The FAIL CT Study: Facilitating Adaptive Expertise in Learning Computed Tomography, a Multicenter Randomized Controlled Trial – TMA 2022-23

I. Specific Educational Aims

Adaptive expertise is the ability to transfer existing skills to novel situations, enabling physicians to reduce preventable medical errors when managing clinical scenarios not encountered in training.[1,2] However, medical education curricula rarely address this learning outcome. **Error Management Training (EMT)** is a pedagogical method with the potential to improve transfer of skills to new contexts.[3–6] We aim to demonstrate that EMT improves adaptive expertise in a cognitive skill, using head computed tomography (CT) interpretation as a model. Our specific aims are:

1. **To compare the effects of EMT and Error Avoidance Training (EAT) on the transfer of cognitive skills and long-term knowledge retention.** We will conduct a multicenter, randomized controlled trial (RCT) across 12 geographically diverse emergency medicine (EM) residency programs. We will deliver head CT curricula using an online radiology simulation platform and assess diagnostic accuracy with immediate and delayed post-tests.
2. **To implement this online curriculum in undergraduate medical education.** We will pilot an asynchronous curriculum with medical students in EM clerkships, using the data from our RCT to inform curricular design for developing adaptive expertise.

This project is a multicenter ***collaboration*** between EM residency programs across the country. Our ***rigorous approach to scholarship*** uses a sound experimental design with an RCT to assess the efficacy of our educational intervention.[7] Our work will ***impact*** a wide range of learners at multiple levels beyond EM. The online head CT curriculum we pilot with medical students can be made into an asynchronous medical student elective at Stanford, which could be disseminated to other medical schools. The curriculum's modular design allows it to be used in diverse residency programs across the country, filling a national need for an emergency neuroradiology curriculum.[8] Under-resourced EM training programs outside of the U.S. also lack emergency neuroradiology curricula; our online curriculum will be easily shared to address this international need.[9] Our online curriculum is a ***sustainable*** tool that can be easily scaled. Furthermore, our work will change how we teach radiology by providing an evidence-based model for using EMT to create curricula that develop adaptive expertise.

II. Project Rationale

The purpose of our research is to reduce medical errors by creating curricula that help medical students and residents develop adaptive expertise. Medical errors can occur when physicians manage novel clinical situations they had not previously encountered during training. Adaptive expertise enables physicians to effectively manage these novel clinical situations.[2] However, medical education traditionally focuses on errorless training that hinders the development of adaptive expertise. Thus, physicians may be at higher risk of committing medical errors during independent practice if they have not committed sufficient errors during training.

A potential antidote is EMT, an instructional methodology that improves transfer of skills and develops adaptive expertise by making learners produce errors when solving difficult problems before being told how to solve them.[4,10,11] Although EMT has been shown to improve adaptive expertise in procedural skills, its impact on cognitive skills in medical training remains underexplored.[4–6] **To fill this gap,** our study aims to demonstrate that EMT improves adaptive expertise for a cognitive skill in medical education, using head CT interpretation as a model. This cognitive skill provides an ideal model for investigating EMT since we can precisely measure performance when comparing learning strategies. We hypothesize that EMT, compared to EAT, will improve adaptive expertise, as measured by skills transfer, when used to teach head CT interpretation to EM residents. Basic head CT interpretation is a vital skill for graduating medical students and physicians of multiple specialties, yet often inadequately covered in didactic curricula.[8,12] Our project presents an opportunity to fill this need. Our previous pilot RCT on head CT curriculum design and assessment provides us with the feasibility data and educational material to successfully complete this proposed study.[13] Using errors during training to develop adaptive expertise will ultimately help physicians reduce errors during unsupervised practice. Showing that EMT improves adaptive expertise for cognitive skills in medical training will provide foundational evidence for using EMT to shape other medical education curricula.

III. Approach

We will conduct a multicenter RCT with EM residents. Our independent variable is the learning strategy: EMT (experimental cohort) and EAT (control cohort). Each cohort will receive an online teaching session, an immediate post-test, and a delayed post-test in three months. We adapted head CT teaching and testing cases, previously developed in a pilot study[13], for an EMT-based educational intervention. The online teaching cases are built with Pacsbin, a HIPAA-compliant, interactive, high-fidelity radiology simulation platform. We will arrange the cases on a website to create the curriculum and use an analytics tracking platform to measure how long residents spend reviewing the head CTs. This will allow us to correct for time-on-task as a potential covariate between cohorts. The EMT cohort will first scroll through a head CT without guidance for each case and attempt to identify critical findings. These are difficult cases where learners are likely to make diagnostic mistakes. Then they navigate to a didactic content page. The EAT cohort navigates directly to the didactic content page for each case without an initial period of free exploration; this prevents them from having the overt experience of making errors. We constructed an assessment tool to measure head CT interpretation skills and will deliver this through REDCap. We recruited 11 other EM residency programs to be study sites and formed the Error Management Training in Education Research Network (EMTERN); all site directors signed a consortium letter of agreement (available in the appendix). We received Stanford IRB approval (IRB letter in appendix). External sites' IRB applications are in process and several sites have already received IRB approval. For our medical student pilot, we will deliver the EMT head CT curriculum as an online, asynchronous component of the medical student EM clerkship. The feedback from this pilot will be eventually used to create a medical student elective prototype using our EMT-based educational intervention.

IV. Timeline and Plan for Implementation

Aug-Oct: Finalize all external sites' IRB approval. Finalize the online curriculum.
Oct-Feb: Deliver educational interventions, collect and analyze immediate and delayed post-test data.
Feb-April: Pilot the medical student asynchronous curriculum, and collect user experience feedback.
March-June: Conference presentations; manuscript preparation and submission

V. Anticipated Work Product

We will produce an evidence-based, emergency radiology head CT curriculum that develops adaptive expertise. This modular curriculum can be used in a synchronous or asynchronous manner for both graduate and undergraduate medical education. Perhaps more importantly, we will provide a model for how to develop such curricula to better meet the goal of creating adaptive experts in medical education.

VI. Evaluation Plan

We will conduct a multicenter blinded RCT to evaluate our educational intervention. Our primary outcome is transfer of head CT interpretation skills. Two secondary outcomes are post-session proficiency and retention at three months. The immediate and delayed post-tests contain cases to assess both transfer and post-session proficiency. Our power calculation showed that 100 total subjects will have 80% power at the 0.05 significance level to detect a 6.0% difference (medium effect size). We will compare cohorts' post-test scores by mixed ANOVA and calculate effect sizes. Our subsequent medical student pilot implementation will assess the feasibility of incorporating an asynchronous curriculum into a clerkship. We will collect students' feedback on frequency of use, user interface, and user experience with the online radiology teaching cases, which will inform the development of a future medical student elective.

VII. Dissemination of Results

We will present the results of our multi-residency program RCT locally at the Stanford SIMEC conference, nationally at the Society for Academic Emergency Medicine conference, and internationally at the Association for Medical Education in Europe conference. We will submit our final work for publication in a medical education journal.

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APPENDIX

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