The Journal of Emergency Medicine, Vol 15, No 3, pp 387–391, 1997

0736-4679/97 $17.00 + .00

ELSEVIER

PII S0736-4679(97)00019-X

Education

PROCEDURAL SKILLS IN MEDICINE: LINKING THEORY TO PRACTICE

George Kovacs, MD, FRCP

Division of Medical Education and Emergency Medicine, Dalhousie University, Halifax, Nova Scotia, Canada
Reprint Address: George Kovacs, MD, FRCP, MHPE, Department of Emergency Medicine, QEII Health Science Center, 1796 Summer Street, Halifax, Nova Scotia, Canada

☐ **Abstract—Emergency departments offer a unique educational setting where housestaff can be exposed to and learn a variety of procedural skills. However, procedural skills are often overlooked as an assumed activity without a formal educational context. The clinical educator's understanding of the educational principals of teaching and learning procedural skills is minimal. This review offers further insight. The "psychomotor domain," which represents a hierarchy of learning motor skills, and relevant motor learning theory extracted from the educational psychology literature are reviewed. These theoretical considerations can be adapted to and provide useful information relevant to procedural medicine. Issues of curriculum content, methods of teaching and learning, and issues of competence relevant to the creation of a procedural skill program are reviewed and discussed. © 1997 Elsevier Science Inc.**

☐ **Keywords—emergency medicine; medical education; skills; procedures; technical skills; psychomotor skills**

INTRODUCTION

Educational reform efforts in medical schools throughout North America have focused on students achieving higher levels of cognitive functioning. Paralleling Bloom's taxonomy of the "cognitive domain" (1), which represents a hierarchy of learning, medical educators are hoping to shift the educational expectations of students from knowledge acquisition to "higher" levels of learning such as problem solving, synthesis, and analysis (2–3). Advocates of this move make the argument that students who attain these cognitive skills are more likely to maintain their problem-solving abilities and become "life-time learners."

Despite the cognitive-domain focus of educational reform, affective issues are finding their way into the undergraduate curriculum. Physicians, previously considered part of an untouchable professional elite, are now being held more accountable. With the introduction of ethics and communication skills teaching as educational representatives of the affective domain, students are learning of the potential interactions among the physician, the patient, disease, and society.

The psychomotor domain has remained the silent partner of both the cognitive and affective domains. Procedural medicine has been an assumed activity of students, without a formal educational context, living within the cliché, "see one, do one, teach one," for too long. Historically, medicine has been a "cognitive art" with our ability to diagnosis exceeding our capabilities to treat and intervene. With the advancements of technology over recent decades, however, medicine has become increasingly interventional. Procedural skills have moved out of the exclusive hands of surgeons and into almost every discipline and specialty of medicine.

Despite these interventional advances, our dedication to understanding the psychomotor domain and instituting educational directives and strategies to address procedural skills have remained minimal. The new formula replacing the previously stated cliché should be "learn_n,

RECEIVED: 29 May 1996; FINAL SUBMISSION RECEIVED: 4 September 1996;
ACCEPTED: 2 October 1996

see$_n$, practice$_n$, do$_n$'' (where n may represent a number of educational opportunities), forcing us to address issues of teaching and learning psychomotor skills.

As academic emergency physicians often surrounded by house staff eager to perform procedures, we should have an understanding of educational issues relevant to psychomotor skills. The following sections are an attempt to provide this background.

The terms *psychomotor skills*, *technical skills*, and *procedural skills* are often used interchangeably in the literature. In this article, psychomotor skills are defined as "the mental and motor activities required to execute a manual task" (4).

THE PSYCHOMOTOR DOMAIN

E. J. Simpson's work on the psychomotor domain is difficult to access in its original form. However, her taxonomy is referred to in other literature on psychomotor learning (5,6). The Advanced Trauma Life Support (ATLS) Instructors' Course uses Simpson's description of the psychomotor domain in teaching ATLS educators (7). Her seven categories of hierarchal learning are listed in Figure 1 and described below.

1. Perception
   - Sensory Stimulation
   - Cue Selection
   - Translation
2. Set
   - Mental Set
   - Physical Set
   - Emotional Set
3. Guided Response
   - Imitation
   - Trial and Error
4. Mechanism
5. Complex Overt Response
6. Adaption
7. Originating

Figure 1. The psychomotor domain.

Perception is the initial step and requires an awareness of performance. The most basic form of perception is *sensory stimulation*, where a stimulus comes into contact with a sense organ. A clinical example would be the tactile sensation of a suture needle penetrating skin. Cue selection involves deciding which cues to respond to while performing a procedure such as bag-mask ventilation. The physician needs to respond to abdominal distention, a cue that the technique may be poor. *Translation* requires a response to the cue; using the same example, the physician would alter the ventilation technique to avoid further gastric distention.

Set is a state of perception or "readiness." *Mental set* requires a knowledge of the steps required to perform a particular procedure. *Physical set* involves a familiarity with the "tools" of the procedure, that is, properly knowing how to hold and manipulate a needle driver is a simple example of physical set. *Emotional set* is a state of context perception where the student demonstrates a desire to achieve the best possible result.

Guided response is the actual motor act under the guidance of an instructor (imitation) or in response to self-evaluation (trial and error). *Mechanism* is a stage where the performance of a skill has become habit or routine.

Complex overt response requires an accomplishment of the previous steps described and represents a higher level of skill proficiency such as the ability to perform a suture wound closure quickly and efficiently, achieving a good cosmetic result with minimal patient discomfort.

Adaptation involves the modification of a motor skill to meet the needs of different problems such as applying the principles of fracture reduction to manage an uncommon or unusual bony deformity. *Originating* is a state of innovation in which new procedural skills are designed.

LEARNING THEORY AND PSYCHOMOTOR SKILLS

Experience has taught us that there are those individuals who have a natural ability to learn and perform a variety of manual tasks. Fleischman described this ability as "trait" ability, which is inherent to the individual and unmodifiable (6). He differentiated this from "skill" ability, which is more specific to a task and can be modified and improved by employing a procedural skills learning strategy. Identifying the "naturals" who will excel in the

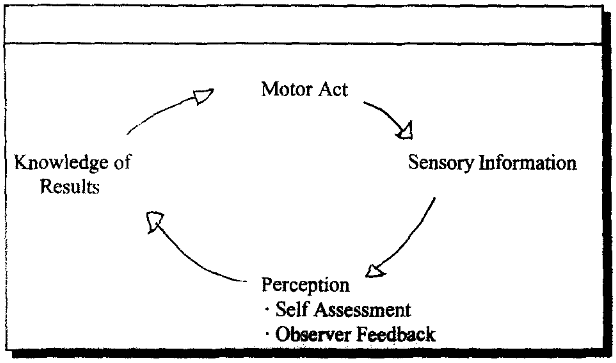

Figure 2. The closed-loop theory.

performance of a procedural skill is less important than building on a basic "trait" ability through an educational process that focuses on improving the "skill" ability of the student.

A more complex issue than identifying learner abilities is addressed by asking the question, How are psychomotor skills learned? Adams (8) was one of the first to propose a theory of motor learning based on experimental evidence. His "closed-looped theory" basically describes the feedback loop where sensory information from a movement is compared with an intended movement or goal. A schematic representation of Adam's theory is illustrated in Figure 2 and explained below.

While learning a motor act, there are a variety of sensory inputs that, if correctly interpreted and perceived as "knowledge of results" and referenced against the original movement, will result in the correction and improvement of its performance. Using suturing as an example, there is a multitude of sensory information that must be interpreted. This input includes the tactile sensation of the pressure required to penetrate skin, the visual information of blood in the field, everted wound edges, or even the facial expressions of a patient grimacing in pain. For this sensory input to become useful feedback, termed "knowledge of results," it must be perceived correctly by the learner. This perception is often left up to self-assessment rather than to experienced observer feedback.

The key point is that knowledge of results is required to learn, correct, and improve the performance of a motor action. This principle is frequently violated in medicine where so many procedures performed by house staff go unobserved. Frequently, "trial and error" with self-assessment is checked only by retrospective information regarding patient morbidity (knowledge of results) rather than by timely feedback with direct observation.

CURRICULUM CONTENT

Because it is often assumed that house staff are familiar with procedural skills, procedure exposure may be left to chance. Thus, the educational experience is often inconsistent and inadequate for students.

Once it is accepted that procedural skills merit a proper pedagogical approach, the first step is to determine which skills should be learned. There have been numerous studies examining which procedural skills are appropriate and required as part of the undergraduate curriculum (9–12). Many of these studies include a broader definition of psychomotor skills than used in this article. Irby et al. (9) listed 43 skills that were determined to be essential as noted by a "committee of clinician educators." A minimum arbitrary agreement of 60% of those surveyed was required for these skills to be labeled as "essential." Although these studies did attempt to determine a core list of procedures by "consensus" of those involved, it assumes that each procedure is of equal importance for all trainees.

Many medical schools are sympathetic to the "cause" and are determining core lists of procedures required for students during the educational process. However, gaps remain between expectations and experience. Students often report an inadequate or lack of exposure to these "essential" procedures (12). Hunskaar and Heim (13), in an attempt to address this problem, looked at the effect of log books on procedural skills experience and found that exposure increased by 30% with the use of these skills.

A more concerning discrepancy between expectation and experience was documented by Wigton (14) who surveyed internal medicine residents at the completion of the program. Of the 30 skills identified as essential to "master," a quarter of the residents responded that they did not feel competent in performing half of these "essential" procedures. There is obviously more to achieving procedure skill competence than ensuring exposure. Issues of teaching and learning psychomotor skills also must be addressed and are examined next.

TEACHING AND LEARNING PROCEDURAL SKILLS

Although choosing appropriate procedural skills to be included in a curriculum may be relatively easy, ensuring appropriate and effective teaching strategies is more involved. Methods pertinent to the teaching and learning of procedural skills have been described in the literature (15,16). The longest standing, most widely recognized program for teaching procedural skills is incorporated into the ATLS course. Although the ATLS format and

1. Conceptualization
2. Visualization
3. Verbalization
4. Practice-subcomponent, linkage, continuous
5. Correction and Reinforcement
6. Skill Mastery
7. Autonomy

Figure 3. The ATLS methodology for teaching and learning procedure skills.

content has been criticized, the instructor's manual for this course outlines a simple and logical methodology meant to promote the teaching principles and learning of procedural skills (7) (Figure 3).

With the goal of skill mastery or, more realistically, proficiency, procedural skills teaching and learning can be divided into two stages. First is the cognitive phase, which essentially involves conceptualization, where the "broader context of the skill" is appreciated by learning the relative anatomy, indications, contraindications and complications related to the procedure. Second, visualization and verbalization require opportunities to see and describe the procedure from start to finish. These activities can be conducted formally in a structured manner for all procedures and achieved through traditional teaching techniques by using a combination of didactic sessions, text, case studies, videos, and demonstrations. They serve as a link or bridge to the next, psychomotor, phase. This stage requires physical practice with correction and reinforcement. As described by ATLS educators, procedures can be broken down into subcomponents that can be linked and then practiced as a continuous process from start to finish. Although "correction and reinforcement" is listed as a separate stage, it should be incorporated into each of the preceding steps because it provides a form of feedback or knowledge of results.

Essentially, two settings exist for the provision of procedural practice. The first is "artificial" and includes using models, cadavers, computers, and fellow students for practice. Although numerous artificial practice settings have been described in the literature, there are obvious limitations (17–20). The major obstacle for such artificial settings is limited resources in terms of availability and cost. In addition, there are some procedures for which established artificial settings are not easily achieved, such as fracture reduction, joint relocation, and lumbar puncture.

The second setting for practice is the "real" clinical setting by using live patients. The anxiety of both patient and physician, the sensation of crossing tissue plains, and working in a bloody field can rarely be reproduced. The problem with incorporating the "real" practice setting into a procedural skills educational program is the difficulty in guaranteeing consistent clinical educational opportunities. In addition, there are obvious concerns related to the "learning curve" and patient morbidity when procedures are being learned using real patients. Although the ATLS methodology for teaching procedural skills includes skill mastery and autonomy as the final stages of learning, they more closely relate to issues of competence.

COMPETENCE

The concept of clinical competence is complex and controversial. Newble (21) defined competence as "the mastery of a body of relevant knowledge and the acquisition of a range of relevant skills." Thus, psychomotor skills are a component of a broader concept of clinical competence. Miller (2) described competence within the context of a pyramidal hierarchy from the most basic level of knowledge where the student "knows" to "knows how," "shows how," and "does" the procedure independently in clinical practice. Miller's conception of competence assumes a level of proficiency that may be represented as part of a continuum from "safe" or "functionally adequate" to a level of "skill mastery." The determination of where in this continuum an individual should aim for a particular procedural skill will depend on student-specific factors such as level of training, and issues related to student "abilities" must be considered. In addition, the attainment of procedural proficiency requires a structured method of teaching and learning.

Frequently, competence is defined by self assessment in absolute terms (yes or no) or represented by the number of exposures to a particular procedure. Practice is an important component to achieving competence, and because of the common assumption that "practice makes perfect," the number of procedures performed is often looked upon as a measure of competence. Wigton et al. (22) surveyed 381 internal medicine program directors and over 1000 practicing general internists to determine how many times a procedure must be done to attain and maintain competence. This survey was done for over 30 procedures. Although many would question the assumed correlation between quantity and competence, the work of Wigton et al. serves to illustrate the concept of procedural specific competence. Although questioned, the number of supervised practice exposures likely does play a role in attaining and maintaining competence. However, this number will depend on the procedure in question and, perhaps more importantly, the individual student. A procedure that can be performed proficiently by one student after *x* number of practice opportunities may require twice that number for another student.

SUMMARY

It should no longer be assumed that the house staff is competent in procedural skills. Deliberate methods must be developed and administered to ensure adequate procedural skill educational opportunities, with the ultimate goal of improving patient outcomes.

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