SimLife®, a new dynamic model for endoscopic sinus and skull base surgery simulation*

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Dear Editor:

Simulation is now used for training surgical residents [(1)]. In endoscopic sinus and skull base surgery (ESSBS), high haptic fidelity simulators for high-acuity low-opportunity training are needed to acquire skills in skull base dissection [(2)]. Cadavers remain the gold standard to provide anatomical fidelity. However, to overcome the difficulties of organizing simulations on cadavers, synthetic models have been developed, mainly by 3D printing, and some can be used to simulate internal carotid artery (ICA) injury [(3)]. Despite their appropriate face and content validity, their main disadvantage is the absence of bleeding management solutions, apart from packing. Yet, bleeding management in the operating room is a key element for residents. Some arteries are at high risk of bleeding during ESSBS: sphenopalatine artery (SPA), anterior ethmoidal artery (AEA), and ICA. Some groups proposed perfused cadaver head models for ICA injury simulation, but to our knowledge none assessed simultaneously SPA and AEA injuries (Supplementary Table) [(4–6)]. The aim of this work was to describe the face validity of SimLife®, a new dynamic cadaveric model to simulate bleeding in ESSBS simulation.

The SimLife® model is based on a donated human body prepared for surgical simulation. It is dynamized by pulsatile perfusion of a warmed blood-like solution [(7,8)]. A specific technical module animated the body (P4P device [Simedys, Poitiers, France]; patent 1 560488, deposit 1 000318748) through vascular cannulas. Cannulas were placed in the axillary vein and artery bilaterally or in the ICA and internal jugular vein bilaterally to provide vascularization with a blood-mimicking fluid at 37°C. The position of the vessels to be cannulated was chosen on the need to preserve neck vessels (Supplementary Figure 1). The blood-mimicking fluid was pumped through the arterial system, recoloring and warming the organs, and it was drawn out of the body by the venous cannulas. The physiological hemodynamic data, correlated with the pressure data, could be mechanically adapted to provide specific hemodynamic conditions as encountered in living patients. This teaching program on a cadaveric model was approved by the French Ministry of Health Ethics Committee (n°DC-2019-3704).

During, the simulation sessions, complete antrostomy, ethmoidectomy, sphenoidotomy and a transsellar approach to the pituitary were performed. Then, an injury was made in the exposed arteries (AEA, SPA or ICA) to record bleeding management and simulate life-threatening conditions. The hands-on training session was video-recorded. Twelve skull base surgeon experts in ESSBS from the French Association of Rhinology performed the complete simulation session in six SimLife® models. These voluntary experts used a Likert scale 1-10 to assess the model realism, ease of use and overall satisfaction [(9)]. A score ranged of [1-4] was considered as poor realism; [4-7] moderate realism and [7-10] high realism.

Mucosal appearance (Figure 1A) was generally realistic: the mean scores for color and mucosal bleeding were 8.4 (±1) and 6.9 (±1.56), respectively. The mean score for overall satisfaction

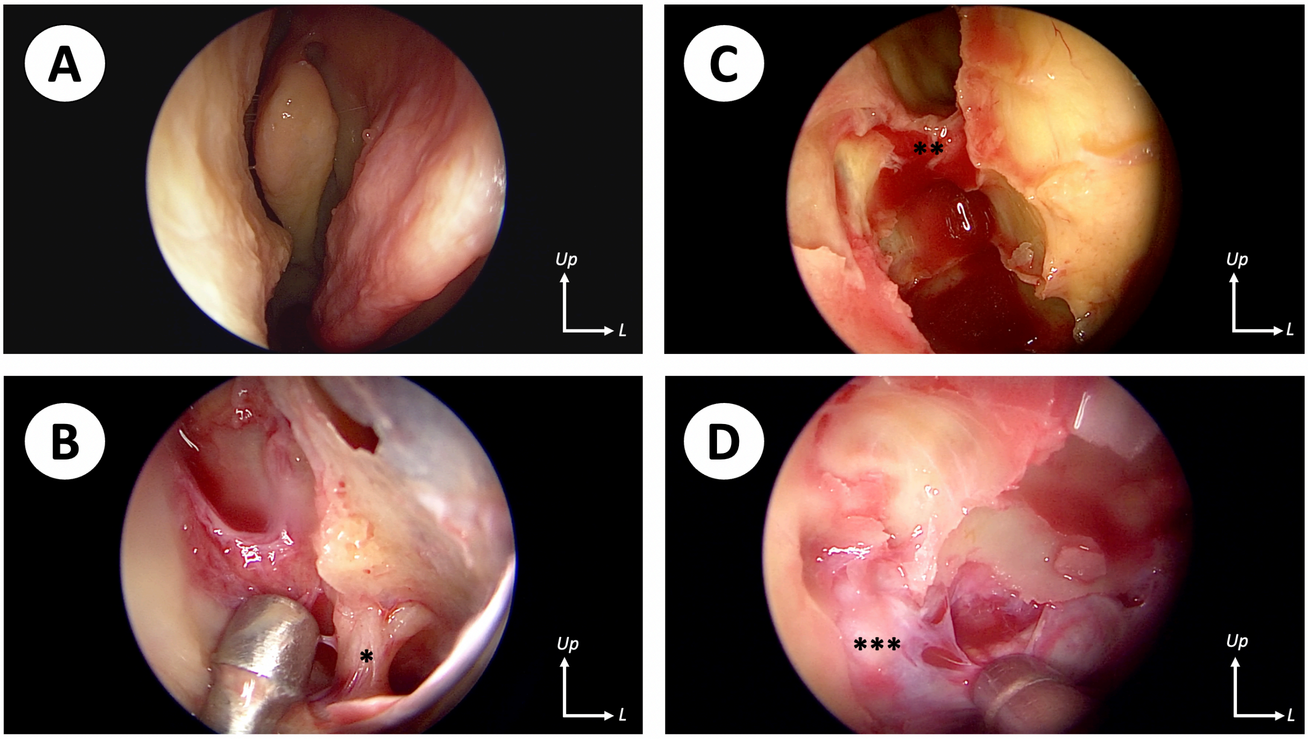

Figure 1. Endoscopic images of the left nasal cavity (A), left sphenopalatine artery (B,*), left anterior ethmoidal artery (C,**) and right internal carotid artery in the sphenoid (D,***)

with the SimLife® model was 9.1 (±0.79). The scores for the realism of the dissection of SPA (Figure 1B), AEA (Figure 1C), and ICA via the transsphenoidal approach (Figure 1D) were 8.9 (±1.08), 8.8 (±0.97), and 9.2 (±0.83), respectively). After injury, bleeding from SPA was moderately realistic (6; ±2.04), and from AEA and ICA very realistic (7.6 (±0.79); 9.3 (±0.65), respectively) (Supplementary videos). The scores for overall anatomic correspondence, ease of use, and overall satisfaction were 9.5 (±0.80), 10 and 9.1 (±0.79).

SimLife® is a hyper-realistic model for ESSBS that effectively simulates bleeding, but not cerebrospinal fluid flow. Small arteries can be coagulated, and larger one may be clipped or packed. The SimLife® model needs to prove its teaching value, but might become a core component of the surgical residents' curriculum.

Abbreviations

ESSBS: endoscopic sinus and skull base surgery; SPA: sphenopalatine artery; AEA: anterior ethmoidal artery; ICA: internal carotid artery.

Authorship contribution

FC: conceptualization, data collection, original writing; MF: data collection, original writing, ML:data collection, original writing; XD: review and editing; JFP: review and editing; DO: review and editing; LF: review and editing; SB: review and editing; MA: review and editing; JD: data collection, original writing; VF: data collection, original writing.

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Conflict of interest

JPF and DO are patent co-owners of the P4P device enabling revascularization and re-ventilation. All other authors declare that they have no conflict of interest.

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This manuscript contains online supplementary material

SUPPLEMENTARY MATERIAL

Supplementary Table 1. Comparision of life cadaver models to SimLife.

1st Author, year	Description of the model	SimLife® advantages compared with the model
Aboud, 2002 [1] van Doormaal, 2018 [2]	Embalmed cadaver head with cannulation of internal and external carotid arteries, vertebral arteries and internal jugular veins. All cannulated arteries are connected to a pump and a false blood reservoir. Veins are filled with dark liquid and then sealed. Simulation of active arterial bleeding only	• Whole cadaver that can be used also for other surgical simulations (e.g. thoracic surgery, orthopedic surgery, visceral surgery) • Improves tissue coloration through mucosa perfusion • Can be used for anterior ethmoidal artery and sphenopalatine artery injury simulation
Pham, 2014 [3] Zada, 2017 [4] Shen, 2018 [5] Donoho, 2021 [6]	Fresh human body with cervical carotid artery or femoral artery cannulation. No vein cannulation. Simulation of internal carotid artery injury only.	• Can be used for anterior ethmoidal artery and sphenopalatine artery injury simulation • Vein cannulation allows the artificial blood to simulate blood circulation and optimize tissue recoloration
Valentine, 2016 [7]	Synthetic model placed over an internal carotid artery of a living sheep to simulate bleeding.	• No need of living animals • Improves tissue coloration through perfusion of the mucosa • Can be used for anterior ethmoidal artery and sphenopalatine artery injury simulation
Pacca, 2017 [8]	Embalmed cadaver head with cannulation of common carotid arteries, vertebral arteries and internal jugular veins. Needs of ligature of all other vessels leaking artificial blood. Simulation of active arterial bleeding only.	• Whole body that can be used also for other surgical simulations (e.g. thoracic surgery, orthopedic surgery, visceral surgery) • Improves tissue coloration through mucosa perfusion • Can be used for anterior ethmoidal artery and sphenopalatine artery injury simulation
Maza, 2019 [9]	Laser-sintered synthetic model with false arterial blood and no pulsatility to simulate transsphenoidal internal carotid artery injury. Mean pressure limited to 67 mmHg.	• Allows pulsatility and physiological blood pressure • Can be used for anterior ethmoidal artery and sphenopalatine artery injury simulation • Possible use of coagulation or clips
Gupta, 2019 [10]	Synthetic perfused limb.	• Whole body that can be used also for other surgical simulations (e.g. thoracic surgery, orthopedic surgery, visceral surgery) • Faithful reproduction of real-life conditions

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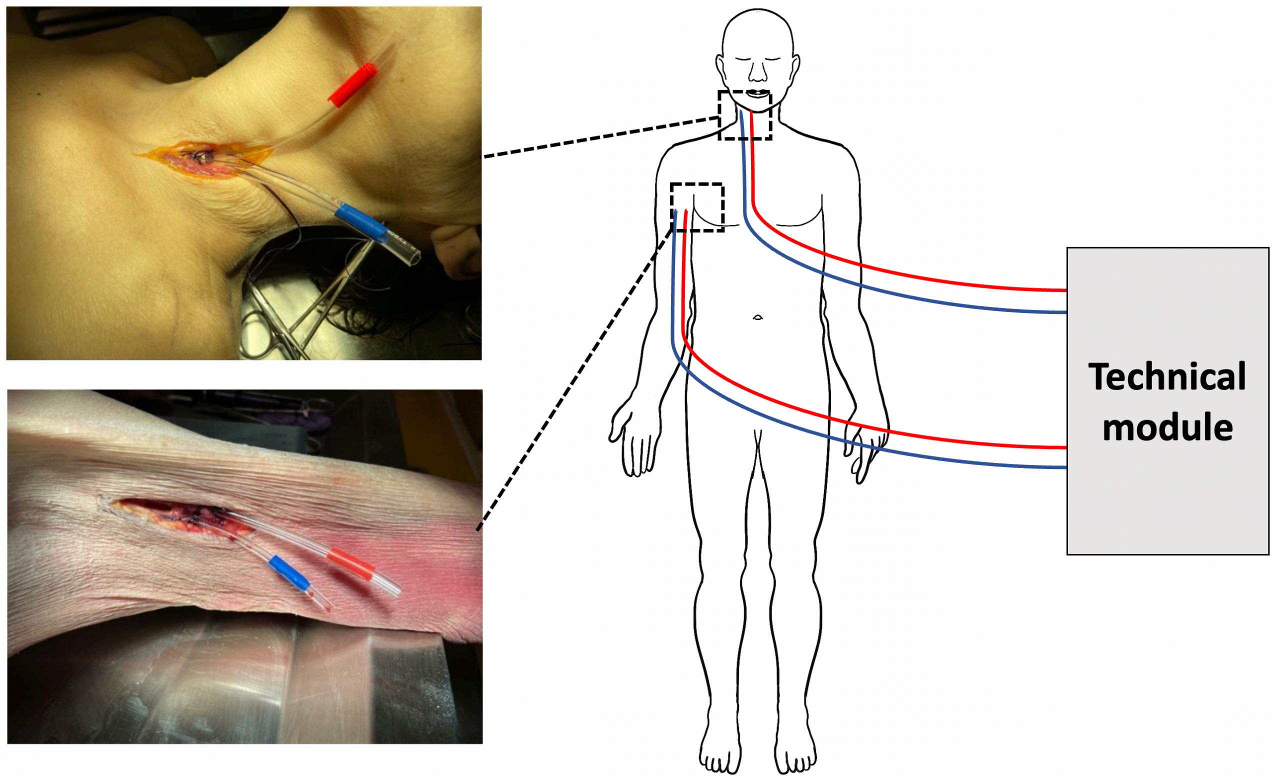

Supplementary Figure 1. Possible placement of the cannulas in the SimLife® revascularized model.