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# BMJ Open

## The Use of 3D Printed Head and Neck Models for Simulating 10 Common ENT Emergency Procedures

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2024-095877
Article Type:	Original research
Date Submitted by the Author:	30-Oct-2024
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Keywords:	Primary Care < Primary Health Care, ACCIDENT & EMERGENCY MEDICINE, OTOLARYNGOLOGY

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# The Use of 3D Printed Head and Neck Models for Simulating 10 Common ENT Emergency

## Procedures

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## Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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**Abstract**

**Objective:** This study aims to validate a high-fidelity 3D-printed head and neck model for training Emergency Medicine physicians, Primary Care physicians, and Allied Health Professionals in managing ten common ENT emergencies.

**Setting:** The study was conducted at an ENT Emergencies course in London.

**Participants:** Were healthcare professionals including Primary Care and Emergency Medicine physicians, Ear, Nose and Throat Consultants and Allied Health Professionals. The study included 90 delegates and 11 consultant ENT surgeons.

**Intervention:** The 3D models, produced using proprietary 3D printing technology (Fuesetec), were used in a one-day ENT emergencies course for validating training and confidence of delegates in performing 10 common ENT emergencies.

**Results:** A total of 86% (n=77) of delegates found the models extremely or very helpful in learning ENT emergencies. Delegates rated the resemblance to real patients as excellent or very good in both haptic feedback (n=58, 64%) and tissue texture (n=67, 74%). Additionally, 74-96% of delegates felt confident in performing the ten ENT procedures after using the models.

**Conclusion:** The 3D models enhanced participant confidence in performing ten common ENT emergency procedures, demonstrating good face, content, and indirect criterion validity. These models could support emergency ENT skill development in local emergency departments.

**Key Words:** ENT, 3D Models, Simulation Training, Procedural Skills, Emergency Medicine, Primary Care.

**Abbreviations:** ENT (Ear Nose and Throat), ED (Emergency Department), UKRI (UK Research and Innovation) and (UK) United Kingdom.

**Word Count:** 2576

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## Article Summary

### *Strengths and limitations of this study*

- A diverse set of ENT emergencies was represented, providing comprehensive training exposure.
- The use of face validity allowed direct feedback on the model's physical realism for procedural training.
- Content and indirect criterion validity ensured the model's alignment with postgraduate training curricula and its impact on self-reported confidence.
- Validation measures did not include objective performance assessments of procedural skills after training.

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**Introduction**

Ear, Nose, and Throat (ENT) disorders are common reasons for seeking care in the Emergency Department (ED) or via Primary Care.<sup>1,2</sup> There is seen to be a lack of undergraduate and postgraduate teaching and training in ENT emergencies, resulting in newly qualified doctors not feeling adequately prepared to practice ENT.<sup>3,4,5</sup> A study by Sharma et al found that 75% of junior doctors have not received sufficient ENT teaching to deal with common ENT emergencies, with 42% of junior doctors not feeling confident in managing common ENT emergencies.<sup>5</sup> It has also been reported that 88% of senior ENT doctors on call are non-resident, which places more onus on junior doctors and the Emergency Medicine (EM) team to manage common ENT emergencies.<sup>3</sup>

Simulation training helps to mitigate patient safety risks by allowing individuals to practice procedures in a safe space without jeopardising patient safety.<sup>6,7</sup> Simulation is an increasingly valuable tool in emergency education, with simulation-based training shown to aid in the acquisition of clinical skills more effectively compared to traditional lectures or tutorials.<sup>7</sup> The increased demand for high-quality, cost-effective medical simulation has led to the incorporation of three-dimensional (3D) printed models to aid in simulation training.<sup>8</sup>

Previous studies have employed 3D models and these have received positive feedback from trainees regarding common emergencies including: tracheostomy tube placement, peritonsillar abscess drainage, and nasal packing.<sup>8-10</sup> However, these studies utilised low-fidelity models with small sample sizes, limiting the ability to draw meaningful conclusions.<sup>8</sup> Furthermore, the models reported within the literature have not been used beyond initial pilot testing, with no model currently being

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3 utilised or validated in clinical courses or teaching.<sup>8-10</sup> ENT emergency procedures can be taught on  
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5 cadavers or animal specimens, but these convey significant financial costs and reduced accessibility.<sup>8</sup>  
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7 Therefore, there is a need for developing a high-fidelity training model that has similar realism,  
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9 haptic feedback, and tissue texture of a real patient without conveying the risks to patient safety or  
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11 the costs associated with cadaveric models.  
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## 17 **Methodology**

### 18 ***3D-printed simulation model design***

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20 The head and neck models were created using ZBrush (Pixologic Inc, California). This digital sculpting  
21  
22 software was used to recreate human anatomy by sculpting basic shapes. The individual anatomical  
23  
24 components were then assembled and further edited on Netfabb (Autodesk, California) for  
25  
26 manufacturing (Figures 1A and 1B). The peritonsillar abscess was developed as a variation of the  
27  
28 model created using the method above. Files were sculpted to include a peritonsillar abscess on  
29  
30 Blender and then printed in place of regular tonsils (Figure 1B). The otology aspect was created using  
31  
32 a combination of the above two methods (Figure 1C). Ear CT scans were segmented using Mimics  
33  
34 (Materialise NV, Belgium). Files that were not clear in scans were digitally sculpted in ZBrush and  
35  
36 fitted into the model. Models were printed using the Stratasys Digital Anatomical Printer (Stratasys  
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38 Ltd, Minnesota). A combination of preset and custom digital materials. The model's various  
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40 components. The models can be seen in Figure 2A, 2B, 2C and Appendix 1.  
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**ENT Emergencies Training Course**

The models were then validated in an ENT emergencies training course. Delegates attended an in-person course on managing 10 common ENT emergencies. The 10 ENT emergencies included foreign body nose removal, epistaxis management, peritonsillar abscess drainage, flexible nasendoscopy for stridor assessment, post-tonsillectomy bleed management, foreign body removal from the throat, pope otowick insertion/ otitis externa management, foreign body removal from the ear, tracheostomy insertion, and drainage of a post-thyroidectomy hematoma.

This was a one-day course consisting of small group lectures and practical skills sessions using 3D printed head and neck models. The faculty consisted of ENT consultants/attending surgeons, with a faculty-to-delegate ratio of 1:5 to aid in procedural steps and teaching. 3D model simulation training was delivered after delegates had received tutorials on common ENT emergencies and their management. Following the completion of the course, delegates were asked to complete paper surveys, which adopted a combination of yes/no items and Likert scales to evaluate their experience with the 3D models. All delegates provided informed consent to have their data used as part of a research study for the validation of the 3D models.

**Validation**

The validation of the 3D models involved a combination of methods. First, face validity was assessed by having delegates evaluate the realism of the models for performing ENT emergency procedures. Second, content validity was ensured through mapping the ENT procedures included to the postgraduate Primary Care and Emergency Medicine curricula.<sup>11,12</sup> Moreover, content validity was further assessed by having ENT consultants rate the realism of the models specifically for performing common ENT emergency procedures. Lastly, indirect criterion validity was determined by assessing

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self-reported confidence of delegates in performing ENT emergency procedures after using the 3D models.

### ***Ethical Statement***

Delegates taking part in the survey provided implied consent to participate in the study and have their data used as part of research by voluntarily completing the survey. All data collected was anonymous, and no patient data was collected or used as part of the qualitative research. In accordance with the ethical guidelines prevailing in the United Kingdom (UK), an extensive ethical assessment was conducted using the UK Research and Innovation (UKRI) Research Ethics Tool prior to the initiation of our study. Ethical approval was not required as per the UKRI Research Ethics Tool.

### **Aim**

This study sets out to validate a high-fidelity head and neck model, printed using proprietary 3D printing technology, that can be used to train EM Physicians, Primary Care Physicians and Allied Health Professionals in 10 common ENT emergencies.

### **Results**

#### **Breakdown of Survey Responses**

A total of 90 delegates and 11 ENT consultant/attending surgeons utilized the 3D printed models for ENT emergency skills training and responded to the survey. Among them, 60% (n=54) were EM residents/trainees, 28% (n=25) were Primary Care residents/trainees, 4% (n=4) were ENT residents/trainees, 4% (n=4) were Emergency Nurse Practitioners, 2% (n=2) was a Primary Care attending physician, and 1% (n=1) was an EM attending/consultant. Prior experience in common ENT

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3 emergencies was assessed for 90 of the delegates (excluding ENT consultant/attending surgeons),  
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5 which is displayed in Appendix 2.  
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10 **Current Teaching in ENT Emergencies**

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12 Delegates (n=90) were asked about their current teaching on ENT Emergency procedures they  
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14 receive within their department. No teaching was received by 58% (n=52) of delegates, while 26%  
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16 (n=23) received lecture-based teaching, 12% (n=11) received small-group teaching, and 4% (n=4)  
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18 received teaching on real patients. None of the delegates had used 3D models within their local  
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20 department teaching.  
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26 **Face Validity: realism of models for delegates**

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31 Face validity was assessed by asking delegates to rate the realism of the models, as displayed in  
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33 Table 1. Results indicated good face validity, with 70-98% (Range: 35-49) of delegates rating the  
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35 realism as very good/excellent.  
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41 The overall realism of the model, including its visual appearance, internal/external anatomy, and  
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43 simulation of procedures, was reported using a five-point scale: excellent, above average, average,  
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45 below average, or poor. Delegates rated the models as “excellent” or “very good” for performing the  
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47 10 emergency procedures: flexible nasendoscopy to assess for stridor (n=77, 86%), assessing and  
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49 removing nasal foreign bodies (n=77, 86%), assessing and removing foreign bodies from the ear  
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51 (n=81, 90%), managing otitis externa with Pope otowick insertion (n=83, 92%), assessment and  
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53 management of a peritonsillar abscess using needle aspiration (n=68, 76%), assessing for and  
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55 removing a foreign body from the throat (n=74, 82%), performing a tracheostomy (n=63, 70%),  
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57 managing a post-thyroidectomy haematoma (n=72, 80%), managing epistaxis using cautery and  
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nasal packing (n=68, 76%), and managing a post-tonsillectomy bleed (n=77, 86%). The full results depicting the delegate-reported realism of the models can be seen in Table 1.

Delegates were asked to rate the realism (five-point scale: excellent, above average, average, below average, or poor) of the haptic/tactile feedback provided by the models compared to real patient tissue. This encompassed the perception of pressure, vibration, and resistance when performing the procedures and comparing these to what one might expect in a real patient. Most delegates rated this as excellent or very good (n=58, 64%), followed by 32% (n=29) rating them as average, and 4% (n=4) rating them as below average.

Furthermore, delegates and ENT consultants were asked to rate the realism (five-point scale: excellent, above average, average, below average, or poor) of the tissue texture and handling compared to real patient tissue, which added to the content validity. This encompassed the firmness, elasticity, and texture accuracy as compared to real tissue. Most delegates rated this as excellent or very good (n=67, 74%), with 24% (n=22) rating them as average and 1% (n=1) rating them as below average.

#### **Content Validity: ENT consultant surgeon ratings of realism of simulation**

Content validity was ensured by mapping the procedures to the Primary Care and Emergency Medicine postgraduate curricula.<sup>11,12</sup> This assurance was further fortified by incorporating 10 common ENT emergency procedures, this was following discussions with ENT surgeons across the United Kingdom. This step ensured relevance of the models and skills to those working in Emergency Medicine and Primary Care. Moreover, having consultant ENT surgeons rate the realism of using the models in simulating 10 common ENT Procedures furthered the content validity. The full results

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depicting ENT consultant reported realism of the models can be seen in Table 2. Similar results between the ENT consultant surgeons and delegates were seen regarding the realism which highlights good content validity.

ENT consultants were asked to rate the realism (five-point scale: excellent, above average, average, below average, or poor) of the haptic/tactile feedback provided by the models compared to real patient tissue. All (n=11, 100%) ENT consultants rated the models to be excellent or very good for haptic/tactile feedback compared to real patient tissue.

Furthermore, ENT consultants were asked to rate the realism (five-point scale: excellent, above average, average, below average, or poor) of the tissue texture and handling compared to real patient tissue. All (n=11, 100%) of the ENT consultants rated the tissue handling in comparison to real patient tissue as excellent/very good.

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Please rate the realism of the 3D models for each of the following procedures and assessment in comparison to real patients or cadavers	Excellent	Above Average	Average	Below Average	Poor	N/A
Assessment of stridor and performing flexible nasendoscopy	43 (48%)	34 (38%)	9 (10%)	2 (2%)	0 (0%)	2 (2%)
Assessing for and removing a foreign body of the nose	36 (40%)	41 (46%)	11 (12%)	0 (0%)	0 (0%)	2 (2%)
Assessing for and removing a foreign body of the ear	52 (58%)	29 (32%)	9 (10%)	0 (0%)	0 (0%)	0 (0%)
Managing otitis externa with the insertion of a Pope otowick	40 (44%)	43 (48%)	7 (8%)	0 (0%)	0 (0%)	0 (0%)

Managing a peritonsillar abscess with needle aspiration	34 (38%)	34 (38%)	18 (20%)	2 (2%)	2 (2%)	0 (0%)
Assessing for and removing a foreign body of the throat	40 (44%)	34 (38%)	9 (10%)	4 (4%)	1 (1%)	2 (4%)
Performing a tracheostomy*	40 (44%)	23 (26%)	0 (0%)	2 (2%)	0 (0%)	11 (12%)
Managing a post-thyroidectomy haematoma	40 (44%)	32 (36%)	9 (10%)	0 (0%)	0 (0%)	9 (10%)
Managing epistaxis including nasal packing and cautery	38 (42%)	31 (34%)	21 (23%)	0 (0%)	0 (0%)	0 (0%)
Managing a post-tonsillectomy bleed	36 (40%)	41 (46%)	4 (4%)	0 (0%)	0 (0%)	9 (10%)

Table 1. Realism Rating of the 3D Models Course Delegates.

\*14 delegates did not complete this question.

Please rate the realism of the 3D models for each of the following procedures and assessment in comparison to real patients or cadavers	Excellent	Above Average	Average	Below Average	Poor	N/A
Assessment of stridor and performing flexible nasendoscopy	5 (46%)	6 (55%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Assessing for and removing a foreign body of the nose	11 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Assessing for and removing a foreign body of the ear	4 (36%)	5 (46%)	2 (18%)	0 (0%)	0 (0%)	0 (0%)



Managing otitis externa with the insertion of a Pope otowick	8 (73%)	2 (18%)	1 (9%)	0 (0%)	0 (0%)	0 (0%)
Managing a peritonsillar abscess with needle aspiration	9 (82%)	1 (9%)	1 (9%)	0 (0%)	0 (0%)	0 (0%)
Assessing for and removing a foreign body of the throat	10 (91%)	1 (9%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Performing a tracheostomy	2 (18%)	3 (27%)	6 (55%)	0 (0%)	0 (0%)	0 (0%)
Managing a post-thyroidectomy haematoma	6 (55%)	3 (27%)	0 (0%)	1 (9%)	0 (0%)	0 (0%)
Managing epistaxis including nasal packing and cautery	2 (18%)	8 (73%)	1 (9%)	0 (0%)	0 (0%)	0 (0%)
Managing a post-tonsillectomy bleed	1 (9%)	7 (64%)	3 (27%)	0 (0%)	0 (0%)	0 (0%)

Table 2. Realism Rating of the 3D Models Course ENT Consultants.

Criterion Validity

Next, we analysed the indirect criterion validity by assessing delegates' self-reported confidence after using the 3D models. The confidence levels of delegates in practicing common ENT emergencies are displayed in Table 3 with most delegates (74-96%) feeling confident in performing the 10 ENT emergency procedures following the use of the 3D models. Hence, demonstrating good indirect criterion validity.

Overall, 56% (n=28) of delegates found the models to be extremely helpful in enhancing their learning of ENT emergencies, with 30% (n=15) finding the models very helpful and 14% (n=7) finding the models moderately helpful to their learning. No respondents found the models slightly or not at all helpful.

To what extent do you agree with the following statements? Following the use of the 3D models on the course I feel confident in:	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Not Performed
Assessing for and removing a foreign body of the ear	56 (62%)	25 (28%)	5 (6%)	2 (2%)	2 (2%)	0
Assessing and managing otitis externa including the insertion of a Pope otowick	54 (60%)	22 (24%)	9 (10%)	2 (2%)	3 (3%)	0 (0%)
Managing a peritonsillar abscess using needle aspiration	47 (52%)	20 (22%)	18 (20%)	4 (4%)	1 (1%)	0 (0%)

Assessing for and removing a foreign body of the throat	54 (60%)	20 (22%)	11 (12%)	0 (0%)	2 (2%)	3 (3%)
Performing a tracheostomy	52 (58%)	20 (22%)	0 (0%)	0 (0%)	7 (8%)	11 (12%)
Managing a post-tonsillectomy bleed	58 (64%)	14 (16%)	11 (12%)	0 (0%)	4 (4%)	3 (3%)
Managing a post-thyroidectomy haematoma	52 (58%)	29 (32%)	2 (2%)	5 (6%)	2 (2%)	0 (0%)
Managing epistaxis including nasal packing and cautery	65 (72%)	20 (22%)	4 (4%)	0 (0%)	1 (1%)	0 (0%)
Assessing for and removing a foreign body of the nose	61 (68%)	23 (26%)	2 (2%)	0 (0%)	2 (2%)	2 (2%)
Assessment of stridor and performing flexible nasendoscopy	38 (42%)	38 (42%)	11 (12%)	0 (0%)	2 (2%)	1 (1%)

**Table 3. Delegate Confidence in Managing Common ENT Emergencies Following the Use of 3D Models.**

**Future Directions**

Overall, 90% (n=81) of delegates would recommend the use of 3D models to other trainees for learning ENT emergency procedural skills, similarly 100% (n=11) of ENT surgeons would recommend the use of 3D models to their trainees. Additionally, 80% (n=72) of respondents stated that they

would prefer to have 3D models in future courses as their preferred method to practice ENT emergency skills, while 20% (n=18) of respondents would prefer to see a combination of 3D models together with cadavers.

Overall, for the delegates and ENT surgeons, 98% (n=99) of respondents felt that implementing the 3D models into local ED/Primary Care settings would help improve trainee confidence in ENT emergency procedural skills, while only 2% (n=2) were unsure about this. Delegates were asked, "What would be the biggest factor in deciding whether to incorporate 3D models into your local department for learning ENT emergency skills?" In response, 62% (n=56) cited the availability of local faculty to assist in teaching, 31% (n=28) stated that cost/price of models would be a determining factor, and 7% (n=6) mentioned that the longevity of the model would influence their decision.

## Discussion

Previous research has revealed that medical professionals often lack confidence in managing common ENT emergencies due to inadequate training and teaching.<sup>5</sup>

Within this study most delegates rated the models as realistic for all 10 of the emergency procedures, which indicates good and consistent face validity. Additionally, a significant proportion of respondents rated the haptic/tactile feedback and tissue handling/texture resemblance from the models as excellent or very good. The utilisation of 3D models, was associated with enhanced participant confidence in performing 10 common ENT emergency skills, thereby highlighting the study's good indirect criterion validity.

**Improving Competence and Confidence of Emergency Care providers**

Within our cohort, the 3D models were associated with increasing self-reported confidence by the delegates performing 10 common ENT emergency procedures. Given the specialised nature and often time-critical state of ENT emergencies, frontline staff, such as EM doctors and Primary Care physicians, should undergo training to develop confidence in performing common ENT emergency procedures.<sup>3,5,7</sup> A doctor’s competency in procedural skills is paramount to patient safety, as evidenced by the increased mortality, morbidity, and prolonged hospital stays associated with procedure-related complications.<sup>13</sup> A previous study highlights that junior doctors working in ED are not confident in identifying and managing common ENT emergencies.<sup>14</sup> Delayed treatment for these conditions can lead to significant patient safety concerns and potentially death. With many ENT departments having an out-of-hours service where, first-line emergency cover is provided by a cross-over system shared by other specialties, the on-call doctor may have no previous ENT experience.<sup>3,14</sup> Hence, there is a clear indication for frontline providers working in the ED and Primary Care to receive training in performing ENT emergency procedures, with 3D models offering a method to facilitate this training.

**Incorporating 3D Models into Local Departments**

Adopting novel 3D head and neck models, has been demonstrated to enhance confidence in performing common ENT emergency procedures following a one-day course. These models were associated with good face, content, and indirect criterion validity.

Overall, 98.4% of our respondents felt that the models should be used in local ED/Primary Care settings to improve trainee confidence in ENT emergency procedures, with the models being adaptable to simulate various ENT pathologies. The availability of locally skilled faculty to allow for

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training was the biggest deterring factor for incorporating the models into local departments. The availability of experienced faculty to oversee and facilitate procedural skills allows for immediate feedback, reflection and learning this in turn enhances simulated skills learning.<sup>15,16</sup> However, the presence of experienced faculty may not be always required. Previous research suggests that independent use of simulators in surgery and procedural skills, without expert feedback, may be advantageous and preferable to proctored simulation.<sup>17</sup> The models do allow for repetitive practice and training amongst trainees which can in turn speed up skill adoption.<sup>18</sup>

The 3D models have the added advantage for gaining experience in certain procedures, where the clinical caseload and exposure may be low. Having locally available 3D models would allow doctors to practice emergency ENT procedures regularly and, therefore, prevent skill-fade.

### Limitations

This study had several limitations. Firstly, each respondent had varied experience in ENT, which was not measured as part of the validation of the models. Secondly, ENT emergency procedure performance via an assessment of competence was not evaluated within this study; therefore, direct criterion validity was not measured. Thirdly, the models were used in a non-validated training programme. Hence, the purpose was not to ensure that delegates were signed off and competent to deliver emergency care; rather, these 3D models were part of a course and are still in the evaluation stage.

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**Funding**

Nil

**Conflict of interest statement**

ML is on the advisory board for the company Fusetec Inc. which provided the technology and Director of Innocrates Ltd.

**Acknowledgements**

We would like to acknowledge the support by Mr John Budgen and Mr Mark Roe from Fusetec Inc. (Adelaide, Australia), who supported the development of the technology and provided the materials for the testing of the models and the validation study.

**Author contributions**

UR conducted the data analysis, involved in study design and conception, manuscript preparation and editing. DC: involved in study design and conception, manuscript preparation and review. SG, PK, AV, JH, PS, CDH, JR, MW, KS, CT, PR, NEL, YB AL, SO: involved in study design and conception and manuscript review and editing. MR, ML involved in data analysis, study design and conception, manuscript preparation, manuscript editing, manuscript review.

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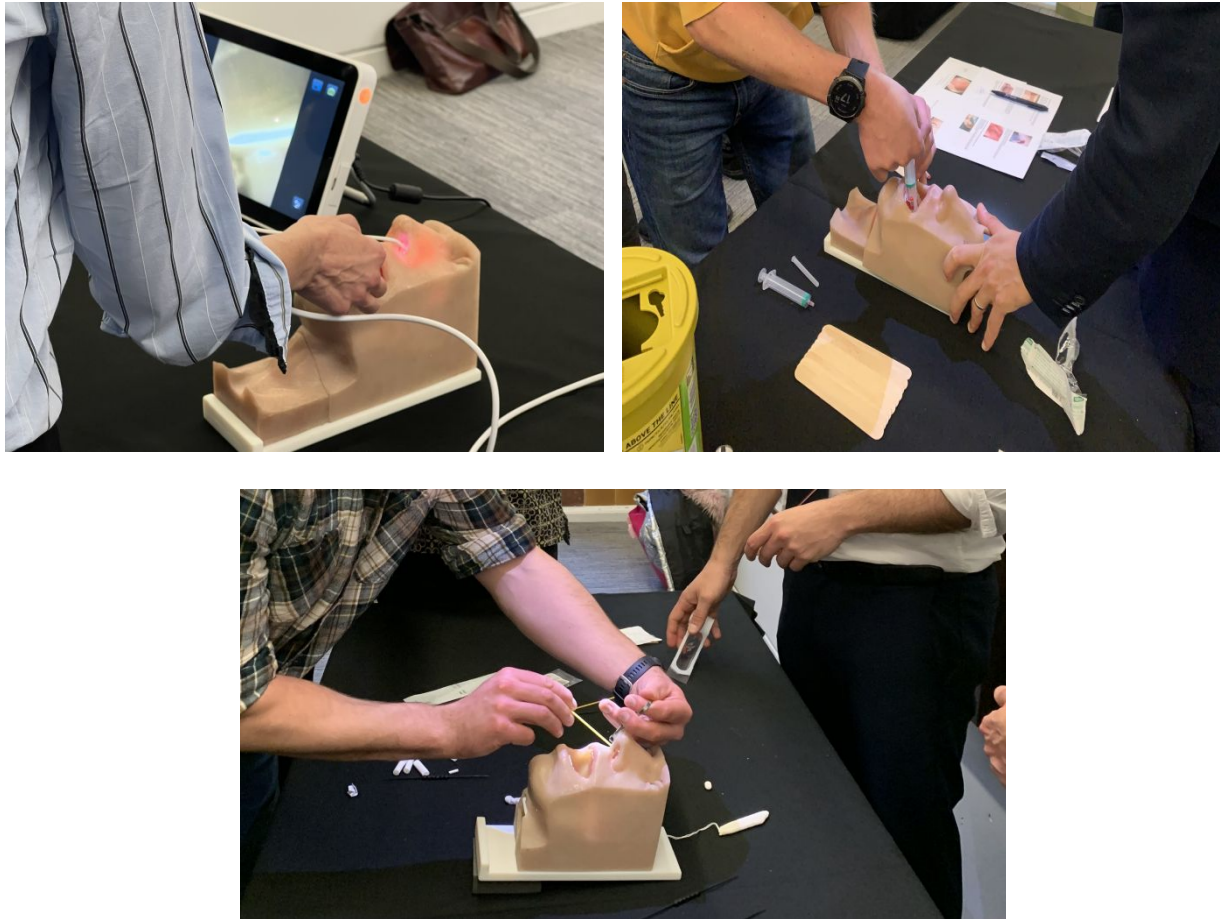
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## Appendix 1



**Appendix 1. Use of 3D models for practical skills training.** (A) Flexible Nasendoscopy (B) Aspiration of Peritonsillar Abscess. (C) Nasal Cautery for Epistaxis Management.

Appendix 2

How many times had you performed the following procedures prior to the course?	0	1-2	3-4	5-6	7-8	>8
Assessing for and removing a foreignn body of the ear	40 (44%)	23 (26%)	13 (14%)	7 (8%)	4 (4%)	3 (3%)
Assessing for and removing a foreignn body of the nose	36 (40%)	22 (24%)	13 (14%)	11 (12%)	4 (4%)	4 (4%)
Assessing for and removing a foreign body of the throat”	61 (68%)	11 (12%)	13 (14%)	5 (5%)	0 (0%)	0 (0%)
Managing a peritonsillar abscess/Quinsy including needle aspiration	65 (72%)	18 (20%)	4 (4%)	3 (3%)	0 (0%)	0 (0%)
Performing a tracheostomy	76 (84%)	5 (6%)	5 (6%)	4 (4%)	0 (0%)	0 (0%)
Managing Otitis Externa with the insertion of a pope otowick	42 (47%)	7 (8%)	4 (4%)	19 (21%)	16 (18%)	2 (2%)
Managing a post- thyroidectomy haematoma	83 (92%)	5 (6%)	2 (2%)	0 (0%)	0 (0%)	0 (0%)

Managing epistaxis including nasal packing and cautery	14 (16%)	25 (28%)	7 (8%)	9 (10%)	4 (4%)	31 (34%)
Managing a post-tonsillectomy bleed	50 (56%)	18 (20%)	7 (8%)	13 (14%)	2 (2%)	0 (0%)
Assessment of stridor and performing flexible nasendoscopy	79 (88%)	5 (6%)	2 (2%)	0 (0%)	2 (2%)	2 (2%)

## Appendix 2. Prior Experience with 10 Common ENT Emergencies.

# BMJ Open

## The Use of 3D Printed Head and Neck Models for Simulating 10 Common ENT Emergency Procedures: a prospective validation study

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2024-095877.R1
Article Type:	Original research
Date Submitted by the Author:	13-Mar-2025
Complete List of Authors:	Rehman, Umar; UCL Division of Surgery & Interventional Science, Colton, Dermot; City and Hackney Teaching Primary Care Trust Gupta, Sanj; Sheffield Children's Hospital Kulloo, Praneta; University Hospital Lewisham Vijendren, Ananth; East and North Hertfordshire NHS Trust Howard, James; Wrexham Maelor Hospital Sangwan, Purnima; Homerton Healthcare NHS Foundation Trust Davies-Husband, Cameron; Charing Cross Hospital Rudd, James; Royal Free London NHS Foundation Trust Whittaker, Max; Homerton Healthcare NHS Foundation Trust Stephenson, Kate; Birmingham Children's Hospital NHS Foundation Trust Taylor, Claudia; Addenbrooke's Hospital, Department of Head and Neck Surgery Roche, Phoebe; Addenbrooke's Hospital, Department of Head and Neck Surgery Eynon-Lewis, Nick; The Royal London Hospital Bajaj, Yogesh; The Royal London Hospital Lau, Andrew; Manchester Royal Infirmary Okhovat, Saleh; Glasgow Royal Infirmary Rollin, Matt; Imperial College Healthcare NHS Trust Lechner, Matt; UCL Division of Surgery & Interventional Science
<b>Primary Subject Heading</b>:	Ear, nose and throat/otolaryngology
Secondary Subject Heading:	Emergency medicine, Surgery
Keywords:	Primary Care < Primary Health Care, ACCIDENT & EMERGENCY MEDICINE, OTOLARYNGOLOGY

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# The Use of 3D Printed Head and Neck Models for Simulating 10 Common ENT Emergency

## Procedures: a prospective validation study

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## Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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**Abstract**

**Objective:** This study aims to validate a high-fidelity 3D-printed head and neck model for training Emergency Medicine (EM) physicians, Primary Care physicians, and Allied Health Professionals in managing ten common Ear, Nose and Throat (ENT) emergencies.

**Setting:** The study was conducted at an ENT Emergencies course in London.

**Study Design:** Prospective validation study.

**Participants:** All delegates (n=90) were healthcare professionals. Among them, 60% (n=54) were Emergency Medicine residents/trainees, 28% (n=25) were Primary Care residents/trainees, 4% (n=4) were ENT residents/trainees, 4% (n=4) were Emergency Nurse Practitioners, 2% (n=2) were Primary Care attending physicians, and 1% (n=1) was an Emergency Medicine attending/consultant. All faculty were consultant ENT Surgeons (n=11).

**Intervention:** The 3D models, produced using proprietary 3D printing technology (Fuesetec), were used in a one-day ENT emergencies course for validating training and confidence of delegates in performing 10 common ENT emergencies.

**Results:** A total of 86% (n=77) of delegates found the models extremely or very helpful in learning ENT emergencies. Delegates rated the resemblance to real patients as excellent or very good in both haptic feedback (n=58, 64%) and tissue texture (n=67, 74%). Additionally, 74-96% of delegates felt confident in performing the ten ENT procedures after using the models.

**Conclusion:** The 3D models enhanced participant confidence in performing ten common ENT emergency procedures, demonstrating good face, content, and indirect criterion validity. These models could support emergency ENT skill development in local emergency departments.

**Key Words:** ENT, 3D Models, Simulation Training, Procedural Skills, Emergency Medicine, Primary Care.

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**Abbreviations:** ENT (Ear Nose and Throat), ED (Emergency Department), UKRI (UK Research and Innovation) and (UK) United Kingdom.

**Word Count:** 2576

## Article Summary

### *Strengths and limitations of this study*

- A diverse set of ENT emergencies was represented, providing comprehensive training exposure.
- The authors utilized face validity to assess the model's physical realism, gathering direct feedback from participants on its suitability for simulating procedural training scenarios. Content and indirect criterion validity ensured the model's alignment with postgraduate training curricula and its impact on self-reported confidence.
- Validation measures did not include objective performance assessments of procedural skills after training.

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**Introduction**

Ear, Nose, and Throat (ENT) disorders are common reasons for seeking care in the Emergency Department (ED) or via Primary Care.<sup>1,2</sup> There is seen to be a lack of undergraduate and postgraduate teaching and training in ENT emergencies, resulting in newly qualified doctors not feeling adequately prepared to practice ENT.<sup>3,4,5</sup> A study by Sharma et al found that 75% of junior doctors have not received sufficient ENT teaching to deal with common ENT emergencies, with 42% of junior doctors not feeling confident in managing common ENT emergencies.<sup>5</sup> It has also been reported that 88% of senior ENT doctors on call are non-resident, which places more onus on junior doctors and the Emergency Medicine (EM) team to manage common ENT emergencies.<sup>3</sup>

Simulation training helps to mitigate patient safety risks by allowing individuals to practice procedures in a safe space without jeopardising patient safety.<sup>6,7</sup> Simulation is an increasingly valuable tool in emergency education, with simulation-based training shown to aid in the acquisition of clinical skills more effectively compared to traditional lectures or tutorials.<sup>7</sup> The increased demand for high-quality, cost-effective medical simulation has led to the incorporation of three-dimensional (3D) printed models to aid in simulation training.<sup>8</sup>

Previous studies have employed 3D models and these have received positive feedback from trainees regarding common emergencies including: tracheostomy tube placement, peritonsillar abscess drainage, and nasal packing.<sup>8-10</sup> However, these studies typically utilize models that simulate only a particular emergency skill and so are not appropriate to teach the full breadth of ENT emergencies.<sup>8</sup>

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Furthermore, the models reported within the literature have not been used beyond initial pilot testing, with no model currently being utilised or validated in clinical courses or teaching.<sup>8-10</sup> ENT emergency procedures can be taught on cadavers or animal specimens, but these convey significant financial costs and reduced accessibility.<sup>8</sup> Cadaveric and animal models are also limited in their ability to simulate pathological conditions. While procedures such as tracheostomy can be taught using these models, skills like quinsy drainage or otitis externa management are challenging to replicate. Therefore, there is a need for a high-fidelity training model that provides realistic anatomy, haptic feedback, and tissue texture comparable to real patients—without the risks to patient safety or the high costs associated with cadaveric models—while encompassing a broad range of ENT emergencies in a single platform.<sup>8-10</sup>

This study sets out to develop and validate a high-fidelity head and neck model, printed using proprietary 3D printing technology, that can be used to train EM Physicians, Primary Care Physicians and Allied Health Professionals in 10 common ENT emergencies.

## Methodology

### *3D-printed simulation model design*

The head and neck models were created using ZBrush (Pixologic Inc, California). This digital sculpting software was used to recreate human anatomy by sculpting basic shapes. The individual anatomical components were then assembled and further edited on Netfabb (Autodesk, California) for manufacturing (Figures 1A and 1B). The peritonsillar abscess was developed as a variation of the model created using the method above. Files were sculpted to include a peritonsillar abscess on Blender (Blender Foundation, Netherlands) and then printed in place of regular tonsils (Figure 1B). The otology aspect was created using a combination of the above two methods (Figure 1C). Ear CT scans were segmented using Mimics (Materialise NV, Belgium). Files that were not clear in scans were digitally sculpted in ZBrush and fitted into the model. Models were printed using the Stratasys

Digital Anatomical Printer (Stratasys Ltd, Minnesota). A combination of preset and custom digital materials. The model's various components. The models can be seen in Figure 2A, 2B, and 2C, as well as in Appendix 1a, with endoscopic appearances shown in Appendix 1b.

**ENT Emergencies Training Course**

The models were subsequently validated in an ENT emergencies training course using a prospective validation study. Delegates attended an in-person course on managing 10 common ENT emergencies. The 10 ENT emergencies included foreign body nose removal, epistaxis management, peritonsillar abscess drainage, flexible nasendoscopy for stridor assessment, post-tonsillectomy bleed management, foreign body removal from the throat, pope otowick insertion/ otitis externa management, foreign body removal from the ear, tracheostomy insertion, and drainage of a post-thyroidectomy hematoma.

This was a one-day course consisting of small group lectures and practical skills sessions using 3D printed head and neck models. The faculty consisted of ENT consultants/attending surgeons, with a faculty-to-delegate ratio of 1:5 to aid in procedural steps and teaching. 3D model simulation training was delivered after delegates had received tutorials on common ENT emergencies and their management. Delegates rotated through ten simulated stations, each starting with a case study of a common emergency presentation related to the skill being practiced. They then spent 30 minutes using the models to practice each emergency procedure under the guidance of ENT consultant surgeons, rotating through each emergency. The equipment provided for each skill mirrored what is typically available in an emergency department, including headlights, tongue depressors, scalpels, syringes, needles, ribbon gauze, and cautery sticks. Additional specialized equipment included microscopes for the otitis externa management, pope otowick, and foreign body ear stations, as well as flexible nasendoscopy for stridor assessment. Following the completion of the course, delegates were asked to complete paper surveys, which adopted a combination of yes/no items and Likert

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scales to evaluate their experience with the 3D models. All delegates provided informed consent to have their data used as part of a research study for the validation of the 3D models.

### **Validation**

The validation of the 3D models involved a combination of methods. First, face validity was assessed by having delegates evaluate the realism of the models for performing ENT emergency procedures. Second, content validity was ensured through mapping the ENT procedures included to the postgraduate Primary Care and Emergency Medicine curricula.<sup>11,12</sup> Moreover, content validity was further assessed by having ENT consultants rate the realism of the models specifically for performing common ENT emergency procedures. Lastly, indirect criterion validity was determined by assessing self-reported confidence of delegates in performing ENT emergency procedures after using the 3D models.

### **Patient and Public Involvement**

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

### **Ethical Statement**

Delegates taking part in the survey provided informed consent to participate in the study and have their data used as part of research by voluntarily completing the survey. All data collected was anonymous, and no patient data was collected or used as part of the qualitative research. In accordance with the ethical guidelines prevailing in the United Kingdom (UK), an extensive ethical assessment was conducted using the UK Research and Innovation (UKRI) Research Ethics Tool prior to the initiation of our study. Ethical approval was not required as per the UKRI Research Ethics Tool (Appendix 2).

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**Results**

**Breakdown of Survey Responses**

A total of 90 delegates and 11 ENT consultant/attending surgeons utilized the 3D printed models for ENT emergency skills training and responded to the survey. Among them, 60% (n=54) were EM residents/trainees, 28% (n=25) were Primary Care residents/trainees, 4% (n=4) were ENT residents/trainees, 4% (n=4) were Emergency Nurse Practitioners, 2% (n=2) was a Primary Care attending physician, and 1% (n=1) was an EM attending/consultant. Prior experience in common ENT emergencies was assessed for 90 of the delegates (excluding ENT consultant/attending surgeons), which is displayed in Appendix 3.

**Current Teaching in ENT Emergencies**

Delegates (n=90) were asked about their current teaching on ENT Emergency procedures they receive within their department. No teaching was received by 58% (n=52) of delegates, while 26% (n=23) received lecture-based teaching, 12% (n=11) received small-group teaching, and 4% (n=4) received teaching on real patients. None of the delegates had used 3D models within their local department teaching.

**Face Validity: realism of models for delegates**

Face validity was assessed by asking delegates to rate the realism of the models, as displayed in Table 1. Results indicated good face validity, with 70-98% (Range: 35-49) of delegates rating the realism as very good/excellent.

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The overall realism of the model, including its visual appearance, internal/external anatomy, and simulation of procedures, was reported using a five-point scale: excellent, above average, average, below average, or poor. Delegates rated the models as “excellent” or “very good” for performing the 10 emergency procedures: flexible nasendoscopy to assess for stridor (n=77, 86%), assessing and removing nasal foreign bodies (n=77, 86%), assessing and removing foreign bodies from the ear (n=81, 90%), managing otitis externa with Pope otowick insertion (n=83, 92%), assessment and management of a peritonsillar abscess using needle aspiration (n=68, 76%), assessing for and removing a foreign body from the throat (n=74, 82%), performing a tracheostomy (n=63, 70%), managing a post-thyroidectomy haematoma (n=72, 80%), managing epistaxis using cautery and nasal packing (n=68, 76%), and managing a post-tonsillectomy bleed (n=77, 86%). The full results depicting the delegate-reported realism of the models can be seen in Table 1.

Delegates were asked to rate the realism (five-point scale: excellent, above average, average, below average, or poor) of the haptic/tactile feedback provided by the models compared to real patient tissue. This encompassed the perception of pressure, vibration, and resistance when performing the procedures and comparing these to what one might expect in a real patient. Most delegates rated this as excellent or very good (n=58, 64%), followed by 32% (n=29) rating them as average, and 4% (n=4) rating them as below average.

Furthermore, delegates and ENT consultants were asked to rate the realism (five-point scale: excellent, above average, average, below average, or poor) of the tissue texture and handling compared to real patient tissue, which added to the content validity. This encompassed the firmness, elasticity, and texture accuracy as compared to real tissue. Most delegates rated this as excellent or very good (n=67, 74%), with 24% (n=22) rating them as average and 1% (n=1) rating them as below average.

**Content Validity: ENT consultant surgeon ratings of realism of simulation**

Content validity was ensured by mapping the procedures to the Primary Care and Emergency Medicine postgraduate curricula.<sup>11,12</sup> This assurance was further fortified by incorporating 10 common ENT emergency procedures, this was following discussions with ENT surgeons across the United Kingdom. This step ensured relevance of the models and skills to those working in Emergency Medicine and Primary Care. Moreover, having consultant ENT surgeons rate the realism of using the models in simulating 10 common ENT Procedures furthered the content validity. The full results depicting ENT consultant reported realism of the models can be seen in Table 2. Similar results between the ENT consultant surgeons and delegates were seen regarding the realism which highlights good content validity.

ENT consultants were asked to rate the realism (five-point scale: excellent, above average, average, below average, or poor) of the haptic/tactile feedback provided by the models compared to real patient tissue. All (n=11, 100%) ENT consultants rated the models to be excellent or very good for haptic/tactile feedback compared to real patient tissue.

Furthermore, ENT consultants were asked to rate the realism (five-point scale: excellent, above average, average, below average, or poor) of the tissue texture and handling compared to real patient tissue. All (n=11, 100%) of the ENT consultants rated the tissue handling in comparison to real patient tissue as excellent/very good.

Please rate the realism of the 3D models for	Excellent	Above Average	Average	Below Average	Poor	N/A
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each of the following procedures and assessment in comparison to real patients or cadavers						
Assessment of stridor and performing flexible nasendoscopy	43 (48%)	34 (38%)	9 (10%)	2 (2%)	0 (0%)	2 (2%)
Assessing for and removing a foreign body of the nose	36 (40%)	41 (46%)	11 (12%)	0 (0%)	0 (0%)	2 (2%)
Assessing for and removing a foreign body of the ear	52 (58%)	29 (32%)	9 (10%)	0 (0%)	0 (0%)	0 (0%)
Managing otitis externa with the insertion of a Pope otowick	40 (44%)	43 (48%)	7 (8%)	0 (0%)	0 (0%)	0 (0%)
Managing a peritonsillar abscess with needle aspiration	34 (38%)	34 (38%)	18 (20%)	2 (2%)	2 (2%)	0 (0%)
Assessing for and removing a foreign body of the throat	40 (44%)	34 (38%)	9 (10%)	4 (4%)	1 (1%)	2 (4%)

Performing a tracheostomy*	40 (44%)	23 (26%)	0 (0%)	2 (2%)	0 (0%)	11 (12%)
Managing a post-thyroidectomy haematoma	40 (44%)	32 (36%)	9 (10%)	0 (0%)	0 (0%)	9 (10%)
Managing epistaxis including nasal packing and cautery	38 (42%)	31 (34%)	21 (23%)	0 (0%)	0 (0%)	0 (0%)
Managing a post-tonsillectomy bleed	36 (40%)	41 (46%)	4 (4%)	0 (0%)	0 (0%)	9 (10%)

Table 1. Realism Rating of the 3D Models Course Delegates.

\*14 delegates did not complete this question.

Please rate the realism of the 3D models for each of the following procedures and assessment in comparison to	Excellent	Above Average	Average	Below Average	Poor	N/A
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<b>real patients or cadavers</b>						
Assessment of stridor and performing flexible nasendoscopy	5 (46%)	6 (55%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Assessing for and removing a foreign body of the nose	11 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Assessing for and removing a foreign body of the ear	4 (36%)	5 (46%)	2 (18%)	0 (0%)	0 (0%)	0 (0%)
Managing otitis externa with the insertion of a Pope otowick	8 (73%)	2 (18%)	1 (9%)	0 (0%)	0 (0%)	0 (0%)
Managing a peritonsillar abscess with needle aspiration	9 (82%)	1 (9%)	1 (9%)	0 (0%)	0 (0%)	0 (0%)
Assessing for and removing a foreign body of the throat	10 (91%)	1 (9%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Performing a tracheostomy	2 (18%)	3 (27%)	6 (55%)	0 (0%)	0 (0%)	0 (0%)
Managing a post-thyroidectomy haematoma	6 (55%)	3 (27%)	0 (0%)	1 (9%)	0 (0%)	0 (0%)

Managing epistaxis including nasal packing and cautery	2 (18%)	8 (73%)	1 (9%)	0 (0%)	0 (0%)	0 (0%)
Managing a post-tonsillectomy bleed	1 (9%)	7 (64%)	3 (27%)	0 (0%)	0 (0%)	0 (0%)

Table 2. Realism Rating of the 3D Models Course ENT Consultants.

Criterion Validity

Next, we analysed the indirect criterion validity by assessing delegates' self-reported confidence after using the 3D models. The confidence levels of delegates in practicing common ENT emergencies are displayed in Table 3 with most delegates (74-96%) feeling confident in performing the 10 ENT emergency procedures following the use of the 3D models. Hence, demonstrating good indirect criterion validity.

Overall, 56% (n=28) of delegates found the models to be extremely helpful in enhancing their learning of ENT emergencies, with 30% (n=15) finding the models very helpful and 14% (n=7) finding the models moderately helpful to their learning. No respondents found the models slightly or not at all helpful.

To what extent do you agree with the following statements? Following the use of the 3D models	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Not Performed
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on the course I feel confident in:						
Assessing for and removing a foreign body of the ear	56 (62%)	25 (28%)	5 (6%)	2 (2%)	2 (2%)	0
Assessing and managing otitis externa including the insertion of a Pope otowick	54 (60%)	22 (24%)	9 (10%)	2 (2%)	3 (3%)	0 (0%)
Managing a peritonsillar abscess using needle aspiration	47 (52%)	20 (22%)	18 (20%)	4 (4%)	1 (1%)	0 (0%)
Assessing for and removing a foreign body of the throat	54 (60%)	20 (22%)	11 (12%)	0 (0%)	2 (2%)	3 (3%)
Performing a tracheostomy	52 (58%)	20 (22%)	0 (0%)	0 (0%)	7 (8%)	11 (12%)
Managing a post-tonsillectomy bleed	58 (64%)	14 (16%)	11 (12%)	0 (0%)	4 (4%)	3 (3%)
Managing a post-thyroidectomy haematoma	52 (58%)	29 (32%)	2 (2%)	5 (6%)	2 (2%)	0 (0%)
Managing epistaxis including nasal packing and cautery	65 (72%)	20 (22%)	4 (4%)	0 (0%)	1 (1%)	0 (0%)
Assessing for and removing a foreign body of the nose	61 (68%)	23 (26%)	2 (2%)	0 (0%)	2 (2%)	2 (2%)

Assessment of stridor and performing flexible nasendoscopy	38 (42%)	38 (42%)	11 (12%)	0 (0%)	2 (2%)	1 (1%)
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**Table 3. Delegate Confidence in Managing Common ENT Emergencies Following the Use of 3D**

**Models.**

**Future Directions**

Overall, 90% (n=81) of delegates would recommend the use of 3D models to other trainees for learning ENT emergency procedural skills, similarly 100% (n=11) of ENT surgeons would recommend the use of 3D models to their trainees. Additionally, 80% (n=72) of respondents stated that they would prefer to have 3D models in future courses as their preferred method to practice ENT emergency skills, while 20% (n=18) of respondents would prefer to see a combination of 3D models together with cadavers.

Overall, for the delegates and ENT surgeons, 98% (n=99) of respondents felt that implementing the 3D models into local ED/Primary Care settings would help improve trainee confidence in ENT emergency procedural skills, while only 2% (n=2) were unsure about this. Delegates were asked, “What would be the biggest factor in deciding whether to incorporate 3D models into your local department for learning ENT emergency skills?” In response, 62% (n=56) cited the availability of local faculty to assist in teaching, 31% (n=28) stated that cost/price of models would be a determining factor, and 7% (n=6) mentioned that the longevity of the model would influence their decision.

**Discussion**

Previous research has revealed that medical professionals often lack confidence in managing common ENT emergencies due to inadequate training and teaching.<sup>5</sup>



Within this study most delegates rated the models as realistic for all 10 of the emergency procedures, which indicates good and consistent face validity. Additionally, a significant proportion of respondents rated the haptic/tactile feedback and tissue handling/texture resemblance from the models as excellent or very good. The utilisation of 3D models, was associated with enhanced participant confidence in performing 10 common ENT emergency skills, thereby highlighting the study's good indirect criterion validity.

### Improving Competence and Confidence of Emergency Care providers

Within our cohort, the 3D models were associated with increasing self-reported confidence by the delegates performing 10 common ENT emergency procedures. Given the specialised nature and often time-critical state of ENT emergencies, frontline staff, such as EM doctors and Primary Care physicians, should undergo training to develop confidence in performing common ENT emergency procedures.<sup>3,5,7</sup> A doctor's competency in procedural skills is paramount to patient safety, as evidenced by the increased mortality, morbidity, and prolonged hospital stays associated with procedure-related complications.<sup>13</sup> A previous study highlights that junior doctors working in ED are not confident in identifying and managing common ENT emergencies.<sup>14</sup> Delayed treatment for these conditions can lead to significant patient safety concerns and potentially death. With many ENT departments having an out-of-hours service where, first-line emergency cover is provided by a cross-over system shared by other specialties, the on-call doctor may have no previous ENT experience.<sup>3,14</sup> Hence, there is a clear indication for frontline providers working in the ED and Primary Care to receive training in performing ENT emergency procedures, with 3D models offering a method to facilitate this training.

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**Incorporating 3D Models into Local Departments**

Adopting novel 3D head and neck models, has been demonstrated to enhance confidence in performing common ENT emergency procedures following a one-day course. These models were associated with good face, content, and indirect criterion validity.

Overall, 98.4% of our respondents felt that the models should be used in local ED/Primary Care settings to improve trainee confidence in ENT emergency procedures, with the models being adaptable to simulate various ENT pathologies. The availability of locally skilled faculty to allow for training was the biggest deterring factor for incorporating the models into local departments. The availability of experienced faculty to oversee and facilitate procedural skills allows for immediate feedback, reflection and learning this in turn enhances simulated skills learning.<sup>15,16</sup> However, the presence of experienced faculty may not be always required. Previous research suggests that independent use of simulators in surgery and procedural skills, without expert feedback, may be advantageous and preferable to proctored simulation.<sup>17</sup> The models do allow for repetitive practice and training amongst trainees which can in turn speed up skill adoption.<sup>18</sup>

The 3D models have the added advantage for gaining experience in certain procedures, where the clinical caseload and exposure may be low. Having locally available 3D models would allow doctors to practice emergency ENT procedures regularly and, therefore, prevent skill-fade.

**Future Directions**

Future research should compare the 3D model to existing training tools, such as cadaveric or animal models, where applicable. However, this may be challenging, as no single comparator method currently exists for all ten ENT emergencies. Cadaveric and animal models cannot accurately replicate certain pathological states, such as quinsy or otitis externa. While procedures like

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tracheostomy can be compared across 3D, cadaveric, and animal models, these traditional methods are often associated with high costs and regulatory constraints. Future studies should incorporate objective skills assessments to evaluate pre- and post-course performance improvements using 3D models. Additionally, including participants with varying levels of experience in ENT emergencies would help distinguish differences between novice and expert groups.

### Limitations

This study had several limitations. Firstly, each respondent had varied experience in ENT, which was not measured as part of the validation of the models. Secondly, ENT emergency procedure performance via an assessment of competence was not evaluated within this study; therefore, direct criterion validity was not measured. Thirdly, the models were used in a non-validated training program, and objective skill assessment scores were not measured pre- and post-course. This could be an area for future research. . Hence, the purpose was not to ensure that delegates were signed off and competent to deliver emergency care; rather, these 3D models were part of a course and are still in the evaluation stage. Finally, ENT experience/exposure was not measured beyond prior experience in performing the ten procedures.

### Funding

Nil

### Conflict of interest statement

ML is on the advisory board for the company Fusetec Inc. which provided the technology and Director of Innocrates Ltd. All other authors have no completing interest to declare.

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**Acknowledgements**

We would like to acknowledge the support by Mr John Budgen and Mr Mark Roe from Fusetec Inc. (Adelaide, Australia), who supported the development of the technology and provided the materials for the testing of the models and the validation study.

**Author contributions**

UR conducted the data analysis, involved in study design and conception, manuscript preparation and editing. DC: involved in study design and conception, manuscript preparation and review. SG, PK, AV, JH, PS, CDH, JR, MW, KS, CT, PR, NEL, YB AL, SO: involved in study design and conception and manuscript review and editing. MR, ML involved in data analysis, study design and conception, manuscript preparation, manuscript editing, manuscript review. ML is the guarantor and corresponding author of the manuscript.

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### Figure Legends

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58 **Figure 1. ENT Emergency Head and Neck Simulation Models Internal Anatomy Reconstruction.** (A)  
59 Head and Neck Model (B) Left-sided Peritonsillar Abscess Model. (C) Narrowed External Auditory  
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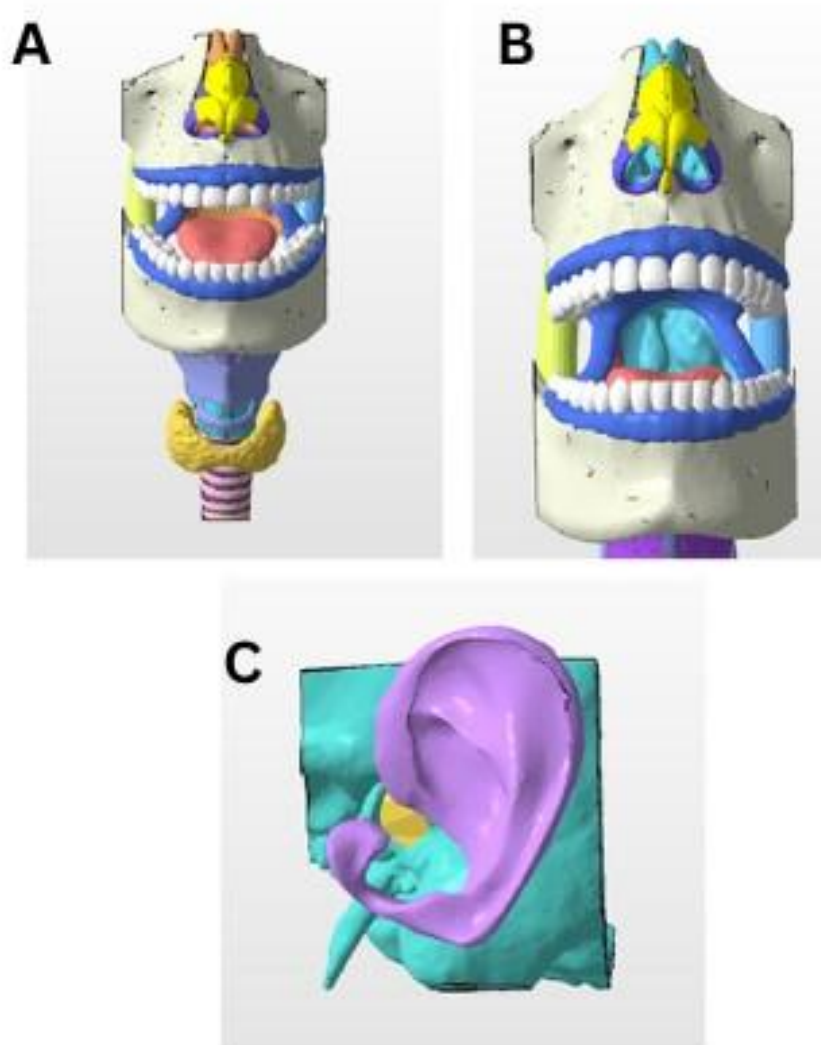
Canal for Otitis Externa Simulation. The internal anatomy is displayed on segmentation software Netfabb (Autodesk, Inc).

**Figure 2. ENT Emergency Simulation Models External Display.** (A) Head and Neck Model for simulating foreign body nose removal, epistaxis management, peritonsillar abscess drainage, flexible nasendoscopy, post-tonsillectomy bleed management and foreign body of the throat removal. (B) Ear Model for simulating pope otowick insertion/Otitis Externa treatment and foreign body ear removal. (C) 3D printed Trachea and overlying Neck for simulating tracheostomy insertion and drainage of a post-thyroidectomy haematoma.

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**Figure 1. ENT Emergency Head and Neck Simulation Models Internal Anatomy Reconstruction.** (A) Head and Neck Model (B) Left-sided Peritonsillar Abscess Model. (C) Narrowed External Auditory Canal for Otitis Externa Simulation. The internal anatomy is displayed on segmentation software Netfabb (Autodesk, Inc).



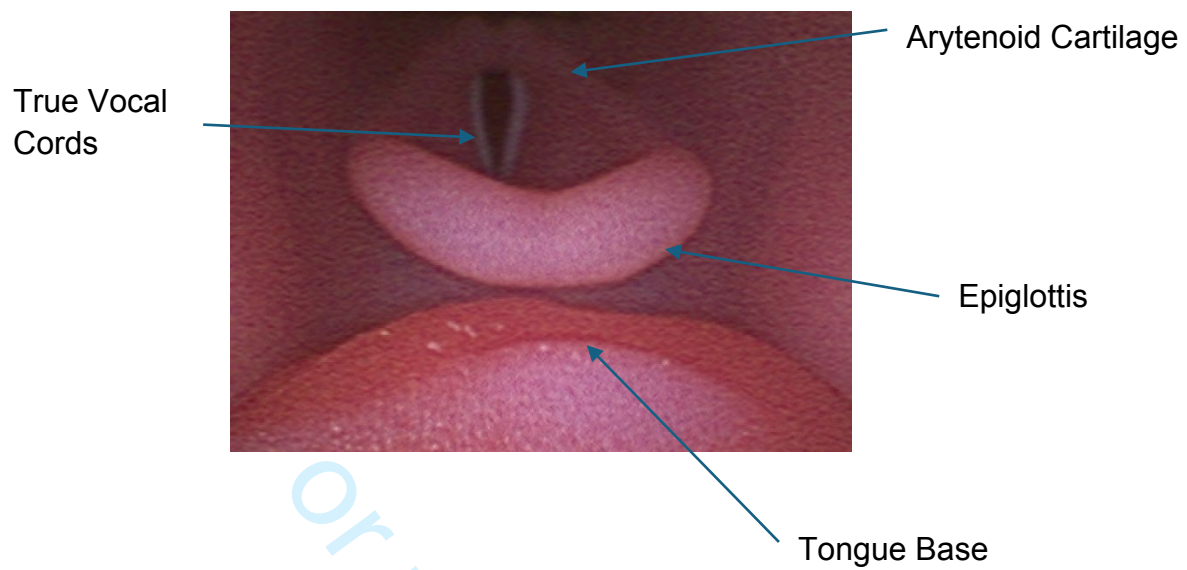
**Figure 2. ENT Emergency Simulation Models External Display.** (A) Head and Neck Model for simulating foreign body nose removal, epistaxis management, peritonsillar abscess drainage, flexible nasendoscopy, post-tonsillectomy bleed management and foreign body of the throat removal. (B) Ear Model for simulating pope otowick insertion/Otitis Externa treatment and foreign body ear removal. (C) 3D printed Trachea and overlying Neck for simulating tracheostomy insertion and drainage of a post-thyroidectomy haematoma.

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Appendix 1



**Appendix 1A. Use of 3D models for practical skills training.** (A) Flexible Nasendoscopy (B) Aspiration of Peritonsillar Abscess. (C) Nasal Cautery for Epistaxis Management.



**Appendix 1b. Endoscopic appearance of a 3D model with visualized vocal cords, epiglottis, tongue base, and arytenoid cartilages.**





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Do I need NHS REC review?



To print your result with title and IRAS Project ID please enter your details below:

Title of your research:

The Use of 3D Printed Head and Neck Models for Simulating 10 Common ENT Emergency Procedures: a prospective validation study

IRAS Project ID (if available):

Your answers to the following questions indicate that **you do not need NHS REC review for sites in England.**

This tool only considers whether NHS REC review is required, it does not consider whether other approvals are needed. You should check what other approvals are required for your research.

You have answered **'YES'** to: Is your study research?

You answered **'NO'** to all of these questions:

Question Set 1

- Is your study a clinical trial of an investigational medicinal product?
- Is your study one or more of the following: A non-CE marked medical device, or a device which has been modified or is being used outside of its CE mark intended purpose, and the study is conducted by or with the support of the manufacturer or another commercial company (including university spin-out company) to provide data for CE marking purposes?
- Does your study involve exposure to any ionising radiation?
- Does your study involve the processing of disclosable protected information on the Register of the Human Fertilisation and Embryology Authority by researchers, without consent?

Question Set 2

- Will your study involve potential research participants identified in the context of, or in connection with, their past or present use of services (NHS and adult social care), including

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participants recruited through these services as healthy controls?

- Will your research involve prospective collection of tissue (i.e. any material consisting of or including human cells) from any past or present users of these services (NHS and adult social care)?
- Will your research involve prospective collection of information from any past or present users of these services (NHS and adult social care)?
- Will your research involve the use of previously collected tissue and/or information from which individual past or present users of these services (NHS and adult social care), are likely to be identified by the researchers either directly from that tissue or information, or from its combination with other tissue or information likely to come into their possession?
- Will your research involve potential research participants identified because of their status as relatives or carers of past or present users of these services (NHS and adult social care)?

### Question Set 3

- Will your research involve the storage of relevant material from the living or the deceased on premises in England, Wales or Northern Ireland without a storage licence from the Human Tissue Authority (HTA)?
- Will your research involve storage or use of relevant material from the living, collected on or after 1st September 2006, and the research is not within the terms of consent for research from the donors?
- Will your research involve the analysis of human DNA in cellular material (relevant material), collected on or after 1st September 2006, and this analysis is not within the terms of consent for research from the donor? And/or: Will your research involve the analysis of human DNA from materials that do not contain cells (for example: serum or processed bodily fluids such as plasma and semen) and this analysis is not within the terms of consent for research from the donor?

### Question Set 4

- Will your research involve at any stage procedures (including use of identifiable tissue samples or personal information) involving adults who lack capacity to consent for themselves, including participants retained in study following the loss of capacity?
- Is your research health-related and involving offenders?
- Does your research involve xenotransplantation?
- Is your research a social care project funded by the Department of Health and Social Care (England)?
- Will the research involve processing confidential information of patients or service users outside of the care team without consent? And/ or: Does your research have Section 251 Support or will you be making an application to the Confidentiality Advisory Committee (CAG) for Section 251 Support?

If your research extends beyond **England** find out if you need NHS REC review by selecting the 'OTHER UK COUNTRIES' button below.

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OTHER UK COUNTRIES

If, after visiting all relevant UK countries, this decision tool suggests that you do not require NHS REC review [follow this link for final confirmation and further information.](#)

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Appendix 2. UK Research and Innovation (UKRI) Research Ethics Tool.

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How many times had you performed the following procedures prior to the course?	0	1-2	3-4	5-6	7-8	>8
Assessing for and removing a foreign body of the ear	40 (44%)	23 (26%)	13 (14%)	7 (8%)	4 (4%)	3 (3%)
Assessing for and removing a foreign body of the nose	36 (40%)	22 (24%)	13 (14%)	11 (12%)	4 (4%)	4 (4%)
Assessing for and removing a foreign body of the throat"	61 (68%)	11 (12%)	13 (14%)	5 (5%)	0 (0%)	0 (0%)
Managing a peritonsillar abscess/Quinsy including needle aspiration	65 (72%)	18 (20%)	4 (4%)	3 (3%)	0 (0%)	0 (0%)
Performing a tracheostomy	76 (84%)	5 (6%)	5 (6%)	4 (4%)	0 (0%)	0 (0%)
Managing Otitis Externa with the insertion of a pope otowick	42 (47%)	7 (8%)	4 (4%)	19 (21%)	16 (18%)	2 (2%)
Managing a post- thyroidectomy haematoma	83 (92%)	5 (6%)	2 (2%)	0 (0%)	0 (0%)	0 (0%)

Managing epistaxis including nasal packing and cautery	14 (16%)	25 (28%)	7 (8%)	9 (10%)	4 (4%)	31 (34%)
Managing a post-tonsillectomy bleed	50 (56%)	18 (20%)	7 (8%)	13 (14%)	2 (2%)	0 (0%)
Assessment of stridor and performing flexible nasendoscopy	79 (88%)	5 (6%)	2 (2%)	0 (0%)	2 (2%)	2 (2%)

Appendix 3. Prior Experience with 10 Common ENT Emergencies.