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The use of a novel perfusion-based cadaveric simulation model with cerebrospinal fluid reconstitution comparing dural repair techniques: a pilot study

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Abstract

BACKGROUND CONTEXT: Watertight dural repair is crucial for both incidental durotomy and closure after intradural surgery.

PURPOSE: The study aimed to describe a perfusion-based cadaveric simulation model with cerebrospinal fluid (CSF) reconstitution and to compare spine dural repair techniques.

STUDY DESIGN/SETTING: The study is set in a fresh tissue dissection laboratory.

SAMPLE SIZE: The sample includes eight fresh human cadavers.

OUTCOME MEASURES: A watertight closure was achieved when pressurized saline up to 40 mm Hg did not cause further CSF leakage beyond the suture lines.

METHODS: Fresh human cadaveric specimens underwent cannulation of the intradural cervical spine for intrathecal reconstitution of the CSF system. The cervicothoracic dura was then exposed from C7–T12 via laminectomy. The entire dura was then opened in six cadavers (ALLSPINE) and closed with 6-0 Prolene (n=3) or 4-0 Nurolon (n=3), and pressurized with saline via a perfusion system to 60 mm Hg to check for leakage. In two cadavers (INCISION), six separate 2-cm incisions were made and closed with either 6-0 Prolene or 4-0 Nurolon, and then pressurized. A hydrogel sealant was then added and the closure was pressurized again to check for further leakage.

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RESULTS: Spinal laminectomy with repair of intentional durotomy was successfully performed in eight cadavers. The operative microscope was used in all cases, and the model provided a realistic experience of spinal durotomy repair. For ALLSPINE cadavers (mean: 240 mm dura/cadaver repaired), the mean pressure threshold for CSF leakage was observed at 66.7 (±2.9) mm Hg in the 6-0 Prolene group and at 43.3 (±14.4) mm Hg in the 4-0 Nurolon group ($p>.05$). For INCISION cadavers, the mean pressure threshold for CSF leakage without hydrogel sealant was significantly higher in 6-0 Prolene group than in the 4-0 Nurolon group (6-0 Prolene: 80.0±4.5 mm Hg vs. 4-0 Nurolon: 32.5±2.7 mm Hg; $p<.01$). The mean pressure threshold for CSF leakage with the hydrogel sealants was not significantly different (6-0 Prolene: 100.0±0.0 mm Hg vs. 4-0 Nurolon: 70.0±33.1 mm Hg). The use of a hydrogel sealant significantly increased the pressure thresholds for possible CSF leakage in both the 6-0 Prolene group ($p=.01$) and the 4-0 Nurolon group ($p<.01$) when compared with mean pressures without the hydrogel sealant.

CONCLUSIONS: We described the feasibility of using a novel cadaveric model for both the study and training of watertight dural closure techniques. 6-0 Prolene was observed to be superior to 4-0 Nurolon for watertight dural closure without a hydrogel sealant. The use of a hydrogel sealant significantly improved watertight dural closures for both 6-0 Prolene and 4-0 Nurolon groups in the cadaveric model.

Keywords: Cadaveric model; Cerebrospinal fluid leakage; Complications; Dural repair; Dural sealant; Simulation model

Introduction

Incidental durotomy is a frequently encountered complication during spinal surgery, with an incidence ranging from 1% to 17.4% [1–4]. Incidental durotomy was observed as the second most common complaint in medical malpractice cases involving lumbar spine surgery [5]. Although an incidental durotomy may not have a direct negative impact on long-term surgical outcomes, it can cause significant morbidity due to postural headaches, meningitis, nerve root entrapment, meningeal pseudocyst, dura-cutaneous fistula, and arachnoiditis [3]. The management of incidental durotomy has commonly included flat bed rest to reduce the risk of CSF leakage and associated complications. However, prolonged bed rest has also been associated with an increased incidence of medical complications [6]. Therefore, it is generally accepted that incidental durotomy should be primarily repaired intraoperatively.

Successful primary durotomy closure is paramount in preventing the myriad of potential complications. Intraoperative management on incidental durotomy is often based on a steep learning curve rather than a structured scheme [4]. The incorporation of simulators for learning is very attractive and is becoming an integral component of many surgical residency training programs [7,8]. The use of simulated surgical models allows for a safe and controlled environment for trainees to hone technical skills without placing patients at risk. The use of cadaveric simulation models augmented with perfusion to reconstitute the cerebrospinal fluid (CSF) can provide an even more realistic opportunity to develop the psychomotor skills that are essential in watertight closure of incidental durotomies [9–13]. To this end, the goal of this report is to describe the feasibility of using a novel cadaveric model for both the study and training of watertight dural closure techniques. Furthermore, we compared various spine dural repair techniques.

Materials and methods

Cadaver

Fresh (unfixed) human cadavers were obtained according to standard procedures at the USC Fresh Tissue Dissection Laboratory. Cadavers were obtained within 7 to 21 days of death and stored in crypts maintained at 5.6°C until 2 hours before use. The laboratory is set up to mock an operating room experience, and is equipped with a full complement of neurosurgical instruments, including a high-speed drill, operative microscope with digital recording capabilities.

Cerebrospinal fluid reconstitution

The perfusion system was modified to reconstitute the CSF system of the body as previously described [9,12,14]. The preparation time was less than 1 hour. In short, a cervical laminectomy was performed and a 3-mm midline durotomy was made. A 12-gauge arterial catheter was then placed into the intradural or subarachnoid space. The catheter was secured in a watertight and multilayer fashion (Fig. 1). The system was then connected to a Medtronic Biomedicus 540 console, with BP80 Bio Pump (Minneapolis, MN, USA) for continuous saline flow at a pressure of 15 to 30 mm Hg.

Spinal laminectomy with repair of durotomy

All suture repairs were performed using standard microsurgical technique under the microscope while using microsurgical instruments (Castroviejo needle holders, fine tip tissue forceps, etc). For the suture repairs, the durotomy was closed in a running fashion with approximately 1 mm of space between the intervening throws and secured at each end with a surgeon's knot. The cervicothoracic dura was exposed from C7 to T12 through a standard laminectomy (Fig. 2). The dura was then opened, and then repaired with