Teaching Temporal Bone Anatomy CT Scan as a Psychomotor Skill; A Quasi-Experimental Study

Mitra Amini
Shiraz University of Medical Sciences
Sepideh Sefidbakht (sepidehsefidbakht@yahoo.com)
Shiraz University of Medical Sciences
Reza Jalli
Shiraz University of Medical Sciences
Fariba Zarei
Shiraz University of Medical Sciences
Hamid Reza Abbasi
Shiraz University of Medical Sciences
Pouya Iranpour
Shiraz University of Medical Sciences
Bijan Bijan
Sutter Medical Center Sacramento

Research article

Keywords: Psychomotor skill, Temporal bone anatomy, Computerized tomography (CT), Gang's method

Posted Date: November 6th, 2019

DOI: https://doi.org/10.21203/rs.2.16896/v1

Abstract

BACKGROUND Reviewing and interpretation of cross-sectional imaging studies has become the main part of Medical Imaging (formerly known as Radiology) practice over the past twenty years. The rapid changes in the practice of medical imaging however has not been paralleled by development of new teaching methods. In the current study, we present a teaching method for the radiology residents the cross-sectional anatomy of the temporal bone as a psychomotor skill.

METHODS In this cross-sectional study, we included a total number of 21 radiology resident of Shiraz University of Medical Sciences for a 2-month period. We provided a teaching scheme based on the Gagne's theory which consisted of 6 steps ie: 1-gaining attention, 2-informing the learner of the objective, 3-stimulating recall of prerequisite learning, 4-presenting the stimulus material, 5-providing learning guidance, and 6-eliciting the performance, 7-providing feedback, assessing the performance and 8-enhancing retention and transfer. The residents were evaluated before and after the training sessions using objective structured clinical examination (OSCE), resident satisfaction and educational goal achievement questionnaires.

RESULTS We have included a total number of 21 radiology residents with mean age of 27.9 ± 8.6 (range from 26-38) years, 14 (66.6%) men and 7 (33.4%) women. We observed that the OSCE score improved significantly after the twenty-minute session (2.57 ± 1.62 vs. 8.02 ± 2.43; $p<0.001$). Mean resident satisfaction score measured by standardized questionnaires was 7.63 ± 2.86 on scale of 10. Regarding the achievement of educational goals, we observed that the score increased significantly after the mini-sessions (4.33 ± 1.22 vs. 8.27 ± 2.46; $p=0.021$).

CONCLUSIONS Considering the interpretation of cross sectional images as a psychomotor skill, may be proven to be an effective teaching method. Using a standardized approach and defining predetermined transition points in moving between orthogonal planes can enhance learning radiology as it is today.

Background

Achieving proficiency and skill for a radiology resident to independently review and analyze the cross-sectional anatomy of the temporal bone in computerized tomography (CT) scans requires the acquisition of unique and complex technical and cognitive skills. The radiology residents routinely learn the interpretation of the temporal bone anatomy in cross-sectional CT studies using traditional case-based learning technique (1–3). Normally the radiology residents will review the images independently, and correlate the findings with the clinical data, and through three basic stages (perception, interpretation/analysis and diagnosis) and then formulate the conclusion (2, 4). The study will then be reviewed and discussed with the attending physician and feedback will be provided to the resident (3). This long-established routine is designed to ensure optimal interactivity and daily communication between the resident and attending physician; however, we believe that this traditional educational method can be enhanced by introduction of a new element of interactivity.

Given the primarily virtual nature of imaging data and the teaching material, and the ubiquity of handheld devices, the radiologist has been increasingly endowed with a variety of new tools that enhance faster and easier access to educational material. Wide availability of educational tools and information has helped the radiology residents an easy access to information (5–7). However, online reviewing of the radiology images is inherently different comparing to day-to-day clinical practice of radiology. An essential part of part of an expert in radiology is the systematic style and consistency of scrolling through the images, which unfortunately we believe is an overlooked part of radiology training and education, which is immensely based on the digital technology for the next generation of medical imagers, the millennium generation radiologists (8).(9).

So far, to the best of our knowledge, there have been very few attempts to adopt the models of instructional design which were originally intended for teaching psychomotor skills to teaching interpreting images. Ultrasound has been correctly approached as a psychomotor skill. (10) Also, a lesson was planned to teach the medical students the interpretation of chest radiography based on Gagne's theory for teaching psychomotor skills (11, 12). In contemporary radiology, however, where cross-sectional imaging constitutes the bulk of radiology workload, the three step model of perception, interpretation and diagnosis appears like an over-simplified representation of how a radiologist performs in the daily clinical practice. The quick scrolling through hundreds, at times thousands of images, choosing and applying appropriate reconstructions, and implementing proper tools from the software menu, together with the basic knowledge that makes all the action coherent and purposeful necessitates a more comprehensive model of teaching and learning radiology. In the current study, we present a method for teaching the radiology residents basic temporal bone anatomy using the educational designs traditionally employed in teaching psychomotor skill.

Methods

Study population

This cross-sectional study was conducted for a period of 2 months from September to November 2017 at Namazi Hospital, a tertiary healthcare center, one of the teaching hospitals of Shiraz University of Medical Sciences, in south of Iran. The protocol was developed at education development center (EDC) and was implemented for testing at Namazi Hospital. We included a total number of 21 radiology residents of Shiraz University of Medical Sciences. They were in PG1, PG2 and PG3. The residents were selected using a random sampling method from a population of 76 radiology residents. The study protocol was approved by institutional review board (IRB) of Shiraz University of Medical Sciences and all the included residents provided their informed written consents to be included for this study.

Study protocol

All the included radiology residents attended the instruction session in which the psychomotor skills were taught using the Gagne's theory of 6 separate steps. This method was based on the Gagne's theory was modified for teaching psychomotor skills (13, 14). These steps are described below:

Step 1: Gaining attention

During a study interpretation session, a normal temporal bone CT scan was presented and the facilitator changed the position or announced the commencement of the mini-session. Later at the time of practice the attending physician gave the place to the included resident. This maneuver clearly signaled the beginning of the mini-session.

Step 2: Informing the learner of the objective

A mini-lesson was introduced for teaching the cross-sectional anatomy of the temporal bone, based on Gagne's theory, designed to be interspersed informally in the daily image interpretation sessions. The session was completed in 15–20 minutes and the late independent practice was postponed temporarily. The goal was to provide a clear roadmap to cover all the major structures of the temporal bone if followed consistently and systematically.

Step 3: Stimulating recall of prerequisite learning

For the resident in the top quartile, this consisted of a few open-ended questions such as, "Describe the anatomy of the inner ear/facial nerve canal/middle ear/ossicular chain." For the more struggling residents, more specific stimulation was required. A quick survey of the residents' previous encounters and observations and their knowledge of the common indications for performing the study can also be performed at this stage. This step could also be interpreted as the conceptualization step of teaching psychomotor skills.

Step 4 and 5 Presenting the stimulus material and Providing learning guidance

For these steps we used a very systematic approach. The detailed anatomy was then presented, starting systematically from the coronal sections of the external auditory canal and the handle of the malleus, using the 3D cursor to scroll back and forth between the reconstructions, the instructor thinking aloud throughout the presentation, moving along the ossicular chain all the way to the oval window. We then touched upon the inner ear structures.

For example, for the anatomy of the course of the facial nerve canal single path was introduced by the facilitator starting from the internal auditory canal (IAC) in axial images, scrolling to the uppermost level to demonstrate the genu, proceeding posterolaterally along the canal as far as it was fully visualized, then using the 3D cursor to transition to coronal sections, then following the canal to the posterior genu and then using the 3D cursor to transit to the axial and sagittal sections. Similar structured predetermined paths were designed for following the ossicles and inner ear structures.

We did not present the cochlear and vestibular aqueducts, the carotid canal and the jugular bulb for the sake of simplicity in this stage, unless the resident has had more experiment and demands a more in-depth discussion (Video 1).

Step 6: Eliciting the performance, providing feedback, assessing the performance and enhancing retention and transfer

In this step we asked the residents to perform the task and think loudly while guiding us through the anatomy in a logical and stepwise manner. The same structured approach that was first introduced by the facilitator (visualization, verbalization) and then repeated by each resident in the group (practice).

Focusing on completeness and coherence as well as verbalization of both the thoughts and actions was encouraged. An example of the narration is as follow: "I start here at the internal auditory canal seen on the axial sections, scroll all the way up to the most cephalad slices to find the geniculate ganglion and the greater petrosal nerve. Now I find the horizontal part of the facial nerve canal and put my 3D cursor here to cross reference the nerve in the coronal view, above the oval window, which I can see it here." Feedback and corrections were provided in real time, as the course unfolds.

Outcome Assessment

We evaluated the residents' ability to define various aspects of temporal bone anatomy on CT images using a pre- and post-session OSCE. We also evaluated the participants' own ability to evaluate the various anatomic structures of the temporal bone using a questionnaire before and after the mini-session. The residents' satisfaction with the session was evaluated using a "resident satisfaction questionnaire". Validity of all three questionnaires was endorsed by the faculty of Medical Education Research Center and Medical Imaging Research Center. The internal consistency of the "resident satisfaction" and "educational goal achievement" forms was also supported with a Cronbach's alpha of 86% and 90% respectively.

Statistical analysis

All the data were entered into a computer database and were analyzed using statistical package for social sciences (SPSS Inc., Chicago, Illinois, USA) version 18.0. All data are presented as mean ± SD and proportion as appropriate. The pre-test and post-test OSCE results were compared using Wilcoxon Signed Ranks Test. A two-sided p-value of less than 0.05 was considered statistically significant.

Results

We have included a total number of 21 radiology residents with mean age of 27.9 ± 8.6 (range from 26–38) years. There were 14 (66.6%) men and 7 (33.4%) women among the participants. The baseline characteristics of the residents are summarized in Table 1. We observed that the OSCE score improved significantly after the mini-session (2.57 ± 1.62 *vs.* 8.02 ± 2.43; $p<0.001$).. The resident satisfaction scores were 7.63 ± 2.86 on scale of 10 as measured by the standard questionnaire. Regarding the achievement of educational goals, we observed that the score increased significantly after the twenty minute sessions (4.33 ± 1.22 *vs.* 8.27 ± 2.46; $p = 0.021$) (Table 2). The trend in changes of the OSCE score, resident satisfaction and the educational goal achievement is demonstrated in Fig. 1.

Discussion

The current study presented a new teaching method for interpretation of the temporal bone anatomy on cross-sectional CT images as a psychomotor skill to the radiology residents. We demonstrated that this method was associated with increased residents' ability to identify anatomical structures of the normal temporal bone on CT images as measured by OSCE examination score. Along the same lines, the self-perceived knowledge was improved in the sample population. These findings demonstrate that the psychomotor skills could be effectively taught using this method which is based on the application of the steps of psychomotor skill educational design, a highly structured approach using predetermined transition points between orthogonal planes, and using the steps designed by Gagne. Comparative studies with routine teaching techniques are required to demonstrate the superiority of this method over the previously described methods.

In 1985 Robert Gagne described the three phases of teaching technical skills, including the cognitive phase (which includes the conscious development of a routine, under the guidance of a facilitator), associative phase (indicating purposeful practice, aimed at integrating skills) and autonomous phase (which indicate ability of independent and automatic performance of a skill) (12). His theory, based on observation of the adult mind during learning sessions, have been applied to adult learning in diverse settings from flying planes to management and medicine. In medicine, focus has been on teaching procedures such as chest tube insertion, airway management or peritoneal catheter insertion (15).

According to Gagne, there are 9 main steps in a well-organized instructional session. These include three steps for preparing the learner for the instruction (gaining attention, informing the learner of the desired outcome and stimulating recall of the prerequisite learning), two steps constituting the core of the teaching process (presenting the stimulus material and providing learning guidance) and the final four steps (eliciting the performance, providing feedback, assessing the performance and enhancing retention and transfer) which are designed to enhance, check and further evaluate and contemplate on the learning experience (11, 12). (Table 3)

Dreyfus brothers, in a different attempt, outline the stepwise acquisition of expertise in 5 levels; i.e. novice, advanced beginner, competent, proficient and expert. Moving from the novice level, where the learner (not having any discretionary judgment) rigidly adheres to the taught fact and guidelines, to the expert level where there is an intuitive grasp of the situation, founded on a background of tacit knowledge, the learner integrates the complex structure of information, attitudes and skills that define the expert practitioner.

Using the Gagne theory as a template, STEPS and SIS-FR methods have been designed for teaching technical skills to novice learners (16). In brief the STEPS technique is a 5 step approach including setting the foundation, the tutor demonstrating skill without explanation, the tutor providing explanation while repeating the skill, the learner practicing under supervision and receiving feedback and then later the learner practicing independently. The SIS-FR approach is devised for structuring non-technical skills, including setting the context, immersing in roles and practicing, intervening for summary, feedback and refining practice according to feedback (17).

Contemplating the one on one teaching sessions of anatomically complex structures such as the temporal bone CT or MR imaging of the joints, we believe that skills such as following the course of the facial nerve between various planes of reconstruction, which is done while using various cursor tools should be categorized as a psychomotor skill and approached accordingly (18) (19).

In teaching a new skill, it is important to first access the prior knowledge of the participants on the subject to avoid disengagement which may result in repetition of the learner's previous knowledge (20). This was accomplished during step 3. We also limited the anatomy to the ossicular anatomy and the facial nerve canal for most learners in order to avoid cognitive overload (21, 22). We limited the cognitive knowledge to the conceptualization step, the facilitator then demonstrated the standard approach, both silently and then verbalizing the steps based on the design first introduced by Fitts et al. (23, 24). The learners then repeated the steps verbalizing through their performance (10, 25).

We acknowledge certain limitations in our study. First, we included a limited number of radiology residents using a small sample size. These residents were selected from PG1 to PG3. We could not include the PG4 residents as the last year residents are not usually active in clinical services during preparation for the upcoming board-examination. A larger sample size and inclusion of all of the residents from all levels of training is recommended in future research. The other limitation was the quasi-experimental design of the study. This study utilized only pre- and post-test analysis, in a single population. Probably a parallel trial, comparing the routine, standard traditional teaching method and the current psychomotor technique should be performed. Then the comparison of these two groups can shed light on the impact of such technique on teaching/learning process. To the best of our knowledge, this is the first study of its kind, evaluating the feasibility of teaching cross-sectional imaging as a psychomotor skill.

Conclusion

In conclusion, approaching the teaching of evaluation and reporting of cross-sectional imaging with instructional designs originally developed for training psychomotor skills might be an effective and efficient approach in teaching radiology.

Abbreviations

CT: Computerized Tomography

EDC: Education Development Center

IAC: internal auditory canal

MR: Magnetic Resonance

OSCE: Objective Structured Clinical Examination

SPSS: Statistical Package for Social Sciences

Declarations

- Ethics approval and consent to participate: The study protocol was approved by institutional review board (IRB) of Shiraz University of Medical Sciences and all the included residents provided their informed written consents to be included for this study.
- Consent to publish: N/A
- Availability of data and materials: The data of the study is available on request as data in brief.
- Competing interests: No conflict of interest
- Funding: The manuscript was financially supported by a grant from vice chancellor of research of Shiraz University of Medical Sciences.
- Authors' Contributions: Concept and Design: MA, SS; Data Gathering: RJ, FZ; Data Analysis and Interpretation: HRA, PI, BB; Drafting the manuscript: SS, FZ; Critically revising the manuscript: All the authors; Approving the submitted version: All the authors.
- Acknowledgements: We would like to thank the participation of the radiology residents in the current study. This is the thesis of Dr Sepideh Sepidbakht for obtaining master degree in medical education with proposal number 13471 that was accreted by deputy of research in Shiraz University of Medical Sciences. We would also like to thank the Diba Negar Research Institute for improving the style and English of the manuscript.

References

1.Fischer K, Sullivan AM, Krupat E, Schwartzstein RM. Assessing the Effectiveness of Using Mechanistic Concept Maps in Case-Based Collaborative Learning. Acad Med. 2018.

2.Kumar V, Gadbury-Amyot CC. A case-based and team-based learning model in oral and maxillofacial radiology. J Dent Educ. 2012;76(3):330–7.

3.Yue JY, Chen J, Dou WG, Liang CH, Wu QW, Ma YY, et al. Using integrated problem- and lecture-based learning teaching modes for imaging diagnosis education. BMC Med Educ. 2018;18(1):183.

4.Fabre C, Proisy M, Chapuis C, Jouneau S, Lentz PA, Meunier C, et al. Radiology residents' skill level in chest x-ray reading. Diagn Interv Imaging. 2018;99(6):361–70.

5.DeBenedectis CM, Gauguet JM, Makris J, Brown SD, Rosen MP. Coming Out of the Dark: A Curriculum for Teaching and Evaluating Radiology Residents' Communication Skills Through Simulation. J Am Coll Radiol. 2017;14(1):87–91.

6.Auffermann WF, Chetlen AL, Sharma A, Colucci AT, DeQuesada IM, 2nd, Grajo JR, et al. Mobile computing for radiology. Acad Radiol. 2013;20(12):1495–505.

7.Cosyns B, De Diego JJ, Stefanidis A, Galderisi M, Ernande L, Underwood SR, et al. E-learning in cardiovascular imaging: another step towards a structured educational approach. European heart journal cardiovascular Imaging. 2015;16(5):463–5.

8.Ratib O, Roduit N, Nidup D, De Geer G, Rosset A, Geissbuhler A. PACS for Bhutan: a cost effective open source architecture for emerging countries. Insights Imaging. 2016;7(5):747–53.

9.Cochon L, Lacson R, Wang A, Kapoor N, Ip IK, Desai S, et al. Assessing information sources to elucidate diagnostic process errors in radiologic imaging - a human factors framework. J Am Med Inform Assoc. 2018.

10.Nicholls D, Sweet L, Hyett J. Psychomotor skills in medical ultrasound imaging: an analysis of the core skill set. Journal of ultrasound in medicine: official journal of the American Institute of Ultrasound in Medicine. 2014;33(8):1349–52.

11.Belfield J. Using Gagne's theory to teach chest X-ray interpretation. The clinical teacher. 2010;7(1):5–8.

12.Buscombe C. Using Gagne's theory to teach procedural skills. The clinical teacher. 2013;10(5):302–7.

13.Khadjooi K, Rostami K, Ishaq S. How to use Gagne's model of instructional design in teaching psychomotor skills. Gastroenterol Hepatol Bed Bench. 2011;4(3):116–9.

14.Ng JY. Combining Peyton's four-step approach and Gagne's instructional model in teaching slit-lamp examination. Perspectives on medical education. 2014;3(6):480–5.

15.Cheung L. Using an Instructional Design Model to Teach Medical Procedures. Medical science educator. 2016;26:175–80.

16.Woo WH. Using Gagne's instructional model in phlebotomy education. Advances in medical education and practice. 2016;7:511–6.

17.Virdi MS, Sood M. Effectiveness of a five-step method for teaching clinical skills to students in a dental college in India. Journal of dental education. 2011;75(11):1502–6.

18.Grimm LJ, Kuzmiak CM, Ghate SV, Yoon SC, Mazurowski MA. Radiology resident mammography training: interpretation difficulty and error-making patterns. Acad Radiol. 2014;21(7):888–92.

19.Grimm LJ, Zhang J, Lo JY, Johnson KS, Ghate SV, Walsh R, et al. Radiology Trainee Performance in Digital Breast Tomosynthesis: Relationship Between Difficulty and Error-Making Patterns. J Am Coll Radiol. 2016;13(2):198–202.

20.Dent JA HR. A practical guide for medical teachers. 3 rd ed. Edinburogh: Churchil Livingstone; 2009.

21.Leppink J, van den Heuvel A. The evolution of cognitive load theory and its application to medical education. Perspectives on medical education. 2015;4(3):119–27.

22.Kantak SS, Winstein CJ. Learning-performance distinction and memory processes for motor skills: a focused review and perspective. Behavioural brain research. 2012;228(1):219–31.

23.Fitts PM PM. Human performance. Belmont (CA): Brooks/Cole; 1967.

24.George JH, Doto FX. A simple five-step method for teaching clinical skills. Family medicine. 2001;33(8):577–8.

25.Nicholls D, Sweet L, Muller A, Hyett J. Teaching psychomotor skills in the twenty-first century: Revisiting and reviewing instructional approaches through the lens of contemporary literature. Medical teacher. 2016;38(10):1056–63.

Tables

Table 1 The baseline characteristics of 21 radiology residents of Shiraz University of Medical Sciences included in the current study.

Variable	Value
Age (years)	27.9 ± 8.6
Gender	
Men (%)	7 (33.4%)
Women (%)	14 (66.6%)
Year	
PG1	7 (33.3%)
PG2	7 (33.3%)
PG3	7 (33.3%)

Table 2 Outcome measures of the study.

	Pre-test	Post-test	p-value
OSCE	2.57 ± 1.62	8.02 ± 2.43	<0.001
Resident satisfaction	5.63 ± 2.86	12.3 ± 5.31	<0.001
Educational goal achievement	4.33 ± 1.22	8.27 ± 2.46	0.021

OSCE: Objective structured clinical examination

Table 3 The nine events of Instruction according to Gagne

1	Gaining attention
2	Informing learners of the objective
3	Stimulating recall of prior learning
4	Presenting the stimulus
5	Providing learning guidance
6	Eliciting performance
7	Providing feedback
8	Assessing performance
9	Enhancing retention and transfer

Figures

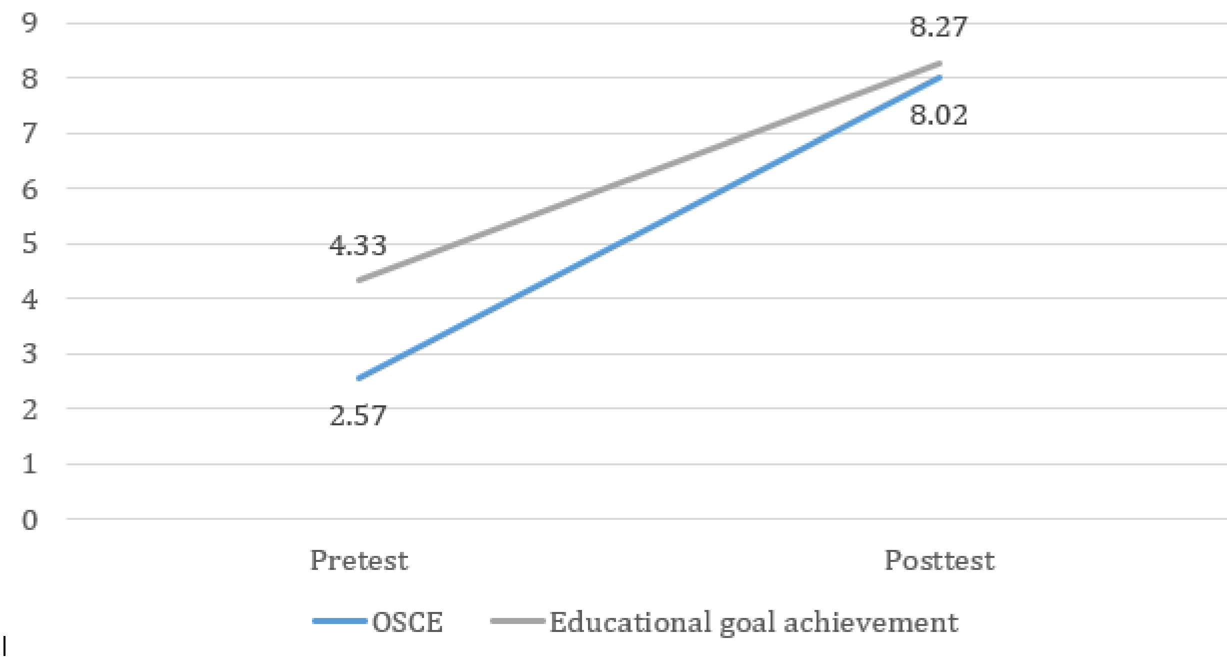

Figure 1

Line diagram demonstrating trends in change of objective structured clinical examination (OSCE), resident satisfaction and educational goal achievement in 21 radiology resident before and after psychomotor skill teaching.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Video1.mp4