# A Virtual Physiological Human Model for Regional Anaesthesia

Victor Voski[1,2], Andreas Herrler[3], Elena Zaitseva[4],
Miroslav Kvassay[5], Yuen Law[6], Remi Bessard Duparc[7], Aaron Sújar[8],
Marcos Garcia Lorenzo[9], Erik Smistad[10], Thomas Deserno[2]
[1]Department of Anesthesiology, Uniklinik RWTH Aachen, Germany,
[3]Faculty of Health, Medicine and Life Sciences, Maastricht University, The Netherlands,
[4,5]Department of Informatics, University of Zilina, Slovakia,
[6]Virtual Reality Group, RWTH Aachen University, Germany,
[7]SHARCA Team, Inria Lille - Nord Europe Research Center, France,
[8,9]Modelling and Virtual Reality Group, Universidad Rey Juan Carlos, Spain,
[10]Department of Medical Technology, Stifelsen SINTEF, Norway,
[2]Department of Medical Informatics, Uniklinik RWTH Aachen, Germany
vvoski@ukaachen.de, deserno@ieee.org

**Abstract**

Current methods for teaching regional anaesthesia (RA) do not consider patient-specific anatomy and therefore have limited capabilities. Developing a virtual reality based simulator and assistant device for training and performing RA requires virtual physiological human (VPH) models. Commercial models such as Zygote and Anatomium are insufficient due to inconsistency, lack of anatomical correctness, and missing structures like the fascia. We collected a variety of imaging data including individual computed tomography and magnetic resonance imaging to build a VPH model that is composed of anatomical structures, physical properties such as needle resistance, and functional features (vessel bending in pulse frequency). The model is applied for RA simulation and assistance.

**Keywords:** VPH, Regional Anaesthesia, Virtual Reality, Simulation, Assistance.

## Introduction

Regional anaesthesia (RA) has perceived advantages in comparison with general anaesthesia, but it is applied rather seldom, since a safe performance of RA requires profound theoretical, practical, and non-cognitive skills. Gaining these skills allow trainees to achieve confidence in its performance and to minimize possible complications. RA permits to inject a local anesthetic directly near the target nerve. It requires multi-tasking for moving simultaneously the transducers in one hand and the needle in the other hand, while analyzing the ultrasound image, wherein a good needling technique is crucial. Inadequate practical skills are one of the most difficult challenges faced by trainees today. Current teaching methods (e.g., manikins, cadavers, observing the expert, performing on-patient) have failed to provide the sufficient experience and do not consider patient-specific anatomy. The Regional Anaesthesia Simulator and Assistant (RASimAs) project aims at developing VHP-based models that allows trainees not only to learn the ultrasound anatomy of the femoral region, but also develop and improve their scanning and needling skills [1].

# VPH Models

Commercial models (Zygote and Anatomium) have been tried to get adopted for the RASimAs project. However, we explored several shortcomings such as inconsistencies, incorrectness, and incompleteness.

**Inconsistencies:** in both of the models, some biologically separated structures (e.g., muscles and skeleton) overlap, making harder the process of image registration of patient-specific images. For example, Figure 1 shows the intersections of the Zygote model's mesh representing blood, muscles, nerves, skeleton, and skin. As it can be clearly seen, the skeleton (Sklt) overlaps muscles, and the blood vessels intersect with bone, partly laying within the bony structures. Table 1 depicts the confusion matrix of the Zygote male anatomical model, where layer intersections occur.

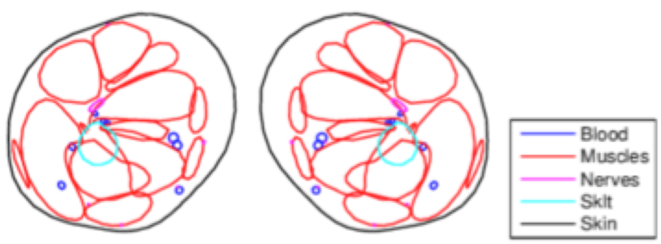


**Figure 1:** Zygote's mesh representing blood, muscles, nerves, skeleton and skin

| Layer | Skeletal | Muscles | Connective | Lymphatic | Circulatory | Nervous |
|---|---|---|---|---|---|---|
| Skeletal | 3.01 % | 23.19 % | 24.83 % | 0.06 % | 0.71 % | 0.65 % |
| Muscles | 12.70 % | 18.30 % | 4.57 % | 0.03 % | 1.05 % | 0.52 % |
| Connective | 20.97 % | 17.23 % | 24.59 % | 0.01 % | 0.80 % | 0.09 % |
| Lymphatic | 1.94 % | 16.75 % | 0.47 % | 12.18 % | 3.56 % | 0.57 % |
| Circulatory | 17.18 % | 11.00 % | 1.24 % | 0.14 % | 9.22 % | 2.26 % |
| Nervous | 22.73 % | 11.81 % | 0.31 % | 0.03 % | 2.97 % | 3,64 % |

**Table 1:** Basic statistics – mathematical correctness of Zygote male model

**Incorrectness:** another problem resulted from the model's incorrectness with respect to the human anatomy. In particular, animated 3D observations and millimeter axial slices showed a wrong positioning in relation to the iliopsoas muscle, which has been manually corrected slice by slice and the 3D resultant was calculated.

**Incompletness:** The fascia iliaca is an important structure for haptic needle interaction on the simulator. However, it is neither contained in the Zygote nor the Anatomium data.

A novel model has been composed for RASimAs from computed tomography (CT) and magnetic resonance imaging (MRI). Fascia lata and fascia iliaca were added in a multi-layered fashion [2]. A skilled anatomist approved the positions of the nerves [3]. Mechanical resistance was attributed to the different tissues based on pig cadaver measurements. In addition, the novel VHP model has added functionality to simulate the inflation and deflation of arterial vessels in the frequency of the heart rate.

# Results

The new RASimAs model has more anatomical details than the Zygote model and the shapes look less artificial (Figure 2). Furthermore, the cross-sectional views demonstrate that the RASimAs model is positioned correctly, i.e., the nerve is closer to muscle and positioned to the left of the artery. In the contrary for the Zygote model, the nerve runs on top of the artery or overlaps with the vein, which is incorrectly representing the human anatomy.

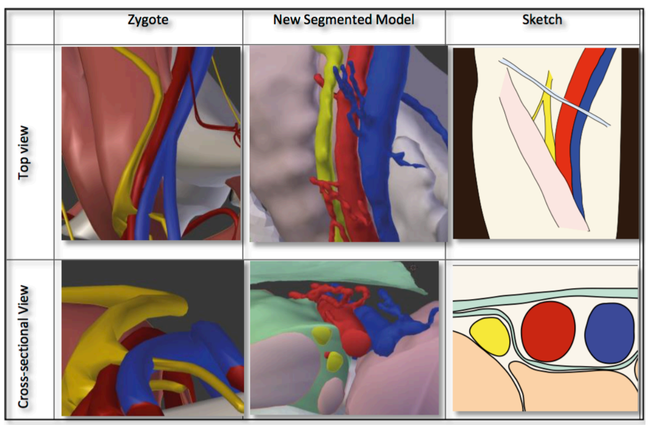


**Figure 2:** Comparison between the Zygote model and new RASimAs model.

# Model application in the RASimAs simulator component

Since we aimed at creating a realistic model, where the trainee believes she is performing RA on a real patient, we focused on effective haptic feedback for needle puncture. Taking into account various forces and surface bending, a realistic experience is obtained. Before the needle tip punctures the skin, the trainee feels some resistance. After puncture, the tissues resist against the axial motion of the needle. The vein compression was also implemented and can be seen by applying some pressure with the ultrasound probe. Furthermore, a pulsation can be felt when the needle is close to the artery. Same as in the practice, once the needle has been inserted, it cannot be rotated much.

## Model application in the RASimAs assistant component

The assistant system and simulator compliment each other. The assistant is designed to provide support during a real procedure. Here, the model is used to get an estimate of the tissue location and to guide the automatic segmentation in real-time. The artery is detected first and tracked during the ultrasound imaging sequence using Kalman filtering. Then, surrounding structures are identified using landmarks and registering them to the mesh model. The assistant detects and marks the femoral vein, artery and nerv, fascia lata and fascia iliaca using a novel algorithm in real time [4].

# Discussion and Conclusion

Since both, Zygote and Anatomium models have several shortcomings, a new VPH model had to be developed and built for RA simulation and assistance. The new model is based on patient-specific anatomy. It is further capable to be matched with individual subject data and hence, develops computational models of human (patho-) physiology. Patient-specific modeling makes it possible to simulate the anatomical variabilities that exist among individuals.

RA is a rapidly growing field, which from another hand appears to be a great challenge for novices in terms of learning a new technique. Although, there are many training methods available, they do not provide a sufficient training giving novices an opportunity to gain all skills required to perform RA safely. The RASimAs prototypes are based on VPH models including anatomy, physics and biological function. The model is now being used in the RASimAs prototypes for the femoral nerve block. Non-compromised realistic "all in one" RA training with no patient contact and assistance during a real procedure are now available and are going to change the regional anaesthesia training concept making it more realistic and effective with no risk for a patient.

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# References

1. Deserno TM, Oliveira JEE, Grottke O. Regional anaesthesia simulator and assistant (RASimAs). Medical image processing supporting anaesthesiologists in training and performance of local blocks. Procs 28th IEEE CBMS, Jun 2015, p 348-51.
2. Oliveira JEE, Giessler P, Deserno TM. Patient-specific anatomical modeling. Procs 5th IEEE EHB 2015, p. 1-4.
3. Serrurier A, Herrler A, Deserno T. Towards realistic patient-specific human models for virtual reality regional anaesthesia simulation. Submitted to ESRA 2015.
4. Smistad E, Lindseth F. Real-time automatic artery segmentation, reconstruction and registration for ultrasound-guided regional anaesthesia of the femoral nerve. IEEE Trans Med Imaging. 2016 Mar; 35(3): 752-61