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Early Experience With Automatic Pressure-Controlled Cerebrospinal Fluid Drainage During Thoracic Endovascular Aortic Repair

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Abstract

Purpose: To report initial experience with automatic pressure-controlled cerebrospinal fluid drainage (CSFD) during thoracic endovascular aortic repair (TEVAR). **Methods:** A prospective nonrandomized study enrolled 30 consecutive patients (median age 68 years, range 42–89; 18 men) who underwent TEVAR between March 2012 and July 2013 and were considered to be at high risk for postoperative spinal cord ischemia (SCI), fulfilling 2 of the following criteria: stent-graft length >20 cm, left subclavian artery coverage, and previous infrarenal aortic repair. All patients received perioperative CSFD via the LiquoGuard system. The protocol aimed for a CSF pressure of 10 mm Hg and duration of CSFD of 3 or 7 days in asymptomatic or symptomatic patients, respectively. Muscle strength of the lower extremities was assessed with the Oxford muscle strength grading scale. **Results:** Completion of the CSFD protocol was achieved in 26 (87%) of 30 patients. CSFD was prematurely stopped due to catheter dislocation in 1 patient and bloody spinal fluid in 3 patients. CSFD was performed for a median of 3 days (range 1–7). Median total CSFD volume was 714 mL (range 13–2369), with a median 192 mL drained per 24 hours. The SCI rate was 3% (1/30). CSFD-related complications were observed in 33% of the patients: 1 fatal intracranial hemorrhage, 3 bloody spinal fluid episodes, 3 persistent CSF leaks requiring epidural blood patch, and 3 post lumbar puncture headaches. Mortality during a median follow-up of 16 months (range 10–25) was 3% (1/30). **Conclusion:** Prophylactic CSFD was associated with a low SCI rate in a high-risk patient collective undergoing TEVAR. Monitoring and drainage by an automatic modus was feasible, reproducible, and reliable but associated with relevant drainage-associated complications.

Keywords

thoracic endovascular aortic repair, cerebrospinal fluid drainage, cerebrospinal fluid pressure, pressure-controlled fluid drainage, automatic fluid drainage, complications

Introduction

Paraplegia resulting from spinal cord ischemia (SCI) is a devastating complication of both open and endovascular thoracic aortic repair (TEVAR). In the latter, long-segment stent-grafting (≥20 cm), overstenting of the left subclavian artery (LSA) without revascularization, and prior or concomitant infrarenal aortic repair were identified as predictive factors of SCI.[1–4] Similarly, as shown by a recent analysis of the EuREC registry,[5] simultaneous closure of at least 2 vascular territories supplying the spinal cord (LSA, intercostal, lumbar, or hypogastric arteries) were directly correlated to the occurrence of symptomatic SCI after TEVAR.

As in open repair,[6,7] prophylactic cerebrospinal fluid drainage (CSFD) is considered to be an important adjunct in high-risk patients undergoing TEVAR to minimize SCI rates.[8–10] Traditionally, CSF pressure is monitored by nurses/anesthesiologists in an intermediate care unit, and drainage is performed manually. The aim of this study was to evaluate a novel system of automatic pressure-controlled CSFD during TEVAR.

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Table 1. Demographics, Pathology, and Procedure Details for the 30 Study Patients.[a]

Age, y	68 (42–89)
Men:women	18:12
ASA classification	3 (2–4)
Hypertension	26 (87)
Smoking history	12 (40)
Diabetes mellitus	1 (3)
Renal insufficiency[b]	2 (7)
Dialysis	1 (3)
Obesity	6 (20)
Coronary artery disease	7 (23)
Previous myocardial infarction	2 (7)
COPD	5 (17)
Peripheral artery disease	4 (13)
Previous infrarenal aortic surgery	7 (23)
Hypogastric artery occlusion	2 (7)
Aortic pathology	
TAAA	12 (40)
TAA	5 (17)
Chronic TBAD	7 (23)
IMH type B	4 (13)
PAU	2 (7)
Urgency	
Elective	25 (83)
Urgent/emergent	5 (17)
Primary LSA revascularization	7/7 (100)
Rapid pacing	7 (23)
Stent-grafts	2 (1–4)
Covered length, cm	23.5 (20–40)

Abbreviations: ASA, American Society of Anesthesiologists; COPD, chronic obstructive pulmonary disease; IMH, intramural hematoma; LSA, left subclavian artery; PAU, penetrating aortic ulcer; TAA, thoracic aortic aneurysm; TAAA, thoracoabdominal aortic aneurysm; TBAD, type B aortic dissection.

[a]Continuous data are presented as the median (range); categorical data are given as the counts (percentage).

[b]Glomerular filtration rate <90 mL/min/1.73 m^2.

Methods

Study Design and Patient Population

This was a prospective, single-center, nonrandomized cohort study. Thirty consecutive patients (median age 68 years, range 42–89; 18 men) underwent TEVAR between March 2012 and July 2013 and received CSFD via an automatic system (LiquoGuard; Möller Medical GmbH, Fulda, Germany). They were determined to be at high risk for postoperative SCI due to stent-graft length >20 cm (n=25), LSA coverage (n=7), and/or a history of infrarenal aortic repair (n=7). Demographic, procedure, and outcome data of these patients were collected prospectively (Table 1). The majority of patients presented with a thoracoabdominal aortic aneurysm (TAAA), followed by chronic dissection. In the same period, 3 patients were excluded due to dual antiplatelet therapy and emergent TEVAR in 2 cases and severe scoliosis in 1 case.

Procedure Details and SCI Risk Profile

Primary revascularization was performed in all 7 patients requiring LSA coverage. All procedures were performed in an endovascular operating room (Artis Zeego; Siemens, Erlangen, Germany). Patients received single-shot antibiotic prophylaxis and 3000 units of heparin at the beginning of the operation. In 3 patients receiving branched endografts for TAAA, heparin administration targeted an activated clotting time (ACT) of 300 seconds. Supra-aortic semi-debranching (carotid-subclavian bypass with left carotid artery reimplantation) was performed in 1 patient and total visceral debranching in another prior to TEVAR. An iliac conduit was used for access in 3 patients; in all other cases, the common femoral artery was surgically exposed. Five (17%) patients had an auxiliary brachial access. The C-TAG stent-graft device (W.L. Gore & Associates, Flagstaff, AZ, USA) was used in 20 patients, the Valiant in 5 (Medtronic CardioVascular, Santa Rosa, CA, USA), and the Zenith (Cook Medical Inc, Bloomington, IN, USA) in 5. Rapid pacing was used for device placement in zones 0 to 2 (n=7). The median covered aortic length was 23.5 cm (range 20–40).

Automatic CSFD

A lumbar drainage catheter (Silverline, Spiegelberg, Germany; 1.6-mm outer diameter, 0.8-mm inner diameter, 80-cm length) was placed between L2/3 using a Tuohy cannula on the day prior to surgery. The catheter was connected to the LiquoGuard system, which has an online pressure transducer for continuous or intermittent drainage according to pre-established parameters and CSF pressure limits (Figure 1). The CSF pressure was set at 10 mm Hg for asymptomatic patients. Maximum and minimum limits were set at 20 and 5 mm Hg, respectively. Target mean arterial pressure (MAP) was ≥100 mm Hg. CSFD was continued postoperatively for 72 hours in asymptomatic patients and for 7 days in patients developing paraparesis or paraplegia. Before removal, the drain was kept closed for 12 hours to see if any clinical symptoms appeared. In case of bloody fluid drainage, the catheter was immediately removed. Spinal and head computed tomography (CT) was performed in patients with bloody spinal fluid and in patients with an acute neurological deficit.

Definitions

Normal CSF pressure, as measured by lumbar puncture, was defined to be between 8 and 15 mm Hg.[11] Muscle strength of the lower extremities was assessed manually according to the Oxford scale, in which 0/5 is no muscle contraction, 3/5 is movement against gravity, and 5/5 movement against gravity with full resistance.[12]

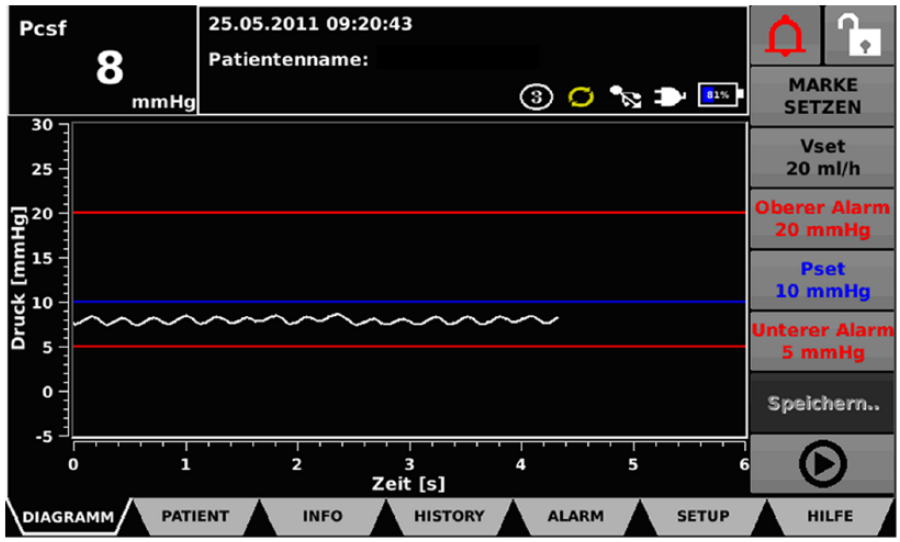

Figure 1. LiquoGuard monitor demonstrating current cerebrospinal fluid pressure of 8 mm Hg, target at 10 mm Hg, upper limit at 20 mm Hg, and lower limit at 5 mm Hg. The color version of this figure is available online at *www.jevt.org*.

Table 2. Cerebrospinal Fluid Drainage Duration and Rates.[a]

Hours of drainage	65 (10–166)
Drainage volume total, mL	714 (13–2369)
Drainage volumes by day	
Day 1 total, mL	207 (4–401)
Hourly range, mL	1 (0–8) to 21 (1–134)
Day 2 total, mL	259 (13–978)
Hourly range, mL	3 (0–11) to 25 (2–206)
Day 3 total, mL	221 (2–619)
Hourly range, mL	2 (0–17) to 24 (2–175)
Day 4 total, mL	158
Hourly range, mL	4–15
Day 5 total, mL	192
Hourly range, mL	2–17
Day 6 total, mL	152
Hourly range, mL	3–19
Day 7 total, mL	185
Hourly range, mL	5–18

[a]Data are presented as the median (range).

Results

Completion of the CSFD protocol was achieved in 26 (87%) of 30 patients. In 4 patients, the drain was removed owing to accidental dislocation (n=1) and bloody cerebrospinal fluid (n=3) on the first postoperative day. The median period of CSFD was 3 days (range 1–7). Median total CSFD volume was 714 mL (range 13–2369). A median 192 mL were drained per 24 hours (Table 2).

The SCI rate was 3% (1/30). A patient receiving a branched stent-graft for a Crawford type I TAAA had open infrarenal aneurysm repair 5 years prior. He developed paraparesis (muscle strength 2/5) on the first postoperative day and did not recover despite CSFD and raised MAP (≥100 mm Hg) for 7 days postoperatively. He was able to walk with assistance after neurological rehabilitation.

The CSFD-related complication rate was 33% (10/30). One (3%) patient developed a large intraparenchymal hemorrhage as seen on CT the first postoperative day. The CSFD was stopped with a total drained volume of 111 mL. The patient underwent immediate trepanation, but died from brain herniation caused by mass effect on postoperative day 9. Three patients developed persistent CSF leaks requiring epidural blood patch, and 3 patients had post–lumbar puncture headaches that were treated conservatively. Infectious complications were not observed. The 3 patients who had bloody spinal fluid did not show spinal hematoma or intracranial hemorrhage on CT.

Median clinical follow-up was 16 months (range 10–25). Other than the patient who died during the hospital stay, no other deaths were observed during follow-up. Two (7%) patients suffered TEVAR-related embolic strokes and developed hemiparesis requiring neurological rehabilitation.

Discussion

This preliminary series demonstrates that automatic pressure-controlled CSFD drainage by the LiquoGuard system is feasible and technically reliable in patients at risk for SCI during TEVAR. Nevertheless, a third of patients experienced drainage-associated complications.

Compared with open repair,[13] SCI occurs less frequently after TEVAR, with a pooled incidence of 3.7% according to a current systematic review.[8] Yet, in that review statistical analysis was very suggestive of publication bias, so the true risk of SCI after TEVAR may be considerably higher, with individual case series reporting up to 20%.[8] Level-1 evidence suggests that prophylactic CSFD is of benefit in open surgery for thoracic aortic disease,[6,7] with the largest randomized controlled trial showing a significantly reduced risk of paraplegia with prophylactic CSFD (13% vs 2.6%, p=0.03).

The risks and benefits and thus the utility of prophylactic CSFD in TEVAR cannot be accurately estimated from the current available literature. According to the review cited above,[8] the pooled SCI rate was 3.2% with routine prophylactic CSFD compared with 3.47% without CSFD and 5.6% with a selective policy for patients deemed at high-risk of perioperative SCI. In the analysis presented herein, the SCI rate of 3% compares favorably with cited publications and thus represents satisfactory use of CSFD for high-risk patients. Acknowledged risk factors of SCI after TEVAR are long-segment stent-grafting (≥20 cm), overstenting of the LSA without revascularization, and prior or concomitant infrarenal aortic repair.[1–5]

Automatic CSFD according to pre-established target CSF pressure and range as presented in this study provides potential benefits compared to traditional "nurse-controlled" CSFD, eliminating the need for intermittent manual drainage by medical staff.[14,15] Furthermore, CSFP peaks can be avoided, and documentation of CSFP and drainage rates is more reliable. Automatic monitoring and drainage helps avoid catheter occlusions observed with the discontinuous manual method, and the portable sensor and monitor unit enhance patient comfort and mobility.[14,15]

Yet, CSFD was associated with several complications in the past,[16] which were also observed in this analysis. Thus, the relative low risk of SCI in this series must be evaluated in this context. Undoubtedly, the most serious complication of CSFD is known to be intracranial bleeding.[16] Subdural and intraparenchymal intracranial hemorrhage was associated with a larger volume of CSFD perioperatively (690 vs 359 mL) in a series of 230 patients after open repair reported by Dardik et al.[17] In adults, the total volume of CSF varies between 120 and 200 mL and is produced at a rate of 0.3 to 0.4 mL/min. Knowing that ~500 to 700 mL of CSF are produced in 24 hours, one could define overdrainage when more than one third of the daily produced CSF (ie, ~150 mL) is being drained. In a study by Wynn et al,[16] a larger volume of CSFD intraoperatively (178 vs 124 mL) was shown to be a significant risk factor for intracranial bleeding. In our series, the patient that developed intracranial bleeding on the first postoperative day had a total drained volume of 111 mL after 35 hours of drainage, far below the reported intraoperative threshold of 178 mL, as reported by Wynn et al.[16]

Although the LiquoGuard system is pressure-controlled, the continuous documentation of the total drained volume and the daily/hourly drainage rates prevents overdrainage so long as a nurse or physician monitors these values listed under the "history" function of the system.

Besides drained volume, pressure limits may influence the incidence of bleeding complications. In the study by Dardik et al,[17] most patients with subdural hematomas were drained to a pressure of 5 cm H_2O (3.0 mm Hg), so the authors recommended draining to a pressure of 10 cm H_2O (7.7 mm Hg). According to the published literature,[6,10,16] most groups drain to a pressure of 10 mm Hg, which is in line with our study. However, a data-driven pressure threshold for CSFD has not been established yet. Blood in the spinal fluid is a very sensitive indicator of intracranial bleeding, even in the absence of neurological symptoms, so such patients should undergo immediate spinal and head CT scans to rule out any relevant bleeding.[16] Therefore, patients with a history of head trauma, cerebral atrophy, arteriovenous malformations, coagulation abnormalities, cerebral aneurysms, and so on, may be at increased risk for hemorrhagic complications and may be at elevated risk and pose relative contraindications for prophylactic CSFD.[18]

Anticoagulation during and after the operation is also related to the risk of bleeding complications with CSFD,[16] yet we could not observe any correlation between more aggressive anticoagulation. Three of our patients receiving branched endografts with an intraoperative ACT of 300 seconds had postoperative intracranial or spinal bleeding. As suggested before, immediate cessation of the CSFD and proactive management of coagulopathy can reduce neurological morbidity and mortality in cases of bleeding.

Headache is another known complication after CSFD with the pathophysiological mechanism thought to be tension on the sensory receptors of the dural sinuses.[19] Fortunately, most patients, such as the 3 in our series, can be treated conservatively by pain management. Epidural blood patch can be an option in patients with therapy-resistant headache, as in patients with persistent CSF leaks after catheter removal.[16] Given the larger outer diameter of the catheter (1.6 mm) required for the LiquoGuard system compared to conventional monitoring (0.5 mm), we observed a relevant rate (10%) of persistent leaks requiring epidural blood patch treatment. This should be addressed in a next-generation device, which should be compatible with a smaller outer diameter catheter.

Even if cases of late paraplegia after TEVAR are anecdotally reported in the literature,[20–22] 72-hour postoperative CSF pressure monitoring should be sufficient in uneventful cases, since there is an increased risk of infection with prolonged CSFD.[23] In cases with neurological deficit, a 7-day postoperative period should be sufficient to observe if there is any symptom recovery under monitored and optimized SCFD. The patients should then undergo neurological rehabilitation.

This study is limited by the small sample size and the lack of a randomized control group of TEVAR patients receiving traditional manual, discontinuous CSFD.

Conclusion

Prophylactic CSFD was associated with a low SCI rate in a high-risk patient collective undergoing TEVAR. Automatic pressure-controlled CSFP monitoring and drainage was found to be feasible and technically reliable. A median CSF volume of 190 mL per day was drained to maintain a target CSF pressure of 10 mm Hg, yet a relevant procedure-associated complication rate was observed, which requires further improvement of the technique.

Declaration of Conflicting Interests

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