Complications of cerebrospinal fluid drainage after thoracic aortic surgery: A review of 504 patients over 5 years

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Background: Cerebrospinal fluid drainage, a well-established means of preventing paraplegia after thoracic aortic aneurysm surgery, can result in serious, sometimes lethal complications. In a large group of patients who underwent surgical thoracic aortic aneurysm repair with cerebrospinal fluid drainage, we examined the incidences of and potential risk factors for these outcomes.

Methods: The records were reviewed of 504 patients who underwent surgical thoracic aortic aneurysm repair with cerebrospinal fluid drainage at the Texas Heart Institute at St. Luke's Episcopal Hospital between February 2005 and December 2009. All historical data, inpatient records, and billing data were searched for evidence of complications.

Results: Of the 504 patients, 14 (2.8%) had intracranial hemorrhage, of whom 10 (72%) had subdural hematoma. Postdural puncture headache developed in 49 patients (9.7%), of whom 17 (34.6%) required epidural blood patch placement for resolution. Multivariable analysis identified having a connective tissue disorder (odds ratio, 3.08; 95% confidence interval, 1.33-7.13) as an independent predictor of postdural puncture headache, but not age less than 40 years (odds ratio, 0.97; 95% confidence interval, 0.94-0.99).

Conclusions: Cerebrospinal fluid drainage, as performed by our method, seems to be associated with a modest rate of intracranial bleeding in patients who undergo surgical thoracic aortic aneurysm repair. In contrast, postdural puncture headache is not uncommon, particularly in patients with connective tissue disease. Clinicians caring for these patients should consider the likelihood of postdural puncture headache, and any such patient with postoperative headache should be assessed for epidural blood patch placement. (*J Thorac Cardiovasc Surg* 2013;146:166-71)

Cerebrospinal fluid (CSF) drainage is a well-established intervention for preventing paraplegia after thoracic aortic aneurysm (TAA) surgery.¹⁻⁷ Through the reduction of CSF pressure, spinal perfusion is optimized during periods of reduced blood flow, which augments oxygen delivery to the spinal cord.

Despite the demonstrable benefit of CSF drainage for patients who undergo TAA repair, several complications have been described. These include catheter fracture⁸; postdural puncture headache (PDPH)⁹⁻¹¹ with and without the need for an epidural blood patch (EBP); neuraxial hematoma¹²;

intracranial hemorrhage, including subdural,¹³ cerebellar,¹⁴ subarachnoid, intraventricular, and intraparenchymal hematomas; meningitis⁷; failed CSF drainage¹⁵; and death.

We sought to characterize the complications associated with CSF drainage in patients who undergo TAA surgery. In addition, we sought to identify risk factors for complications that are specific to this surgical population. This retrospective cohort analysis of 504 consecutive patients examined the incidence of common complications associated with the use of CSF drainage for TAA surgery over a 5-year period (during which the same equipment and management methods were used consistently) at a single high-volume institution.

MATERIALS AND METHODS

Institutional review board approval was obtained for the collection and analysis of clinical data. Informed consent was obtained from all patients enrolled after protocol approval; waiver of consent was granted for patients who underwent surgery before protocol approval.

Cerebrospinal Fluid Drain Placement and Management

Our standard procedure is as follows: After induction of general anesthesia, endobronchial intubation, and establishment of adequate intravenous access, the patient is placed in the right lateral decubitus position. The lumbar area is cleansed with povidone-iodine solution and allowed to dry before a sterile drape is placed. A 14-gauge Tuohy needle is advanced into a lower lumbar interspace (L3-L4 or L4-L5) until CSF is

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Abbreviations and Acronyms	
CI	= confidence interval
CSF	= cerebrospinal fluid
CTD	= connective tissue disease
EBP	= epidural blood patch
OR	= odds ratio
PDPH	= postdural puncture headache
TAA	= thoracic aortic aneurysm

obtained. An 80-cm stylet catheter (1.6-mm outer diameter, Integra NeuroSciences, Plainsboro, NJ) is advanced through the needle a sufficient distance to allow all drainage orifices to rest in the subarachnoid space, and the Tuohy needle is removed. After free flow of CSF from the catheter is confirmed, the catheter is connected to a pressure transducer and ventricular drainage system. Sterile dressings are applied to the insertion site. Opening CSF pressure is recorded.

During the operation, CSF is drained when the CSF pressure exceeds 10 to 15 mm Hg for the duration of aortic crossclamping; the amount drained is limited to 30 mL over a 1-hour period. Once the procedure is complete, CSF is drained as needed to maintain spinal CSF pressure between 10 and 15 mm Hg. The amount drained is limited to 25 mL over a 1-hour period and 40 mL over a 4-hour period. The catheter is clamped after bilateral lower-extremity function is confirmed postoperatively and removed after 24 hours of intact neurologic function (usually the second postoperative day). Our method for CSF drain placement and our general approach to drain management remained consistent during the period of observation.

Patients taking preoperative medications that impair coagulation present a particular clinical challenge. In general, we place CSF drains in patients who are receiving aspirin therapy regardless of whether they have continued taking the medication before surgery. For patients who have been receiving warfarin therapy, we only place a CSF drain if the medication has been withheld until the international normalized ratio is less than 1.5. If a patient has been receiving thienopyridine therapy (ie, clopidogrel, prasugrel), we place a drain if the medication has been withheld and normal platelet function confirmed. In urgent or emergency situations, we attempt to normalize coagulation by administering vitamin K, fresh-frozen plasma, or platelets to enable CSF drain placement. We do not insert a CSF drain in patients in whom we are unable to withhold medications for a sufficient period before surgery.

In patients who develop PDPH, the initial treatment is bed rest, hydration, and occasionally caffeine administration. We consider EBP in those patients who do not show substantial improvement within 24 hours after medical treatment is initiated.

Data Collection and Analysis

The records of all patients who underwent elective, urgent, or emergency thoracoabdominal and descending thoracic aortic repair (open or endovascular) with CSF drainage between February 2005 and December 2009 were obtained by review of the Texas Heart Institute/Baylor College of Medicine Cardiovascular Surgery Database. Demographic and clinical data were recorded, including the age, sex, procedure, duration of CSF drainage, and presence and type of connective tissue disease (CTD) (Marfan syndrome, Loeys–Dietz syndrome, or vascular-type Ehlers–Danlos syndrome). In addition to database-derived information, all historical data, daily progress notes, surgical notes, anesthetic records, perfusion records, nursing notes, radiology reports, intensive care unit records, physical and occupational therapy records, and billing documents in patients' charts were searched for evidence of complications. PDPH was defined as headache that intensified with seated or standing posture, improved with recumbency, and had a bifrontal or occipital location. Need for EBP, retained

TABLE 1. Summary of complications due to cerebrospinal fluid drainage (N = 504)

Complication	n (%)
Any complication	64 (12.7)
PDPH	49 (9.7)
Intracranial hemorrhage	14 (2.8)
Catheter fracture	1 (0.2)
Meningitis	0 (0)
Epidural abscess	0 (0)
Spinal/epidural hematoma	0 (0)

PDPH, Postdural puncture headache.

spinal catheter, intracranial hemorrhage, meningitis, epidural abscess, epidural hematoma, and death associated with CSF drainage were also recorded.

Statistical Analysis

All statistical analyses were performed with SAS software (SAS Institute Inc, Cary, NC) at the Texas Heart Institute's Department of Biostatistics. The incidence of each complication is reported as a percentage of the total cases evaluated. After the incidence of complications was determined, univariate analysis of commonly accepted risk factors, including age less than 40 years, sex, and the presence of any CTD, was performed. Chi-square analysis was used to compare categorical data, and odds ratios (ORs) and confidence intervals (CIs) were calculated for each defined risk factor. Age and CSF drain duration were further evaluated as discrete data with unpaired *t* tests and are presented as mean and standard deviation. Multivariable analysis was used to further define the effects of age, sex, and CTD on the occurrence of complications.

RESULTS

The records of 504 patients who underwent TAA repair with CSF drainage were identified. Intracranial hemorrhage (Table 1) occurred in 14 patients (2.8%), of whom 10 (72%) had subdural hematoma (Table 2). The low incidence of intracranial hemorrhage precluded any analysis of risk factors for this complication. One comatose patient (0.2%) with a large subdural hematoma died after care was withdrawn; this was the only death that may have been attributable to CSF drainage. One patient with a subdural hematoma and 1 patient with combined cerebellar/subarachnoid bleeding had global cerebral dysfunction and later died after hemodynamic collapse. One case (0.2%) of catheter fracture necessitated laminectomy for catheter removal. No episodes of meningitis, spinal/epidural abscess, or spinal hematoma were observed.

PDPH developed in 49 patients (9.7%), of whom 17 (34.6%) required EBP placement for resolution. The PDPH resolved after the initial EBP in 16 patients and after repeat EBP in 1 patient. The risk of PDPH decreased with advancing age (Table 3); patients aged less than 40 years had a significantly higher rate of PDPH after CSF drainage than older patients (OR, 2.71; 95% CI, 1.22-6.04; *P* = .02). Patients with PDPH were younger (48.5 ± 12.7 years vs 62.2 ± 11.5 years, *P* < .001) and underwent a shorter duration of CSF drainage (1.79 ± 0.78 days vs 2.26 ± 1.38 days,

TABLE 2. Characteristics of intracranial hemorrhage after cerebrospinal fluid drainage

Patient	Age (y)	Bleed type	Presentation	Duration of CSF drainage (d)
1	80	SDH	Confusion	2
2	62	SDH/SAH	Balint syndrome	1
3	80	SAH	Hemiplegia	3
4	73	SDH	Coma	2
5	75	SDH	Delayed emergence	1
6	58	CBL/thalamic	Leg weakness	4
7	74	SDH/IVH	Delayed emergence	3
8	67	SDH/IPH	Confusion	2
9	60	SDH	Confusion	3
10	78	SDH/IVH	Coma	4
11	76	SAH/CBL	Altered mental status	7*
12	63	SDH	Severe headache	2
13	56	SDH	Respiratory arrest	3
14	65	SDH	Weakness	4

CSF, Cerebrospinal fluid; SDH, subdural hematoma; SAH, subarachnoid hematoma; CBL, cerebellar hematoma; IVH, intraventricular hematoma; IPH, intraparenchymal hematoma. *CSF drain removed on postoperative day 2 and immediately replaced because of acute-onset paraplegia. Altered mental status was observed after drainage resumed. Total duration of drainage was 7 days.

$P = .03$) than patients who did not experience headache. PDPH occurred in 10.5% and 8.7% of male and female patients, respectively (OR, 1.24; 95% CI, 0.66-2.31; $P = .5$). PDPH complicated CSF drainage in 30.3% of patients diagnosed with CTD as opposed to 7.4% of unaffected individuals (OR, 5.82; 95% CI, 3.00-11.29; $P < .001$). Of the patients with Marfan syndrome, 30% had PDPH (OR, 5.13; 95% CI, 2.56-10.29; $P < .0001$). In addition, 55.6% of patients with CTD and PDPH required EBP placement, compared with 22.5% of patients without CTD (Table 4; OR, 2.46; 95% CI, 0.80-7.59; $P = .11$).

Because patients with CTD tend to present for TAA surgery at a younger age, multivariable analysis was performed to attempt to separate the effects of the potentially confounding variables of age and CTD on the incidence of PDPH. The presence of CTD remained significantly associated with the development of PDPH (OR, 3.08, 95% CI, 1.33-7.13), but age less than 40 years did not (OR, 0.97, 95% CI, 0.94-0.99). Ten of the 18 patients with CTD who developed PDPH were aged more than 40 years. Intracranial hemorrhage or other serious complications of CSF drainage did not develop in any patients with CTD.

DISCUSSION

Immediate spinal cord deficit complicates 2.1% of Crawford extent I and II repairs² and results from inadequate spinal perfusion, presumably because aortic crossclamping is associated with reduced radicular arterial pressure and collateral flow¹⁶ coupled with increased central venous pressure and spinal CSF pressure.¹⁷ CSF drainage is a proven modality for decreasing the incidence of paraplegia and is

TABLE 3. Risk factors for postdural puncture headache after cerebrospinal fluid drainage: Categorical data

Demographic	n	PDPH (%)	Odds ratio (95% CI)	P
All patients	504	49 (9.7)	—	—
Age < 40 y	43	9 (20.9)	2.71 (1.22-6.04)	.02
Female sex	183	16 (8.7)	1.24 (0.66-2.31)	.5
Any CTD	59	18 (30.5)	5.86 (3.00-11.29)	<.001
Marfan syndrome	51	15 (29.4)	5.13 (2.56-10.29)	<.0001

PDPH, Postdural puncture headache; CI, confidence interval; CTD, connective tissue disease.

used routinely in high-risk TAA procedures.^{6,18} Other modalities described for spinal cord protection include left heart bypass, intrathecal papaverine administration, reattachment of intercostal arteries, hypothermia, and pharmacologic therapy (naloxone hydrochloride, mannitol, and glucocorticoids).

The reported incidences of intracranial hemorrhage and subdural hematoma after TAA repair with CSF drainage are 0.45% to 3.5% and 0.45% to 2.1%, respectively,^{9,15} and these complications may be associated with a mortality rate as high as 50%.¹³ With our technique for CSF drain placement and management, we found incidences of 2.8% and 1.9% for intracranial bleeding and subdural hematoma, respectively, and a combined mortality rate of 14.3% among patients with these complications (Table 2). We attribute our modest rates of bleeding complications to the conservative volumes of CSF drained to maintain spinal perfusion pressure. No cases of neuraxial hematoma formation were observed during this observational period, nor were any episodes of meningitis or spinal/epidural abscess recorded. (In the 2 years since data collection for the present study was completed, our service has performed approximately 200 additional thoracic aneurysm repairs. In that series, we have observed 2 instances of spinal hematoma associated with CSF drainage. These will be included in a future report. One of these cases was presented as a Medically Challenging Case at the 2011 Annual Meeting of the American Society of Anesthesiologists, Chicago, Ill, October 15-19, 2011 [Youngblood S, Pan W. Spinal Epidural Hematoma After CSF Drainage During Thoracic Aneurysm Repair]).

PDPH occurs in 0.72% to 2.5% of CSF drain-placement cases.^{9,10} Known risk factors for PDPH include young age, female sex, the needle size, and the shape of the needle bevel. However, these risk factors have been

TABLE 4. Incidence of epidural blood patch placement in patients with and without connective tissue disease who developed postdural puncture headache

Demographic	EBP (%)	Odds ratio (95% CI)	P
Any CTD	10/18 (55.6)	2.46 (0.8-7.59)	.11
Marfan syndrome	8/15 (53.3)	2.36 (0.72-7.74)	.15
No CTD	7/31 (22.5)	—	—

EBP, Epidural blood patch; CI, confidence interval; CTD, connective tissue disease.

predominantly described in cases of accidental dural puncture during the placement of epidural catheters, intentional penetration of the dura with small needles for the institution of spinal anesthesia, or diagnostic removal of CSF. The relevance of these risk factors in patients who undergo CSF drainage for TAA surgery is unknown.

In this case series, patients with CTD had PDPH more frequently than unaffected individuals (30.3% vs 7.4%). Marfan syndrome is caused by mutations in the fibrillin-1 gene that result in elastic fiber fragmentation.¹⁹ As much as 75% to 85% of patients with Marfan syndrome present with aortic dilatation,²⁰ resulting in a significant presence of these individuals among the TAA surgical population. These patients have weakening of the connective tissue of the dura, culminating in dural incompetence. Consequently, dural ectasia (expansion of the dural sac around the spinal cord) is a common manifestation of Marfan syndrome, occurring in 63% to 92% of patients, and typically occurs in the lumbar spine.²¹⁻²³ Idiopathic intracranial hypotension and spontaneous CSF leaks have been reported,²⁴⁻³⁰ but no association between PDPH and Marfan syndrome has been described.

Loeys–Dietz syndrome and vascular-type Ehlers–Danlos syndrome are inherited in an autosomal dominant pattern and share many clinical manifestations with Marfan syndrome. A review of the literature yielded no case reports of headache in association with Loeys–Dietz syndrome. One study suggested a rare association of spontaneous headache with vascular-type Ehlers–Danlos syndrome.³¹

Our analysis revealed that the incidence of PDPH was more than 4 times higher in patients with CTD than in unaffected individuals who present for the same procedures. In addition, patients with CTD who developed PDPH had twice the risk of requiring EBP to resolve their headache, although this difference failed to reach statistical significance, probably because our sample size was too small. These findings will improve our ability to provide more accurate preoperative counseling. When discussing risks of CSF drainage with patients, we now warn patients with CTD that they are at a higher than usual risk of PDPH and will probably need EBP if this complication occurs.

The association between CTD and PDPH may result from the disorganization of dural elastic fibers. On breach of the dura in unaffected persons, elastic forces probably pull any residual defect closed, thereby minimizing CSF leakage and contributing to a lower incidence of both PDPH and the need for EBP when PDPH arises. In contrast, in patients with CTD, the dura remains lax, thus allowing persistent CSF leakage through the dural defect. This increases both the incidence of PDPH and the need for subsequent placement of an EBP for headache resolution. Other groups have postulated a similar mechanism in the development of postural headache and spontaneous CSF leaks in patients with Marfan syndrome.²¹

To our knowledge, this is the first study to show that CTD is a risk factor for the development of PDPH and, possibly, for the need for EBP. Of note, no intracranial hemorrhage occurred in the CTD group. For this reason, despite the apparent higher risk of a CSF leak as evidenced by the occurrence of PDPH, we recommend that CSF drainage be used in these patients for the purpose of preventing postoperative paraplegia. However, earlier consideration of EBP placement in lieu of a trial of conservative therapy may be more appropriate in this patient subset.

Female sex and youth are commonly accepted as risk factors for the development of PDPH. In our analysis, no significant difference in the occurrence of PDPH was observed between men and women. Patients aged less than 40 years seemed to have a higher incidence of PDPH, and those patients who experienced PDPH were on average 14 years younger than those who did not have PDPH. However, after multivariable analysis, youth was not associated with the development of PDPH.

In our analysis, patients who developed PDPH underwent CSF drainage for a significantly shorter period than their unaffected counterparts (1.79 vs 2.26 days). Similar observations have been made in patients who received subarachnoid catheters after accidental dural puncture during the attempted initiation of epidural anesthesia.³² An inflammatory response probably occurs at the site of dural penetration, and leaving the catheter in longer may allow edema and fibrin formation to occur at the site of the dural defect. On catheter removal, this inflammatory response may minimize CSF leakage and prevent the occurrence of PDPH. However, this benefit must be balanced against the risk of infection that prolonged catheterization incurs.

Several studies have sought to define the incidence of complications associated with CSF drainage; however, each has had important limitations. Some retrospective studies have used data collected over long periods of time (range, 12-21 years), during which operative technique and methods of drain management changed substantially.^{9,10,15} For example, 2 groups changed the size of both the Tuohy needle and the drainage catheter during the study period.^{10,15} Wynn and colleagues¹⁵ began the routine use of fluoroscopy 13 years into their 21-year review, limiting the applicability of their findings to landmark-guided placement of CSF catheters. Our analysis sought to overcome these limitations by collecting data at a high-volume center that uses a consistent technique for placing and managing CSF drainage catheters coupled with consistent surgical, anesthetic, and intensive care management. Although previous studies included similar numbers of patients, none included this density of cases over a short period of time during which techniques were consistent. Likewise, no previous review has evaluated the effect of CTD on the incidence of complications.

Study Limitations

The current analysis has several limitations. First, the study was retrospective and based on database and record review. However, to prevent complications from being overlooked, the entire chart of each patient was reviewed, including physician progress notes, anesthesiology procedure notes, radiology reports, nursing notes, and physical/occupational therapy records. Second, our definition of PDPH did not necessarily capture every incident of this complication. A large number of patients reported headache during the perioperative period. However, we included only documented episodes associated with the classic presentation of PDPH. The number of patients who experienced but never reported headache cannot be quantified in our analysis; thus, the true incidence of PDPH in this population could be higher than estimated. Third, we may have over- or underestimated the true incidence of intracranial bleeding. Preoperative neuroimaging is not routine in our practice; thus, patients with intracranial hemorrhage due to preexisting cerebrovascular disease may have been inadvertently included in this analysis. Likewise, we do not routinely perform postoperative neuroimaging in all patients, so some cases of subclinical intracranial hemorrhage may have been overlooked. The incidence of intracranial hemorrhage described in this report therefore represents the incidence of clinically significant bleeding.

CONCLUSIONS

CSF drainage—an established modality for preventing paraplegia during extensive TAA repair—can cause serious complications, including intracranial hemorrhage, spinal hematoma, failed CSF drainage, PDPH with the potential need for EBP, retained spinal catheter, and death. The landmark-guided placement of CSF catheters and the pressure-guided, volume-limited approach to CSF drainage used at our institution (the Texas Heart Institute at St. Luke's Episcopal Hospital) result in a modest risk of intracranial bleeding and other serious complications. In addition, CTD is common in this population and seems to be a risk factor for PDPH and, perhaps, the need for EBP placement. Nevertheless, because no other serious complications were noted in the CTD group, we continue to recommend the use of CSF drainage in this patient population.

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