Toward an Interactive, Patient-specific, VR-based Obstetrics Simulator

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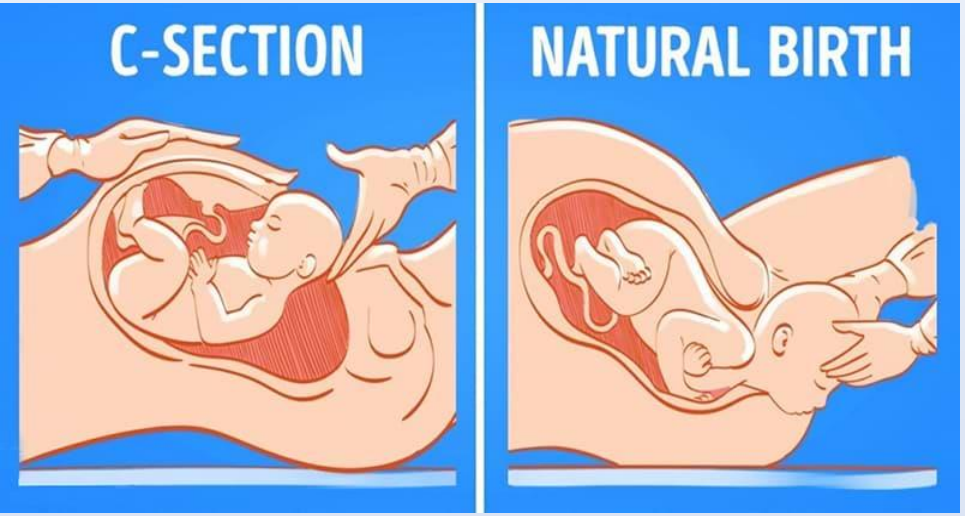
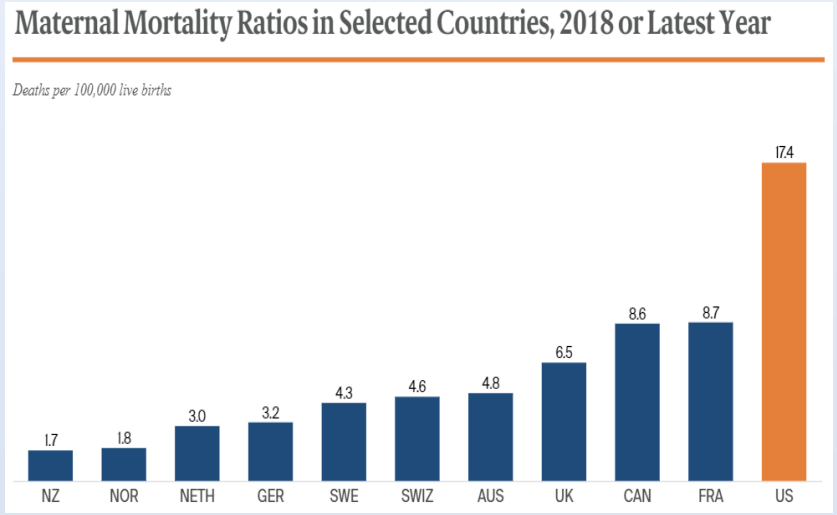
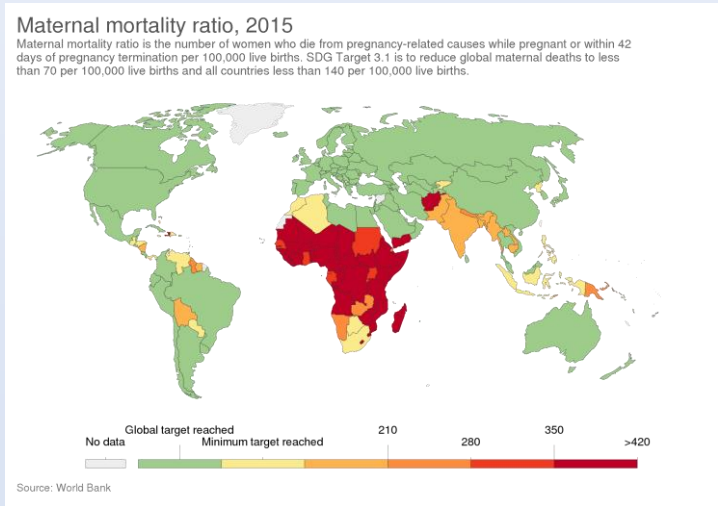
Urgency in Obstetrics

- ***US - High variability in obstetrics performance*** & underperformance vs developed countries.
  - ***13% of 4 million US women*** giving birth annually experience ***major complication(s).***
  - ***Vaginal deliveries***: Low-graded vs better hospitals w. complication rates: 22.55% vs 10.42%.
- ***US - worst-performing*** in maternal mortality among ***11 developed countries*** (2018).
- ***Developing countries***: 530,000 women die annually; 95% of deaths in Africa and Asia.



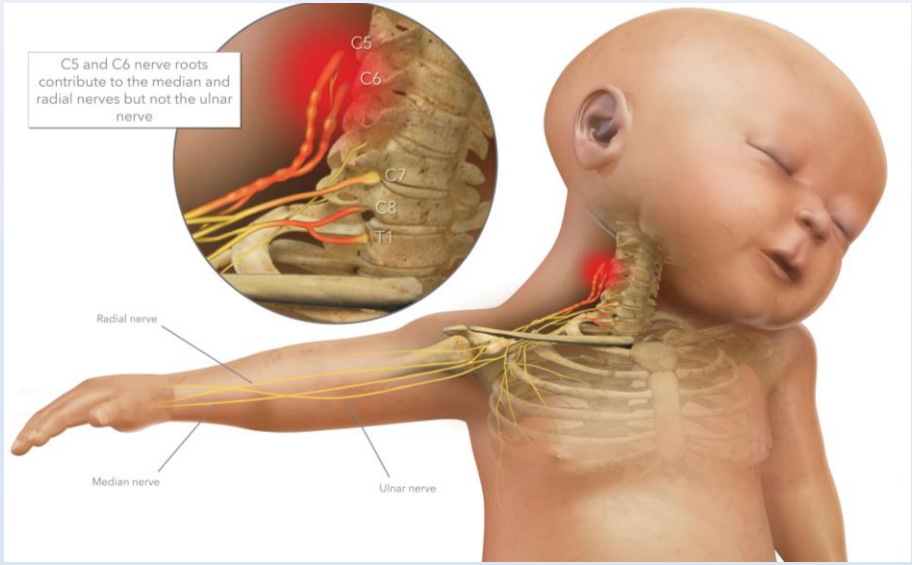


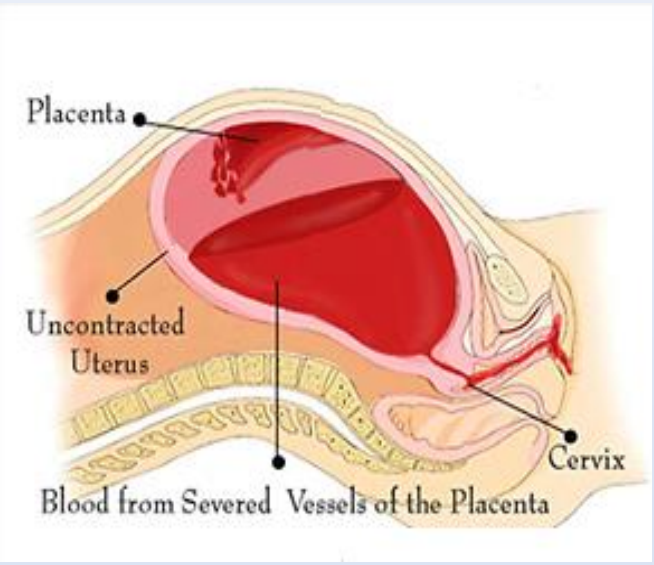


https://www.gaudiumivfcentre.com/blog/how-to-decide-between-caesarean-and-normal-delivery/ https://en.wikipedia.org/wiki/List_of_countries_by_maternal_mortality_ratio
https://www.commonwealthfund.org/publications/issue-briefs/2020/nov/maternal-mortality-maternity-care-us-compared-10-countries

Risk Factor: shoulder dystocia

- Risk factor is ***shoulder dystocia***: difficulty in delivery of fetal shoulders after delivery of head.
- ***Incidences***: 1% for babies < 4 kg, 5% for babies @ 4-4.5 kg, & 10% for babies > 4.5 kg.
- ***Neonatal complications*** include death and cerebral palsy from oxygen loss to baby's brain from dystocia, & brachial plexus injury complications such as Erb's palsy.
- ***Maternal complications*** include vaginal lacerations & post-partum hemorrhage.





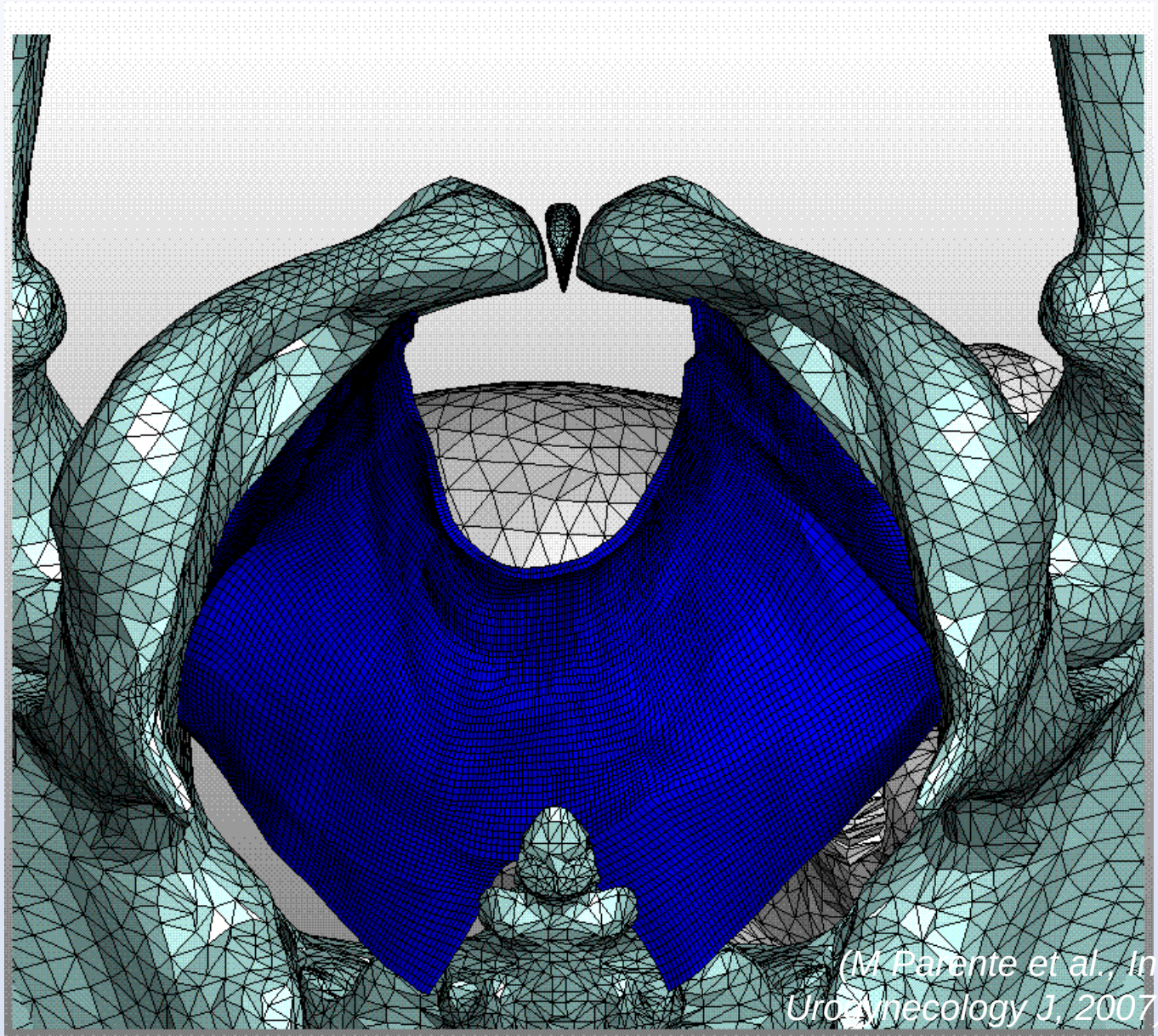
https://www.clorelaw.com/insights/shoulder-dystocia-damage https://highimpact.com/case-studies/9m-verdict-showing-shoulder-dystocia-birth-trauma https://www.medindia.net/patients/patientinfo/postpartum-hemorrhage.htm

Current Simulation-based Training

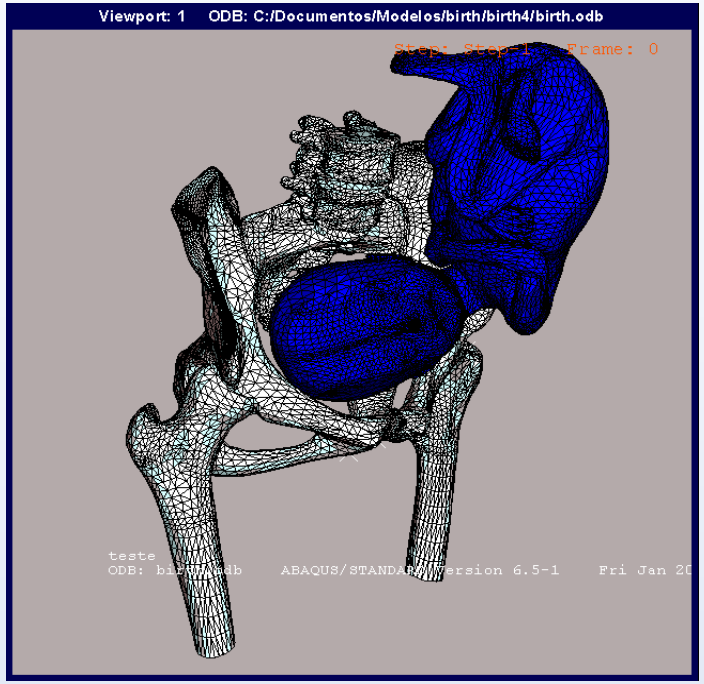
- Existing simulation training centers on ***mannequins***, such as ***SimMom & Victoria.***
- There is some Mixed Reality-based simulation, limited to simple ***best-case scenarios***.
- No pure VR simulation reproduces ***patient-specific worst-case birth scenarios.***

https://laerdal.com/ca/products/simulation-training/obstetrics-pediatrics/simmom/ https://www.gaumard.com/obstetricmr

Foundational Birthing Simulation



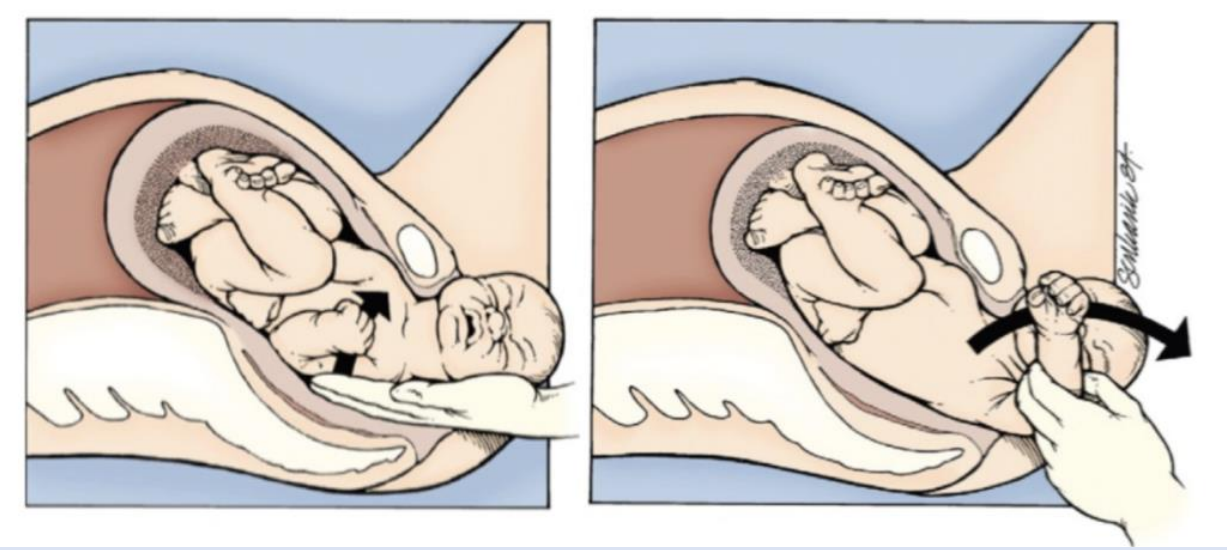
(M Parente et al., Int Uro-gynecology J, 2007)

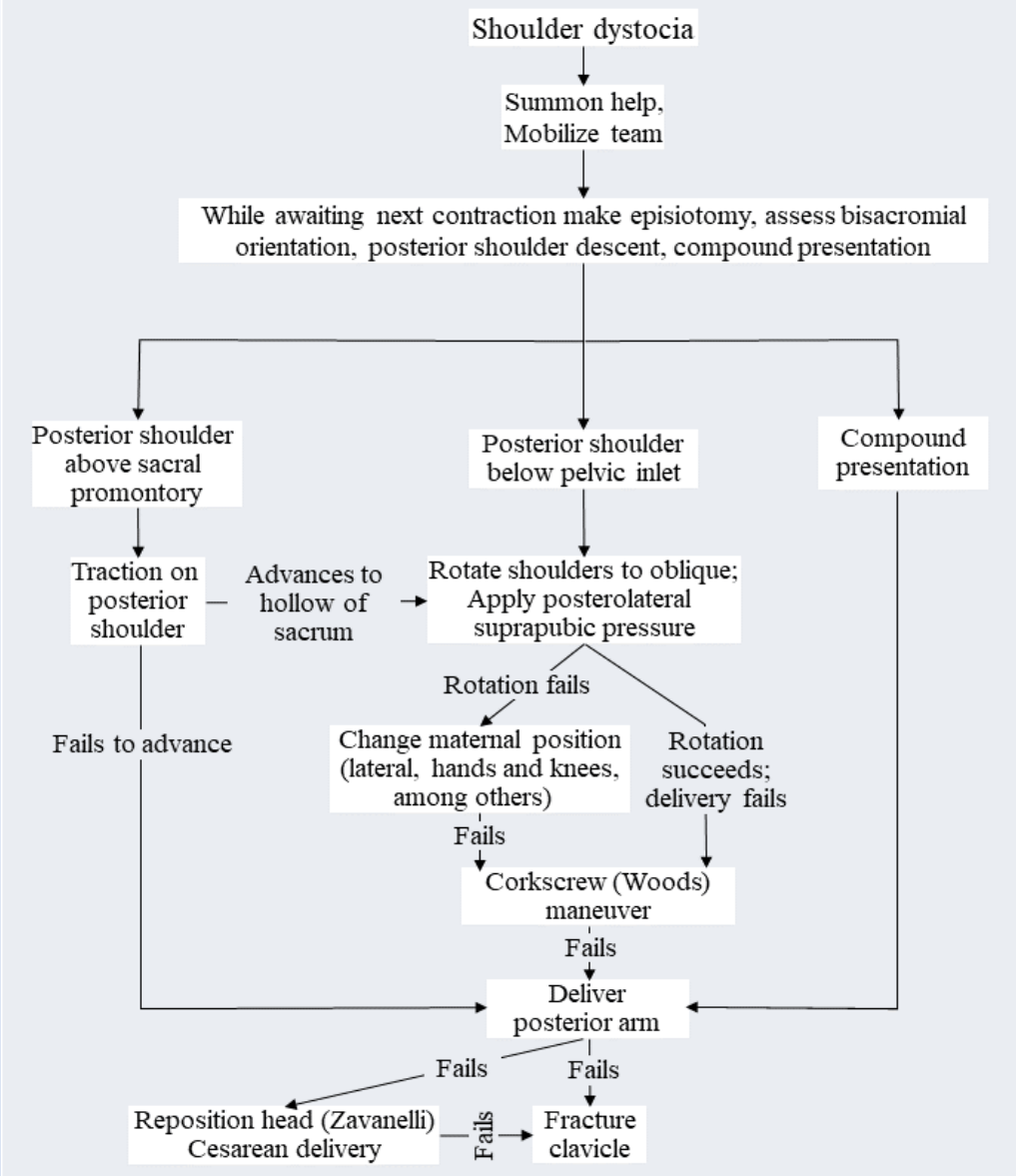


This project in haptics-driven obstetrics simulation founded on finite elements- based birthing simulation by Univ. Porto's Marco Parente, Dulce Oliveira & Renato Natal Jorge.

Challenge 1: Clinically Relevant Medical Simulation

- For ***clinically relevant medical simulation***, we advocate use of ***medical ontologies, or workflows,*** with high-level description of medical procedure.
- An important obstetrics technique is ***Posterior Arm Delivery.***
- PAD training ***not possible in mannequins.***

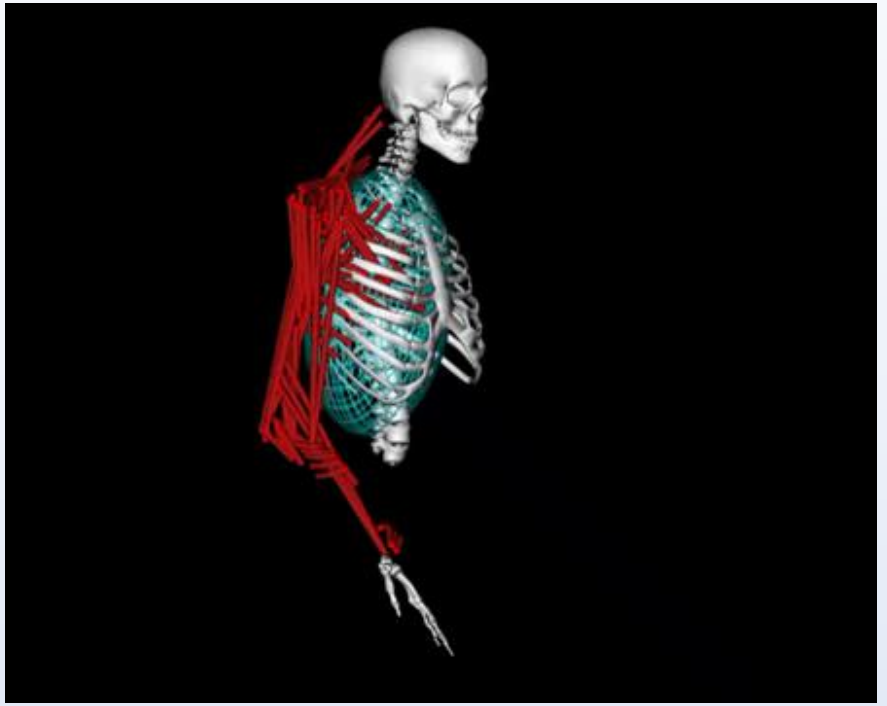




Shoulder dystocia: prediction and management. . Hill MG, Cohen WR. s.l. : Womens Health (Lond)., 2016, Vols. 12(2):251-61. doi: 10.2217/whe.15.103. Epub 2016 Feb 22.

Challenge 2: Haptics-driven Real-time PAD Simulation

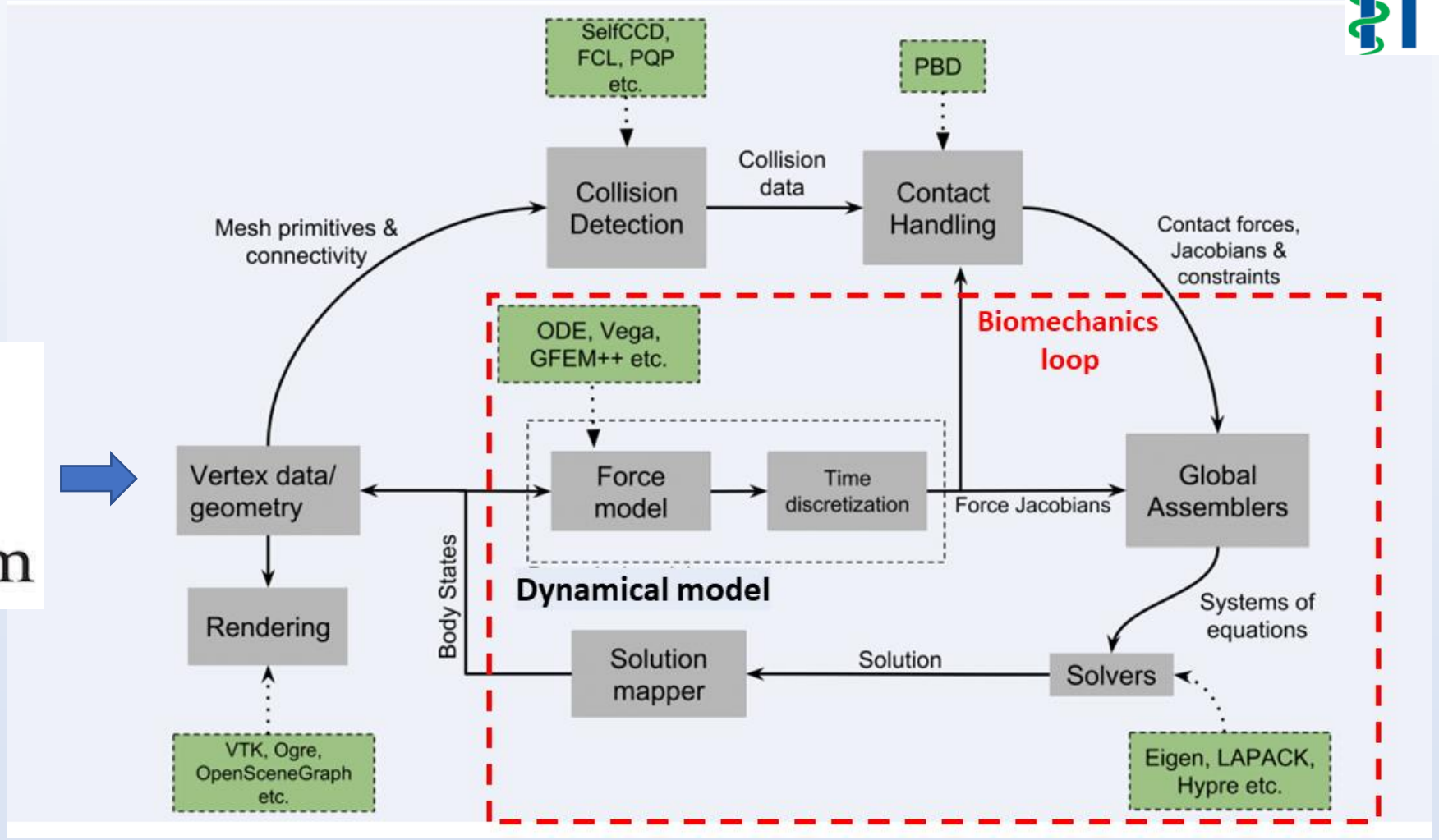
- For PAD, need musculoskeletal modeling of newborn and sense/stimulate ObGyn hands.
- Need to sense fingers: ***Haptx haptic gloves***.
- If ObGyn ***hooks finger under baby's arm***, bones must be liftable & muscles must follow.
- ***OpenSim*** musculoskeletal modeling.
- ***iMSTK*** soft tissue modeling.



Haptx.com simtk.org/projects/upexdyn imstk.org

Challenge 2: Haptics-driven Real-time PAD Simulation

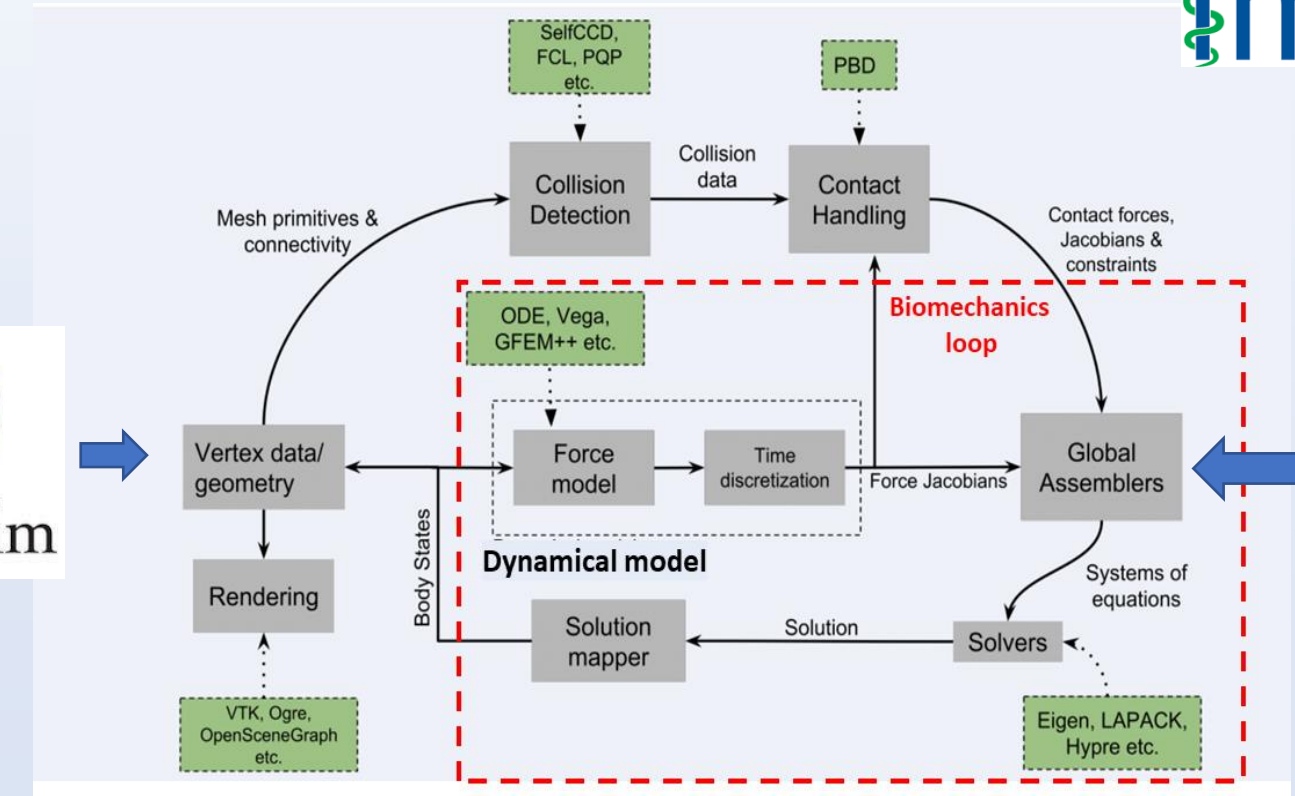
- Real-time soft tissue modeling in iMSTK: new efficiencies needed.



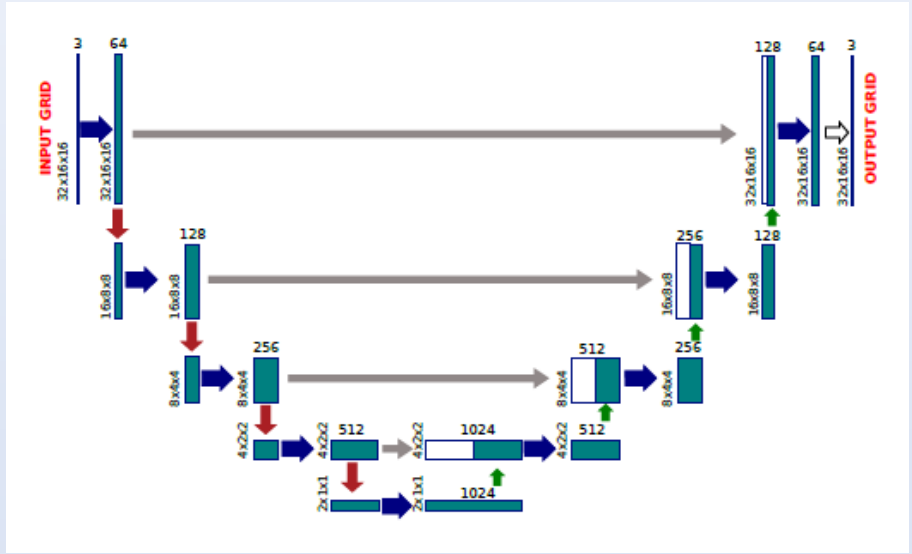
Challenge 2: Haptics-driven Real-time PAD Simulation

- Further efficiencies iMSTK: ***deep neural network-based finite elements synthesis.***
- DNN via Mendizabal's U-Mesh & De's PhyNNeSS: ***solution in millisecs feasible.***

imstk



OpenSim



De S, Deo D, Sankaranarayanan G, Arikatla VS. A Physics-driven Neural Networks-based Simulation System (PhyNNeSS) for multimodal interactive virtual environments involving nonlinear deformable objects. Presence (Camb). 2011 Aug;20(4):289-308.

Mendizabal, Andrea et al. "Simulation of hyperelastic materials in real-time using Deep Learning." Medical image analysis 59 (2020): 101569 .

Challenge: Patient-specific modeling

- ***Atlas-based anatomical modeling:*** baby & mother.
- Start: fetal MRI volume, followed by ***digital MS atlas fitting to MRI***, for baby and mother.
- A key technique is ***Anatomy Transfer*** for registering atlas to fetal sac & mother's body (Ziva Dynamics).
- ***Fetal sac segmentation*** via DNN on GitHub.

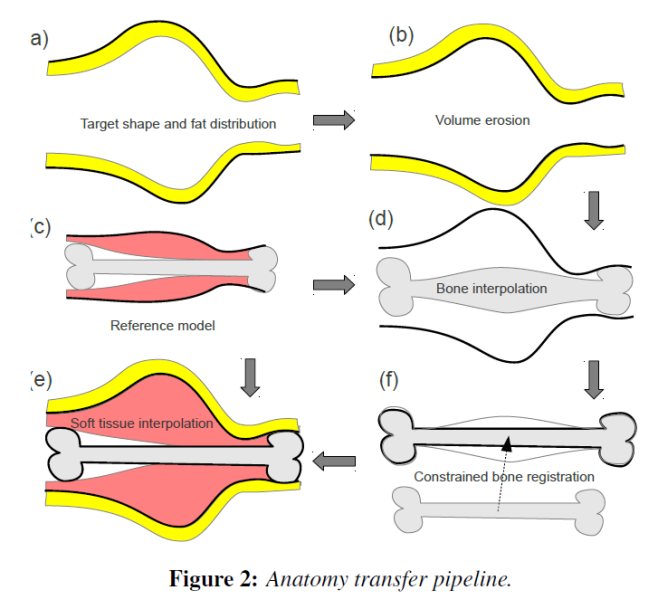
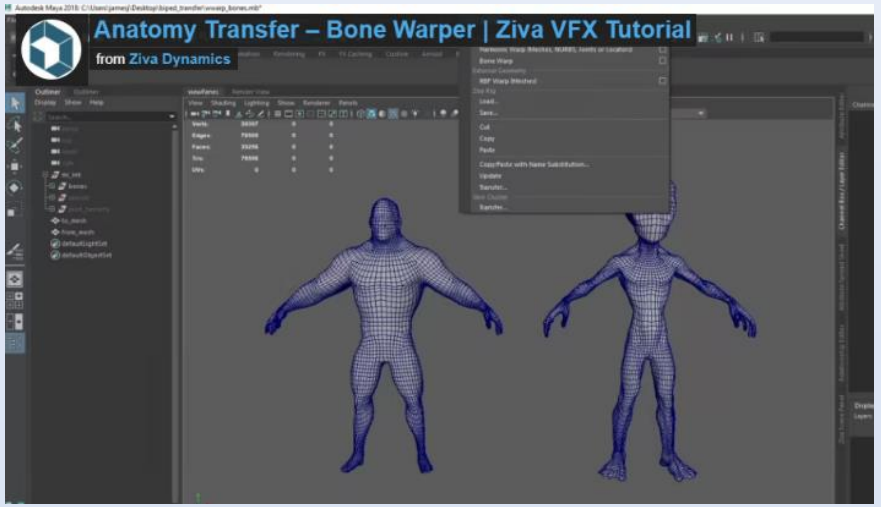
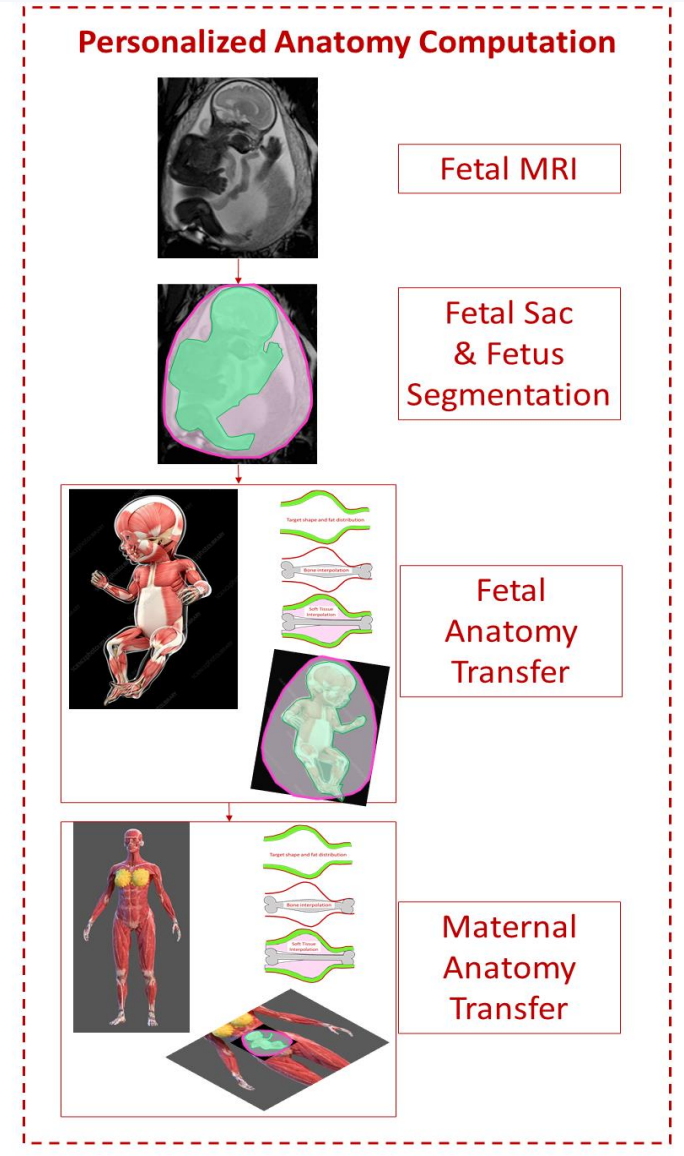


Figure 2: *Anatomy transfer pipeline.*

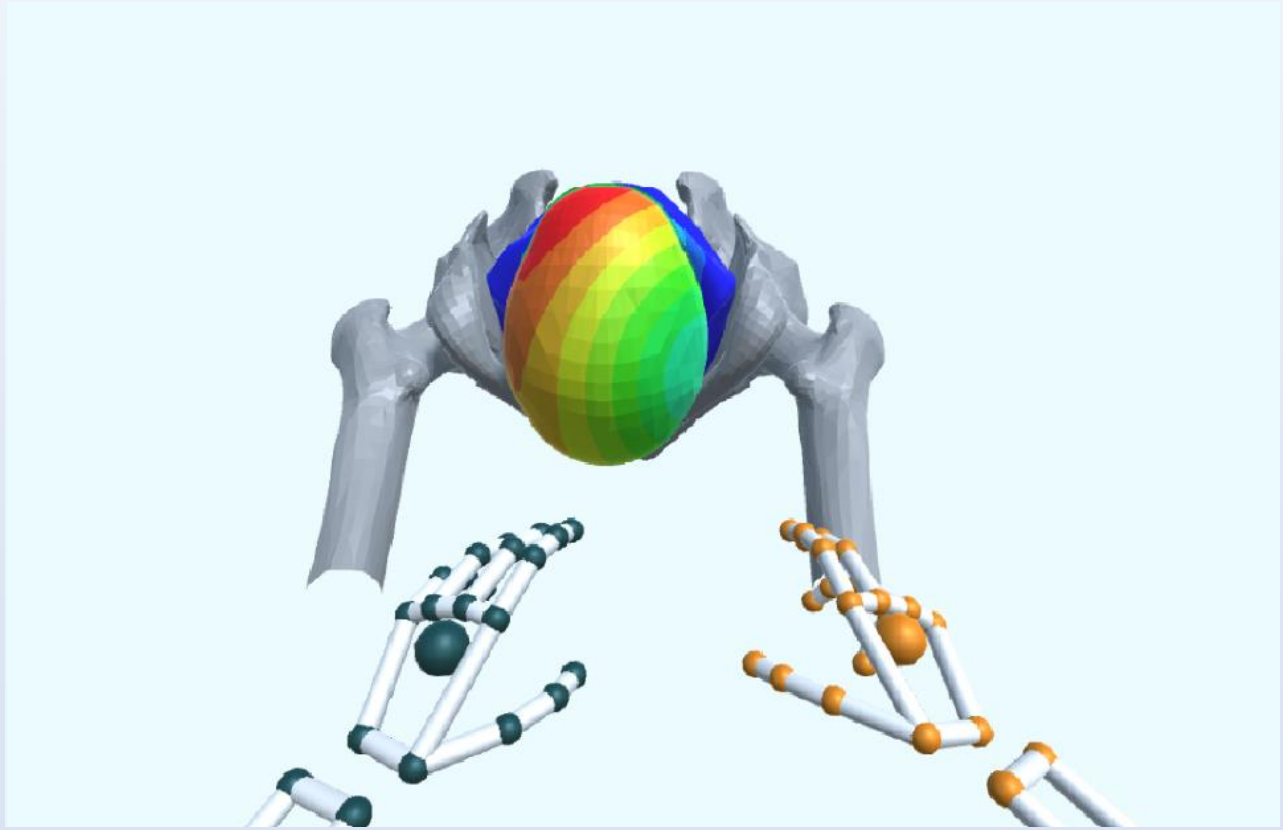


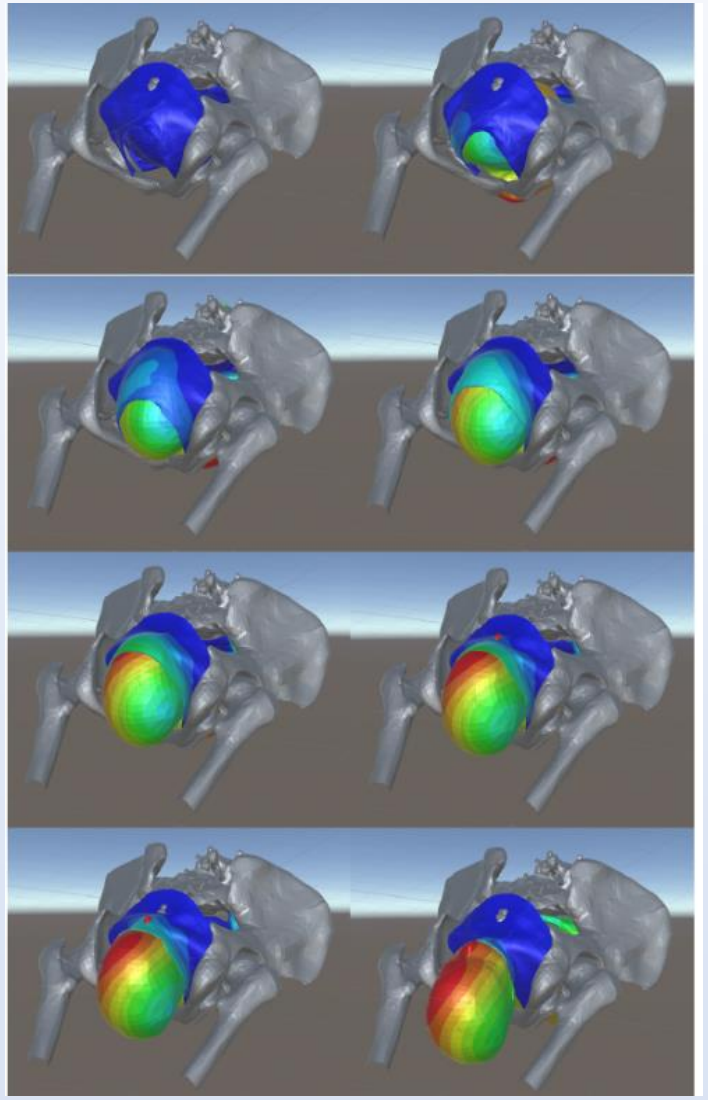


zivadynamics.com/resources/anatomy-transfer Yang X, et al. Towards Automated Semantic Segmentation in Prenatal Volumetric Ultrasound. IEEE Trans Med Imaging. 2019 Jan;38(1):180-193.

Preliminary Results

- ***Proof of concept*** of bimanual haptics based on ***Leap Motion range-sensing*** and ***hand model fitting.***
- Work of Pinto & Parente.





Pinto SLA. Aplicação de Técnicas de Realidade Virtual na Simulação do Parto. s.l. : University of Porto, 2017. www.ultraleap.com

Summary

- Preliminary work on interactive, ***bimanual haptics-driven obstetrics simulator.***
- Dire need: ***inequities in obstetrics outcomes*** & complications in ***developing world.***
- ***Many challenges***: clinical requirements, fidelity to MS dynamics, real-time bimanual haptics.
- Solutions based on ***open-source tools*** like OpenSim and iMSTK, ***commercial*** Ziva Dynamics s/w.
- Applicable to ***developed & developing countries*** – tablet version for midwives; portable US.