The Effectiveness of a Cognitive Task Analysis Informed Curriculum to Increase Self-Efficacy and Improve Performance for an Open Cricothyrotomy

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OBJECTIVE: This study explored the effects of a cognitive task analysis (CTA)-informed curriculum to increase surgical skills performance and self-efficacy beliefs for medical students and postgraduate surgical residents learning how to perform an open cricothyrotomy.

METHODS: Third-year medical students and postgraduate year 2 and 3 surgery residents were assigned randomly to either the CTA group (n = 12) or the control group (n = 14). The CTA group learned the open cricothyrotomy procedure using the CTA curriculum. The control group received the traditional curriculum.

RESULTS: The CTA group outperformed the control group significantly based on a 19-point checklist score (CTA mean score: 17.75, standard deviation [SD] = 2.34; control mean score: 15.14, SD = 2.48; $p = 0.006$). The CTA group also reported significantly higher self-efficacy scores based on a 140-point self-appraisal inventory (CTA mean score: 126.10, SD = 16.90; control: 110.67, SD = 16.8; $p = 0.029$).

CONCLUSIONS: The CTA curriculum was effective in increasing the performance and self-efficacy scores for postgraduate surgical residents and medical students performing an open cricothyrotomy. (J Surg 68:403-407. © 2011 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: cognitive task analysis, self-efficacy, open cricothyrotomy, procedural skills, surgical skills, curriculum development

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

INTRODUCTION

In the current surgical education model, mastery in surgery is highly dependent on the ability of an expert surgeon to transfer the necessary knowledge and skills to novice resident learners. This has become increasing challenging over the past decade because of work-hour restrictions, patient safety concerns, and decreased operating room availability. To address this issue, many programs have moved surgical skills education into simulated environments where trainees are often required to demonstrate competency before performing a procedure on a patient. Many programs now rely on structured checklists and a standardized skill curriculum. A significant barrier to this educational model is that it relies on subject matter experts to teach and generate instructional materials. Recent studies examining the teaching of complex knowledge have shown that experts omit a significant amount of knowledge when trying to describe a task,[1-3] largely because repeated years of practice causes knowledge to become automated; automated knowledge is no longer accessible to conscious processes.[4-6]

Cognitive task analysis (CTA) refers to a variety of methods used to elicit the knowledge and skills experts use to solve difficult problems and perform complex procedures.[7] CTA methods have been employed effectively to design surgical skills

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training and improve performance by providing step-by-step protocols and checklists that identify expert decisions made during a procedure.[8,9] CTA is a viable option for developing instruction materials because it allows analysts to break down the complex automated skills of experts into manageable tasks and steps.[7]

Another consideration for educators when designing surgical skills curricula is the influence of self-efficacy. Self-efficacy beliefs are judgments a person makes about his or her ability to perform a task successfully and has been shown to effect learner motivation and performance achievement.[10] In academic settings, previous research has found that higher self-efficacy is related to greater use of self-regulated learning strategies as well as higher achievement.[11] According to Bandura,[10,12] how individuals behave can often be predicted better by their beliefs about their capabilities than by what they are actually capable of accomplishing; these beliefs help determine what individuals do with the knowledge and skills that they have. Compared with persons who doubt their capabilities, those with high self-efficacy for accomplishing a task participate more readily, work harder, persist longer when they encounter difficulties, and achieve at a higher level.[10,12] Competency-based training, such as CTA-informed instruction, has been shown to influence self-efficacy beliefs positively in other disciplines[10]; however, CTA needs further exploration in surgery. Although CTA-informed curricula has had positive effects on surgical resident and medical student performance, the effects of CTA-informed instruction on self-efficacy have yet to be examined.

The purpose of this study was to determine whether CTA-informed instruction had a positive effect on both surgical performance and self-efficacy beliefs of postgraduate surgical residents and medical students learning how to perform an open cricothyrotomy.

METHODS

Cognitive Task Analysis

Part 1: task list. Six expert trauma surgeons participated individually in structured CTA interviews using the methods described in Clark et al.[1] Each expert answered questions regarding the goal of the open cricothyrotomy procedure, the necessary equipment required, the major steps of the procedure, the indications and contraindications for performing the procedure, the action and decision steps including the conditions for each alternative decision, and the standards required for performing the procedure successfully. The transcripts from each expert were used to create a procedural CTA document organized around the major tasks associated with the procedure (Fig. 1), which was then sent to the respective surgeons to review. Once the revisions were collected, they were compiled into 1 gold standard CTA document. This document was sent to each expert for further review and revision.

Part 2: procedural checklist. The gold standard CTA was analyzed to identify the critical decision points associated with the procedure. These decision points were combined with the action steps and used to generate a procedural checklist. The experts reviewed the task list and procedural checklist to ensure conformity to the CTAs. This information served as a framework for curriculum development.

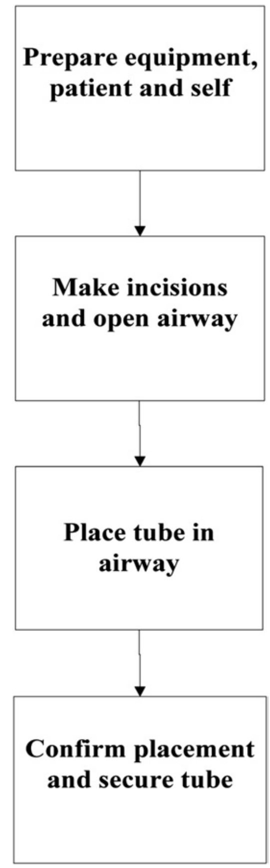

FIGURE 1. Major task list for performing open cricothyrotomy procedure.

Part 3: development of cta curriculum. The major task list and procedural checklist provided the curriculum overview and step-by-step actions and decisions required to perform an open cricothyrotomy procedure. An instructor script, PowerPoint presentation (Microsoft Corporation, Redmond, Washington), and job aid for student practice were developed from the checklist.

Subjects and Procedure

Third-year medical students on the surgical clerkship and PGY 2 and 3 surgery residents in the Department of Surgery at the University of Southern California (USC) (n = 26) were assigned randomly to either the CTA group (n = 12) or the control group (n = 14). To assess prior knowledge and experience, participants completed a 6-item pretest that posed open-ended questions regarding actions and decisions required to conduct the procedure given a specific scenario before instruction. Participants could score 17 possible points, which were based on expert responses. The pretest also gathered education level and previous experience performing an open cricothyrotomy. At the end of the instruction and practice session, learners were given a similar posttest assessing their knowledge of the procedure. Parallel forms of the pretest and posttest instruments were developed using different case scenarios. To avoid pretest and post-test sensitization, pretest A was matched with posttest B and vice versa, respectively. In addition, learners completed a self-efficacy rating scale after the instruction.

Participants in the control group learned the open cricothyrotomy procedure using the traditional method in the Surgical Skills Simulation and Education Center. This included a didactic PowerPoint lecture, observation of a demonstration on an inanimate model, followed by guided practice and feedback. The power point presentation was comprehensive and included information regarding the objectives, indications, contraindications, equipment, pitfalls, complications and suggested readings. In addition, the presentation included a step-by-step description of the procedure with guiding pictures. The instructor for the control group did not participate in the CTA interviews and did not review any of the CTA instructional materials. The instructor for the experimental group was 1 of the surgeons interviewed to develop the gold standard CTA and had reviewed all the CTA materials before the session. Participants in the CTA group received the identical instruction. The only difference between the groups was the instructor's use of the CTA-informed PowerPoint presentation and script, as well as the procedural job aid students used during guided practice. The instructors were matched regarding teaching experience, level of training, and quality of teaching evaluations. This study was approved by the USC Institutional Review Board and informed consent was obtained.

Evaluation

There were three outcome measures for this study: (1) cognitive knowledge of the actions and decisions required to perform the open cricothyrotomy procedure successfully, measured by pretests and posttests; (2) procedural knowledge as demonstrated by the performance of the actions and decisions steps in the correct order, measured by the procedural checklist; and (3) self-efficacy beliefs about performing the procedure, measured by a self-efficacy self-appraisal inventory adapted from Bandura.[13]

Five expert surgeons, who were blinded to participant groups, evaluated participants performing the procedure on an inanimate model. Raters used a 17-step procedural checklist and marked items as "correct," "incorrect," or "not done." The checklist also included a question that asked whether all the items were performed in the correct order and, if not, which items were not performed sequentially. Each step had a value of one point except for step 2, which included 2 additional substeps for a total of 19 points (Table 1).

The self-appraisal scale for this study included 14 items in which participants rated their confidence based on a 10-point Likert scale with 0 indicating "Cannot do at all," 5 indicating "Moderately certain I can do," and 10 indicating "Certain I can do." There were 140 points possible for the self-appraisal inventory that focused on the perceived capabilities for performing the action and decision steps of the task successfully (Table 2). Independent samples t tests were used for all comparisons.

TABLE 1. Procedural Checklist for Open Cricothyrotomy Procedure

Task: I	Not Done (N) or Incorrect (I)	Done Correctly
1. Correct reasons for performing procedure	N I	1
2. Prepare required equipment		
a. Test tracheostomy tube for working cuff	N I	1
b. Pull inner cannula out of the tube and put obturator into the appliance	N I	1
c. Assemble CO_2 monitor onto bag	N I	1
3. Correct patient position	N I	1
4. Prepare patient	N I	1
5. Prepare self and position self	N I	1
6. Stabilize trachea with non-dominant hand	N I	1
7. Identify incision location	N I	1
8. Make vertical incision (1.5-2.5 cm)	N I	1
9. Retract area with retractor and confirm cricothyroid location by touch	N I	1
10. Make transverse incision across cricothyroid membrane	N I	1
11. Spread the cricothyroid opening 5-10 mm	N I	1
12. Insert tube inside opening	N I	1
13. Remove obturator, inflate the cuff and place inner cannula into tube	N I	1
14. Connect patient to CO_2 monitor and check for CO_2 return	N I	1
15. Confirm tube placement	N I	1
16. Suction airway	N I	1
17. Secure tube	N I	1
Total:		

TABLE 2. Group Comparison for the Self Appraisal Inventory Results

Self Appraisal Inventory Item	CTA Group Mean Score (N = 10)	Control Group Mean Score (N = 21)	p-value
1. Recognize the indications for when to perform the procedure.	9.00	7.33	0.03
2. Recognize the contraindications for when not to perform the procedure.	9.00	5.14	<0.01
3. Prepare yourself using universal safety precautions.	10.00	8.67	0.01
4. Prepare the necessary equipment to perform the procedure.	9.60	9.05	0.10
5. Choose the appropriate tube for the procedure.	8.60	8.24	0.56
6. Put the patient in the optimal position.	9.20	8.62	0.19
7. Visualize the anatomic landmarks.	8.80	8.86	0.93
8. Identify the location to make the incision.	9.00	8.86	0.83
9. Make the necessary incisions.	9.00	8.24	0.30
10. Place the tube inside the opening correctly.	9.20	7.38	0.01
11. Recognize the indicators for successful performance.	9.60	8.52	0.01
12. Perform the procedure in an emergency situation.	8.30	7.24	0.24
13. Perform the procedure in 5 minutes or less.	8.50	7.29	0.14
14. Perform the procedure without making any major mistakes.	8.30	6.50	0.03

Scale: 0 "Cannot Do At All" to 10 "Certain I can Do."

RESULTS

A data analysis revealed no difference between the groups regarding prior cognitive knowledge of the procedure (CTA mean score 5.4, SD = 1.68; control mean score 5.5, SD = 1.83; p = 0.39). Therefore, equivalency of the groups was established. In addition, no significant difference was found between groups on posttest scores of cognitive knowledge (CTA mean score 18.17, SD = 3.61; control mean score 16.71, SD = 2.64; p = 0.59). However, the CTA group outperformed the control group significantly on procedural knowledge based on a 19-point procedural checklist (CTA mean score: 17.75, SD = 2.34; control mean score: 15.14, SD = 2.48; p = 0.006). In addition, the CTA group reported significantly higher self-efficacy scores based on a 140-point self-appraisal inventory (CTA mean score: 126.10, SD = 16.90; control: 110.67, SD = 16.8; p = 0.029).

DISCUSSION

The results of this study add to the existing body of research demonstrating that CTA is an effective method to improve the content and instructional design of surgical skills curricula. Previous research demonstrated that subjects who received instruction based on the results of cognitive task analysis interviews outperformed their colleagues who were not provided with the same instructional support.[8,9,14] It is important to note that all these studies were performed in a surgical skills center. However, considering that fact that expert surgeons teach in the clinical arena, it is reasonable to suggest that the benefits of using CTA informed instruction would extend to the patient care environment.

Although many medical education programs incorporate procedural checklists into surgical skills education, the strength of the CTA-informed checklist is that it provides additional (and most often expert omitted) cognitive information about when and how the procedure should be performed. CTA provides a method for eliciting knowledge that has accumulated through years of experience, a framework for compiling that information so that it is meaningful to novices, and a map for tracking the performance of the action and decision steps as measurable points within a procedure.

The results of this study also demonstrate the usefulness of CTA to increase learner self-efficacy when performing a medical procedure. These results are promising because of the paucity of research in this area. A search of the medical literature did not reveal any empiric evidence regarding the relationship of CTA with self-efficacy in the surgical setting. Because increased self-efficacy has been linked to achievement in other disciplines,[10] this is an area that deserves subsequent investigation. Future studies should focus on the influence of CTA methodology on the relationship between self-efficacy and surgical performance.

In addition, future research should be conducted to focus on examining the role of CTA instruction on self-efficacy for surgical performance on more complex surgical procedures. The open cricothyrotomy procedure is relatively straightforward and is not performed very often, even by expert surgeons. However, since the addition of surgical skills laboratory training for surgical residents, more opportunities are available to examine the effects of CTA-informed instruction on trainees. Because CTA methods and CTA-informed instruction are designed to provide training for more complex tasks, a replication of this study targeting a surgical procedure that is complex and performed often would be a valuable contribution. Furthermore, future research efforts should focus on the effects of CTA instruction on self-efficacy and performance over a longer period.

Last, future research investigating the effectiveness of CTA-informed instruction should focus on patient outcomes, such as decreased complication rates, operative time of surgical procedures, and overall surgical success. CTA research in surgical education is still in its infancy. As the field develops, it will be important to determine whether CTA instruction has an impact on long-term patient outcomes.

CTA has emerged in surgical education as a promising resource that can be used to extract the cognitive decisions and essential procedural steps of surgical instruction from experts. Information obtained from CTA interviews can be incorporated into instructional materials for learners at all levels. Using CTA techniques, it is possible to optimize competency-based learning experiences with the knowledge and skills experts use to perform complex procedures effectively and efficiently. As we add to the CTA knowledge base and train future CTA analysts, the goal of streamlining CTA curriculum development for multiple surgical procedures is within reach.

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