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Dural Repair Simulation Model

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Introduction

Dural tear or incidental durotomy (ID) is a common complication in pediatric spine surgery. The incidence of ID varies depending on the procedure, with incidence reported as low as 0.34% for primary surgery and as high as 18.5% for revision surgery.[1] Postoperative complications after ID include the need for revision surgery, durocutaneous fistula, pseudomeningocele, and arachnoiditis. Pediatric patients with an ID have 2.7 times greater odds of being readmitted within 30 days of surgery.[2] The foundation of intra-operative management of ID is direct suture repair of the dura. Because of the proximity of the tear to neural structures as well as the desire for a watertight repair, dural tears are often repaired by the attending surgeon rather than fellows or residents.

Numerous efforts have been made to improve simulation in surgical training. The impetus for these efforts is a combination of the decreased exposure to the clinical environment due to duty hour regulations as well as the increased attention on improved safety in the training environment.[3] Simulation models vary in their fidelity. Low-fidelity models typically use industrial materials which have the benefit of being lower cost and more easily accessible. High-fidelity models better mimic the true surgical environment; however, the materials (e.g., cadaveric specimens) are costly and harder to acquire.

We developed a dural repair simulation model to give trainees an outlet to practice dural suturing while also gaining experience with handling the instruments required for dural repair (e.g., Castroviejo needle holder, micro forceps). The primary goals of the model were to be accessible (i.e., supplies are easy to obtain), inexpensive, and relatively high-fidelity in the absence of any human or animal tissue. While adult spine surgeons manipulate and sew dura with reasonable frequency, this model will be most beneficial for those that are first learning the technique (i.e., residents and fellows) or those that operate on the spine but do not repair dura often (which may be the case with pediatric spine surgeons who commonly perform scoliosis surgery).

We incorporate this simulation into the intern "surgical skills month" in our residency program as well as with the trainees on the orthopaedic spine surgery service (post-graduate year PGY2 resident, PGY4 resident, and fellows). The performance on the dural repair simulation can be objectively measured as outlined below, and the trainee's progress is tracked year-to-year. The trainees anecdotally benefit from the experience of using microsurgical instruments not only for their confidence in dural repair but also for other subspecialties such as hand surgery.

We objectively evaluate the performance and development of trainees by measuring the time it takes to complete the dural repair. Additionally, after completion of the repair, the flow rate (drops/min) in the drip chamber is recorded, which represents the amount of fluid leaking from the repair site. Subjectively, the appearance of the dural repair is assessed by fellowship-trained orthopaedic spine surgeons (Appendix 1).

Description of Simulation Exercise

The materials, set up, and demonstration of the model can be seen in the supplemental video. The materials and their associated cost can be found in Appendix 2.

A 1" outer diameter PVC tubing (simulating the bony spinal column) is cut to a length that will fit inside a plastic food container. A 1 cm x 4 cm cut-out is made in the tubing to simulate the exposure after laminectomy. A small notch is made on one end of the tube to allow for the feed bag tubing to enter. The long finger of a latex glove is removed from the remaining glove and is used to simulate the dura. An O-ring is passed over the glove finger to facilitate attachment to the feed bag tubing. On the other end of the glove finger, a suture is tied and used to thread the glove finger into the PVC tubing. The PVC tubing is placed into the plastic food container and the end of the suture attached to a clamp to provide tension. The feed bag is filled with tap water and hung with the drip chamber 30 cm above the model to simulate cerebrospinal fluid pressure (approximately 30 cc H_2O).

A #11 scalpel is used to make a 1 cm linear durotomy (durotomy length can be variable). A timer is started, and the participant closes the durotomy using the suture and microsurgical instruments.

When the repair is completed, the time elapsed is recorded. The drip chamber is then examined, and the flow rate (drops/min) is recorded. This represents the amount of fluid leaking from the durotomy repair. Additionally, the repair configuration can be subjectively assessed for completeness and symmetry.

To increase the difficulty of the simulation, a number of factors can be modified. The glove can be exchanged for a condom to simulate thinner dura. The PVC tubing can be placed deeper into the plastic food container to simulate a thicker soft tissue envelope. The durotomy can be made closer to the edge of the cut-out which mimics a dural tear on the lateral aspect of the thecal sac, which can be harder to visualize and repair. Alternatively, the participant can look through a surgical microscope.

Summary

Surgical simulation is a critical aspect of surgical training. Models should seek to be as high-fidelity as possible while also be inexpensive and accessible. This dural repair model has evolved over time to enhance the fidelity while decreasing costs. Early iterations used operating room caliber instruments, which are costly. We found that microsurgical instruments purchased online (typically marketed for office-based dermatology and plastic surgery procedures) were significantly cheaper and did not hamper performance of the simulation. Over time, the material used to simulate the dura changed. Animal tissue was obtained but is expensive and carries the risks of disease transmission as well as the challenges and costs of storage. Condoms are inexpensive, of appropriate shape to mimic the thecal sac, and can be purchased online or at retails stores, but we found that many types are thin and tear with suturing. Accordingly, we have switched to using a latex glove which does not rip as easily and is similarly inexpensive and available.

The teaching of spine surgery to trainees is difficult because of the high complexity nature of spine surgery as well as the high risk of injury to the thecal sac and neural elements. Accordingly, the management of intra-operative complications, such as incidental durotomy repair, are infrequently managed by trainees. This dural repair model simulates the hands-on skill of repairing dura and has objective metrics that can be used to compare intra- and inter-participant performance. We feel that this model, which costs approximately $50 to build, can be of great value to orthopaedic and neurological surgery residents and fellows.

Disclaimer

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Appendices

Appendix 1. Dural Repair Simulation Model Scoring Rubric

Dural Repair Simulation Model Scoring	
Attempt #1	
Completion time (s)	
Drip rate after completion (drops/min)	
Subjective appearance (graded 1-3)	
Attempt #2	
Completion time (s)	
Drip rate after completion (drops/min)	
Subjective appearance (graded 1-3)	
Attempt #3	
Completion time (s)	
Drip rate after completion (drops/min)	
Subjective appearance (graded 1-3)	

Scoring Instructions

1. **Completion time**: Time from starting dural repair to the completion of last suture, measured in seconds.
2. **Drip rate after completion:** Drip rate (drops/min) in the drip chamber of the feed bag after repair is performed. Feed bag is hung 30 cm above the simulation model.
3. **Subjective appearance of repair (scale 1-3)**: Subjective appearance of repair after completion
   i. 1 point – Inconsistent spacing of suture. Multiple holes from unnecessary suture passes. Inconsistent width of suture pass. Loose knots.
   ii. 2 point – Nearly consistent but non-uniform spacing of sutures. Suture pass width may vary. Some knots loose.
   iii. 3 point – Robust repair. Consistent spacing of suture. Consistent width of suture passes. Tight knots.

Appendix 2. Materials and Costs of the Dural Repair Simulation Model

Material	**Cost**
1” outer diameter clear PVC piping	$3/ft
Plastic food container (5 cup volume)	$3.00
Latex glove	$0.24
Nylon suture	$1.28
1000 ml feed bag	$3.43
¼” O-ring	$0.18
Microsurgical instruments (needle driver, forceps, scissors)	$28.00
Clamp	$4.00
Disposable #11 scalpel	$1.80
7-0 suture	$8.90
TOTAL	**$53.83**

All materials can be purchased online or at hardware stores.