny because it is associated with patient safety risks, as trainees cannot safely perform a medical procedure after having observed it only once[3].

A mastery learning model is an approach to competency-based training, in which participants must acquire specific skills before moving on to the next stage of training. The basic principle of mastery learning is that all participants can achieve the highest standard of learning objectives with the minimum possible variation in results. Meta-analysis results show that mastery learning significantly leads to skill improvement, has a moderate effect on patient outcomes compared to the traditional apprenticeship

method, but might demands more time than other methods. Mastery learning-based training provides consistent positive results and has a beneficial effect on both patient care and the budget spent during the training process[4].

A simulation-based training (SBT) method has been also proposed as an alternative to replace the old teaching method. The use of simulators to acquire psychomotor abilities has been widely studied and recommended by leading educational institutions. With a SBT method, trainees can achieve procedural competence without compromising patient safety, particularly in those procedures that require practical experience and visual-spatial skills[5]. Additionally, skills of the operator can be improved and the length of the procedure reduced by using a simulator. Finally, simulators can also be used to evaluate trainee progress[6].

SBT and mastery learning methods have several benefits over the traditional apprenticeship model. This article reviews the role of simulation-based mastery learning (SBML) in gastrointestinal endoscopy and describes the planning and management for the implementation of this model, including experiences regarding its application.

DEVELOPMENT OF GASTROINTESTINAL ENDOSCOPY TRAINING

Since 1962, the American Society for Gastrointestinal Endoscopy has held symposiums about teaching methods in gastrointestinal endoscopy and has later formed a formal endoscopy training program. Along with the development of science and the advancement in the complexity of endoscopic procedures, gastroenterological education began to be developed independently as part of a subspecialty of internal medicine[4]. The development of specific training in endoscopy and gastroenterology also impacted on the education period for this field, which initially consisted of one-two years and then was extended to three years[4]. Currently, there is no global standardization of the gastroenterology education length. Some countries, such as the Netherlands, are now expanding their gastroenterology curriculum to three-four years, starting it with two years of general internal medicine training[7,8]. In Korea, endoscopy

training is conducted for one-two years during a gastroenterology fellowship program[9]. Meanwhile, in Japan, a physician must complete three years of internal medicine residency and five years of gastroenterology fellowship to become a board-certified endoscopist[10]. The World Gastroenterology Organization states that a student must complete three years of internal medicine residency before pursuing gastroenterological-specific education and training for the next three years[11].

The current state of endoscopy training is defined by the conventional apprenticeship model, with a strong emphasis on case/procedure volume and without a formal curriculum. Trainees usually are assigned the minimum number of cases or procedures they need to achieve competency or practical eligibility. The duration of the training program is commonly fixed, and an assessment is conducted near the end of the program. This training method has potential variability in terms of skill outcomes. As trainees might be overwhelmed at the start of the program, the initial cases they encounter can be ineffective for learning. A European survey showed significant differences in various gastroenterology training among 16 European countries, ranging from the minimum number of procedures required, training period, form of supervision to whether some interventional procedures were performed [12]. Recently, curriculum-based medical education (CBME) has recently been proposed to improve endoscopy training. CBME model includes The American Society of Gastrointestinal Endoscopy STAR (Skills, Training, Assessment, and Reinforcement) program with a curriculum that combines hands-on training, formative feedback, and post-course skills and knowledge assessments[13].

One of the learning methods that has been developed for endoscopy training is the simulated-based approach. Endoscopy simulator models have continued to be developed and advanced in the last decades, ranging from mechanical simulators, animal model simulations, and computer simulators [14]. The evolutions of endoscopy simulators are described in table 1. These developments provide opportunities for trainees to learn various diagnostic and therapeutic techniques. Generally, these simulators use an endoscope that is inserted into a mannequin. Consequently, trainees

can be more familiar with endoscopic procedures and be able to practice them on an actual patient. Some advanced computer simulators also provide a realistic picture on the monitor and can simulate a patient's response. The computer simulator also combines training to learn hand-eye coordination, recognition of pathological features, and immediate feedback output[15]. A systematic review showed that skills acquired from SBT were transferable to the clinical setting, as participants of SBT scored higher global assessment scores and fewer errors [16]. Moreover, forms of simulation that can be considered in endoscopy training include [17,18]:

Patient simulation: A simulated mannequin that resembles a human with respiration, pulse, and other vital signs is used. This type of simulation can be used for simple physical-examination scenarios.

Clinical environment simulation: In this simulation, a room that resembles an actual clinical practice room, for example, an operating room, is prepared. Thus, trainees become more familiar with the actual situation.

Virtual procedure simulation: These simulations have equipment relevant to the procedure, such as esophagogastroduodenoscopy or colonoscopy, and can also present various disease scenarios according to the needs of trainees.

Electronic medical record simulation: This simulation uses artificial data about cases, including disease history and laboratory results, which can be integrated with other systems.

MASTERY LEARNING IN GASTROINTESTINAL ENDOSCOPY

Mastery learning is a form of competency-based training in which trainees have to achieve specific skills or be deemed good enough to perform a procedure before moving on to the next stage of training. Competence is the minimum level of skill, knowledge, or expertise acquired through training necessary to perform a task or procedure and to ensure that safe and technically successful procedures are carried out and that observations and results are accurate[25,26]. Mastery learning focused on the trainees instead of the patient. The old teaching has resulted in inconsistent teaching,

testing, and retention of skills; while mastery learning demands trainees to acquire and maintain specific skills and knowledge through deliberate practice without time limit. Deliberate practice consists of nine elements: highly motivated learners with good concentration, clear learning objectives, an appropriate difficulty level, repetitive practice, rigorous measurements, informative feedback, monitoring and error correction, performance evaluation, and advancement to the next task[27]. Mastery learning effectively developed both the therapeutic skill and high self-efficacy to utilize the skill [28].

Mastery of basic endoscopic techniques is essential for every endoscopist, because if the procedure is performed incorrectly, it can cause severe complications that might threaten the condition of patients. The essential steps of endoscopy are endoscope insertion, precise observation, and appropriate imaging[29]. Skills developed by each endoscopist may vary and are influenced by differences among supervisors during the procedure. Hence, standardized training is necessary to maintain the competence of trainees[30].

Traditionally, competence in endoscopy is acquired after completing a specific number of recommended procedures based on expert opinions published by medical gastroenterology societies or associations, as described in Table 2. However, according to the aforementioned mastery learning principles, competence cannot be determined only by the number of procedures performed. A defined and detailed assessment tool should be incorporated to objectively assess trainees to deliver high-quality care [31].

To ensure competence in mastery learning, two aspects are needed: training and subsequent assessment by endoscopy experts or trainers. Through this training, trainees acquire the necessary technical and cognitive skills[25]. Examples of technical and psychomotor skills associated with endoscopy include scope handling and strategies for scope advancement, loop reduction, recall, and mucosal inspection. Cognitive competence reflects knowledge acquired about endoscopy and its application in clinical practice. Cognitive skills include choosing the most appropriate endoscopy test to assess and treat clinical problems, recognizing the lesion, and managing sedation.

Crucial integrative competencies to endoscopy include decision-making, teamwork, communication, leadership, awareness of the situation, professionalism, and patient safety awareness[26].

Based on the psychological aspect, three factors underlie mastery learning: behavioral development, constructive learning, and social cognition. Behavioral development pursues the acquisition and maintenance of technical and communication skills. Clinical thinking, community approach, ethics, advocacy, and regular self-reflection aim to shape social and cognitive constructs. Social cognition is a prerequisite for professionalism. These three aspects support the formation of SBML, which includes a curriculum design to set learning objectives[37].

SIMULATION-BASED TRAINING IN GASTROINTESTINAL ENDOSCOPY

The SBML method uses an instructional approach, meaning that trainees must have a certain level of competence in a simulated environment before performing procedures on actual patients[24]. With this method, trainees progress through different simulations with increasing difficulty. SBML provides opportunities for students to practice as often as possible to improve their performance before operating on patients. This method can optimize clinical outcomes and reduce the risk of complications or other hazards for patients that may occur during the operation period of a novice endoscopist[17,38]. In addition, SBML can minimize variations between trainees upon completion of the program[24,39].

Several studies in other fields of medical procedural training have shown the benefits of SBT and mastery learning over the traditional apprenticeship model. A meta-analysis by Harrison *et al* included 14 studies involving 633 trainees in cardiology procedures and found that SBT followed by structured training provided superior results than traditional methods. The quality of patient care and patient feedback obtained by this method were better than those obtained by a conventional training approach[40]. A meta-analysis by Cook *et al* included 82 studies evaluating SBML in procedural settings such as surgeries and airway management. They found that SBML was significantly

better at improving procedural skills than traditional methods but might takes more time[41]. A systematic review on patient outcomes in simulation based medical education also reported small-moderate patient benefits in comparison with no intervention [38]. A study published in 2014 revealed the effectiveness of colonoscopy training with virtual simulation in the early learning curve of novices. Performance improvements were also found later during patient-based colonoscopy [42]. Another multicenter study found higher objective competency rates during the early phase of colonoscopy training [43].

A prospective randomized study that evaluated the diagnostic abilities of trainees using upper gastrointestinal endoscopy concluded that structured SBT was superior to SBT or clinical training alone. This study also found that the use of the simulator was valuable as the first step in developing diagnostic skills to perform upper gastrointestinal endoscopy, but it was not sufficient to ensure the overall competencies[30]. Several reports on SBT for gastrointestinal endoscopy are described in Table 3.

Generally, studies on SBT in gastrointestinal endoscopy training showed favorable results, especially in the early phase of training, as it reduces the time required to reach technical competence and the number of endoscopic procedures needed to perform it independently. With SBT, trainees can perform the procedures and exercises repeatedly using a simulator. This repetition improves the cognitive and practical skills of students and allows them to become more acquainted with endoscopic features and settings. A meta-analysis showed that simulation can increase patient safety and decrease the risk of adverse events, as trainees are more skilled and familiarized with the clinical settings at the moment of performing the endoscopy [49]It also provides an opportunity for trainees to learn at their own pace [54]

However, some systematic reviews have reported inconclusive evidence supporting SBT as a replacement for conventional training. SBT might be more beneficial as a supplement to conventional training, especially in the early phase. Nevertheless, reducing patient-based training in favor of SBT is not recommended as it cannot replace conventional patient-based training[48,51,52]. Hence, simulation must be accompanied by

direct clinical experience with patients in order to understand the actual clinical setting[39]. A study conducted in 2004 found that simulation without feedback from experts did not improve the skills of trainees. Providing trainees access to a simulator cannot guarantee appropriate learning by itself. Therefore, SBT should be delivered purposefully within a developed curriculum to allow trainees to practice essential skills, receive feedback from experts, and develop skills gradually and appropriately to achieve mastery[55]. Feedback and debriefing are essential in SBT to allow trainees identify their weakness and improve their performance accordingly [56]. Simulation with a proper environment or scenario is also beneficial to the improvement of endoscopic non-technical skills, such as communication and teamwork, situation awareness, leadership, judgment, and decision-making[57]. A previous study showed that integrating endoscopic non-technical skills training improved novice trainees' performance and competency, which might benefit patients[58].

EXPERIENCES IN SIMULATION-BASED MASTERY LEARNING FOR ENDOSCOPY TRAINING

Several studies have showed endoscopy mastery learning experiences. Nguyen-Vu *et al* reported a two-week course for gastroenterology fellows at the University of California with no prior experience in endoscopy. They divided the learning period into two phases: the first week for learning the basics of endoscopy and the second week for learning various therapies in endoscopy. These phases were further divided into specific endoscopic skills such as endoscopic tip control, image documentation, biopsy, and clip administration. Trainees were assigned readings and underwent online assessments before attending hands-on training with a simulator. They had to pass the competency assessment for a specific skill before moving on to the next topic. This study showed that the SBML program could rapidly help trainees acquire endoscopic skills through a comprehensive curriculum. Online reading and assessments enabled trainees to learn at their own pace, and using a simulator provided them with a chance

to engage in repetitive practice. Dividing endoscopic skills also allowed trainees to focus on the specific skills they needed to refine[59].

Ritter *et al* reported an endoscopy training system (ETS) using an SBML curriculum implemented with general surgery residents to pass the Fundamentals of Endoscopic Surgery (FES) skills examination. They divided ETS into five tasks which were organized in two tabletop units. The first unit included scope manipulation, tool targeting, and retroflexion tasks using a simple endoscopic tool. The second unit consisted of loop management and mucosal inspection tasks using a stylized body form. Most participants completed this simulation-based curriculum in less than a week with more than 90 minutes of practice per day. This study suggested that the application of the SBML curriculum to flexible endoscopes provides significantly improved results on post-training assessments compared with pre-training assessments. This study also found that after five sessions of SBT, participants could produce post-test scores equivalent to those of doctors who had performed 150–300 endoscopy procedures. This result implies that vast clinical experience is not needed to participate in the SBML program [60]. The ETS was further developed by setting the training standards for the SBML curriculum, resulting in attainable standards that improved FES scores in the skills exam[61]. Another subsequent study published in 2021 evaluated the effect of SBML curriculum implementation early in residency. It revealed that early implementation of SBML curriculum for flexible endoscopy training resulted in comparable performance to those with high level of clinical endoscopic experience [62].

Soetikno *et al* developed a 6-week SBML program for first-year gastroenterology fellows of the Philippine Society of Digestive Endoscopy. SBML involved learning fine-tip control, structured upper endoscopy examination, and endoscopic therapies. Basic knowledge and interpretation of endoscopy findings were learned simultaneously. Interestingly, the first five weeks of the program were conducted remotely using virtual coaching. Trainees used simulators and recorded their own performance, number of attempts, and completion time for each attempt, and then supervisors provided

feedback based on these attempts. During the last week, trainees underwent in-person endoscopic therapy training after having passed the standard for fine-tip control and structured upper endoscopy examination. This study found that the adoption rates for basic endoscopic techniques, such as image documentation and biopsy, were 93% and 100%, respectively, after two-month of training. Meanwhile, the adoption rates of endoscopic therapies, as clipping, band ligation, or injection, were more variable (7–79%)[63]. Soetikno *et al* also conducted an SBML course in gastrointestinal bleeding endoscopic therapy and found that SBML quickly disseminated technical knowledge and skills. They proposed SBML as an additional method for teaching before trainees performed the procedure on patients[64].

PLANNING AND MANAGEMENT OF SIMULATION-BASED MASTERY LEARNING IN GASTROINTESTINAL ENDOSCOPY

As stated above, the SBML program requires a developed and tested curriculum to ensure that all trainees can achieve competence in endoscopy. Kern *et al* constructed a six-step approach to build an SBML curriculum. The steps are problem identification and general need assessment, specific need assessment, targets and objectives, educational strategies, implementation, and evaluation and feedback [65]. Hospitals and medical institutions should delegate a specific team to plan the SBML curriculum. After planning, a pilot study should be conducted to evaluate satisfaction of trainees with the program and patient outcomes. Once SBML has been implemented, continuous monitoring and evaluation should be performed to maintain the quality of the program[37].

SBML begins with an initial assessment of the knowledge and abilities of trainees. After training, students will be tested again, and training will continue until they meet the minimum passing standards. Once trainees meet the minimum passing standards, they can advance to the next stage of training (Figure 1). Periodic examinations will be conducted along with the planned practices to ensure expected competencies are maintained[37]. Some training centers might provide materials for self-learning before

the simulation starts to improve the initial knowledge of trainees. A study by Cheung *et al* showed that preparation before SBML is substantial to improve the effectiveness of SBML. They found that web-based observational practice is superior to reading materials alone, as it increases learner engagement with instructional materials [66].

Learning targets should be determined from the beginning of the SBML program and arranged according to the SMART acronym: (1) specific, (2) measurable, (3) attainable, (4) relevant, and (5) time-bound[59,60]. Trainees, trainers, and supervisors have to understand learning targets before starting the program. This understanding is beneficial because trainees can focus their learning on the important and necessary skills, and trainers and supervisors can provide structured feedback. Feedback is important in SBML and should be delivered in a specific manner: with only one or two important points at a time and preferably immediately after the procedure or simulation to be properly understood by trainees[67,68]. Feedback should also be constructive and not vague, allowing trainees to self-reflect and come up with potential solutions [31].

In addition to training or lesson planning, an assessment plan is needed to create a training environment with maximum results. Assessment is vital to provide trainees with future directions for improvement and to ensure patient safety by issuing a passing standard[69]. At the beginning of mastery learning, a pre-test has to be conducted to evaluate the initial knowledge of trainees [67]. Within the program, assessments are classified as formative or summative assessments. Formative assessment aims to direct training and to support the self-reflection and intrinsic motivation of trainees[70]. Meanwhile, summative assessment seeks to evaluate competency and practice eligibility[71]. There are five criteria to indicate the quality of an assessment: reliability, which shows the accuracy and reproducibility of a test; validity, which shows whether the test can be performed to evaluate the intended focused parameter; future impact of the assessment; acceptability by trainees and supervisors; and reasonable cost. Assessments can be conducted through written examinations,

direct evaluations by clinical supervisors, direct observations, clinical simulations, or portfolios[69].

THE FUTURE OF SIMULATION-BASED MASTERY LEARNING IN GASTROINTESTINAL ENDOSCOPY

It is reasonable and expected that novice endoscopists do not perform endoscopic procedures on human patients unless they have shown satisfactory skills on a simulator. Endoscopy training should move from the traditional apprenticeship model to objective competency-based mastery learning, integrating simulators, deliberate practice, and prompt feedback from supervisors. The SBML curriculum is acknowledged as a method to boost the efficiency and efficacy of endoscopy training through repetitive practice and expert feedback, which allow trainees to learn the basic structure of endoscopic techniques. One of the limitations of the traditional apprenticeship model is the reduced time for questions, feedback, and adequate skill assessment during a procedure on an actual patient, which results in self-learning; thus, not all trainees might develop a proper form and technique. Incorporating simulators can reduce this limitation of the conventional apprenticeship model by allowing trainees to practice basic endoscopic maneuvers repeatedly, as each trainee has a different absorption rate. In fact, acquiring proper techniques is essential for trainees, as they can progress to the next stage of training which is more complex. Simulators also limit the possibility of patient discomfort and injury, thereby allowing trainees to improve their skills. Additionally, the standardization of simulator-based instruction methods is essential to maximize the positive impact of the training method[8]. The integration of simulator in endoscopy training should be within a structured curriculum that combines constructive feedback and complementary knowledge [72]. Previous randomized trial compared the outcome of structured comprehensive curriculum to progressive learning-based curriculum, and revealed that those who received SBT that progressed in complexity and difficulty had superior technical and communication skills and global performance in the simulated setting[73].

A proper SBML curriculum for gastrointestinal endoscopy should subsequently consist of cognitive, technical, and integrative skill training. The COVID- 19 pandemic has accelerated the acceptance of online video/web-based learning, video mentoring, and video proctoring. Web-based learning in the form of online modules is now expected for cognitive skill training, which allows trainees to review learning modules at their own pace and to avoid cognitive overload due to a stressful environment[59]. The main drawbacks of simulation-based learning are model realism and less real-world experience for new endoscopists. Hence, hybrid learning that combines simulator-based and one-on-one training is ideal for building the learning curves of trainees and identifying their deficiencies[74]. Improved performance in simulator training has been shown to translate into the clinical area[60].

CONCLUSION

The traditional apprenticeship model in gastrointestinal endoscopy training must be revised to ensure competency and practical eligibility of novice endoscopists. By moving the focus from a case volume-based to a competency-based training, mastery learning can help lower the variability between skills of trainees and provide optimal results. Previous experiences with the SBML program in endoscopy training showed promising results and positioned that method as an additional course to be incorporated before the apprenticeship is started and also as a complementary course to one-on-one training. The use of a simulator in SBML can help trainees become acquainted with the endoscopic equipment, settings, and situations that might arise during their direct practice on patients. The SBML program should be planned and managed by a specific team and conducted within a developed and tested curriculum.

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