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Abstract

Evaluation of 3D printed vascular phantoms for medical training and education

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Animal models are reportedly still widely used and sacrificed for neurointerventional surgery training today [1]. The growing need for the training of physicians to safely perform an increasing number of complex surgical procedures necessitates the development of alternative training modalities that are as realistic as possible.

A vascular simulator, replicating a real patient's anatomy for the use in neurointerventional surgery training was developed using Autodesk Fusion 360 and Netfabb CAD software. The main parts were manufactured by 3D printing on Form 2 SLA printers using Elastic 50A resin at 100 µm layer height and Clear V4 resin at 25 µm layer height [2]. The accuracy of this replication was evaluated by repeating a vessel scan using the printed neurovascular models and quantitively assessing its accuracy in comparison to the original patient's anatomy in CloudCompare. Additionally, experienced physicians participating in several training sessions evaluated the simulation anonymously using a questionnaire adapted from Nawka et al. [3], recording their feedback using a 5-point-likert scale from high levels of agreement (1) to high levels of disagreement (5).

The mean accuracy of our 3D printed neurovascular models was determined to be 0.091 mm (mean SD 0.116 mm). Given the current resolution of medical vascular imaging, these vessel phantoms are virtually indistinguishable from the underlying patient's anatomy. 30 neurointerventional surgeons comprising a total of 144 years of neurointerventional experience (mean 5.15 years, median 3 years) evaluated their hands-on simulation training experience. Their responses indicated moderate to high levels of agreement (1.9 – 1.2) regarding all aspects of the simulation and their current overall confidence in 3D model training.

In this study, we developed and validated a high accuracy, 1:1 patient-specific neurointerventional simulator manufactured using benchtop 3D printers. Expert feedback overwhelmingly favored 3D model training over animal-based and digital training modalities. Therefore, this type of 3D model simulation appears ready to replace animal-based training in neurointerventional surgery. Further research should explore the need for and feasibility of elastic vascular models and the replication of a broader range of pathologies using advanced 3D-printing techniques.

AUTHOR'S STATEMENT

Conflict of interest: the Authors state no relevant conflict of interest. Ethical approval: The research related to use of clinical data complies with all relevant national regulations, institutional policies and was performed in accordance with the tenets of the Helsinki Declaration and approved by an institutional review board (University of Lübeck: registry number 20-121a). Research funding: This research was supported by a grant from the "Förderstiftung des UKSH".

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