Complications of Spinal Fluid Drainage in Thoracic and Thoracoabdominal Aortic Aneurysm Surgery in 724 Patients Treated From 1987 to 2013

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Objective: **To study complications from spinal fluid drainage in open thoracic/thoracoabdominal and thoracic endovascular aortic aneurysm repairs to define risks of spinal fluid drainage.**

Design: **Retrospective, prospectively maintained, institutionally approved database.**

Setting: **Single institution university center.**

Participants: **724 patients treated from 1987 to 2013**

Interventions: **The authors drained spinal fluid to a pressure ≤6 mmHg during thoracic aortic occlusion/reperfusion in open and ≤8 mmHg after stent deployment in endovascular procedures. Low pressure was maintained until leg strength was documented. If bloody fluid appeared, drainage was stopped. Head computed tomography (CT) and, if indicated, spine CT and magnetic resonance imaging (MRI) were performed for bloody spinal fluid or neurologic deficit.**

Measurements and Main Results: **Spinal fluid drainage was studied for bloody fluid, CT/MRI-identified intracranial and spinal bleeding, neurologic deficit, and death. Seventy-three patients (10.1%) had bloody fluid; 38 (5.2%) had intracranial blood on CT. One patient had spinal epidural hematoma. Higher volume of fluid drained and higher central venous pressure during proximal clamping were associated with intracranial blood. Most patients with intracranial blood were asymptomatic. Six patients had neurologic deficits: of the 6, 3 died (0.4%), 1 (0.1%) had permanent hemiparesis, and 2 recovered. Three of the six deficits were delayed, associated with heparin anticoagulation.**

Conclusions: **10% of patients had bloody spinal fluid; half of these had intracranial bleeding, which was almost always asymptomatic. In these patients, immediately stopping drainage and correcting coagulopathy may decrease the risk of serious complications. Neurologic deficit from spinal fluid drainage is uncommon (0.8%), but has high morbidity and mortality.**

KEY WORDS: spinal fluid drainage, thoracic aortic aneurysm, thoracoabdominal aortic aneurysm, paraplegia, TEVAR

EXPERIMENTAL STUDIES in animal models of spinal cord ischemia have shown that spinal fluid drainage (SFD) reduces the risk of paraplegia in thoracic (TAA) and thoracoabdominal aortic aneurysm (TAAA) repair.[1,2] Although only a small number of randomized clinical trials support the role of SFD in reducing paralysis in TAAA surgery,[3–5] most centers reporting results of TAAA surgery use this adjunct.[6–11] The risks associated with spinal fluid drainage in TAAA surgery are significant. Reported complications include drain failure,[12] catheter fracture,[13] headache,[14,15] spinal fluid leak,[14] infection,[14] spinal and spinal epidural hematoma,[15,16] intracranial bleeding (subdural,[12,14,15] epidural,[17] and intraparenchymal[12]), neurologic deficit,[14,15] and death.[12,14,15] These risks must be balanced against the benefit of SFD in reducing paralysis in TAA and TAAA repair. This retrospective study reports the incidence of complications associated with SFD in patients undergoing open TAA and TAAA surgery and thoracic endovascular aortic aneurysm repair (TEVAR) at a single institution from 1987 to 2013 to help define the morbidity and mortality associated with SFD. The authors hypothesized that the benefit of spinal fluid drainage in decreasing paralysis after TAAA repair justified the risks associated with this intervention.

METHODS

All patients treated for TAA and TAAA from 1987 to 2013 were analyzed retrospectively using a concurrently maintained, institutionally approved database to study the incidence of complications associated with SFD. Open TAA and TAAA surgeries were performed by 4 vascular surgeons using simple cross-clamp technique without assisted circulation or systemic heparinization. TEVAR patients were heparinized and activated clotting times of 200 to 250 seconds were maintained. Aneurysms involving the distal aortic arch were repaired using deep hypothermic circulatory arrest.

Indications for SFD in patients having open surgery were TAA; Crawford types-I, II, and III TAAA; and Crawford type-IV TAAA, for which repair required clamping in the distal third of the descending thoracic aorta and visceral artery reimplantation. Spinal drains were placed in patients with acute presentation unless they were extremely unstable. All elective and acute patients having ≥15 cm descending thoracic aortic coverage with TEVAR had SFD.

Six cardiac anesthesiologists cared for all patients during the time of the study. All patients had standardized anesthetic and postoperative management. Anesthetic technique used fentanyl, benzodiazepines, amnestic volatile agent, low-dose naloxone, barbiturates, and moderate systemic hypothermia (33°C-34°C).[18,19] Nitroglycerin, beta-blockers, dopamine, epinephrine, and norepinephrine were used as indicated for hemodynamic control. Standardized guidelines for mean arterial pressure (MAP), cardiac index, spinal fluid pressure (SFP), hemoglobin, and preventing coagulopathy were followed, with the goals of optimizing volume status, cardiac function, cardiac index and MAP; reducing tissue oxygen demand and increasing tissue oxygen delivery; maximizing direct and collateral network perfusion to the spinal cord; and preventing coagulopathy.[20,21] TEVAR and open surgery patients received intravenous mannitol (before proximal clamping or graft deployment), and patients with Crawford type-II, III, and IV TAAAs also received cold crystalloid perfusion containing mannitol into the renal arteries after aortic occlusion. Fig 1 shows the timeline of observed/expected paralysis in the patient population (O/E ratios for paralysis)[19,21] and changes in anesthetic and surgical techniques during the time of the study.

Cardiac anesthesiologists placed all spinal drains in the operating room immediately before surgery. Abnormal preoperative coagulation parameters were corrected before drain placement, and after 2003, anesthesiologists followed the American Association of Regional Anesthesia Guidelines for Anticoagulation and Neuraxial Blocks[22] in patients anticoagulated

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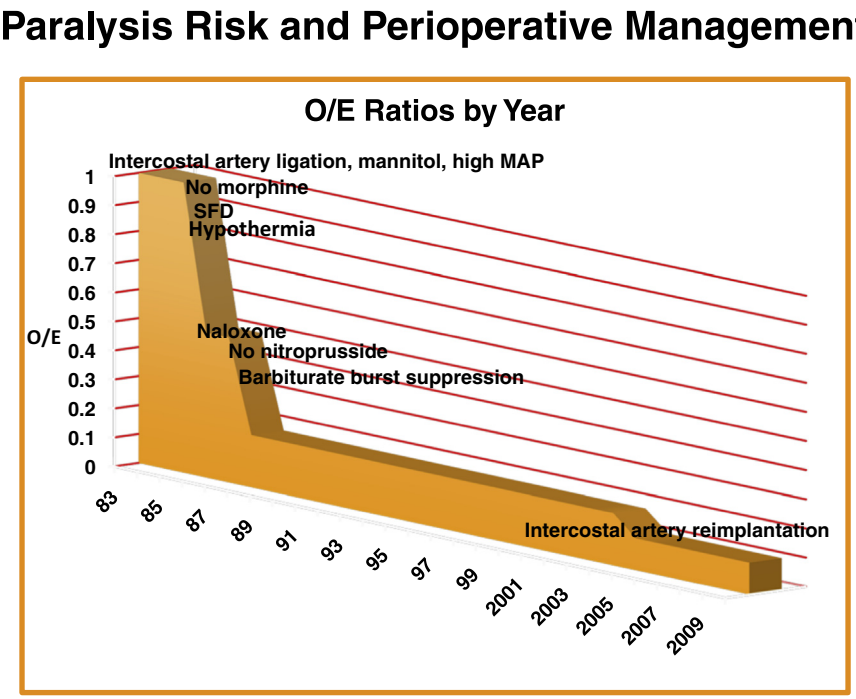

Fig 1. Timeline of O/E paralysis ratios[19,21,62] (y axis) and changes in anesthetic management and surgical technique by year (x axis). E = [0.1 × CI + 0.2 × CII + 0.05 × CIII + 0.02 × CIV + 0.01 × TAA] + [0.3(acute + dissection)], where CI, CII, CIII, and CIV are Crawford TAAA Types I to IV, TAA is thoracic aneurysm, and O/E ratio is the observed/expected paralysis in a patient population.[19] Abbreviations: O, observed paralysis; E, expected paralysis; MAP, mean arterial pressure; SFD, spinal fluid drainage.

preoperatively. Thrombin inhibitors that became available during the years of the study were held for a minimum of 2 to 3 half-lives before spinal drain placement in elective patients, depending on drug metabolism and excretion, renal function, and age. Dabigatran was discontinued 3 to 6 days before surgery, depending on age and renal function.[23]

Before 2000, 19-gauge ARROW Epidural Catheterization Kit (Reading, PA) (through a 17-gauge Tuohy needle), placed using anatomic landmarks, were used for SFD. Since 2000, 16-gauge Medtronic EMD Lumbar Drains (Minneapolis, MN) (through a 14-gauge Tuohy needle), positioned using fluoroscopy with the catheter tip at T9-10, have been used for SFD. To minimize trauma from needle placement, a 22-gauge finder needle and fluoroscopy were used to position the 14-gauge needle. Because of time urgency, acute patients had drain placement using anatomic landmarks. Although the catheter and method of placement changed during the time of the study, drain protocols and management were the same. Protocol required sterile drain placement (in the operating room with gown and gloves) and manually draining spinal fluid to gravity in increments of 5 to 10 mL to achieve an SFP $\leq$6 mmHg during thoracic aortic occlusion and reperfusion in open procedures and $\leq$8 mmHg during and after endograft deployment in TEVAR. Guidelines did not specify a limit on total volume drained or volume drained/hour. Low SFP goals were chosen to ensure a greater difference between spinal cord collateral network pressure and SFP, because it was observed that distal mean arterial pressure during aortic occlusion was $<$30 mmHg. Non-heparinized, nonpressurized transducers were zeroed at the level of the right atrium and SFP was monitored continuously, except when manually draining. Following surgery, SFP was kept at 6 to 8 mmHg until normal leg strength was observed, usually within 6 hours of surgery. After normal leg strength was observed, spinal fluid pressure was monitored but fluid was not drained unless leg weakness occurred. Thus, very little drainage occurred postoperatively in patients with intact leg strength. If any trace of blood appeared in the fluid during SFD (aside from the initial blood tinge that sometimes occurs at placement), SFD was stopped immediately. Head computed tomography (CT) and, if indicated, spine CT or magnetic resonance imaging (MRI) were performed in patients with bloody spinal fluid or neurologic deficit. If head CT was negative, SFD sometimes was continued, but to a higher goal pressure in the highest-risk patients, until normal leg strength was demonstrated. Drainage was stopped in low-risk patients even if head CT was negative. Spinal fluid drainage was stopped if head CT showed intracranial blood.

Spinal drains were removed 48 hours after surgery if leg strength was normal. Patients with headache were treated with epidural blood patch. Persistent fluid leak was treated with epidural blood patch or skin suture at the puncture site. If delayed paresis/paralysis occurred, the spinal drain was reinserted and SFD resumed until neurologic function stabilized.

Patient demographic characteristics, intraoperative hemodynamic variables, aortic occlusion time, spinal fluid pressures at baseline and during aortic occlusion, reduction in spinal fluid pressure from baseline, volume of spinal fluid drained, surgical blood loss, and complications associated with spinal fluid drainage were analyzed. The incidence of being unable to place spinal drains, spinal drain failure (not being able to drain enough fluid to achieve target SFP), catheter fracture with retained intrathecal fragment, headache and epidural blood patch, spinal fluid leak, infection, bloody spinal fluid (any blood tinge occurring during SFD, other than the transient blood tinge that sometimes occurs with placement), intracranial and spinal bleeding found by CT or MRI, neurologic deficit, and death were examined. Statistical analysis used SAS-JMP software for univariate analysis and multivariate modeling. Fisher's exact test, Pearson chi-square test, and one-way analysis of variance were used to evaluate for significance. Variables significant on univariate analysis were chosen for multivariate modeling.

RESULTS

One thousand patients had open TAA/TAAA repair and TEVAR between 1987 and 2013. Seven hundred twenty-four