A Surgical Simulation Model for Myelomeningocele Repair

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Introduction

A simulation model for the surgical repair of the congenital defect, myelomeningocele (spina bifida cystica), was developed as a training platform for neurosurgery residents.

Background

Congenital Spinal Cord Defects

Myelomeningocele (spina bifida cystica) is a common, severe congenital neural tube defect that can cause significant disability or mortality.¹

Fig 1 Illustration of spina bifida.²

Fig 2 Incidence of spina bifida before and after folic acid fortification in the U.S.³

Simulation-based Learning

Advantages of medical simulator models:

- Greater availability, lower risk and costs than patient or cadaver cases
- Less ethical debate, greater anatomical accuracy than animal models

Methods

Model Design:

- Digital modeling of simulator geometry
- Digital modeling of mold designs
- Additive fabrication of molds
- Multiple-stage silicone casting of ‘tissue’ layers

Fabrication:

- Application of surface coatings to control layer adhesion
- Measurement of forces on spinal cord by pressure transducer
- Model evaluation by experienced pediatric neurosurgeon

Results

Comparison of Surgical and Simulated Repair

Simulated surgery was performed on the model by an experienced pediatric neurosurgeon. Figures 9-12 depict video stills of the procedure (above) and corresponding images from actual surgery (below).⁴

While its incidence has been declining with folic acid supplementation, spina bifida continues to emerge with an unknown specific etiology.⁵

Fig 3. 3D sketches of myelomeningocele model design.

Fig 4. Mold pieces produced by additive fabrication.

Fig 5. Casting of silicone spinal cord.

Fig 6. Spina bifida model showing caudal access ports.

Fig 7. Spina bifida model showing caudal access ports.

Discussion

The model represented both pathological anatomy and tactile properties of tissue. Simulated repair using traditional surgical techniques was successfully performed.

Application as a Training Model

Simulator models will be used to train neurosurgery residents. Their performance will be evaluated by reviewing:

- Video captures of surgery
- Surgical duration
- Leakage of closure
- Pressure recordings

Fig 8. Sagittal cross section of simulation model.

Second Generation Design Refinements

- Increase simulated tissue flexibility by using lower durometer silicone
- Improve suture retention by incorporating nylon mesh into tissue layers
- Improve measurements of force exerted on the cord with hollow spinal cord design

Fig 9. Aspiration of cerebrospinal fluid.

Fig 10. Incision through dura into meningeal cavity.

Fig 11. Dissection of tissue layers (spinal cord, dura, skin).

Fig 12. Closure after correction of defect.

References