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Three-dimensional printed models for multidisciplinary flexible nasopharyngoscopy training

***Corresponding Author: Kilee Bayne**
Tel: 860-930-4441; Email: baynekilee@gmail.com

Kilee Bayne*; Thomas Kepler; Michael Pascolini; Todd Brickman; Eugene Potesta
Department of Otolaryngology Head and Neck Surgery, Bon Secours Mercy Health, St. Elizabeth Boardman Hospital 8401 Market St, Boardman-OH 44512, USA.

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Abstract

Objective: To assess the effectiveness of a three-dimensional (3-D) printed head and neck model printed from our residency's small 3D printer for the medical education and training of residents in nasopharyngoscopy.

Study design: Survey based study.

Setting: Resident education classroom.

Methods: Computed tomography images were used to create an anatomically accurate 3-D printed model of the head and neck region. Participants took a pre-training and post-training surveys with an intervention incorporating didactic instruction by fellowship trained Otolaryngologist on how to perform nasopharyngoscopy. Participants Nasopharyngoscopy (FNP) attempts on the model were video recorded, timed and scored by a blinded reviewer with a predefined rubric. Changes in scores and timing of the procedure were evaluated.

Results: Twenty-three participants from a single institution Emergency Medicine residency program completed the intervention. There were roughly equal proportions of senior, junior and intern residents. Thirty percent of participants were female. Sixty five percent of residents improved the overall time (in seconds) to identify anatomic landmarks and complete FNP. The participants had a statistically significant improvement in comfortability of performing FNP when comparing pre and post intervention.

Conclusion: With increased use of nasopharyngoscopy not only by Otolaryngologist, 3D models of are beneficial to training other specialties less familiar with head and neck anatomy, in a low-pressure environment. Having the basic skills of nasopharyngoscopy will assist in the development of other procedures such as nasotracheal intubation, head/neck/airway evaluation, etc. for the Emergency Room Department. This can assist in the efficiency of evaluation and treatment of head and neck conditions.

Introduction

Three-dimensional models or simulation based medical training has been used for many years across multiple disciplines. More recently with enhanced three-dimensional (3D) printed technology and the accessibility of 3D printers, many training programs are using simulation based training for a variety of procedures. More specifically in Otolaryngology, 3D models of the sinus, temporal bone, upper airway and ear have been created [1-3].

Simulation based medical training provides trainees with the opportunity to practice procedures in a low-risk environment [1,2-5]. It also provides the opportunity for repetitive procedural practice. In otolaryngology, many of the procedures can be tenuous, involving high-risk anatomic sites. Therefore, practice on a model can be very beneficial before primary surgery on a live patient.

In the advent of COVID19 and its reduction in performing certain aerosolization otolaryngologic procedures, simulation-based education has provided a vital resource for trainees to continue to practice essential skills. Our goal was to not only train Otolaryngologist on basic otolaryngology procedures but to use 3D models to assist training other specialties such as emergency medicine physicians in mutual otolaryngology procedures such as nasopharyngoscopy. We sought to develop an anatomically accurate 3D printed head and neck model to provide emergency medicine and otolaryngology residents the opportunity to develop Flexible Nasopharyngoscopy skills (FNP) in a low-pressure environment without the risk of airborne particle aerosolization.

Materials and methods

Approval by Bon Secours Mercy Health St. Elizabeth Hospital Institutional Review Board was obtained. A fellowship trained head and neck otolaryngologist reviewed a non-contrast Computed Tomography (CT) scan of the sinuses and deemed it to have accurate anatomy that would be favorable for nasopharyngoscopy. The CT scan was imported into 3D Slicer software for model design. Once imported, the slicer developed a stl file that could be used in our 3D printer. Using the Form Labs 2 printer with tough resin, the head and neck model was printed, settings listed in Table 1. The head and neckpieces were printed separately due to the size limit of our printer. The head and neck models were then placed on top of each other. The superior aspect of the head model was left exposed in order to visualize the anatomy and watch the scope passing through the nasal cavity (Figure 1).

Participants from the study were recruited from a single institution emergency medicine residency. All post graduate year residents were included. Each resident was given a pre-intervention survey that included 10 questions assessing their comfortability and familiarness (5-point scale) with head and neck anatomy, flexible nasopharyngoscopy procedure, and 3D model training experience. Each resident was then allowed to undergo one attempt of flexible nasopharyngoscopy on the 3D model. FNP performance was timed using smart phone stopwatch and video recorded using *Ambu scope* monitor. After baseline evaluation, the participants completed teaching intervention, incorporating didactic and performance sessions. The didactic session was a 30-minute lecture instructed by a fellowship trained head and neck surgeon which included a review of relevant head and neck anatomy and discussion of flexible endoscope design, function, and operation, a systematic approach to FNP-aided physical examination of the upper aerodigestive tract, and tips for troubleshooting issues encountered while performing FNP. The participants were then asked to perform FNP on the same 3D printed model. FNP performance was then again timed, and video recorded in the same fashion. Participants then completed a 10 question post-intervention survey (5-point likert scale) which assessed comfortability with head and neck anatomy, FNP and application of FNP in practice as well as realism and effectiveness of the 3D printed model. FNP pre and post intervention video recordings were reviewed by a single, blinded, expert Otolaryngologist and scored on a 10-point scale using a predefined rubric. The expert reviewer is an experienced Otolaryngologist who frequently performs FNP for diagnostic, surveillance, and treatment purposes.

Statistical analysis included comparison of pre- and post-intervention FNP scores and time for FNP procedure (seconds) to identify and quantify improvement in ability secondary to the intervention, using the paired sample t-test, and ANOVA. Additionally, pre- and post-intervention surveys were analyzed to assess comfortability toward performing FNP in a clinical setting after using the simulated model. All statistical analysis were performed using IBM SPSS software version 25, using 2-sided statistical testing at a 0.05 significance level.

Results

A total of 23 participants were included in the study. Written consent was obtained. The participants included Emergency Medicine residents ranging over post-graduate years 1-3. Baseline characteristics are available in Table 2. Participants were spread equally over post-graduate year. The majority of participants were male, had not completed a prior otolaryngology rotation, and had no prior formal training on FNP. About half of the participants had never performed FNP while the other half had performed FNP in varying amounts. Most participants had completed training with simulation models in the past.

FNP skill was objectively assessed pre- and postintervention via blinded review of video recordings and timed sessions. The participants' skill was evaluated using a standardized 10-point rubric. Mean ± Standard Deviation (SD) pre-intervention score was 6.61±1.47. Postintervention mean ± SD score was 6.30±0.93. This translated to a mean ± SD decrease in score of 0.30±1.71. There was not a significant improvement in score when comparing pre vs post intervention (P=0.91). The score did depend on Postgraduate Year (PGY) level (P<0.02). The score did not depend on gender (P=0.11), whether or not the participant had previously completed a ENT rotation (P=0.69) or performed FNP prior (0.48) or received previous training in FNP (P=0.14). Results shown in Table 3.

FNP skill was objectively assessed pre- and postintervention via blinded review of video recordings and timed sessions. The participants' skill was then evaluated using time to complete nasopharyngoscopy in seconds. Mean ± standard deviation (SD) pre-intervention time to complete FNP in seconds was 67±29. Postintervention mean ± SD time to complete FNP in seconds was 51±26. This translated to a mean ± SD decrease in time in seconds of 16±26 to complete FNP. There was a statistically significant improvement in time to complete flexible nasopharyngoscopy when comparing pre vs post intervention (P<0.008). The time to complete FNP in seconds did not depend on gender (P=0.45), Postgraduate Year (PGY) level (P=0.73), whether or not the participant had previously completed an ENT rotation

(P=0.11) or performed FNP prior (P=0.52), or received previous training in FNP (P=0.95). Results shown in Table 4.

Participants' level of comfortability performing FNP pre vs post intervention was then compared using a 5-point likert scale with a score of 1 being not comfortable to a score of 5 being very comfortable. Mean ± Standard Deviation (SD) pre-intervention comfortability score was 2.22±0.85. Postintervention mean ± SD comfortability score was 4.00±0.60. There was a statistically significant improvement in comfortability performing FNP when comparing pre vs post intervention (*P*<0.009). This translated to a mean ± SD increase in comfortability score of 1.78±0.74. The participants had a statistically significant improvement in comfortability of performing FNP when comparing pre and post intervention. Results show in Table 5.

Table 1: 3D Form labs printer settings.

	Head Model	Neck Model
Resin	Clear V4, 299 ml	Durable V2, 459 ml
Hours	8 hours 3 minuets	22 hours 25 minuets
Layers	851	1011

Table 2: Baseline characteristics of participants.

Characteristic	N0. (%)
Sex	
Male	16(70)
Female	7(30)
Post graduate year	
1	9(40)
2	7(30)
3	7(30)
Prior ENT rotation	
yes	1(5)
no	22(95)
Prior formal FNP training	
yes	5(22)
no	18(78)
No. of FNP performed prior	
0	12(52)
1-3	6(26)
4-6	4(17)
7-10	1(5)
Experience with simulation based medical training	
yes	15(65)
no	8(35)

Abbreviations: ENT: Ears, Nose, Throat); No.: Number; FNP: Flexible Nasopharyngoscopy.

Table 3: Comparing pre and post-intervention score of flexible nasopharyngoscopy.

	Minimum	Maximum	Mean	Standard Deviation
Total Pre-intervention Score	4	9	6.61	1.47
Total Post-intervention score	4	7	6.30	0.93
Total Score Difference Pre vs Post	0	3	-0.30	1.71

Table 4: Comparing pre and post-intervention time of flexible nasopharyngoscopy.

Minimum (seconds)	Maximum (seconds)	Mean (seconds)	Standard Deviation	Standard Deviation
Total Pre-intervention Time	30	128	67	29
Total Post-intervention Time	29	131	51	26
Total Time Difference Pre vs Post	1	3	16	26

Table 5: Comparing pre and post-intervention comfortability of flexible nasopharyngoscopy.

	Minimum	Maximum	Mean	Standard Deviation
Total Pre-intervention Comfortability score	1	4	2.22	0.85
Total Post-intervention Comfortability Score	3	5	4.00	0.60
Total Score Difference Pre vs Post	2	1	1.78	0.74

Discussion

In the modern era of medical education, three-dimensional printed models are becoming widely used for teaching. Especially in the COVID19 pandemic era, 3D models give medical trainees the ability to practice their skills in a personal, non-patient interface. Three-dimensional printing has been adopted by otolaryngology as a tool in surgical simulation for high-risk, low-frequency procedures [1-3]. With the advent of video assisted flexible nasopharyngoscopy, this allows for interdisciplinary sharing of head and neck examination aiding in diagnosis, patient counseling, resident teaching, and the monitoring of therapy in head and neck disorders [6]. Therefore, it is paramount to teach colleagues who can benefit from knowing how to do a more extensive head and neck evaluation, such as our emergency medicine department.

We found that the majority of Emergency Medicine (EM) residents had not performed FNP, had not received any training in FNP or completed an ENT rotation. Most of the EM residents were not comfortable performing FNP prior to the training session. After the training session and working with the 3D head and neck model, the majority of residents felt more comfortable having to perform FNP in a real-life situation. While the more senior residents had high base line comfortability with performing FNP, all level of residents felt more comfortable performing FNP after formal teaching and practice on the 3D model. The time it took the participants to perform FNP significantly decreased when comparing pre and post intervention time (in seconds). This indicates the participants felt more comfortable with the mechanics of the procedure and had an improved knowledge of head and neck anatomy to navigate the flexible fiberoptic scope. Having a valid representative of a head and neck model for trainees to practice high risk procedures in a low stress environment improves the skillset of the trainee, preparing them for real life situations [4].

Within Emergency medicine, there are numerous ways a flexible nasopharyngoscope can be utilized. For example, nasotracheal intubation is one high-risk procedure that EM residents should be familiar with performing. Practicing this skill on a 3D printed model in a low stress environment will assist in the development of foundational skills. When participants were asked on a scale of 1 to 5 with 1 being strongly disagree to 5 being strongly agree, if the training of FNP on the 3D model could be applied to other EM procedures such as nasotracheal intubation, 74% of participants strongly agreed and 26% of participants agreed. This indicates that a simple, low cost, realistic 3D head and neck model can assist in a multidisciplinary skill set. A similar study was performed with radiation oncology trainees, which showed improvement in score of FNP and comfortability of FNP when practicing on 3D models [5]. Three dimensional models are utilized not only in the head and neck but in multiple anatomic sites for the education and training of residents in a low cost, low stress environment with the support of their accuracy and fidelity [5].

Our study showed a non-significant decrease in score from pre and post intervention assessment of FNP. The scoring was done by a single blinded otolaryngology expert. It is hypothesized as the videos were graded; the expert reviewer was more critically analyzing the FNP performance. The order of pre or post intervention video was unknown to the reviewer. Another hypothesis is that the model had increased wear and tear on the nasal cavity making it more difficult to pass the flexible scope, potentially increasing the difficulty of performing the exam for the trainee. This was not supported by the time of completion of FNP as the time it took the participants to perform FNP decreased at the post intervention FNP assessment. When replicating this study, having more than one single blinded expert reviewer would help strengthen the validity of the scoring results.

Future research can be done incorporating the use of video recorded flexible nasopharyngoscopy and the time to treat a head and neck otolaryngologic procedure. In our study, we found that after training EM residents, their time to complete flexible nasopharyngoscopy improved by an average of 13 [6]. Seconds. If there is a patient in the emergency room and the EM provider performs a flexible nasopharyngoscopy, records the video and sends the video to the Otolaryngologist on call, it can be hypothesized that the amount of time to diagnose a head and neck condition could be significantly decreased.

Our study supported the literature of the high fidelity of 3D printed models for the training of various head and neck procedures for medical trainees [1-5]. Head and neck anatomy models can be used for not only Otolaryngology residents but also for Emergency Medicine residents as in our study for other specialist that also perform FNP such as Radiation oncologists [5]. With the addition of video assisted FNP, the evaluation of the FNP skill can be further evaluated and perfected by exerts of FNP, and utilized for interdisciplinary management of head and neck conditions [6].

Conclusion

Three-dimensional printed models have been proven beneficial for medical education. Our study supports the efficacy and feasibility of using 3-D printed models for resident training. With the increase use of nasopharyngoscopy not only by Otolaryngologist, 3D models of anatomic accuracy are beneficial to training other specialties less familiar with head and neck anatomy, in a low-pressure environment. Having the basic skills of nasopharyngoscopy will assist in the development of other procedures such as nasotracheal intubation, foreign body removal, head/neck/airway evaluation, etc. for the Emergency Room Department. This can assist in the efficiency of evaluation and treatment of head and neck conditions.

Declarations

Conflicts of interest: There are no conflicts of interest to disclose.

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