Cerebrospinal fluid drainage to prevent paraplegia during thoracic and thoracoabdominal aortic aneurysm surgery: A systematic review and meta-analysis

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Objectives: We undertook a quantitative systematic review of randomized controlled trials (RCTs) and observational studies to determine the effectiveness of cerebrospinal fluid (CSF) drainage to prevent paraplegia in thoracic aneurysm (TA) and thoracoabdominal aortic aneurysm (TAAA) surgery.

Methods: We included RCTs and cohort studies that met the following criteria: elective or emergent aneurysm surgery involving the thoracic or thoracoabdominal aorta, documentation of postoperative neurologic deficits, and patient age older than 18 years. We excluded studies that reported results in 10 or fewer patients and duplicate publications. We identified eligible studies by searching computerized databases, our own files, and the reference lists of relevant articles and review articles. Database searching, eligibility decisions, relevance and method quality assessments, and data extraction were performed in duplicate with prespecified criteria.

Results: Of 372 publications identified in our search, 14 met our eligibility criteria. Three RCTs reported 289 patients with type I or type II TAAA. Lower limb neurologic deficits occurred in 12% of patients who underwent CSF drainage and 33% of control subjects (number needed to treat, 9; 95% confidence interval [CI], 5-50). The pooled odds ratio (OR) for development of paraplegia in patients in the CSF drainage group was 0.35 (P = .05; 95% CI, 0.12-0.99). Similar results were found in five cohort studies with a control group (pooled OR, 0.26; P = .0002; 95% CI, 0.13-0.53). When all studies were considered together the pooled OR of TA and TAAA was 0.3 (95% CI, 0.17-0.54). There was no statistical heterogeneity among studies included in the meta-analysis. In six cohort studies without a control group, the incidence of paraplegia in high-risk TA and TAAA was 7.6%.

Conclusions: Evidence from randomized and nonrandomized trials and from cohort studies support the use of CSF drainage as an adjunct to prevent paraplegia when this adjunct is used in centers with large experience in the management of TAAA. (J Vasc Surg 2004;40:36-44.)

Paraparesis and paraplegia complicate surgical repair of thoracic and thoracoabdominal aneurysms in 6% to 40% of patients.1,2 They are associated with a 20% increase in mortality rate,3 require resource-intensive rehabilitation and chronic care, and result in a major burden for patients, families, and society. The mechanism of spinal cord injury is multifactorial, and includes inadequate pre-existing vascularization of the spinal cord, interruption of blood flow, inadequate revascularization of spinal arteries during aortic reconstruction, spasm of the microcirculation, and increased spinal fluid pressure.4-6 Techniques to minimize cord ischemia include reduction of cross-clamp time, reattachment of the intercostal arteries (either indiscriminately or after localization of spinal cord circulation contributors), intrathecal papaverine injection,7,8 intrathecal papaverine injection,7,8 intraoperative administration of naloxone,9 administration of steroid or barbiturate agents,10 distal perfusion, pump bypass,11 regional cooling of the spinal cord,12,13 systemic cooling,14 and drainage of cerebrospinal fluid (CSF).

The rationale for the use of CSF drainage is based on animal evidence that suggests that decreasing CSF pressure to less than 10 mm Hg during clamping of the thoracic aorta enhances perfusion of the spinal cord and decreases the risk for ischemic injury.6,15,17 While CSF drainage appears to be a promising intervention to reduce the incidence of paraplegia, there exists uncertainty as to the effectiveness of this intervention in human beings.18

We conducted a systematic review and meta-analysis to address the effectiveness of CSF drainage to prevent spinal cord–related neurologic injury during surgery for thoracic aneurysms (TAs) and thoracoabdominal aortic aneurysms (TAAAs).
METHODS

Reports of TA and TAAA repair were identified by means of the search strategy outlined in the Appendix. We included studies that met the following criteria: randomized and nonrandomized trials of patients undergoing elective or emergent surgery to treat dissecting and nondissecting TAs and TAAAs (the latter classified in four different types, according to Svensson et al.19), and patient age older than 18 years. We excluded studies that reported results for 10 or fewer patients and duplicate publications.

The primary outcome for the review was any postsurgical in-hospital neurologic deficit (paraparesis, paraplegia) that was either transient or permanent, early or delayed. Secondary outcomes were in-hospital mortality, 30-day mortality, and complications associated with CSF drainage.

To determine study eligibility two reviewers (G.A., A.L.) independently assessed all citations identified in the search. Data extraction was also performed in duplicate, with a standardized form to collate details of study design, patient selection, baseline characteristics, surgical procedure, co-interventions, follow-up, and outcome assessment. We evaluated study internal validity (method rigour) with a series of prespecified questions to assess type and direction of enquiry (randomized controlled trial [RCT], retrospective or prospective cohort study), documentation of demographic data, and description of intervention. The Jadad three-item scale, with a highest total score of 6, was used to summarize the quality of RCTs.20 The senior author (C.S.C.) resolved all eligibility and data extraction disagreements.

We undertook the data analysis with Review Manager 4.2 software (Cochrane Collaboration, 2003) with double data entry. The protocol of CSF drainage differed in the included studies. We combined results with the assumption that, although the magnitude of the treatment effect could be different among studies, the direction of the effect should not. To increase the robustness of the analyses, random effects models were used to estimate pooled odds ratio (OR), absolute risk reduction (ARR), and 95% confidence interval (CI).21 We explored publication bias with funnel plot analysis.22 This is a simple scatter plot of the treatment effect from individual studies (expressed on the x-axis as OR) versus a measure of the sample size (expressed as the log of the standard error) on the y-axis. The precision of the treatment effect increases with the size of the study. Therefore larger studies will gather at the top close together, and smaller studies will scatter more widely at the bottom of the graph. A gap in the bottom left corner of the graph shows that publication bias exists. GraphPad StatMate 1.01 and InStat 3.0 were used to calculate proportions and 95% CI. P < .05 was considered significant. All statistical testing was two-tailed. Agreement between reviewers was assessed with the Cohen κ, which is a measure of agreement on a scale of 0 to 1, where 0 represents agreement that is no better than chance, and 1 is perfect agreement (κ 0.4–0.6 is considered moderate agreement, 0.6–0.8 is good to very good agreement, and > 0.8 is excellent agreement).23 The κ value was calculated with Arcus QuickStatBiomedical 1.0.

RESULTS

Search results. Our search identified 372 citations, of which 53 studies, which appeared potentially relevant, were marked for retrieval. Fourteen publications fulfilled our eligibility criteria, of which three were RCTs, five were cohort studies with a control group, and six were cohort studies without a control group.

Relevance and validity. Interobserver reliability for judgment of relevance was excellent (κ = 0.83; 95% CI, 0.64–1.0). Interobserver agreement for decisions related to methodologic quality was excellent for description of study design (κ = 0.89), good for outcome assessment (κ = 0.77), description of surgical intervention (κ = 0.61), and moderate for description of patient demographics (κ = 0.42).

Methodologic quality of included studies. Key indicators of quality for the included studies are summarized in Table I, online only.

There were three RCTs enrolling 289 patients.7,24,25 The sample size of the trials was small, ranging from 17 to 74 patients per treatment group. In all but one trial the outcome assessors were blinded to treatment allocation.24 The Jadad score was 5, of a total of 6, for the three studies. Co-interventions (use of adjuncts for distal perfusion, number and location of intercostal arteries reattached, distal thoracic pressure during proximal aortic perfusion, postoperative central and peripheral hemodynamics, drug administration, hemodilution, hemostasis) were not described in detail. Five cohort studies reported results obtained in a group of patients who underwent CSF drainage (n = 311) and in a control group without CSF drainage (n = 250).2,26–29 All studies provided an adequate description of the intervention. Two studies2,29 provided an adequate description of patient demographic data, one study27 reported the use of an independent assessor of neurologic outcome, and none specified whether the assessor was blinded. The direction of inquiry (prospective, retrospective) is summarized in Table II, online only. Mortality outcomes for the treatment and control groups were not reported separately.

Six cohort studies reported a total of 251 patients undergoing CSF drainage during TA and TAAA surgery. The direction of enquiry was retrospective in three studies30–32 and prospective in three studies.33–35

Randomized controlled trials. All studies enrolled patients with type I and II TAAA (Table III, online only), and enough data were provided to conduct intention-to-treat and on-treatment analyses of the results for the primary outcome (Table IV), and the mortality outcome (Table V; Fig 1).

Crawford et al.24 randomized 100 patients with a median age of 65 years. Demographic variables were similar between treatment and control groups. The amount of CSF drainage was limited to 50 mL, no intrathecal papaverine was used, and the subarachnoid catheter was removed
in the operating room before transferring patients to the intensive care unit (ICU). Atriofemoral bypass (AFB) was used in 42% of the treatment group and 38% of the control group, and intercostal and lumbar arteries were reattached in 80% and 79% of patients, respectively. No details of the number and location of the arteries reattached in the two groups were given. Neurologic deficits occurred in 28% of the treatment group and 35% of the control group. The surgical team, which was aware of the treatment allocation, assessed neurologic deficits, and when an event occurred it was reviewed by an independent, blinded neurologist.

In the study conducted by Svensson et al, 33 patients met inclusion criteria. Their mean age was 66.1 years, and there was no difference between treatment and control groups with respect to demographic variables and co-interventions. CSF drainage was implemented before surgery, and was continued postoperatively for 48 to 60 hours, to achieve CSF pressure of 10 mm Hg or less. Intrathecal papaverine was also used in the treatment group. An independent neurologist, blinded to the treatment, conducted the neurologic assessment. A preplanned interim analysis stopped the study after only one third of patients were recruited, because of the statistically significant increase in paraplegia in the control group.

Coselli et al operated on 202 patients with type I or II TAAAs, and 156 were randomized. Preoperative exclusion criteria were previous TAAA surgery, shock, contraindication to spinal catheter placement, and logistic issues. Median patient age was 65 ± 10.5 years, and there was no difference between treatment and control groups with respect to demographic variables and co-interventions. All patients underwent AFB, moderate heparinization, and mild hypothermia. Reattachment of intercostal and lumbar arteries from T7 to L2 was done whenever possible, and distribution of the intercostal and lumbar arteries reattached in the two groups was the same.

### Cohort studies with a control group
Details of these studies are summarized in Table II, online only. Hollier et al compared a retrospective cohort of 108 patients undergoing surgery for type I, II, III, or IV TAAA, with a prospective cohort of 42 patients who also underwent adjunctive CSF drainage to maintain pressure of 10 mm Hg or less during surgery and for 3 days postoperatively. Intraoperative and postoperative co-interventions were similar in both groups: blood glucose concentration less than 220 mg/dL; administration of steroid agents, mannitol, nimodipine, and thiopental sodium; permissive hypothermia; and reattachment of intercostal arteries. Mean patient age was 68 years, and 89 patients were men. Forty-eight percent of patients in the protocol group had a type I or II TAAA, versus 35% of patients in the control group. Neurologic deficits occurred in six patients in the control group (5.5%) and in none in the treatment group. Overall mortality rate was 10%, and there was no significant difference between the two cohorts of patients.

Murray et al compared a retrospective cohort of 49 patients undergoing surgery at the Mayo Clinic to treat TAs and TAAA type I, II, and III TAAAs with a retrospective cohort of 50 patients who received adjunctive CSF drainage with the goal of maintaining pressure at 15 mm Hg or lower. Demographic variables were similar in the two groups. CSF, Cerebrospinal fluid; n/N, number of events/number of patients.

### Table IV. Randomized controlled trials: paraplegia and paraparesis

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<th>Treatment group</th>
<th>Control group</th>
<th>Treatment group</th>
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| CSF, Cerebrospinal fluid; n/N, number of events/number of patients. |

### Table V. Randomized controlled studies: mortality outcomes

<table>
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<th>Treatment group</th>
<th>Control group</th>
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| n/N, Number of events/number of patients. |

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groups, except for extent of aneurysm: there was a greater prevalence of types II and III TAAAs in the treatment group (62%) compared with the control group (20%). Perioperative hypothermia was also lower in the control group compared with the treatment group (33.5 ± 0.8°C and 34.0 ± 1.4°C, respectively; \( P < 0.05 \)). In the control group, AFB was used in 19% of patients, and an aorto-aortic shunt was used in 24%, compared with 29% and 8%, respectively, in the treatment group. No intercostal or lumbar arteries were reattached. CSF drainage was 45 ± 34 mL (median, 33 mL). Initial CSF pressure was 15.5 mm Hg. During clamping, maximum CSF pressure was 13 ± 5 mm Hg, and minimum pressure was 9 ± 5 mm Hg. In six patients in the treatment group CSF pressure less than 15 mm Hg was not achieved, because of technical difficulties, and in one of these patients a neurologic deficit developed.

The overall mortality rate was 12% (12 of 99 patients). Four patients in the control group and three patients in the treatment group never recovered from anesthesia, and postoperative morbidity was assessed in the remaining 45 and 47 patients, respectively. Neurologic deficit developed in four of 45 patients (8.9%) in the control group and four of 47 patients (8.5%) in the treatment group.

Acher\(^27\) reported a retrospective study of consecutive patients undergoing surgery to treat types I, II, III, and IV TAAAs or for TAs. Of these, 147 underwent CSF drainage, with low-dose naloxone (1 μg/kg/hr), and 58 composed the control group. Surgery was done with simple clamping, moderate hypothermia, and renal cooling. All intercostal arteries were suture ligated. Demographic variables were not described separately for each group. Mortality rate was 6.7% in the treatment group and 16.4% in the control group. Paraplegia occurred in five of 147 patients (3.4%) in the treatment group and 12 of 58 patients (21%) in the control group.

Safi and Miller\(^28\) retrospectively reviewed data for 263 patients operated on to treat types I and II TAAAs; 164 patients underwent CSF drainage, 99 did not. Demographic variables were similar between the two groups, except there were fewer women, a greater number of chronic dissections in the treatment group (35.0% vs 15.9%; \( P < .001 \)), and more patients with type II TAAAs (35.2% vs 17.9%; \( P < .001 \)). CSF drainage was used intraoperatively and for 3 days postoperatively, and pressure was maintained at 10 mm Hg or lower. In the control group aneurysms were repaired with simple cross-clamp technique, whereas in the treatment group AFB and moderate hypothermia were used. The incidence of neurologic deficit was 15.2% (15 of 99 patients) in the control group and 4.9% (8 of 164 patients) in the treatment group (\( P < .004 \)).

Estrera et al\(^29\) reported a retrospective cohort study of 148 elective patients who underwent repair of the descending thoracic aorta. Spinal cord protection with AFB and CSF drainage (pressure ≤10 mm Hg for 3 days) was used in 105 patients. The control group consisted of 39 patients, of which 11 were operated on with simple clamping and 28 underwent AFB. Demographic variables for the two groups were not described. Intercostal arteries between T7 and T12 were reimplemented when feasible. Paraplegia developed in 1% (1 of 105) of the treatment group and 8% (3 of 39) of the control group (\( P < .04 \)).

Cohort studies without a control group. Details of this study are provided in Table VI, online only. Cambria et al\(^30\) reported 15 consecutive patients undergoing surgery to treat varying extent TAAAs with adjunctive CSF drainage. No details of the protocol used were given, no shunts or AFB were used, and the extent of intercostal artery reattachment was not specified. None of these patients died or had neurologic deficits.

Svensson et al in 1988\(^34\) reported a retrospective cohort study of 80 nonconsecutive patients who underwent surgery to treat TAs and TAAAs (type I, II, III, or IV) at two institutions; 11 underwent CSF drainage and were given intrathecal papaverine, and 19 underwent only CSF drainage. CSF drainage was used only during surgery, with the goal of draining no more than 50 mL of fluid. AFB and other techniques of distal aortic perfusion were used inconsistently. Neurologic deficit occurred in nine patients.
In 1990 the same authors reported a cohort of 11 patients (one included in the previous study) who underwent CSF drainage, with intrathecal papaverine. The average amount of CSF drained was 61 mL, and the average pressure was 15 ± 2 mm Hg. No neurologic deficits developed in any patients, and no patients died.

Jacobs et al. conducted a prospective study of 52 consecutive patients who underwent surgery to treat types I and II TAAAs; 46% of patients were women, and median patient age was 60 years. Comorbid conditions were well represented. All patients underwent distal aortic perfusion, mild hypothermia, CSF drainage, and motor evoked potential monitoring. CSF pressure was maintained at 10 mm Hg or less, and the catheter was left in place for at least 72 hours. Intercostal and lumbar arteries between T6 and L3 were reattached when feasible. An independent neurologist assessed neurologic status. The mortality rate was 8%, and partial neurologic deficit developed in only one patient (2%).

Wada et al. reported a retrospective cohort study of 80 patients who underwent elective surgery to treat TAs and TAAAs; 15% of patients were women, and average patient age was 62 years. All patients underwent temporary bypass shunting or partial cardiopulmonary bypass, CSF drainage, and monitoring of somatosensory evoked potentials. CSF pressure during surgery was 12 ± 5 mm Hg. In one patient the CSF pressure rose to greater than 20 mm Hg, and delayed paraplegia developed. In-hospital mortality rate was 7.5% (6 of 80), and neurologic deficits developed in three patients (4%).

Weaver et al. reported a retrospective cohort study of 62 patients who underwent TAAA repair with adjunctive CSF drainage. Forty-five patients (45%) were men, and mean patient age was 67 years. Demographic data and co-interventions were not described. CSF drainage was left in place for a mean of 2.4 days. Intraspinal hematoma occurred in two patients (3.2%); one recovered without neurologic deficits, and paraplegia developed in the other patient. Overall neurologic deficit occurred in six patients (9.7%), and the mortality rate was 4.8%. No data about the amount of CSF drained and CSF pressure were given.

Meta-analyses of randomized and nonrandomized studies with a control group. In eight studies neurologic events were described in patients with and without CSF drainage. The pooled OR of developing paraplegia in patients who underwent CSF drainage was 0.30 (95% CI, 0.17-0.54; \(P = .0001\); Fig 1). The ARR was 9% (95% CI, 5%-13%; \(P = .0001\)), and the corresponding number needed-to-treat was 11 (95% CI, 8-20). Funnel plot analysis (Fig 2) disclosed asymmetry around the axis of the treatment effect. Heterogeneity was not significant (\(P = .19\)).

Meta-analyses of randomized studies. Three RCTs reported 289 patients with type I and type II TAAAs, 150 in the treatment group and 139 in the control group. A dissection was present in 107 patients, with no difference between control and treatment groups. In the treatment group there were 64 type I TAAAs and 75 type II TAAAs, and in the control group there were 69 type I TAAAs and 68 type II TAAAs. With intention-to-treat meta-analysis, the pooled OR for developing paraplegia in patients treated with CSF drainage was 0.35 (95% CI, 0.12-0.99; \(P = .05\); Fig 3). Lower limb neurologic deficits occurred in 12% of patients who underwent CSF drainage and in 33% of control subjects (number needed to treat, 9; 95% CI, 5-50). In-hospital mortality was not statistically different between the two groups (\(P = .56\); Fig 4).

Meta-analyses of nonrandomized studies. Five cohort studies reported 854 patients, 505 in the treatment group and 349 in the control group. Acher et al. did not specify the distribution of type of aneurysms in their 205
patients. In the remaining 649 patients included in the meta-analysis the distribution of type of aneurysm was 114 type I, 92 type II, 33 type III, six type IV, and 116 TA in the treatment group, and 92 type I, 64 type II, 29 type III, 47 type IV, and 62 TA in the control group. Results of the meta-analysis are shown in Fig 5. The ARR was 9% (95% CI, 3%-13%), corresponding to number needed to treat of 11 (95% CI, 8-20). The six cohort studies without a control group reported a total of 249 patients treated with CSF drainage, and an incidence of neurologic deficits of 7.6% (95% CI, 5%-12%).

Complications. CSF drainage was used in 1396 patients included in this review. In our own experience, 90 patients underwent thoracic vascular and TAAA surgery with adjunctive CSF drainage. Thus the total number of observations is 1486. Three major complications were reported (0.2%): subdural hematoma requiring surgical decompression in two patients, complicated by paraplegia in one patient; and fatal meningitis in one patient.

DISCUSSION

The use of CSF drainage to prevent paraplegia has been suggested on the basis of theoretical constructs and animal evidence\(^1\)\(^5\)\(^\text{,17}\) regarding hemodynamic changes that occur in blood flow through the spinal cord during thoracic aortic clamping. The effectiveness of this intervention, however, is controversial.\(^18\)

Meta-analysis is a technique of synthesis that combines data from individual published studies to improve the level of statistical significance and the precision of point estimates of effect. The inferences drawn depend on the methods of the review and the quality of the available studies. We undertook a systematic review, and present the available evidence using the criteria derived from consensus statements for reporting meta-analysis of randomized\(^36\) and nonrandomized controlled trials.\(^37\) A systematic review by Ling and Arellano\(^18\) identified the complexity in defining the role of CSF drainage as an adjunct to decrease paraplegia, but did no attempt a formal meta-analysis. A large number of variables influence the incidence of this complication, including age, extent of aneurysm, collateral circulation, use of adjuncts for distal aortic perfusion, reattachment of intercostal arteries, intravascular volume during and after surgery, hemodynamics, and pharmacologic manipulation. New randomized\(^25\) and nonrandomized\(^28\)\(^,\text{29\text{\footnote{Cinà et al \(J\text{OURNAL \ OF \ VASCULAR \ SURGERY\) Volume 40, Number 1}}}}\) trials, and discrepancies in a previous review\(^18\) regarding inclusion criteria and data interpretation explain the differences between the systematic review of Ling and Arellano and our review.

Our work shows that cohort studies and randomized trials provide encouraging evidence to support the use of CSF drainage to decrease paraplegia and lower limb neurologic deficits. The ARR is 10% (11% in cohort studies, 9% in RCTs), which corresponds to a number needed to treat of 10; that is, only 10 patients need to be treated with CSF drainage to prevent paraplegia from developing in one patient.
One RCT and two cohort studies did not find CSF drainage effective in preventing paraplegia. In these studies the highest volume of CSF allowed to be drained was 50 mL, a significant number of patients had CSF pressure greater than 10 mm Hg, and CSF was drained only during surgery and not in the postoperative period.

A number of cohort studies supporting the use of CSF drainage have potential biases that limit interpretation of results. In two studies the distribution of the extent of aneurysms between treatment and control groups was not described. Hollier et al. reported a low incidence of paraplegia, but included patients with type IV TAAAs, who are at low risk for this complication. In the cohort study by Safi and Miller the use of AFB in the treatment group but not in the control group was a confounder potentially affecting results in favor of CSF drainage.

The use of CSF drainage is supported by reports of delayed neurologic deficits reversed by implementing this intervention. In our recent experience, reversal of a neurologic deficit after use of CSF drainage occurred in one patient, in addition to one previously reported by our group. Similar experience has been described by others. In our meta-analysis the magnitude of the effect of CSF drainage may be overestimated as a result of biases inherent in the included studies. The sample size was generally small, which reflects the relative rarity of this condition. The outcome assessor was blinded in two RCTs; most cohort studies were retrospective, and the assessor was not blinded. In all studies the condition treated often had different extent of TAs and TAAAs. The intervention was different with respect to the volume of CSF drained, CSF pressure threshold, and duration of drainage after surgery. Co-interventions were poorly described, which likely had a significant effect on the differences observed between treatment and control groups and also among studies. Despite these potential sources of bias, there was no clinical heterogeneity with respect to the direction of the effect of the intervention, and no statistical heterogeneity. Publication bias was identified with funnel plot analysis, which suggested that studies with negative results are not represented in the published literature (Fig 2). The inference drawn from our meta-analysis, however, is strengthened by the large effect size, the similarity of results between nonrandomized and randomized trials, and the direction of the effect, which in all studies was similar, even when the difference between treatment and control groups was not significant.

A further issue is the generalizability of results of the RCTs, because they were conducted in centers with large experience in management of TAAAs. The incidence of paraplegia depends on a large number of factors, including the expertise of the surgical team.

Several questions remain unclear regarding CSF drainage, including the true magnitude of the effect, the ideal threshold of CSF pressure, the relationship between this and systemic arterial and filling pressures, duration of drainage, its role in decreasing delayed neurologic deficits, and complications associated with this intervention. Such complications may be serious and potentially lethal. In a series of 63 patients undergoing CSF drainage to treat CSF fistulas the incidence of meningitis was 8%, with a mortality rate of 1%. In the present review only one study reported two subdural hematomas that required surgical exploration (3.2%), and one patient with paraplegia (1.5%). In our own experience with 25 patients with TAs and 65 with TAAAs (types I, II, III) who underwent CSF drainage, one patient died of meningitis associated with this intervention (1.7%).

Paraplegia, however, is the most dreaded complication of TAAA repair, because of the dramatic changes in quality of life. We believe that the evidence is strong enough to support the use of CSF drainage in all patients with TAAA at high risk for paraplegia (type I, II, III, with and without dissection). It is also plausible to continue CSF drainage for the first 72 hours when hemodynamic instability, reperfusion injury, changes in the collateral circulation, and spinal cord edema might decrease the blood supply and cause ischemic injury.

In view of the many questions still unanswered, we suggest that centers caring for these patients prospectively collect further data.
variables known to be related to the incidence of paraplegia and to the potential effectiveness of CSF drainage.

**APPENDIX**

**Search strategy.** The following search strategy was conducted (upper case is used to indicate pre-exploded Medical Subject Headings or coding terms, and lower case to indicate text words): Medline database from 1966 to June 2002, using Ovid software and the content strategy (AORTA, ANEURYSM, AORTIC ANEURYSM, THORACIC AORTA, THORACIC AORTIC ANEURYSM, or [thoraco-abdominal, thoracoabdominal, thoraco abdominal, and aneurysm], or PARAPLEGIA, CEREBROSPINAL FLUID, or [cerebrospinal fluid drainage]) combined with a previously validated sensitive method filter strategy for identification of randomized controlled trials in this database and the Cochrane randomized controlled trial strategy. The search was amplified with papers from the authors’ files and review of the reference lists of relevant articles and review articles, and limited only to human study subjects.

**REFERENCES**


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