Development of Aortic Surgery simulators

Dr. R. Devotini

Erice, 1st - 5th May 2015
Scientific and technological advances in cardiac and vascular surgery a translational approach

EACTS 2013 Ethicon Cardiovascular Simulation Award  Aortic root surgery
In recent years there has been increasing emphasis on skills and simulation training for trainees in cardiothoracic surgery.

The use of simulators has been shown to improve surgical skills of trainees compared to traditional approaches.
The Contest is to create a Simulator which replicates for training purposes one teachable component of an Aortic root surgery (Preferably as many different teachable components as possible and most certainly the essential ones: a low fidelity substitute for the aortic root prosthesis (essential), sizing, commissures, coronary re-implantation, valve or root implantation).

Development Criteria of the Simulator: Low Fidelity, Cost Effective, Reusable, Portable/Flat Pack assembly.

The project will be submitted in the form of a transportable self-construction package. It will have a graphical description of its building process and a textual description of the materials.

Is it really possible to create a simulator for the surgery of the aortic root?

These were our initial beliefs...

... our starting point!
First steps
It was necessary to build an ideal prototype!

basic requirements :

• simulator able to reproduce the anatomical details of the aortic root.

• use of materials with excellent performance, realistic for the similarity with vascular structures in: resistance, elasticity and difficulty of exposition.

• low cost and simple construction tools.

• a complete simulator for - the structure (bulb, ring and aortic cusps and coronary ostia).
  - the operating mechanism.

• easy reproducibility.
Goals

Reproduce, in a real way the scenario offered to the surgeon in the operating room

Recreate the anatomy of the aortic root in detail

The materials used behave similarly to the vascular tissue as: silicone rubber – rubber latex

Realize the molds for a production serial, easy and quick.

Aortic root Simulator

University Division of Cardiac Surgery – Città della Salute e della Scienza - Torino
behind a simple idea it is hidden a more complex project that arises from the consideration anatomic aortic root as the set of four distinct components:

- the sino-tubular junction (STJ)
- the bulb with the aortic sinuses of valsalva,
- the aortic valve with its aortic annulus and
- junction ventriculoarterial (VAJ).

in everyday practice, the surgeon is often called upon to treat pathologies of these anatomical structures of the aortic root individually or with varying degrees of association.
STEP BY STEP

THIS ANATOMICAL AND PHYSIOPATHOLOGICAL CONSIDERATION WAS THE INSPIRATION FOR THE PROTOTYPE COMPOSED OF THREE COMPONENTS:

1) ASCENDING AORTA
2) AORTIC ROOT (the simulator)
3) SUPPORT (the heart)

FIXED COMPONENT

INTERCHANGEABLE COMPONENTS
The smooth intimal surface of the aorta was reversed. Filling the aortic lumen with a sponge to prevent the collapse of the walls.

Aorta with silicone rubber coating

Casting marmorina

Mould marmorina

Coating of the mold with rubber latex

Aorta rubber latex
STEP BY STEP

THIS ANATOMICAL AND PHYSIOPATHOLOGICAL CONSIDERATION WAS THE INSPIRATION FOR THE PROTOTYPE COMPOSED OF THREE COMPONENTS:

1) ASCENDING AORTA
2) AORTIC ROOT (the simulator)
3) SUPPORT (the heart)

INTERCHANGEABLE COMPONENTS

FIXED COMPONENT
AORTIC ROOT: SEQUENCES OF REALIZATION

Mold silicone rubber aortic root

Aortic root in rubber latex

Mold of the aortic root in marmorina
Mold Aortic Root Pig: these limits

- Annulus and aortic roots often small.

- Aortic annulus is a structure scarcely represented in the pig heart.

- In fact, in SC right the annulus is almost absent and the right cusp continues with SIV.
Modifications the mold of the aortic root:

1) enlargement of the diameter

2) creation of the aortic annulus executing an incision mold
SERIAL PRODUCTION OF AORTIC ROOTS USING THE MOLD OF MARMORINA

JUST IN ONE STEP

University Division of Cardiac Surgery – Città della Salute e della Scienza – Torino
THIS IS THE AORTIC ROOT COMPLETE!

- **Sinuses of Valsalva**
- **Ventriculoaortic Junction**
- **Aortic Cusps**
- **Aortic Ring**
- **Coronary Ostia**
The neoaorta created, latex rubber, is perfectly elastic like the human aorta.

You can create a positive pressure within the neovaso, infusing normal saline.
Finally we have created a working prototype

In fact, you can create a positive pressure within the neovaso with the infusion of normal saline.

This allows surgeons to train in:
- packing of the aortic bags
- in the aortic cannulation
Aortic bags and aortic cannulation

University Division of Cardiac Surgery – Città della Salute e della Scienza - Torino
David procedure: example

You can really appreciate the simulator just trying it
STEP BY STEP

THIS ANATOMICAL AND PHYSIOPATHOLOGICAL CONSIDERATION WAS THE INSPIRATION FOR THE PROTOTYPE COMPOSED OF THREE COMPONENTS:

1) ASCENDING AORTA
2) AORTIC ROOT (the simulator)
3) SUPPORT (the heart)

INTERCHANGEABLE COMPONENTS

FIXED COMPONENT

University Division of Cardiac Surgery – Città della Salute e della Scienza di Torino
**Support simulator:** realization

**The support:**

- It is a mold rubber latex of a pig heart
- It favors the orientation of the surgeon respect to anatomical structures in continuity with the aortic root
An incision (Konno procedure) It is made across the SIV and a triangle of myocardium is removed allows:

- The visualization of intra-ventricular anatomical structures in continuity with the aortic valve

- The possibility to continuously inspect every single surgical act performed by the surgeon on the aortic ring or the aortic cusps
SEQUENCE OF REALIZATION OF THE SUPPORT OF THE PROTOTYPE (AORTIC ROOT)

Preparation of the heart to perform the mold

Silicon rubber mold of the heart

Mould Marmorina
Sequence of realization of the support of the prototype

Support of the prototype in rubber latex
Aortic Root simulator complete

University Division of Cardiac Surgery – Città della Salute e della Scienza - Torino
Our simulator allows the following procedures:

- David procedure
- Yacoub procedure
- Plastic aortic cusps
- Bentall procedure
- Florida sleeve procedure
- ...of course substitution of the aortic valve and annulus widening
  (Nicks and Manoughian techniques)
Simulator Aortic Root - today

University Division of Cardiac Surgery – Città della Salute e della Scienza - Torino
Features of the Aortic simulator

- realistic and rechargeable
- compact
- easy to assemble
- stable

University Division of Cardiac Surgery – Città della Salute e della Scienza - Torino
What I would like for the future .......?
• Produce molds aortic root according to the various forms of aortic regurgitation (classification of El Khoury)

• Use molds as scaffold for seeding stem cell

• Create a root pathological entirely organic

• Create a box to verify via a pulse duplicator with a true $\Delta$ pressure set to ECG and visual monitoring, pressure and echocardiographic

• Increasing the degree of confidence and success regarding the procedures of conservative surgery of the aortic valve

University Division of Cardiac Surgery – Città della Salute e della Scienza - Torino
Using simulation for high impact training
Thanks for your attention

Good work!
University Division of Cardiac Surgery - City Health and Science of Turin
behind a simple idea it is hidden a more complex project that arises from the consideration anatomic aortic root as the set of four distinct components:
Our simulator allows the following procedures:

- David
- Yacoub
- Plastic aortic cusps
- Bentall
- Florida sleeve
- …of course substitution of the aortic valve and annulus widening (Nicks and Manoughian techniques)

It allows to improve the understanding of conservative surgery on the aortic valve

Increase the skills in surgical sutures such as the sutures of coronary tokens
Costo per 1 simulatore

Costo per il supporto = 20 €
Costo per la radice aortica + aorta = 0,21 € (ricaricabile)