Mastery Learning of Temporary Hemodialysis Catheter Insertion by Nephrology Fellows Using Simulation Technology and Deliberate Practice

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Background: Temporary hemodialysis catheter (THDC) insertion is a required skill for nephrology fellows. Traditional fellowship training may provide inadequate preparation to perform this procedure. Our aim was to use a central venous catheter (CVC) simulator to assess nephrology fellows' THDC insertion skills and evaluate the impact of an educational intervention on skill development to mastery standards.

Study Design: Prospective observational cohort study.

Setting & Participants: 18 nephrology fellows from 3 academic centers in Chicago from May to August 2008. Six graduating fellows (traditionally-trained) underwent assessment of internal jugular THDC insertion skill using a CVC simulator. Subsequently, 12 first-year fellows (simulator-trained) underwent baseline testing and received a 2-hour education session featuring deliberate practice with the CVC simulator. Simulator-trained fellows were retested after the intervention and expected to meet or exceed a minimum passing score.

Predictor: Completion of CVC simulation education session.

Outcomes: THDC insertion skill performance.

Measurements: Skills examination was scored on a 27-item checklist. Minimum passing score was set by an expert panel.

Results: Performance of traditionally-trained graduating fellows in THDC insertion was poor (mean, 53.1%), and only 17% met the minimum passing score. Performance of simulator-trained first-year fellows improved from a mean of 29.5% to a mean of 88.6% after simulator training ($P = 0.002$). Simulator-trained fellows showed significantly higher THDC insertion performance than traditionally-trained graduating fellows ($P = 0.001$). The education program was rated highly.

Limitations: Although it represents fellows from 3 programs, sample size was small.

Conclusions: A curriculum featuring deliberate practice dramatically increased the skill of nephrology fellows to mastery standards in THDC insertion. This program illustrates a feasible and reliable mechanism to achieve and document procedural competency.

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INDEX WORDS: Central venous catheterization; clinical competence; mastery learning; medical education; nephrology; simulation-based education; temporary hemodialysis catheter; ultrasound.

Editorial, p. 4

The American Board of Internal Medicine requires candidates seeking certification in nephrology to be competent in temporary hemodialysis catheter (THDC) insertion.[1] Traditional nephrology fellowship education may not provide the skills needed to perform this procedure safely. In a recent national survey, nephrology fellowship program directors reported variable education and experience with THDC insertion.[2]

The preferred site for THDC insertion is the internal jugular (IJ) or femoral vein.[3-5] The subclavian (SC) vein should be avoided because of the risk of venous stenosis.[6,7] Femoral vein catheterization is not recommended in obese or ambulatory patients because of increased risks of infection and deep venous thrombosis.[5] Proper training in IJ THDC insertion is needed because this approach carries the risk of potentially life-threatening complications such as pneumothorax and carotid puncture.[8-10] There is evidence that education and training reduce central venous

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catheter (CVC) insertion–related complications because more experienced physicians have lower complication rates.[8,9,11] Proper use of an ultrasound to assist with IJ CVC and THDC insertion also has been shown to decrease mechanical complications.[8,10,12-14]

Simulation technology is one method to improve procedural training and assessment. Simulation has been used to increase knowledge, provide opportunities for deliberate and safe practice, and shape the development of clinical skills.[15,16] Simulation also has been used to assess trainee competence in procedures such as carotid angiography,[17] emergency airway management,[18] basic bronchoscopy,[19] endoscopy,[20,21] advanced cardiac life support,[22,23] and thoracentesis.[24]

Recently, we used simulation technology to enable internal medicine residents to reach mastery skill levels in CVC insertion.[25] Mastery learning,[26] an extreme form of competency-based education,[27] requires learners to acquire clinical knowledge and skill measured against fixed achievement standards. In mastery learning, educational results are uniform, whereas educational practice time varies.[23-26] After the simulation-based mastery learning intervention, simulated and actual CVC insertion performance by residents improved significantly.[25]

The present study had 3 aims. The first was to assess the skill of graduating nephrology fellows in THDC insertion. The second was to determine whether the mastery model used for CVC insertion could be extended to THDC insertion. The third was to compare THDC insertion skills of simulator-trained first-year nephrology fellows with traditionally-trained graduating nephrology fellows.

METHODS

Study Design

The study was a pretest-posttest design[28] of a simulation-based mastery learning educational intervention in IJ THDC insertion that included a posttest-only comparison group. First-year (simulator-trained) fellows had a pretest in THDC insertion skills using a CVC simulator, a simulation-based educational intervention, and a posttest. Graduating nephrology fellows (traditionally-trained) completed the THDC insertion clinical skills examination (posttest) and served as the comparison group. Traditional training was defined as conventional nephrology fellowship education at participating institutions.

Setting and Participants

Participants were 18 nephrology fellows from 3 university-affiliated academic centers in Chicago, IL. The study period was May to August 2008. Simulator-trained participants were 12 first-year nephrology fellows evaluated during the first 2 months of fellowship training. Traditionally-trained participants were 6 second-year nephrology fellows evaluated during their last 2 months of fellowship training. The Northwestern University Institutional Review Board (Chicago, IL) approved the study, and participants provided informed consent.

Procedure

The study was conducted using CentralLineMan (Simulab, Seattle, WA).[29] This CVC insertion model is a realistic anatomic representation of a right upper torso with external jugular, IJ, and SC veins and carotid and SC arteries. The model features realistic tissue with ultrasound compatibility, an arterial pulse, and self-sealing veins and skins. Needles, dilators, and guidewires can be inserted and realistic venous and arterial pressures simulated.

Simulator-trained first-year fellows underwent a clinical skills examination pretest using a 27-item IJ THDC insertion checklist. They subsequently received a 2-hour education session featuring a lecture, ultrasound training, deliberate practice with the simulator, and directed feedback. All participants were required to complete the educational program regardless of pretest performance. Sessions were supervised by a senior faculty member with expertise in CVC insertion and simulation-based education (J.H.B.). Fellows were expected to use the ultrasound device to insert the IJ THDC. If the SC approach was used, the carotid artery was punctured, or more than 2 needle passes (skin punctures) were used, the simulation was stopped and the remaining checklist items were marked incorrect. Within 1 week after the educational intervention, simulator-trained fellows were retested (posttest) and required to meet or exceed a minimum passing score (MPS) on the clinical skills examination checklist. Fellows who did not achieve the MPS had more deliberate practice and were retested until the MPS was reached, a key feature of mastery learning.[26,30] Traditionally-trained graduating fellows underwent testing in IJ THDC insertion using the simulator and 27-item checklist and served as a comparison group. All skills examinations were evaluated by an unblinded reviewer and videotaped for future review.

Measurement

A 27-item checklist (Item S1, provided as online supplementary material available with this article at www.ajkd.org) was developed for the THDC insertion procedure using relevant sources[8,10,25] and rigorous step-by-step procedures.[31] Each skill or other action was listed in order and given equal weight. A dichotomous scoring scale of 1, indicating done correctly, and 0, indicating done incorrectly, was imposed for each item. The checklist was designed by 1 author (J.H.B.) with expertise in CVC insertion and checklist design and reviewed for completeness and accuracy by others with expertise in checklist design (D.B.W.) and THDC insertion (S.N.A.).