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]

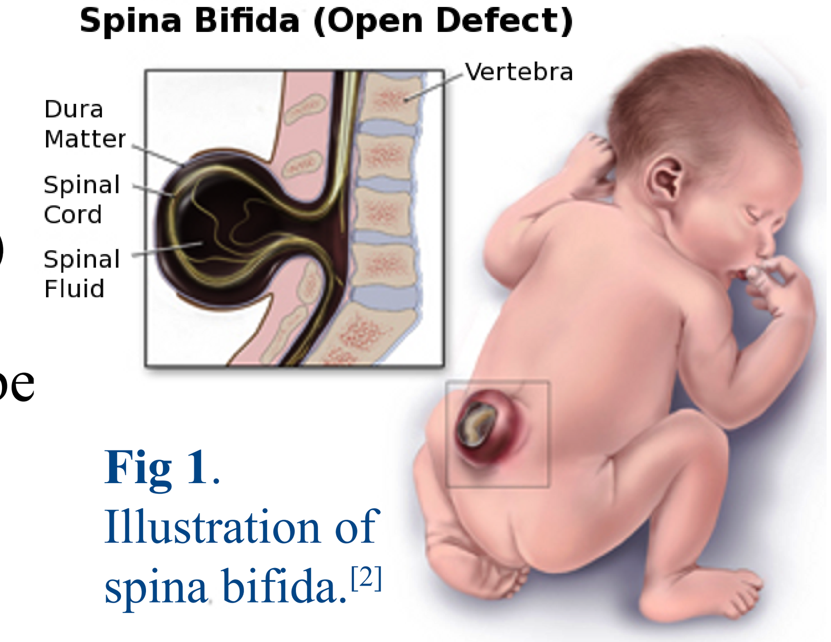

Fig 1. Illustration of spina bifida.[2]

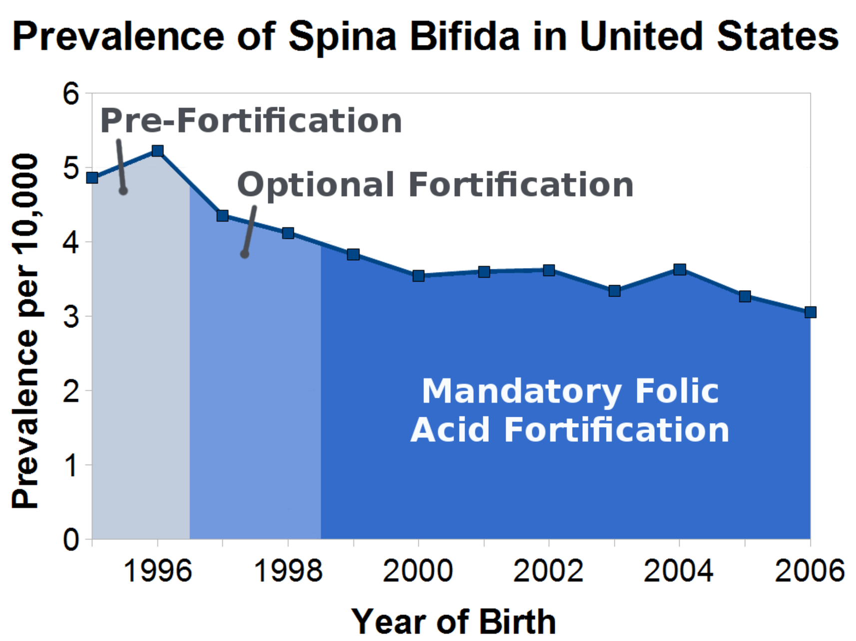

Fig 2. Incidence of spina bifida before and after folic acid fortification in the U.S.[4]

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

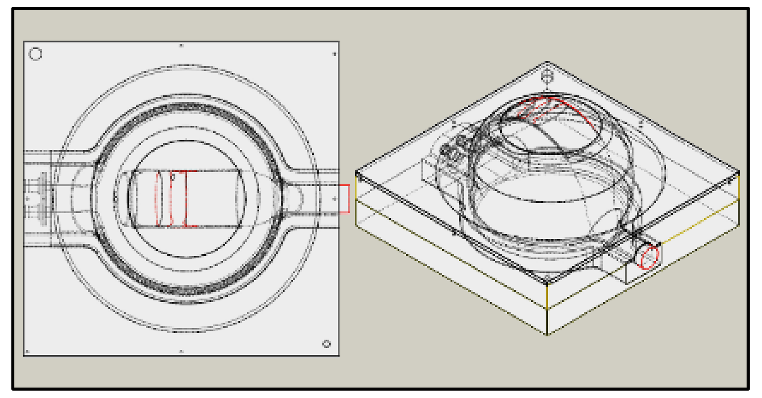

Fig 4. 3D sketches of myelomeningocele model design.

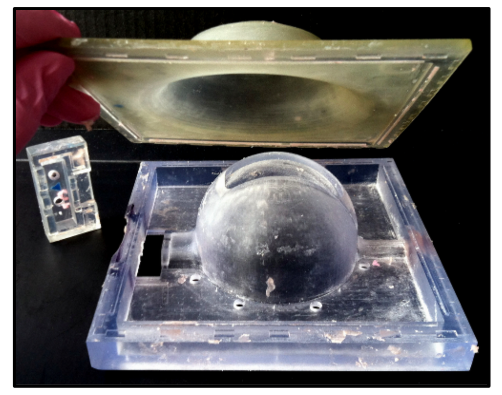

Fig 5. Mold pieces produced by additive fabrication.

Fig 6. Casting of silicone spinal cord.

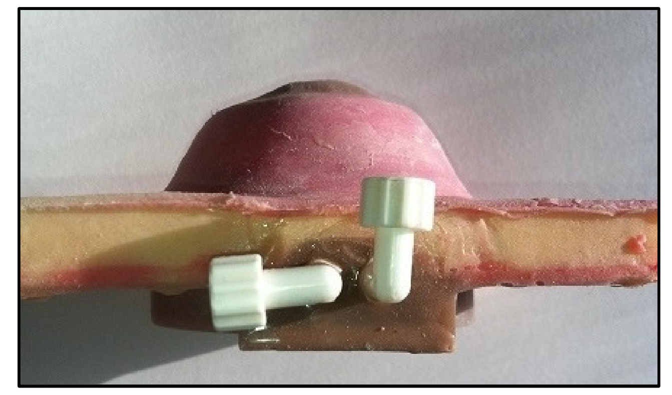

Fig 7. Spina bifida model showing caudal access ports.

Model Design:
- Digital modeling of simulator geometry
- Digital modeling of mold designs

Fabrication:
- Additive fabrication of molds
- Multiple-stage silicone casting of 'tissue' layers
- Application of surface coatings to control layer adhesion

Implementation:
- Measurement of forces on spinal cord by pressure transducer
- Model evaluation by experienced pediatric neurosurgeon

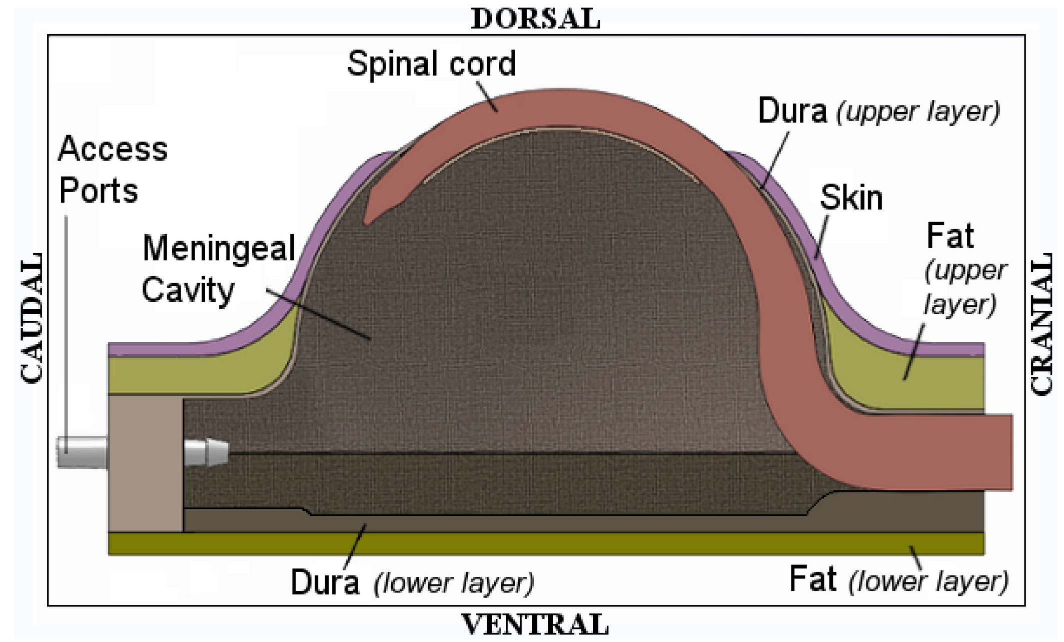

Fig 8. Sagittal cross section of simulation model.

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)*.[5]

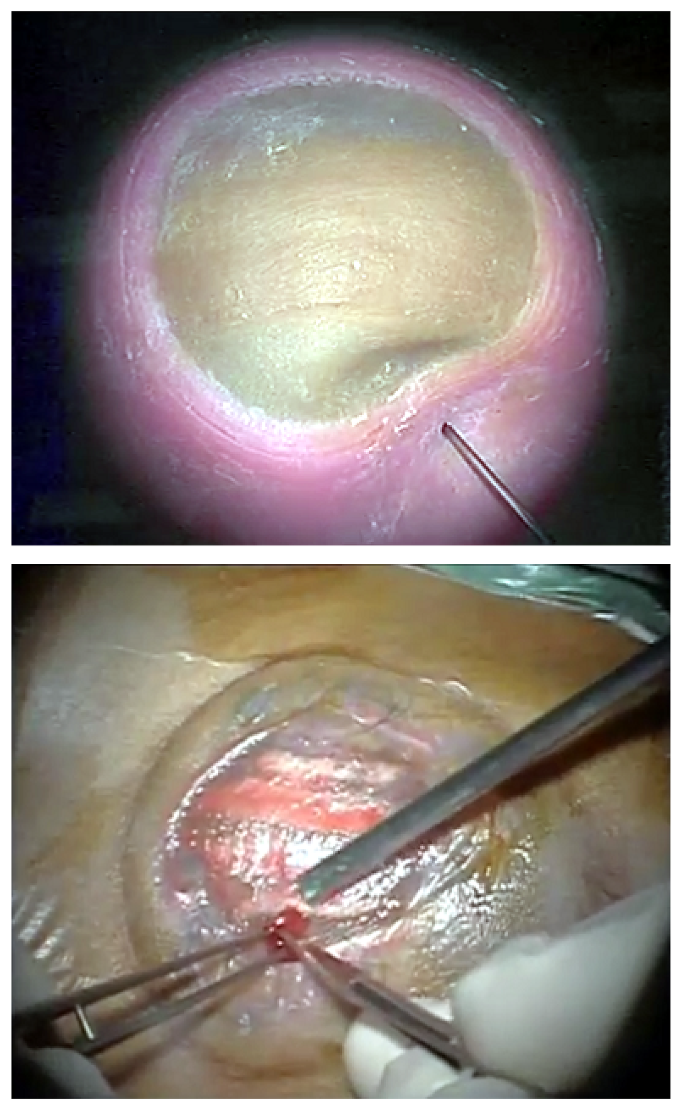

Fig 9. Aspiration of cerebrospinal fluid.

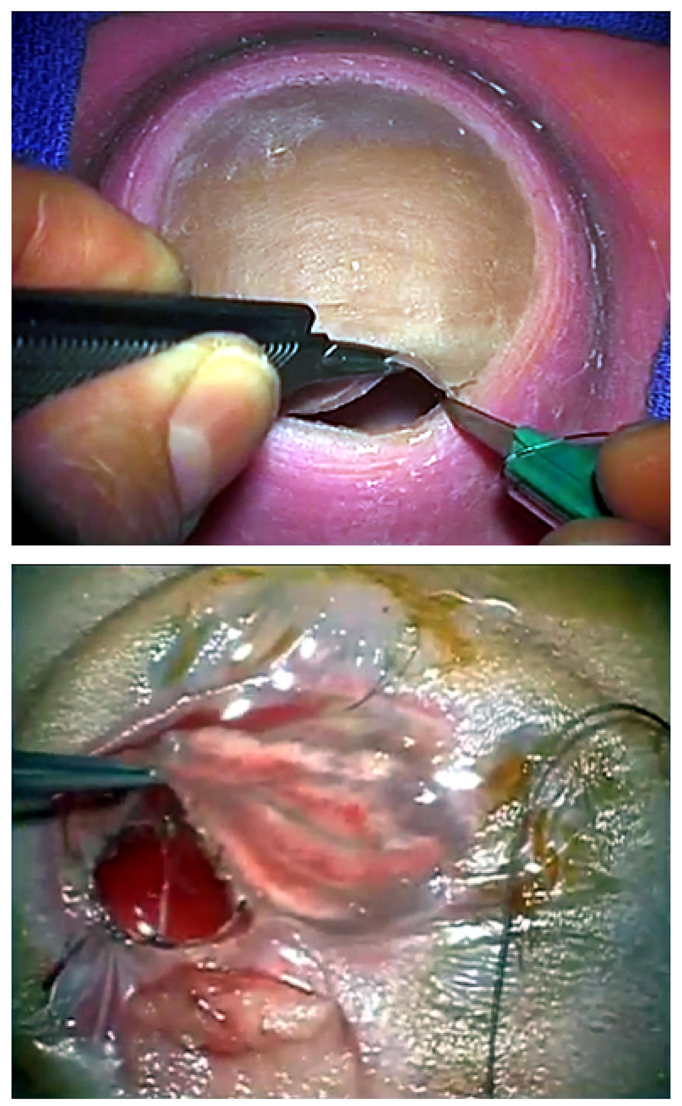

Fig 10. Incision through dura into meningeal cavity.

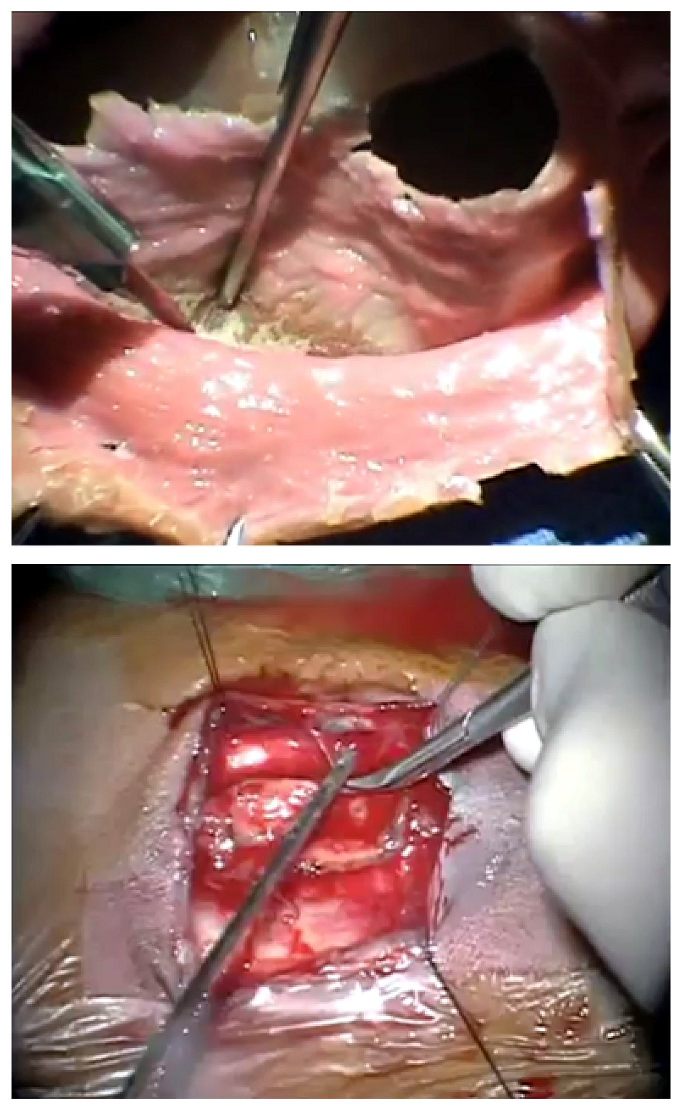

Fig 11. Dissection of tissue layers (spinal cord, dura, skin).

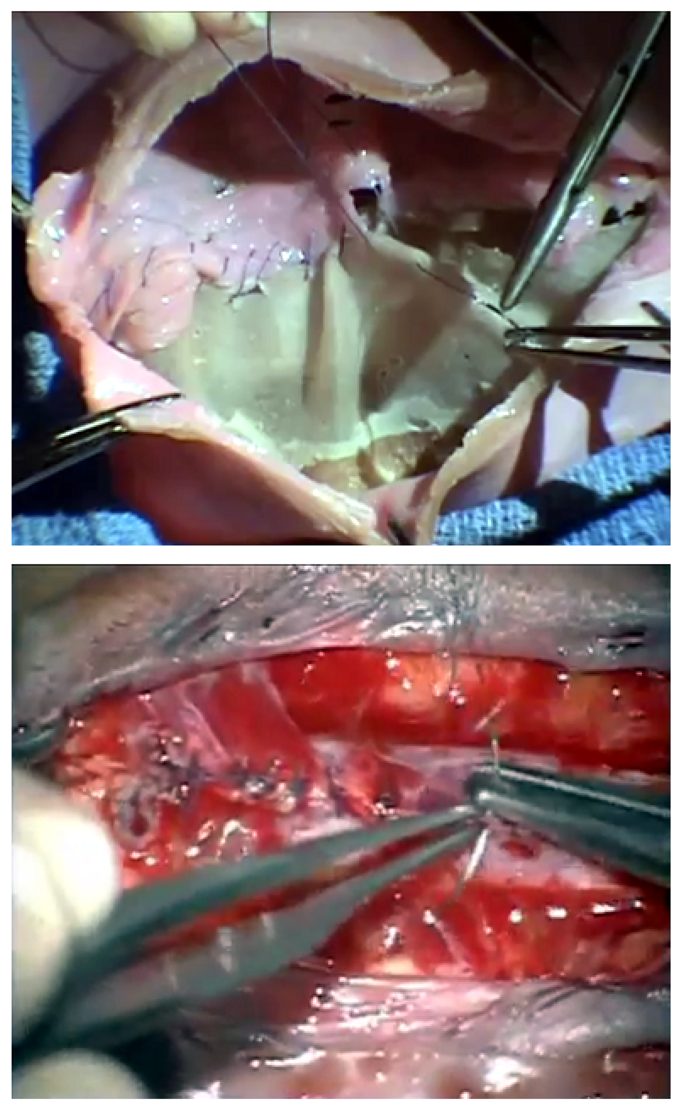

Fig 12. Closure after correction of defect.

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

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

References

[1] Cherny, W. B., "Myelomeningocele Repair," 2000. Barrow Quarterly, 16(4), pp. 11-14. [2] Centers for Disease Control and Prevention, 2013. "Spina Bifida, Facts – NCBDDD," from http://www.cdc.gov/ncbddd/spinabifida/facts.html. [3] Bowman, R.M., Boshnajaku, V. and McLone, D.G., 2009, "The Changing Incidence of Myelomeningocele and Its Impact on Pediatric Neurosurgery: A Review from the Children's Memorial Hospital," Childs. Nerv. Syst., 25(7), pp.801–806. [4] Figure derived from: Centers for Disease Control and Prevention, 2011. "Spina Bifida, Data and Statistics – NCBDDD," from http://www.cdc.gov/ncbddd/spinabifida/data.html. [5] Figures derived from: Sirikit National Institute of Child Health, Neurosurgical Unit PVT, 2012. "Myelomeningocele Repair," from http://www.youtube.com/watch?v=ZQoPbmmr4EI.