Procedural skills education – colonoscopy as a model

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M Raman, T Donnon. Procedural skills education – colonoscopy as a model. Can J Gastroenterol 2008;22(9):767-770.

Traditionally, surgical and procedural apprenticeship has been an assumed activity of students, without a formal educational context. With increasing barriers to patient and operating room access such as shorter work week hours for residents, and operating room and endoscopy time at a premium, alternate strategies to maximizing procedural skill development are being considered. Recently, the traditional surgical apprenticeship model has been challenged, with greater emphasis on the need for surgical and procedural skills training to be more transparent and for alternatives to patient-based training to be considered. Colonoscopy performance is a complex psychomotor skill requiring practioners to integrate multiple sensory inputs, and involves higher cortical centres for optimal performance. Colonoscopy skills involve mastery in the cognitive, technical and process domains. In the present review, we propose a model for teaching colonoscopy to the novice trainee based on educational theory.

Key Words: *Colonoscopy; Education; Procedural skills*

Enseignement des techniques : La colonoscopie comme modèle

De tout temps, l'apprentissage des techniques, chirurgicales et autres, a été une formation qui allait de soi pour les étudiants en dehors d'un contexte didactique formel. Compte tenu des obstacles croissants qui réduisent l'accessibilité aux patients et aux blocs opératoires, par exemple, la réduction des heures de travail hebdomadaires des résidents ou l'accès limité aux blocs opératoires et au temps d'endoscopie, d'autres stratégies sont à l'étude pour maximiser l'apprentissage des habiletés interventionnelles.
Récemment, le modèle classique de l'enseignement de la chirurgie a été remis en question puisque l'on met de plus en plus l'accent sur la nécessité de rendre l'enseignement des techniques chirurgicales et interventionnelles plus transparent et de trouver des solutions de rechange à la formation au chevet des patients. La technique de la colonoscopie est une procédure psychomotrice complexe qui demande au praticien de tenir compte simultanément de plusieurs stimuli et données de nature sensorielle et qui sollicite les centres corticaux élevés pour l'obtention d'un rendement optimal. La colonoscopie exige une maîtrise sur les plans cognitif, technique et interventionnel. Dans le présent article, nous proposons un modèle d'enseignement de la colonoscopie aux stagiaires novices basé sur la théorie didactique.

Traditionally, surgical and procedural apprenticeship has been an assumed activity of students, without a formal educational context, following the old adage hinging on 'seeing one, doing one and teaching one'. Sheer volume of exposure to surgical and procedural caseload has represented the cornerstone of surgical training as opposed to any formally constructed curriculum for the impartment of motor skills grounded in educational theory. With increasing barriers to patient and operating room access such as shorter work week hours for residents, and with operating room and endoscopy time at a premium, alternate strategies to maximize procedural skills development are being considered.

Recently, the ability to perform procedural skills has moved out of the exclusive hands of surgeons, and is now in the domain of most medical disciplines. Despite this, dedication to understanding the psychomotor domain, and instituting educational directives and strategies addressing procedural skills have remained minimal across disciplines.

Traditionally, over their years of training, the resident physician encountered a wide range of medical and surgical presentations, gradually accumulating knowledge and skill for independent practice. Recently, the traditional surgical apprenticeship model has been challenged, with greater emphasis on the need for surgical training to be more transparent and for alternatives to patient-based training to be considered (1). The present paper provides an overview of the learning theories that exist for teaching psychomotor skills, and describes a model grounded in theory for the instruction of colonoscopy skills.

PSYCHOMOTOR DOMAIN

Three stages of motor skills acquisition have previously been described (2,3). These include cognition, integration and automation. The process of cognition refers to the ability to understand a task. In this phase, the learner is provided with an explanation regarding the theory of the skill and observes the skill performed by experts. The learner may perform segments of the skill in an erratic manner with distinct steps. For example, during the cognitive phase of colonoscopy performance, the trainee should be familiar with the basic functions of the scope, in addition to the anatomy of the large intestine. The learner should be intellectually familiar with concepts such as looping and paradoxical scope movement, and should be able to theoretically describe how to counteract these obstacles, such as the application of pressure and reducing the length of the bowel. During this phase of colonoscopy performance, trainees may withdraw the scope from the cecum or attempt to make their way through the sigmoid colon. During the phase of integration, the learner should be able to comprehend and perform the mechanics of the skill, with deliberate practice and feedback provided. The skill becomes more fluid, with fewer interruptions. In the integrative phase of colonoscopy education, the learner should be able to navigate through the straight sections of the colon, and perhaps a relatively simple procedure. However, learners may need constant verbal feedback through the procedure and may need assistance with flexures. Finally, during the automation phase, the learner should be able to perform the task with speed, efficiency and

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Received for publication May 25, 2008. Accepted May 26, 2008

precision. The skill undertaken should require minimal cognitive input, with the focus directed toward refining performance. The skill at this point should become fluid, continuous and adaptive.

Based on the phases of motor skills development outlined above, various taxonomies for hierarchical psychomotor learning have been described in the literature. These include Simpson's (4) and Harrow's (5) taxonomies. For the purpose of the present review, we will focus on Simpson's taxonomy.

Simpson's taxonomy

Similar to Bloom's taxonomy (6) reflecting learning in a hierarchical framework with respect to cognitive skills, Simpson's taxonomy is referred to in the literature on psychomotor learning (5,6). The seven steps of this hierarchical learning model include perception, set, guided response, mechanism, complex overt response, adaption and originating. 'Perception' refers to the initial step of learning a motor skill and requires an awareness of the need to perform any given motor skill, usually in the form of sensory stimulation. 'Set' refers to the state of readiness, reflecting knowledge of the necessary steps required to perform a procedure, and knowledge of the tools required to perform the procedure. In the case of colonoscopy, 'set' may refer to gaining familiarity with the colonoscope, anticipating possible pathological findings and reviewing contraindications to the procedure. 'Guided response' refers to the actual performance of the motor skill under the guidance of an instructor, with deliberate instruction and feedback provided by the teacher to the learner during performance of the skill. 'Mechanism' is a stage during which the motor skill has become a habit or routine. 'Complex overt response' assumes adequate proficiency in the above steps, in addition to possessing the ability to perform a motor skill quickly and efficiently, with minimal patient discomfort. Referring to learning colonoscopy, 'complex overt response' refers to the ability to reach the cecum in a minimal amount of time, with minimum patient discomfort and minimal complications.

'Adaption' involves the ability to modify the motor skill to meet the needs of different problems. For example, in a complicated or difficult colonoscopy, such as in a patient with previous abdominal surgery and with the presence of adhesions causing increasing patient discomfort and looping of the bowel, the 'adaption' stage would involve the ability to perform manoeuvres such as repositioning the patient, applying abdominal pressure, reducing the length of the bowel and considering using a pediatric scope among other techniques to successfully achieve the desired goal of completing the colonoscopy. The final stage, 'originating', is seldom achieved, and refers to the stage when new procedural skills are designed. Simpson's taxonomy for learning procedural skills in part arises from educational learning theories. Some of the concepts of educational learning theory are described next.

LEARNING THEORIES

Common misbeliefs about learning include that everyone has a desire to learn, people learn in similar ways and at the same rate, knowledge lasts forever once learned, and individuals all have the ability to integrate knowledge. Unfortunately, although the above traits would make teaching and learning, as a whole, much easier, these beliefs are not true.

There are individuals who have a certain level of innate ability to learn and perform a number of different manual tasks. This is referred to as a 'trait' ability, which is inherent and not modifiable (7). However, this differs from 'skill' ability, which is task-specific and can be improved by employing a procedural skills learning strategy. Identifying individuals who possess inherent trait ability is less important than building and improving the skill ability of the learner (8).

Different people learn in different ways, and an awareness of individual learning styles is essential to avoid deleterious consequences (9). The behaviourist school uses the stimulus-response principle, focusing on observable behaviour rather than on the internal processes of thought (10). The cognitive approach focuses on the internal mental processes, highlighting the importance of perception, meaning and insight to make sense of environmental stimuli (10,11). The humanist approach assumes that humans are self-determining and responsible, and have an innate urge to develop their potential (12). These theories are not mutually exclusive and each may be useful in understanding different elements of procedural skills learning.

Behaviourism relates to the acquisition of specific motor skills that, when mastered, become part of the surgeons' unconscious routine. The cognitive approach addresses how a learner processes information, and how to create new knowledge in that area, such as improving existing instruments or answering research questions. The humanist approach may serve to unite a variety of learning experiences into a meaningful whole.

With the goal of skill proficiency as a realistic end point of skill education, teaching and learning procedural skills can be reduced into two stages based on the learning theories described above. First, the cognitive phase involves conceptualization and mental training, during which the indications for, contraindications to, complications and basic technique of the procedure are understood. Visualization and verbalization allow the learner to see and describe the procedure from start to finish. Procedures often may involve many complicated fine motor movements that are not part of the normal repertoire of body movements. These motor skills often are similar to those performed by professional and amateur athletes. Hence, training methods in surgery and procedural skill may be designed using skills involved in sport as a reference (13).

Mental training and visualization, systematically and repeatedly performed, have been validated and applied successfully in professional sports for a long time (14). One recent study (15) sought to examine whether additional mental training was more effective in optimizing the performance of laparoscopic cholecystectomy than standard training or additional practical training. In this study, 98 surgeons undergoing basic laparoscopic training participated in a randomized, controlled trial, in which 31 surgeons received additional mental training facilitated by a sports psychologist in the areas of relaxation and visualization, 32 received additional practical training and 35 received no additional training. Primary outcome was performance measured by the modified objective structured assessment of technical skills. Results showed that additional mental training was more effective at improving technical specific skill than additional practical training or no additional training. Findings from this study suggest that both mental and practical training should be combined in procedural skills development rather than using practical training alone.

Cognitive activities can be taught in a formally structured manner using a combination of didactic sessions, case studies, videos and demonstrations. These instructional methods serve

as a bridge to the second phase, namely the psychomotor stage, requiring physical practise with correction and reinforcement.

Second, the psychomotor phase provides the opportunity for procedural practice. Two settings exist for the provision of procedural practice (8). The first is 'artificial' and includes instruction with models, cadavers, computers and fellow students, where appropriate. Many artificial practice settings have been described; however, the major limitations in accessing these scenarios include limited resources in terms of availability and cost. The second setting for practice is the 'real-life' clinical setting, by using live patients.

The concepts from the learning theories described above can be applied to colonoscopy instruction.

COLONOSOCOPY

In the field of gastrointestinal (GI) endoscopy, psychomotor skills are generally acquired by practising on real patients. Trainees have to perform a critical number of procedures to gain competency (16). Colonoscopy performance is a complex psychomotor skill, requiring practitioners to integrate multiple sensory inputs, and involve higher cortical centres for optimal performance. The higher cortical functions required for colonoscopy performance include attention control, behavioural organization, and gross and fine motor movement. Colonoscopy skills involve mastery in the cognitive, technical and process domains. Cognitive skills require an understanding of the correct indications for and contraindications to the procedure, recognition of normal and abnormal findings, and planning appropriate management based on the findings. Technical skills involve appropriate hand-eye coordination, control of the scope dials and application of torque, ability to finish a procedure in a reasonable amount of time, and appropriate therapeutic management, where necessary. Process skills required for successful colonoscopy include obtaining informed consent, patient preparation and risk assessment, providing appropriate sedation and analgesia, communication with nursing staff and the patient, and providing written documentation of the details of the procedure.

The training period for colonoscopy is usually associated with increased procedure times, patient discomfort and complications. Over the past two decades, a number of simulators for GI endoscopy have been developed, with a view to allow trainees to practise skill development in a controlled and safer environment. One recent study (17) provided quantitative evidence of the impact of psychomotor training on performance in simulated endoscopy. The authors determined that psychomotor training significantly improves the performance of novices. Similarly, in another prospective pilot study (18), eight GI fellows were randomly assigned to one of two different colonoscopy training curricula. Four fellows received 6 h of computer-based colonoscopy simulation training over a two-day period, representing the intervention group. The four remaining fellows served as a control group and underwent traditional colonoscopy training consisting of staff-supervised, patient-based colonoscopy. Subsequently, fellows were assessed on patient-based colonoscopy, during which they were supervised by faculty on several performance parameters. Results indicated that the median depth of unassisted insertion (rectum, sigmoid, transverse colon, cecum), the percentage of colonoscopies completed independently, the ability to identify landmarks, the ability to safely insert the scope and the ability to adequately visualize the mucosa during withdrawal were significantly better in the intervention group than in the control group. Additionally, during the two one-half days of the computer-based colonoscopy simulation training, faculty were able to perform an average of eight colonoscopies compared with the traditional fellow-based group averaging 3.5 procedures.

Procedural instruction

Appropriate curriculum design is important in teaching a complex psychomotor skill like colonoscopy. The teacher should clearly communicate the expectations of the learner at the beginning of the rotation. The expectations should depend on the level of experience and pre-existing skill of the learner, and these goals and objectives should be fluid, such that they change as the level of skill of the learner increases. The curriculum should provide adequate time for learner preparation, both mentally and technically. This can be done through reading materials, videos and observation of experienced individuals. Technical preparation may be provided during simulator training. The procedural curriculum should be transparent, allowing for faculty consistency in instructional methods and clear objectives for the fellow to attain. The expectations and objectives, predetermined for the learner, should be the basis for assessment and may define competency.

Seven principles for teaching procedural and technical skills in general include (19):

- Planning ahead – this phase allows the instructor to review or develop performance objectives, conduct a needs assessment of the learner, and ensure that the learner has cognitively prepared themselves adequately for the task at hand.
- Procedure demonstration – the expert demonstrates the procedure, providing explicit commentary during the demonstration.
- Learner observation – this stage allows the learner to attempt the procedure, under direct supervision. The expert should expect verbalization of the technique from the learner. The expert should encourage self-assessment and reflection on the part of the learner.
- Feedback – specific and descriptive feedback should be provided to the learner. The feedback should be nonjudgmental and performance-based.
- Self-assessment – the learner should be encouraged to comment on his or her perceived level of comfort and skill with the procedure at various time points, in addition to identifying areas requiring improvement.
- Practise – after obtaining basic proficiency, the learner should practise the skill under less-than-ideal conditions, ensuring various degrees of complexity.
- Approach modification – finally, the instructor should have an approach to modify the above steps in the event of an unprepared learner or if the opportunity for teaching arises at an unscheduled time or location. This takes advantage of 'opportunistic' learning and teaching.

These steps of psychomotor skills teaching are derived from the various taxonomies for learning motor skills, highlighting the close relationship among skill theory, learning theory, and practical teaching and learning.

A model for teaching colonoscopy

The present paper proposes a model for teaching colonoscopy to the novice trainee, based on the educational principles described above. This model includes the following sequence of events:

- Provision of adequate reading materials, bibliography and video materials for the learner to interact with before observation of the first colonoscopy.
- Assessment of the learners' current cognitive knowledge regarding indications for, contraindications to and risks of the procedure.
- Demonstration of a colonoscopy in entirety, including positioning the patient, administering sedation, testing the scope for function and, finally, the technical portion of the scope, with the instructor verbalizing the techniques and manoeuvres performed. During this demonstration phase, the instructor should comment on pathology encountered and steps taken to address that pathology.
- Following the demonstration phase and observational phase, if resources allow for a colonoscopy simulator, the learner should be encouraged to practise his or her technique on a high-fidelity simulator. In concordance with previous simulator-based studies, learners should complete between 10 and 20 simulator-based colonoscopies before their first patient-based colonoscopy. In centres where colonoscopy simulators are not available, patient-based colonoscopy is the traditional alternative.
- The instructor should allow the learner to go through the process of consenting and positioning the patient, administering sedation and testing the scope for function, while verbalizing the sequence of his or her actions. Subsequently, the learner should perform a digital rectal examination, comment on the findings and intubate the rectum. Generally, navigating through the sigmoid colon will be quite challenging for the novice. Hence, specific time constraints should be applied, considering the safety and comfort of the patient. When the novice is unable to advance further, the instructor should advance through the difficult sections of the bowel, verbalizing his or her technique, and hand the scope back to the learner when time permits. Hence, the learner will perform his or her first several colonoscopies in a piecemeal fashion.
- The learner should verbalize his or her technique in the early stages of learning, and explain his or her rationale for adopting the approach he or she is using (ie, positioning the patient on his or her back, reducing the loop, etc).
- Following the completion of a colonoscopy, the learner should self-assess his or her performance.
- The instructor should provide specific and constructive feedback on the technical aspects of the scope.
- Critical numbers of scopes and repetition are vital for progress to achieve the 'mechanism' stage of Simpson's taxonomy, whereas performance of critical numbers of difficult and complicated procedures are required to achieve the 'complex overt response' stage, toward which fellows are being trained to achieve.

CONCLUSIONS

Procedural skills teaching theory has evolved significantly from the old adage of 'seeing one, doing one and teaching one'. A more modern concept might include 'seeing one, practising many, doing one and teaching one'. Given the increasing recognition of patient comfort, procedural complications, and surgical and endoscopy suite efficiency, considerations to alternate methods of skill acquisition should be made, such as the use of simulators where available. Regardless of the availability of simulators, attention to psychomotor curriculum development – given learning theory and motor taxonomies outlining methods and stages of skill development – is necessary to achieve results in a logical and safe fashion. Consideration should be provided by endoscopy training programs to develop a procedural instruction curriculum based on psychomotor learning theory.

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