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# Virtual reality case-specific rehearsal in temporal bone surgery: A preliminary evaluation

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ABSTRACT

*Objectives:* 1. To investigate the feasibility of performing case-specific surgical rehearsal using a virtual reality temporal bone simulator. 2. To identify potential clinical applications in temporal bone surgery.
*Design:* Prospective assessment study.
*Setting:* St Mary's Hospital, Imperial College NHS Trust, London UK.
*Participants:* Sixteen participants consisting of a trainer and trainee group.
*Method:* Twenty-four cadaver temporal bones were CT-scanned and uploaded onto the Voxelman simulator. Sixteen participants performed a 90-min temporal bone dissection on the generic simulation model followed by 3 dissection tasks on the case simulation and cadaver models. Case rehearsal was assessed for feasibility. Clinical applications and usefulness were evaluated using a 5-point Likert-type scale.
*Results:* The upload process required a semi-automated system. Average time for upload was 20 min. Suboptimal reconstruction occurred in 21% of cases arising when the mastoid process and ossicular chain were not captured ($n = 2$) or when artefact was generated ($n = 3$). Case rehearsal rated highly (Likert score >4) for confidence (75%), facilitating planning (75%) and training (94%). Potential clinical applications for case rehearsal include ossicular chain surgery, cochlear implantation and congenital anomalies. Case rehearsal of cholesteatoma surgery is not possible on the current platform due to suboptimal soft tissue representation.
*Conclusion:* The process of uploading CT data onto a virtual reality temporal bone simulator to perform surgical rehearsal is feasible using a semi-automated system. Further clinical evaluation is warranted to assess the benefit of performing patient-specific surgical rehearsal in selected procedures.


## 1. Introduction

The desire to improve patient safety and training has led to the application of virtual reality (VR) simulation in ENT surgery.[1–4] Temporal bone simulation produces a three-dimensional (3D) recreation of the surgical environment. It enables objective assessment of competency in a patient-free, risk-free environment.[5] It also offers the possibility of performing case-specific surgical rehearsal (CSSR). The intended surgical procedure may first be performed in an interactive virtual environment using patient-specific computerised tomography (CT) data uploaded onto the simulator.

Procedural skills rehearsal is well established in non-medical fields such as aviation. Bone and Lintern compared conventional map study to simulator rehearsal in 36 pilots preparing for a flight mission.[6] A subsequent test of navigation knowledge demonstrated that simulator rehearsal was superior for route knowledge acquisition. The role of VR simulated case rehearsal in carotid endovascular surgery has also been reported.[7–10] Results suggest that it facilitates case selection and improves surgical performance.

Several temporal bone simulators have been developed.[5,11–13] The Voxelman Temposurg has previously been validated for postgraduate training at Imperial College London and demonstrated adequate face, content and construct validity.[2,3,14] However, the process of uploading CT data to a temporal bone simulator to

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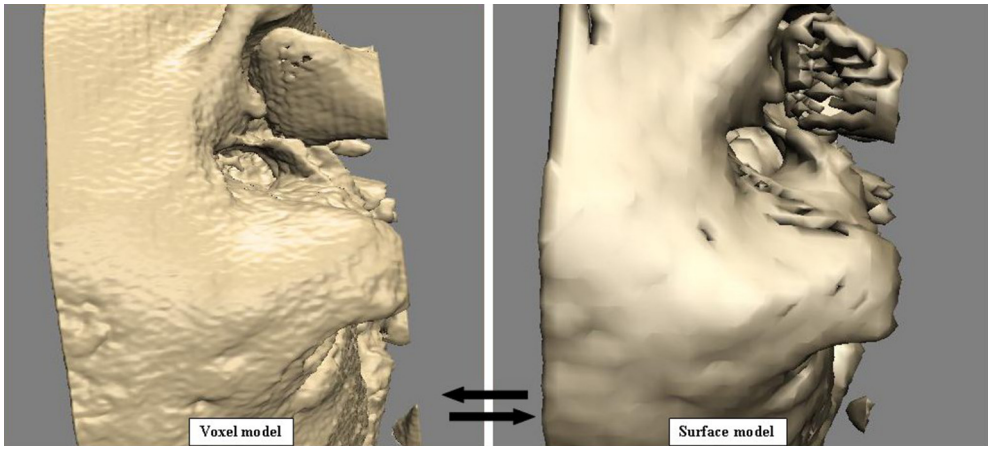


**Fig. 1.** High-resolution voxel model and temporary conversion to a low-resolution surface model during segmentation.

perform case rehearsal has not been reported. The objective of this study was to determine the feasibility of performing case rehearsal and identify potential clinical applications in temporal bone surgery.

## 2. Method

### 2.1. Ethical considerations

National Research Ethics Service (NRES) reviewed the study and ethical approval was not required under NHS research governance arrangements. The study was exempt from review by Imperial College and Imperial College Healthcare Joint Research Office.

### 2.2. Participants

Sixteen participants were recruited comprising of 8 otolaryngology trainers (minimum of 400 mastoid operations as primary surgeon) and 8 otolaryngology trainees (mean experience of 19 months). All the trainees had prior experience in temporal bone drilling consisting of laboratory (cadaver (3/8), plastic (7/8)), virtual (8/8) and operating room experience (8/8). Thirty-eight percent (3/8) of the trainee group had previously drilled 2 or more cadaver temporal bones.

### 2.3. Simulator platform

The Voxelman TempoSurg surgical site is displayed in stereoscopic mode. The operator uses shutter glasses to visualise a 3D representation of the temporal bone. The station houses a computer with software linked to a force-feedback hand device. This serves as a 'virtual drill' which is activated by the foot pedal. The drill responds to contact which allows the user to experience changes in pressure. The computer records a number of performance measures such as excessive force. The user is able to alter the surgical orientation, drill size, type, and rotation speed. The 1st iteration of the Voxelman simulator platform was used for this study in which suction and blood functions are not a feature.

### 2.4. Evaluation of case-specific surgical rehearsal

#### 2.4.1. Feasibility

Twenty-four formalin-fixed cadaver temporal bones were scanned using a Philips iCT 256 CT-scanner. Data were saved in Digital Imaging and Communications in Medicine (DICOM) format to a compact disc for upload using the data import module. The process of reconstruction is described as the 'segmentation phase'. The user selects a threshold range and converts the data into a 3D voxel model. To enable the model's orientation to be changed in real time, the image was temporarily converted into a low-resolution surface model (Fig. 1). Data transfer and retrieval were evaluated for: slice spacing and thickness, field of view and intensity range. The segmentation process was assessed for artefact and the threshold required for adequate reconstructions. The time for each temporal bone upload was recorded to assess the learning curve.

#### 2.4.2. Clinical application

Participants were assigned a cadaver temporal bone and its corresponding VR upload. All subjects undertook a standardised 30-min familiarisation session and 90-min temporal bone dissection on the generic simulator training model before performing 3 standardised tasks on the virtual and cadaver temporal bones: extended cortical mastoidectomy, posterior tympanotomy and cochleostomy. Standardised written instructions for each task were provided. Successful task completion was judged by 2 co-authors using a task-based checklist to ensure the objectives were fulfilled (Fig. S1). Following completion, participants assessed the role of case rehearsal and accuracy of representation over 9 domains. Questions were rated on a 5-point Likert scale, in which 1 represented *strongly disagree*; 2 as *disagree*; 3 as *neutral*; 4 as *agree*; 5 as *strongly agree*. A score of 4 was the minimum threshold for acceptability. Differences between the trainer and trainee groups were analysed with the independent *t*-test. A $p$ value of $<0.05$ was considered significant.

Qualitative data were collected using videos of 90-min focus group sessions where the trainer and trainee groups were independently asked standardised open-ended questions. The videos were saved as digital files, manually transcribed and underwent thematic analysis, as described by Fereday and Muir-Cochrane.[15]

## 3. Results

### 3.1. Evaluation of case-specific surgical rehearsal

#### 3.1.1. Feasibility

Each temporal bone had CT data comprising 156 slices, 0.33 mm × 0.33 mm pixel size and 1 mm slice spacing. In all cases, CT-DICOM data were within the standard intensity range. The entire mastoid process was inadvertently not captured in 2