

Computer-Enhanced Visual Learning Method: A Paradigm to Teach and Document Surgical Skills

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Abstract

Innovation Changes in health care are stimulating residency training programs to develop new methods for teaching surgical skills. We developed Computer-Enhanced Visual Learning (CEVL) as an innovative Internet-based learning and assessment tool. The CEVL method uses the educational procedures of deliberate practice and performance to teach and learn surgery in a stylized manner.

Aim of Innovation CEVL is a learning and assessment tool that can provide students and educators with quantitative feedback on learning a specific surgical procedure. Methods involved examine quantitative data

of improvement in surgical skills. Herein, we qualitatively describe the method and show how program directors (PDs) may implement this technique in their residencies.

Results CEVL allows an operation to be broken down into teachable components. The process relies on feedback and remediation to improve performance, with a focus on learning that is applicable to the next case being performed. CEVL has been shown to be effective for teaching pediatric orchiopexy and is being adapted to additional adult and pediatric procedures and to office examination skills. The CEVL method is available to other residency training programs.

Introduction

Changes in the environment for surgical residents' training are prompting residency programs to rethink and restructure how to teach surgical skills to residents.¹ Among many changes causing concern, the reduction in duty hours is the one most frequently cited. Limits on residents' hours are a logical predicament because of the assumption that they result in reduced operative volume and fewer opportunities to teach residents in the operating room, with the potential to contribute to decreased surgical competency in residency graduates. We describe Computer-Enhanced Visual Learning (CEVL) as a pragmatic approach to improve residents' learning and participation in operative practice. We developed CEVL as a tool to enable residents to obtain feedback on their surgical performance in an era

of significant changes in medical education and practice.² CEVL is an alternative to the traditional process of learning procedural skills simply by performing more cases, frequently without a defined strategy to improve performance. We believe that teaching surgery using the CEVL method uses time in the operating room more efficiently, allowing residents to finish their rotations with better skills and more confidence than before. The objective of CEVL is to provide a method for learning surgery inside and outside of the operating room.

CEVL is an Internet-based program that teaches pediatric urologic surgical procedures in 3 steps. First, residents use Internet access to study the procedure. Procedures are presented as components that incorporate intraoperative video and images, explanatory text, and computer animations. Second, residents perform the procedure with supervision. Third, residents study remediation strategies using online computerized learning resources. The residents build their skill sets using the deliberate practice- and case-focused feedback that CEVL provides. We believe that the method is widely applicable to teach residents to perform routine health care procedures.

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Background of Building CEVL

Since 2003, the Division of Urology at Children's Memorial Hospital has been exploring methods to advance the

FIGURE

FIGURE COMPUTER-ENHANCED VISUAL LEARNING (CEVL) DASHBOARD. A, THE CEVL ICON DEPICTS MENTAL INTERNALIZATION OF A TASK, WHICH FACILITATES PERFORMANCE OF THE TASK. B, THE PROCEDURE IS PRESENTED AS A SERIES OF COMPONENTS. C, EACH COMPONENT IS SUBDIVIDED TO INCLUDE OBJECTIVES OF THE COMPONENT, A VIDEO AND AUDIO TOUR OF THE STILL IMAGES, THE STEPS OF EACH COMPONENT DETAILED AS STILL IMAGES (MANY OF WHICH CONTAIN EXPLANATORY TEXT AND VIDEO CLIPS), A SUMMARY OF THE MATERIAL EXPECTED TO BE GRASPED, AND A SELF-TEST. D, THE STEPS OF THE COMPONENT ARE ITEMIZED. E, THUMBNAILS PREVIEW THE IMAGE IN THE MAIN STAGE (F). G, THE ORIENTATION OF THE PATIENT IS SHOWN TO HELP REFERENCE THE ANATOMICAL DETAILS PRESENTED. H, THE RESIDENT MAY SELF-TEST HIS/HER KNOWLEDGE OF THE ANATOMY SHOWN IN THE STILL IMAGES BY TOGGING THE IMAGE ANNOTATIONS ON AND OFF. I, EXPLANATORY TEXT IS AVAILABLE FOR FURTHER UNDERSTANDING. J, BEFORE PERFORMANCE OF EACH SURGICAL PROCEDURE, THE RESIDENT IS EXPECTED TO SATISFACTORILY COMPLETE THE “SHOW YOUR READINESS FOR SURGERY” MODULE. MORE INFORMATION ON THESE MODULES IS AVAILABLE ONLINE.⁴



teaching of routine surgical procedures to residents. By serendipity, the current changed environment and the availability of technology created an opportune environment to explore alternative techniques to teach surgery and concurrently evaluate residents' performance and progress.

Foundation for the CEVL Method Began by Exploring Residents' Needs and Views

Our research began with many accumulated hours of informal weekly conversations with residents. During this time, we explored various aspects of the residents' immersion in the operating room, including how residents think and learn to perform surgery; what residents want, respect, and emulate; and why some methods of teaching surgery are more effective than others. This needs assessment identified the following 2 major desires of residents in the operative arena: (1) to learn how to perform surgery, presented as broad components and specific steps, and (2) to receive immediate focused feedback on performance and remediation of suboptimal aspects. These and other characteristics of pediatric urology residents as a group are listed in the TABLE, along with the CEVL method responses.

Teaching Surgery by Adapting Established Pedagogic Methods to Teach and Learn Psychomotor Skills

The method by Ericsson³ of using deliberate practice to learn psychomotor skills has been applied to a range of activities from playing the piano to ice skating. The mantra of the method is a cycle that begins with study of the basic skill (eg, how to play a scale on the piano). Next, the learner performs the skill with teacher supervision, and the learner then receives specific feedback on how to improve performance (eg, how to adapt the finger positions to sound the fourth note in the scale). This routine facilitates improved student performance as elements that are suboptimal are identified and instructions for remediation are structured.

The CEVL method adapts the method by Ericsson³ and modifies it to present surgical skills learning as a repeated cycle of the following 3 steps: (1) mentally internalize the procedure, (2) perform the procedure, and (3) make improvements based on feedback. CEVL modification promotes the concept of “deliberate performance”-based deliberate practice. The learner internalizes the remediation strategies to execute during the next performance or the next case. This allows performance ratings to spiral upward. The CEVL logo graphically depicts this notion of internalizing a task to facilitate performance (FIGURE).⁴

Computerization of the CEVL Modules

Anecdotal observations recognized that, while teaching occurs in the operating room, residents derive additional benefit from resources outside of the operating room. These can enhance their operative experience and help them solidify their skills. Desired processes for learning include the review of operating room teaching dialogue via Internet access and the evaluation of data. To this end, a secure website page (<http://www.cevlforhealthcare.org>) was created to provide Internet access to the curriculum content. This provides residents access to study the surgical procedure and to view their performances, feedback, and remediation strategies. The elements of the CEVL program are described herein.

CEVL Dashboard We aimed to formalize residents' education by presenting the information in a stylized manner. A dashboard of curricular content was built by combining the insights of several of us in biomedical visualization (E.M., R.S., and C.Y.) with surgical perspectives (M.M.). The dashboard presents the performance of surgery as a series of major procedural segments called *components*. Each component in turn is subsegmented into steps. The information is presented as text and visuals (FIGURE).

CEVL Script The CEVL script for how to perform the surgery is publicly displayed in the operating room. An important observation on residents' behavior is that residents frequently are not yet comfortable enough to think logically and clearly in the operating room. While they may solidly understand the basics of a procedure when studying at home, insecurity may overwhelm this understanding once they enter the operating room to an extent that the resident cannot lead the operation because he/she no longer is confident of the steps involved. We found that such experiences may be minimized by developing an agreed-on CEVL script to perform the procedure, which is posted plainly for all operating room staff to view.⁴ In this manner, the instruments and protocols to be used are known to all operating room staff, and the script can be referred to as needed during the case. This readily available knowledge of the procedure bolsters residents' confidence (TABLE).

Performance Rating, Feedback, and Remediation Planning Are Archived in Internet-Accessed Forms Rating the performance of surgery is a checklist function to objectively assess a resident's performance of component and integrative skills. After each procedure, the supervising surgeon gives the resident qualitative and quantitative feedback on his/her performance using an online feedback and rating form. The resident and attending can access this form for review once completed, and the attending reviews the performance with the resident. The form also allows the resident to note the steps he/she would like to improve at the next case. Strategies to remediate skills are formulated collectively by the resident and the attending during the

postprocedure discussion. The resident studies these steps for improvement and prepares to execute them during the next case.

Review of CEVL Scores CEVL provides reports of residents' performance ratings as the clinical rotation progresses. Residents and attendings may review these ratings to confirm that there is progress toward improved performance and/or to identify problem areas that need special attention. Initial results show that 96% of residents improve their CEVL scores.² The average results improved by at least 50% from entry to best rating ($P < .0001$). Further research is needed to validate the CEVL scoring system and to compare it with global assessment ratings. The checklist nature of the ratings complies with Accreditation Council for Graduate Medical Education standards.

How the CEVL Innovation Works

Residency PD Approval of CEVL Content

The residency PD reviews and evaluates CEVL content to determine if the template-driven performance of surgery showcased on CEVL matches the needs of the given program, and the PD is able to modify the surgical content to meet local needs. For example, if the program chooses to use a sterile button to help anchor the testis at orchiopexy, this step is added for this program's content, but the content of other programs in the CEVL system is not altered.

Registration for CEVL

The PD transmits e-mail addresses of the residents who will be using the CEVL program. During registration at <http://www.cevlforhealthcare.org>, only authorized residents may log in to CEVL by using a secure username and password. Residents and the PD may view residents' performance in real time. At present, no financial charges are associated with the use of CEVL.

Residents' Use of CEVL

Residents and attending faculty can access CEVL on-site or from home. When logging in, they are greeted with a "Tip of the Day," a bit of surgical wisdom to supplement the larger curriculum (eg, "Prior to starting the surgery, review the child's pertinent x-ray images with the attending to confirm the side of the operation, as well as the pathology being addressed"). The resident may choose a procedure to study, review his/her evaluation reports, or check CEVL scores for a procedure. Residents are expected to study and practice the steps depicted in the CEVL procedure module. This develops mental imagery of the planned surgery that residents rely on during subsequent performance of the surgery. Available information also includes attending physicians' rating of residents' performance, detailed feedback on cases, and structured remediation strategies for each component.

TABLE		GROUP CHARACTERISTICS OF PEDIATRIC UROLOGY RESIDENTS AND HOW THE COMPUTER-ENHANCED VISUAL LEARNING (CEVL) METHOD RESPONDS	
Characteristic of Pediatric Urology Residents as a Group		CEVL Response	
How Residents Learn			
After a procedure is performed, residents like immediate focused feedback and remediation		CEVL response archives a feedback form, which organizes their knowledge building and specific improvement recommendations for the deliberate practice of surgical skills	
Magical thinking creates the illusion that the more they do a procedure the better they will be at performing it		More cases done with deliberate practice that is based on feedback and remediation will improve their skill and comfort better than just performing more cases	
Residents like to learn procedures that are broken down into broad components, with each containing specific steps		CEVL response breaks down performance of surgery into broad building blocks and specific steps of the procedure so that residents can focus their learning	
Effective methods to teach residents include review of the procedure to be performed before and after the case		Residents show their clarity of the surgical procedure about to be performed by successfully completing the “readiness for surgery” CEVL module before each case	
Residents’ learning styles differ and include learning by reading, viewing images with annotations on and off, viewing video, viewing animations, and aural learning		CEVL modules include content addressing each of these unique learning styles	
Operating Room Integrative Skills			
Residents are not yet comfortable enough in the operating room to think logically; they are using primitive reflexes of reaction to stimuli		The posted script levels the methods of the surgical task to be performed	
Residents are confused by the diverse empiric and idiosyncratic procedures of the different attending teachers they learn from; this is because different attendings “do things differently” for the same surgical procedure		Standard script to perform surgery is agreed on by all attending teachers; a special individualized script is prepared to document and showcase each attending’s method; the resident now has clarity while interacting with each attending	
Their role in the operating room is unclear		The category “integrative skills” was built into the procedure rating form to better build their concept of what their role actually is	
Common Perceptions of Residents			
Want to be proficient and want to be liked; however, they convert this want into “doing a procedure fast” so operating room staff will interpret this as proficiency		Proficiency is more realistically represented to them as CEVL skill scores, which are reviewed with the attending	
Residents are uncomfortable, even intimidated, working under some attendings whom they regard as unpredictable		Presentation of the CEVL surgical script prevents attendings’ accusing residents of lack of knowledge of the procedure	

Attending Use of CEVL

Attendings may access the online skills assessment of residents with whom they have worked to identify strengths and areas for improvement. This permits the attending to focus his/her next encounter with the resident on working to improve problem areas (H. J. Silberstein, MD. communicated, March 2009).

Feedback and Performance Improvement Remediation

Each component in a resident’s performance of a procedure is rated using a Likert-type scale, addressing specific elements of a procedure that are necessary for a resident’s improvement and allowing attendings to structure feedback and remediation. The resident can then focus improvement on specified component skills in preparation for the next procedure (D. R. Gosset, communication, February 2009).

Development of New CEVL Modules

The CEVL curriculum is developed collaboratively between attendings and residents of the residency program, along with technical support from the CEVL staff. Residents pick a procedure for CEVL development and identify elements of a procedure that they find problematic or confusing (eg, how to find the hernia during an orchiopexy). Attending surgeons develop a standardized script (components and steps) for CEVL training on that procedure and gather images and video for curriculum content. The script and content are melded into a cohesive comprehensive module. The content of the module is presented via the CEVL dashboard. Residents and attendings then collaborate on final edits and prepare the lesson for alpha testing by the next rotation. This ensures that CEVL is continually revised and adapted to meet residents’ needs. The module is tested

and retested until satisfaction is attained by the PD. The module is offered to a limited number of other participating PDs for beta testing.

Experience With CEVL

Initial results show that residents improved their CEVL scores. Seven attending surgeons rated 24 residents on 166 pediatric orchiopexies performed in 2006–2007. CEVL scores improved in 96% of residents over an average of 7 cases.² Our institutional experience shows that residents and attending physicians have found the CEVL method to be a practical way to teach and learn surgery. Residents are especially pleased with the reduced uncertainty about how to perform procedures and express increased confidence during surgery. They believe that their performance is improved by methodically studying specific components of a procedure, as well as by practicing and rehearsing the specific steps involved. Archived feedback and remediation provide a clear means to improve performance at subsequent operative opportunities. Access to the surgical preferences of individual attendings before surgery familiarizes residents with attending physicians' idiosyncrasies, which further lessens apprehension in the operating room. Perhaps most important, residents appreciate that the CEVL method floats the focus of the residents' OR experience to emphasize their training.

CEVL also provides a method for assessment of a resident's surgical skills. Surgical programs are increasingly seeking means for evaluating a resident's surgical ability. This checklist method of skills evaluation allows surgical training programs to assess and monitor improvement of technical skills. Attending physicians report that the surgical curriculum platform of CEVL enhances interaction because of clearer communication with residents and reduces uncertainty by preparing residents for procedures. We observed that residents and attendings report increased satisfaction with their overall interaction and communication using the CEVL method.

Limitations of Data Analysis

Although the CEVL method of evaluation has not yet been validated as an assessment tool, recent ongoing multi-institutional research demonstrates that 3 institutions using CEVL as a teaching tool for pediatric orchiopexy showed comparable improvement in residents' skills. From this experience, we conclude that the use of CEVL is generalizable across institutions.⁵ Further studies to evaluate CEVL are in process. They include comparison with standard global assessments of training that are commonly used in surgical residents' evaluations. In addition, the CEVL assessment tool is being examined for reliability and validity. Initial reliability investigations show that there were no substantial differences (by 1-way ANOVA) in rating skills performance using the CEVL method among 7 raters.²

Future Directions

The CEVL method is a platform to teach psychomotor skills that began with pediatric urologic procedures. We are working with other specialties within our pediatric hospital to teach basic and advanced specialty skills such as gastrostomy, eye muscle surgery, and casting and fracture repair. CEVL is also being developed to teach pediatric residents basic office examination skills such as how to examine a boy for an undescended testis or how to reduce a phimotic foreskin. Pediatric radiology training modules will demonstrate reduction of an intussusception using fluoroscopy. With Chicago's Prentice Women's Hospital, we are developing CEVL modules to assess residents' comfort with safely performing newborn circumcision (D. R. Gossett, communication, February 2009). At a national level the CEVL method is being presented as an educative innovation⁶ and is being used to further training in endoscopic management of posterior urethral valve.⁷ More recently, the use of the CEVL method has been explored for teaching Chiari 1 decompression (H.J. Silberstein, MD, communication, 3/2009) and laparoscopic nephrectomy (R. G. Moore, MD, communication, March 2009).

Conclusions

Our institutional experience shows that CEVL has been an effective method to teach and learn surgery by enabling residents to better engage in practicing surgical procedures in the current landscape of reduced duty hours. This has been done using Internet-based content on how to perform surgical procedures and the study of remediation strategies. CEVL is being developed for additional pediatric and adult training programs. The flexibility inherent in the CEVL program permits other institutions to use this method for teaching and assessment in their surgical programs.

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