British Journal of Anaesthesia **112** (1): 124–32 (2014)
Advance Access publication 24 September 2013 · doi:10.1093/bja/aet326

BJA

QUALITY AND PATIENT SAFETY

Clinical decision-making augmented by simulation training: neural correlates demonstrated by functional imaging: a pilot study

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Editor's key points

- The neurocognitive mechanisms underlying the beneficial effects of simulation training on performance are poorly understood.
- Functional magnetic resonance imaging was used to monitor brain activation patterns in parallel with physiological indices of stress in subjects answering multiple choice questions after undergoing simulation or online-based training.
- This pilot proof-of-concept study demonstrated differences in cerebral activation patterns between the two groups in areas activated in response to stress consistent with simulation-induced stress attenuation.

Background. Investigation of the neuroanatomical basis of clinical decision-making, and whether this differs when students are trained via online training or simulation training, could provide valuable insight into the means by which simulation training might be beneficial.

Methods. The aim of this pilot prospective parallel group cohort study was to investigate the neural correlates of clinical decision-making, and to determine if simulation as opposed to online training influences these neural correlates. Twelve third-year medical students were randomized into two groups and received simulation-based or online-based training on anaphylaxis. This was followed by functional magnetic resonance imaging scanning to detect brain activation patterns while answering multiple choice questions (MCQs) related to anaphylaxis, and unrelated non-clinical (control) questions. Performance in the MCQs, salivary cortisol levels, heart rate, and arterial pressure were also measured.

Results. Comparing neural responses to clinical and non-clinical questions (in all participants), significant areas of activation were seen in the ventral anterior cingulate cortex and medial prefrontal cortex. These areas were activated in the online group when answering action-based questions related to their training, but not in the simulation group. The simulation group tended to react more quickly and accurately to clinical MCQs than the online group, but statistical significance was not reached.

Conclusions. The activation areas seen could indicate increased stress when answering clinical questions compared with general non-clinical questions, and in the online group when answering action-based clinical questions. These findings suggest simulation training attenuates neural responses related to stress when making clinical decisions.

Keywords: computer simulation; magnetic resonance imaging, functional; stress, psychological

Accepted for publication: 12 July 2013

Simulation has been increasingly used in anaesthesia training.[1] Previous studies indicate that students taught using high-fidelity simulation performed better in simulated[2 3] and clinical settings.[4] Reasons cited for simulation as a tool for effective learning have included the provision of feedback and evaluation, and the facilitation of experiential learning.[5] Simulation training may also facilitate stress reduction in the workplace,[6] which can adversely affect human and team performance,[7] and impair non-technical skills.[8] Research is still required to demonstrate the cognitive processes which may be responsible for the perceived benefits of simulation training.

We used functional magnetic resonance imaging (fMRI) to examine the neural correlates of clinical decision-making. Analysis of fMRI images allows identification of brain regions involved in the function of interest, referred to as activated regions.[9] fMRI has been used, for example, to compare situation-based and text-based learning of language,[10] but has not yet been used to investigate clinical methods of learning. This pilot exploratory study was used to demonstrate proof of concept, using a small number of subjects. While it would not be possible to draw firm conclusions from the study, proof of concept should aid the justification of a larger scale study with more subjects.

This was a pilot prospective parallel group cohort study. We hypothesized that by using fMRI, we could explore the cognitive processes behind clinical decision-making in medical students. Further, that we might be able to identify neural processing differences, if any, between learners trained by simulation *vs* online training.

It remains unclear what neural differences exist between simulation-based or online-based learning. Therefore, the imaging analysis was run in an exploratory fashion in order to avoid missing important areas of neural activation. Given the possibility raised for stress reduction after simulation training,[6] we measured behavioural data to correlate with stress, that is, salivary cortisol levels, heart rate, arterial pressure, and visual analogue scales. The control of human emotions involves various limbic and paralimbic structures.[11] Specifically, the anterior cingulate cortex and medial prefrontal cortex have been shown to respond to stress.[12] Therefore, changes in activation patterns in any of these areas could be an indication for the induction of stress during the testing session.

The main aim of this study was to investigate the neural correlates of clinical decision-making, that is, the identification of cognitive processes behind clinical decision-making. The secondary aim was to determine if simulation training as opposed to online training influences these neural correlates.

Methods

Ethical approval was granted by Cambridgeshire 2 Research Ethics Committee. Written informed consent was obtained from participants.

Participants

We recruited medical students from Cambridge University (aged 20–21) in the academic year 2010–11. As this was a pilot study, a power calculation was not performed. We recruited 12 participants (6 in each group). Inclusion criteria were that participants were in their third undergraduate year, and spoke English as their first language. These students had no prior experience in the clinical diagnosis and management of anaphylaxis.

Exclusion criteria were refusal to participate in the study, contraindications to MRI scanning, claustrophobia, pregnancy, medication such as antidepressants, or medical conditions which may affect cognitive performance, such as history of significant traumatic brain injury or of significant psychiatric illnesses. Since the experiment had a strong language element, and because of language lateralization in the brain with handedness, we excluded left-handed volunteers.

Volunteers were randomly assigned into two groups using computer-generated random numbers. One group was assigned to simulation-based training and the other to online-based training.

The teaching session

Volunteers were taught using simulation-based or online-based training, for a total of 30 min each (identical factual content), on anaphylaxis. The online-based session was a supervised session, and the student could ask questions freely. The simulation-based session was structured into an introductory 5 min of factual slides with the same slides from the online session on features, diagnosis, treatment, and aftermath, and a shorter version of the pathophysiology. Information from the online session describing the airway, breathing, circulation, disability, and exposure approach to managing a critically ill patient were instead taught for 10 min using the simulator (METI Human Patient Simulator, Sarasota, FL, USA). The student then participated in a scenario on anaphylaxis for 10 min, followed by 5 min for debriefing and summary.

The same researcher structured the teaching sessions, facilitated the simulation-based sessions, and supervised the e-learning sessions for all volunteers in order to reduce bias. The researcher was not actively teaching during the online session, so the researcher was not blinded to the nature of the study. In the information sheet, it was stated that high-fidelity simulation may lead to improved teaching and learning, and that the aim of the study was to determine the effect of simulation-based learning on brain networks which mediate clinical decision-making by comparing brain activations between the group taught online and the group taught via simulation. An interval of 3–7 weeks elapsed before the scanning session. The difference in the intervals between the teaching and scanning sessions in the two groups was not statistically significant (P=0.62).

The scanning session

At the beginning of the scanning session, the volunteers underwent computerized neuropsychological tests taken from the Cambridge Neuropsychological Test Automated Battery (CANTAB, Cambridge Cognition Ltd; www.cantab.com) to test for equivalent cognitive abilities between the groups. The following tests were performed in a quiet room: simple reaction time, paired associates learning, big/little circle, intra/extradimensional shift, and information sampling task. The tests measured speed of response, episodic memory, comprehension and learning, rule acquisition and impulsivity, and decision-making, respectively.

Scanning involved answering questions to a multiple choice question (MCQ) task. Volunteers familiarized themselves with the format of the task before entering the scanner by answering 10 practice questions. They also completed a visual analogue scale (VAS) to measure anxiety, and a salivary cortisol sample was taken. Heart rate and non-invasive arterial pressure was measured every 5 min during the scanning session (Precess, InVivo Corp., Orlando, FL, USA). Immediately after the scan, a second salivary cortisol sample was taken, and a repeat VAS for anxiety completed.

The fMRI MCQ task

An event-related fMRI paradigm was used. The participants answered 80 MCQs presented in random order using a box with four buttons. These were equally divided into clinical and non-clinical (control) questions. All clinical questions were based on anaphylaxis, testing only what was taught in