Embracing Errors in Simulation-Based Training: The Effect of Error Training on Retention and Transfer of Central Venous Catheter Skills

Aimee K. Gardner, PhD, Kareem Abdelfattah, MD,* John Wiersch, MD,† Rami A. Ahmed, DO,‡ and Ross E. Willis, PhD†*

*UT Southwestern Medical Center, Dallas, Texas; †UT Health Sciences Center, San Antonio, Texas; and ‡Summa Akron City Hospital, Akron, Ohio

INTRODUCTION: Error management training is an approach that encourages exposure to errors during initial skill acquisition so that learners can be equipped with important error identification, management, and metacognitive skills. The purpose of this study was to determine how an error-focused training program affected performance, retention, and transfer of central venous catheter (CVC) placement skills when compared with traditional training methodologies.

METHODS: Surgical interns ($N = 30$) participated in a 1-hour session featuring an instructional video and practice performing internal jugular (IJ) and subclavian (SC) CVC placement with guided instruction. All interns underwent baseline knowledge and skill assessment for IJ and SC (pretest) CVC placement; watched a "correct-only" (CO) or "correct + error" (CE) instructional video; practiced for 30 minutes; and were posttested on knowledge and IJ and SC CVC placement. Skill retention and transfer (femoral CVC placement) were assessed 30 days later. All skills tests (pretest, posttest, and transfer) were videorecorded and deidentified for evaluation by a single blinded instructor using a validated 17-item checklist.

RESULTS: Both the groups exhibited significant improvements ($p < 0.001$) in knowledge and skills after the 1-hour training program, but the increase of items achieved on the performance checklist did not differ between conditions (CO: IJ $\Delta = 35\%$, SC $\Delta = 29\%$; CE: IJ $\Delta = 36\%$, subclavian $\Delta = 33\%$). However, 1 month later, the CO group exhibited significant declines in skill retention on IJ CVC placement (from 68% at posttraining to 44% at day 30; $p < 0.05$) and SC CVC placement (from 63% at posttraining to 49% at day 30; $p < 0.05$), whereas the CE group did not have significant decreases in performance. The CE group performed significantly better on femoral CVC placement (i.e., transfer task; 62% vs 38%; $p < 0.01$) and on 2 of the 3 complication scenarios ($p < 0.05$) when compared with the CO group.

CONCLUSIONS: These data indicate that incorporating error-based activities and discussions into training programs can be beneficial for skill retention and transfer. (J Surg Ed 72:e158-e162. © 2015 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: simulation, error management training, central line, transfer, retention

COMPETENCIES: Patient Care, Medical Knowledge, Practice-Based Learning and Improvement

> To make no mistakes is not in the power of man;
> but from their errors and mistakes
> the wise and good learn wisdom for the future.
> –Plutarch

INTRODUCTION

As noted by DaRosa and Pugh,[1] surgical education curricula often overlook the beneficial role of errors. Frequently, faculty spend so much time teaching residents the correct way to perform a procedure that they neglect to explicitly discuss how to recognize and manage errors.[2] Increasingly, however, educators are concluding that errors play a valuable role in medical training.[1,3-6] When trainees are explicitly encouraged to make, discuss, and reflect on errors during the initial acquisition of skills, it is believed that they

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Correspondence: Inquiries to Aimee K. Gardner, PhD, Department of Surgery, UT Southwestern Medical Center, 5323 Harry Hines Blvd, Dallas, TX 75390; fax: (214) 648-6752; e-mail: aimee.gardner@utsouthwestern.edu

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would have a deeper understanding of the procedure, subsequently affecting retention and transfer of skills.[4] In fact, work from other domains has demonstrated that trainees who are encouraged to actively explore and make errors exhibit better skill acquisition,[7] decision making,[8] transfer of training, and performance.[9] Simulation-based settings offer an ideal opportunity to examine the value of this educational paradigm for surgical procedures, as trainees can make errors in a safe setting without negatively affecting patient care.

One procedure that is frequently trained in simulated settings[10] and that can be fraught with errors is central venous catheter (CVC) placement. If done incorrectly, the patient can contract infection, pneumothorax, arterial puncture, or bleeding.[11] Thus, trainees need to have a well-developed understanding of the rationale and consequences for the various steps in the procedure, as well as an appropriate awareness of how to detect and manage any errors that may occur. However, the ideal way to design curricula to facilitate this understanding within simulation-based training programs remains unclear. The aim of this study was to investigate the effect of an error-training curriculum on the acquisition, retention, and transfer of CVC skills.

MATERIALS AND METHODS

This study was approved by the institutional review board at the University of Texas Southwestern. A total of 30 general surgery postgraduate year–1 residents (13 categorical, 9 preliminary, 4 oral and maxillofacial surgery, and 4 urology) at University of Texas Southwestern were required to complete the training program.

All interns participated in a 1-hour educational session featuring an instructional video and faculty-guided instruction with a CVC simulator and ultrasound. Interns were randomly divided into either a "correct-only" (CO, $N = 16$) group or "correct + error" (CE, $N = 14$) group. All interns underwent baseline knowledge and skill assessment for internal jugular (IJ) and subclavian (SC, pretest) CVC placement before beginning training. Questions were created by the authors (R.W., A.G., and R.A.) based on review of literature. These items were then assessed by clinical faculty to ensure that all items appropriately reflected knowledge within the content domain, that no items measured content or knowledge outside the domain of central line placement, and that no component of the procedure was disproportionately influenced by the items, thus establishing content validity of the quiz. The knowledge test consisted of 10 multiple-choice central line scenarios to assess understanding of the CVC placement technique. Example items include "place the Seldinger steps in the proper order," "how can the carotid artery be distinguished from the internal jugular vein on ultrasound," and "which of the following is the most reliable method to distinguish arterial from venous blood." IJ and SC CVC placement skill assessments were performed using the Blue Phantom (CAE Healthcare) central line trainer. Residents were expected to use the ultrasound device for all IJ CVC insertions, but not for SC CVC insertions. Skill assessments were videorecorded.

After pretesting, interns then watched 1 of the 2 instructional videos of 20-minute duration that highlighted IJ and SC CVC placement techniques. The CO video showed each procedure being performed correctly twice (10 min), whereas the CE video showed each procedure being performed correctly once (10 min), with a specific description of common errors and how to manage them shown twice (10 min). Complications and errors in the video included losing the wire, incorrect wire insertion, puncturing an artery, and air embolisms.

Interns then participated in a 30-minute practice session with a trained faculty member. Interns in the CO group were provided with instruction and feedback that focused on performing the correct steps of the procedure. Any deviation from the correct method/sequence was quickly identified by the faculty member, and residents were guided back to the appropriate steps. In contrast, interns in the CE group were provided with feedback and instruction that positively framed errors and encouraged learning from errors while they practiced the procedure in the simulated environment. Instructors responded to errors with statements such as the following:

So you got off track a bit-that's okay. Now think about what would happen as a result of that error and how you would manage it;

Errors are good when you're first learning something, because they show you where you need to focus your practice; and

Great, you made an error! I'm glad you got that out of the way before you were with a real patient.

After training, interns completed a knowledge posttest that addressed the same content as the pretest, but which

TABLE 1. Pretraining and Posttraining Scores for Correct-Only and Correct + Error Groups on Internal Jugular (IJ) Procedure, Subclavian (SC) Procedure, and Knowledge (Know) Assessments

	Pre–IJ (%)	Post-IJ (%)	Δ	Pre-SC (%)	Post-SC (%)	Δ	Preknow (%)	Postknow (%)	Δ
Correct only	32	68	$p < 0.001$	30	63	$p < 0.001$	66	78	$p < 0.05$
Correct + error	35	70	$p < 0.001$	33	62	$p = 0.001$	65	78	$p < 0.01$