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Intra-cardiac surgery on infants and small children
Complex individual morphology
Surgical outcome will influence an entire life-time
Surgical simulation in congenital heart disease

- Preoperative planning
  - Virtual cardiotomy is now clinically feasible
- Training and education
  - Initial work...
Overview

Virtual cardiotomy

3D MRI

Training and education
2 months old boy
- Double outlet right ventricle
- VSD / septum deviates to the right
- Resembling Taussig-Bing heart
- Intramural course of coronary arteries

Biventricular repair possible? Switch or intracardiac repair?
Virtual cardiotomy
Univentricular heart
- Dextrocardia, hypoplastic right ventricle, discordant V-A connections
- TCPC
- Restrictive VSD apparent from 3D MRI
  - How do we access the defect?
Setup

- State of the art pc with high-end graphics card
  - €2500
- Two Phantom Omnis for force feedback
  - 2 x €2000

Force feedback for faster interaction
Technical contributions

- GPU used for computing the biomechanical model
  - i.e. tissue deformation
  - >50 acceleration over the CPU

- GPU used for force feedback computation
  - i.e. one can “feel” the model

- GPU used for sophisticated visualization
  - i.e. the visualization resolution exceeds the physical simulation resolution
Isotropic 3D MRI

- Transversal view
- Coronal view
- Sagittal view
The reconstruction process
In the previous slides we segmented only the blood pool.

For our virtual cardiotomy simulator we need to segment the myocardium also.
  - Use green paint to mark the myocardium.
Segmented 3D MRI from 41 patients
- Age 0-10 (median 1.5 years)
- Median heart rate 96 bpm
- Median weight 11.5 kg

Average segmentation time: 58.2 minutes
- ranging from 40-85 minutes
Example: VSD closure
Part II – training and education

- Preoperative planning
  - patient-specific virtual models

- Surgical training
  - generalized virtual models
An example

- 3D MRI of a volunteer
  - (Several) VSDs added manually in post-processing
- How can we best access the VSD?
  - Trans-ventricular or trans-atrial incision?
“Configurable” septal defects
Yet another movie
Summary

- **Available now / near future**
  - Isotropic 3D MRI
  - Virtual cardiotomy in clinically acceptable reconstruction times.

- **Short term research goals (pending funding)**
  - Improved suturing and handling of patches
  - Surgical anastomoses (BT-shunt, Norwood, Fontan)

- **Longer term research goals**
  - Full support for training and educational scenarios
  - Electrophysiology
Limitations

- Valves missing!
  - Not visible in the underlying MRI data
  - Consider integrating generic models
- End systole imaging
  - ... of a blood filled heart
- Shunts and high heart rates can degrade the MRI quality
  - Coils can also cause signal void
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http://www.daimi.au.dk/~sangild
- Movies and key papers available