The use of lumbar drains in preventing spinal cord injury following thoracoabdominal aortic aneurysm repair: an updated systematic review and meta-analysis

Nickalus R. Khan, MD,¹ Zachary Smalley, BS,² Cody L. Nesvick, BA,² Siang Liao Lee, MD,³ and L. Madison Michael II, MD^{1,4}

¹Department of Neurosurgery, ²College of Medicine, University of Tennessee Health Science Center, Memphis, Tennessee;

³Department of Surgery, Metropolitan Group Hospitals, University of Illinois at Chicago, Chicago, Illinois; and ⁴Semmes-Murphey Neurologic & Spine Institute, Memphis, Tennessee

OBJECTIVE Paraplegia and paraparesis following aortic aneurysm repair occur at a substantially high rate and are often catastrophic to patients, their families, and the overall health care system. Spinal cord injury (SCI) following open thoracoabdominal aortic aneurysm (TAAA) repair is reported to be as high as 20% in historical controls. The goal of this study was to determine the impact of CSF drainage (CSFD) on SCI following TAAA repair.

METHODS In August 2015 a systematic literature search was performed using clinicaltrials.gov, the Cochrane Library, PubMed/MEDLINE, and Scopus that identified 3478 articles. Of these articles, 10 met inclusion criteria. Random and fixed-effect meta-analyses were performed using both pooled and subset analyses based on study type.

RESULTS The meta-analysis demonstrated that CSFD decreased SCI by nearly half (relative risk 0.42, 95% confidence interval 0.25–0.70; $p = 0.0009$) in the pooled analysis. This effect remained in the subgroup analysis of early SCI but did not remain significant in late SCI.

CONCLUSIONS This meta-analysis showed that CSFD could be an effective strategy in preventing SCI following aortic aneurysm repair. Care should be taken to prevent complications related to overdrainage. No firm conclusions can be drawn about the newer endovascular procedures at the current time.

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KEY WORDS aortic aneurysm; cerebrospinal fluid; endovascular; lumbar drain; spinal cord injury; vascular disorders

PARAPLEGIA remains the most devastating complication in both open and endovascular repair of thoracic and aortic aneurysms. Permanent neurological deficit is a major cause of morbidity and leads to decreased long-term survival of patients with thoracoabdominal aortic aneurysm (TAAA) repair;^{13,46} the incidence of paraplegia has been reported to be as high as 20% in the early 1990s.⁴⁶ Risk factors identified for developing spinal cord injury (SCI) following TAAA repair include aneurysm extent (related to the number of segmental arteries), location of the aneurysm (lumbar aneurysms have less robust collateral arteries), and prolonged aortic cross-clamping times. All of these risk factors point toward an ischemia/

infarction model for the pathophysiology of SCI following TAAA repair.²² Anatomical work performed by Etz et al. resulted in a better understanding of the relationship between segmental and radicular arteries.²⁰ This work has influenced our knowledge of ischemic injuries that occur during TAAA repair. A variety of measures to attenuate the ischemic pathophysiology have been investigated, such as elevation of mean arterial pressure, reattaching critical segmental arteries, and CSF drainage (CSFD).^{2,10,12,15,21,38,41} The introduction of CSFD and adjunctive neuroprotective therapies have reduced the risk of SCI to 4%–7% in the current literature.^{1,3,19,23,32,50} The first reports of CSFD as an adjunctive measure for reducing the risk of paraple-

ABBREVIATIONS CI = confidence interval; CSFD = CSF drainage; df = degrees of freedom; NNT = number needed to treat; NOS = Newcastle-Ottawa Scale; OCEBM = Oxford Center for Evidence-Based Medicine; OR = odds ratio; RCT = randomized controlled trial; RR = relative risk; SCI = spinal cord injury; TAAA = thoracoabdominal aortic aneurysm; TEVAR = thoracic endovascular aortic repair.

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gia following aortic aneurysm repair were from a seminal report on a canine model by Miyamoto et al. in 1960 and Blaisdell and Cooley in 1962.^{6,35} This topic has since been addressed by several prospective cohort studies and randomized controlled trials (RCTs), resulting in 2 systematic reviews that showed significant protective odds ratios (ORs) of 0.30 and 0.57 in 2004 and 2012, respectively.^{8,31} Neurosurgeons are often consulted for insertion and management of this adjunctive therapy. It is prudent for the neurosurgical community to understand the risks, benefits, and indications of this procedure as it relates to the natural history of this disease. This systematic review and meta-analysis was undertaken to provide an updated and thorough review about the use of CSFD in TAAA repair. The primary aim of this analysis was to determine if CSFD decreases SCI following TAAA repair.

Methods

This study was conducted using the “Assessment of Multiple Systematic Reviews” (AMSTAR) measurement tool,⁴² and reporting was conducted according to the guidelines defined by “Meta-analysis Of Observational Studies in Epidemiology” (MOOSE)⁴⁵ and “Preferred Reporting Items for Systematic reviews and Meta-Analyses” (PRISMA).³⁶ The research question for this study was, “Does CSFD in TAAA repair decrease postoperative paraplegia and paraparesis?”

Search Strategy

The systematic search strategy involved a search through multiple electronic databases, bibliographies of relevant articles, and consultation with the senior author (L.M.M.). We electronically searched clinicaltrials.gov, The Cochrane Library, PubMed/MEDLINE, and Scopus to find English-language articles—excluding gray literature—with no timeframe restrictions in August of 2015.

The following terms in various combinations were used: aortic aneurysm, cerebrospinal fluid, endovascular, lumbar drain, paraplegia, paraparesis, and spinal cord ischemia. Three independent researchers (Z.S., C.L.N., and S.L.L.) conducted 3 separate independent literature searches with the help of librarians at the University of Tennessee Health Science Center. If there was any question as to the eligibility of an article, consensus was reached through discussion with the senior author. When necessary, additional contact was made with the authors of the articles we included to confirm data.

Inclusion Criteria, Data Extraction, End Points, Definitions

The goals of the search were to find articles that met the following inclusion criteria: 1) described a group of adult patients (> 18 years of age) with surgical repair of a TAAA treated with CSFD; 2) described a control group not treated with CSFD; 3) had the use of CSF diversion as the main treatment difference between the 2 groups; and 4) reported the number of patients and number of neurological deficits for each group. Thus, noncomparison studies, case reports, and pediatric reports were excluded.

Three separate individuals (Z.S., C.L.N., and S.L.L.) screened all potential articles and extracted data indepen-

dently. The data extracted from each article included: 1) information regarding the timeframe and drainage parameters for CSF diversion; 2) the total number of participants, in both treatment and control groups; 3) early and late post-surgical neurological deficits (i.e., paraparesis, paraplegia); 4) complications related to the use of CSF diversionary procedures; and 5) length of follow-up. The level of evidence for each study was evaluated using the Oxford Centre for Evidence Based Medicine (OCEBM) guidelines (<http://www.cebm.net/ocebmllevels-of-evidence/>). Study quality (i.e., assessment of bias within individual studies) was determined using the Jadad³⁰ scale for RCTs and the Newcastle-Ottawa Scale (NOS) for quality assessment of controlled observational cohort studies.⁴⁹ Disagreements among any of the above data points were resolved through discussion among the authors.

Meta-Analysis

For each study, the numbers of neurological deficits (early and late) in patients treated with CSF diversion were identified and a relative risk (RR) was calculated. The overall risk ratio was computed using the method of DerSimonian and Laird.¹⁶ Analysis was performed using Review Manager software (version 5.3, Cochrane Collaboration 2014).

A random effects meta-analysis was performed on selected studies. A random effects model, in contrast to a fixed effects model, does not assume that the relative risk is the same across studies and yields a more conservative estimate of effect. Heterogeneity between studies was assessed by the Cochran Q test and I² statistic. Heterogeneity is calculated by taking a weighted sum of the squared differences between individual study effect sizes and the overall pooled effect estimate. The greater the difference, the more likely it is that significant methodological and clinical differences exist between the included studies. Heterogeneity was considered statistically significant when the p value derived from the Cochran Q test was less than 0.1. For the qualitative interpretation of heterogeneity, I² values of at least 50% are usually considered to represent substantial heterogeneity, while values of at least 75% indicate considerable heterogeneity according to the Cochrane Handbook.¹⁸

Publication bias (i.e., assessment of bias across studies) was graphically evaluated using a funnel plot.^{17,43,44} The theory of a funnel plot is that smaller studies should have more variation in effect sizes compared with larger studies with more robust data. A plot measuring the log of the standard error (correlated to the size of the study) and overall effect should yield a symmetric funnel-shaped diagram in the absence of publication bias.

Results

Search Results and Included Articles

After a comprehensive search of PubMed/MEDLINE, Cochrane/Ovid, Scopus, and clinicaltrials.gov, we identified 3478 unique titles. Of these titles, 93 articles were identified for abstract review after excluding articles not in English (n = 624) and articles not directly pertinent to the use of CSFD in TAAA repair (n = 2761). Of these 93 arti-

cles, 27 were identified for full-text review after excluding case reports ($n = 29$), case series ($n = 19$), commentaries and nonsystematic reviews ($n = 12$), animal studies ($n = 4$), and articles with no aortic aneurysms in the study population ($n = 2$). Of these 27 articles, 17 met inclusion criteria; however, 8 had data from the same research groups with overlapping dates and were excluded. Two articles were excluded because they selected only patients at high risk of SCI for CSFD, thus no utility between lumbar drains preventing SCI could be meaningfully assessed.^{7,26} Additionally, a single article was identified after mining the bibliographies of included articles, leaving a final total of 10 included articles comprising 1319 patients receiving lumbar drainage and 784 control patients (Fig. 1). There were 3 RCTs and 7 cohort studies. The overall quality of the evidence for the included observational studies was moderate. The average number of stars using the NOS

was 5.5 ± 2.1 out of a maximum of 9 stars. Each of the 3 RCTs^{11,13,47} received 3 points using the Jadad criteria.³⁰ Table 1 lists the characteristics of each study included in this analysis.

Overall SCI Following TAAA Repair

A total of 10 studies had sufficient information to extract overall rates of both transient and permanent SCI. All but 1 study⁴ showed a protective benefit against SCI when using CSFD compared with a control group.^{5,11,13,27,28,37,40,47,48} The OR was 0.42 with a 95% confidence interval (CI) of 0.25–0.70 ($p = 0.0009$; Fig. 2). A funnel plot was used to assess publication bias (Fig. 3). There was moderate, but not significant ($p = 0.11$), heterogeneity as indicated by an I^2 statistic of 37%. The absolute risk reduction was 7% with a number needed to treat (NNT) of 14.

FIG. 1. Flow diagram of the search strategy used in the study.

TABLE 1. Characteristics of studies included for analysis

Authors & Year	Grade of Evidence (Jadad score)	OCEBM	Endo vs Open	Study Type	Indications for LD	CSF Pressure & Drainage Targets, Vol Drained (total)	Length & Location of LD	Co-intervention	Compl	SCI				Conclusions
										Overall	Early	Late	FU	
Crawford et al., 1991	2 (3/5)		Open	RCT	Random	10–15 mmHg, 24–120 mL (median 52.5)	Removed immediately postop, L3–4 or L4–5 inserted 5–10 cm depth	None	NES; "head-ache & infection did not occur"	14/46 (LD), 17/52 (Control)	10/46 (LD), 11/52 (Control)	4/36 (LD), 6/41 (Control)	NES; 30-day mortality	"Thus CSF drainage as we used it, was not beneficial in preventing paraplegia."
Hollier et al., 1992	4		Open	Retro	NES	≤10 mmHg, up to 500 mL	Removed POD 1–3, L-2 or L-3, depth NR	Permissive hypothermia (32–34°C), intercostal artery reattachment, nimodipine, steroids, mannitol	NR	0/42 (LD), 6/108 (Control)	0/42 (LD), 3/108 (Control)	0/42 (LD), 3/108 (Control)	NES; 30-day mortality	"A multimodal-intensity protocol appears to be effective in reducing the risk of spinal cord injury during thoracoabdominal aortic replacement."
Murray et al., 1993	4		Open	Retro	Types I, II, III TAAAs & descending thoracic aneurysms	≤15 mmHg 3–150 mL (median 33 mL)	NES	CSFD group, permissive hypothermia (34°C)	NR	4/47 (LD), 4/45 (Control)	2/47 (LD), 3/45 (Control)	2/47 (LD), 1/45 (Control)	NES; >96 hrs, 30-day mortality	"The study was unable to demonstrate improved neurologic outcome for patients undergoing repair of descending thoracic and TAAA."
Svensson et al., 1998	2 (3/5)		Open	RCT	Random	≤7 to 10 mm Hg, 12–1157 mL (mean 447 mL)	Removed after 2–60 hrs (mean 40 hrs), L3–4 & L4–5, depth NR	Permissive hypothermia (29°–31°C); CSFD group, intrathecal papaverine	NR	2/17 (LD), 7/16 (Control)	NR	NR	3 yrs	"For high-risk thoracoabdominal aneurysms, CSFD+IP was effective in reducing the incidence and severity of neurologic injury."

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TABLE 1. Characteristics of studies included for analysis

Authors & Year	Evidence (Jadad score)	Study Type	Endo vs Open	Indications for LD	CSF Pressure & Drainage Targets, Vol Drained (total)	Length & Location of LD	Co-intervention	Compl	SCI				Conclusions
									Overall	Early	Late	FU	
Tefera et al., 2000	4	Retro	Open	NES	≤10 mm Hg, (mean 116 ml)	"Typically" removed POD 2, L1–2 inserted 6-cm depth	Intercostal artery reattachment & permissive hypothermia (32°–34°C); CSFD group, naloxone	NR	5/150 (LD), 12/67 (Control)	NR	NR	NES	"In our experience, CSF drainage and naloxone use has shown significant spinal cord protection, significantly reducing neurologic complications."
Coselli et al., 2002 ²¹	2 (3/5)	RCT	Open	Random	≤10 mm Hg, 10–250 ml during op (mean 64 ml) & 40–864 ml (mean 261 ml) after op	Removed POD2, continued if SCI present; L-3 or L-4, depth NR	Lt heart bypass, permissive hypothermia, heparinization, reattachment of intercostal & lumbar arteries T7–L2	Cather occlusion (2), catheter dislodged (1), infections (0), CSF leaks (0)	2/82 (LD), 9/74 (Control)	1/82 (LD), 7/74 (Control)	1/82 (LD), 2/74 (Control)	NES; 30-day mortality	"Perioperative CSFD reduced the rate of paraplegia after repair of extent I and II TAAAs."
Safi et al., 2003	3 or 4	Retro	Open	NES	≤10 mm Hg, vol of drainage NR	Removed POD3, L-3 or L-4, depth NR	CSFD group, distal aortic perfusion & permissive hypothermic	NR	18/741 (LD), 18/263 (Control)	18/741 (LD), 18/263 (Control)	NR	NES; 30-day mortality	"These long-term results indicate that cerebrospinal fluid drainage and distal aortic perfusion are safe and effective adjunct for reducing morbidity and mortality following thoracic and thoracoabdominal aortic repair."

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Authors & Year	OCEBM Grade of Evidence (Jadad score)	Study Type	Endo vs Open	Indications for LD	CSF Pressure & Drainage Targets, Vol Drained (total)	Length & Location of LD	Co-intervention	Compl	SCI				Conclusions
									Overall	Early	Late	FU	
Arnaoutakis et al., 2014	3 or 4	Retro	Endo	TEVAR for included lesions	≤10 mm Hg intraop; <15 mm Hg postop, NR	Placed day before op & replaced preop if malfunctioning, clamped POD1, removed POD2, L-3 or L-4 interspace	CSFD group, 12 had lt subclavian artery bypass	NR	2/60 (LR), 1/30 (Control)	NR	NR	NES; 30-day & 1-yr mortality	"Preoperative CSF drain placement allows for rapid, intensive therapy for SCI and should be considered when clinically feasible."
Hnath et al., 2008	4	Retro	Endo	TEVAR for included lesions	≤15 mm Hg intraop; <10 mm Hg postop, "no set limit on volume"	Clamped 12 hrs postop, continued if SCI present, L2–4	None	NR	0/56 (LD), 5/65 (Control)	NR	NR	NES; ICU for >24 hrs	"Perioperative CSF drainage with augmentation of systemic blood pressures may have a beneficial role in reducing the risk of paraplegia in patients undergoing endovascular thoracic aortic stent graft placement."
Bisdas et al., 2015	3	Retro	Endo	TEVAR for included lesions	NR, (mean 64 ml)	Continued for LE weakness, NR	None	Cranial hypotension syndrome (4), EVD required (2)	12/78 (LD), 11/64 (Control)	Immediate: 5/78 (LD), 5/64 (Control); <24 hrs: 6/78 (LD), 5/64 (Control)	>24 hrs: 1/78 (LD), 1/64 (Control)	NES; 30-day mortality data	"Prophylactic use of CSFD could not reduce the SCI rate and was associated with 6% adverse events."

Compl = complications; Endo = endovascular; FU = follow-up; IP = intrathecal papaverine; LD = lumbar drainage; LE = lower extremity; NES = not explicitly stated; NR = not reported; POD = postoperative day; Random = randomized; Retro = retrospective.

FIG. 2. Forest plot of all studies with their respective RRs and 95% CIs, events (SCI), and overall RR. M-H = Mantel-Haenszel.

Early SCI Following TAAA Repair

A total of 6 studies had sufficient information to extract early rates of transient and permanent SCI. One study showed an increase in early SCI when using CSFD⁷ and the remaining 5 showed a protective benefit. The OR was 0.48 with a 95% CI of 0.30–0.76 ($p = 0.002$; Fig. 4). There was mild heterogeneity as indicated by an I^2 statistic of 15%. The absolute risk reduction was 4.3% with an NNT of 23.

Late SCI Following TAAA Repair

A total of 5 studies had sufficient information to extract late rates of transient and permanent SCI. One study showed an increase in late SCI when using CSFD³⁷ and the remaining 4 showed a protective benefit. The OR was 0.73 with a 95% CI of 0.29–1.81 ($p = 0.49$; Fig. 5). A funnel plot was used to assess publication bias. There was minimal heterogeneity as indicated by an I^2 statistic of 0%.

Subgroup Analysis of RCTs

A total of 3 RCTs were included in the subgroup analysis. Two studies showed a protective benefit when using

CSFD in preventing SCI and 1 did not. Using a fixed-effects meta-analysis, the OR was calculated to be 0.48 with a 95% CI of 0.25–0.92 ($p = 0.03$). There was moderate ($p = 0.09$) heterogeneity as indicated by an I^2 statistic of 59% (Fig. 6).

Complications of CSFD

Of the 10 studies that met criteria, only 3 reported complications when using lumbar drainage for CSFD. Bisdas et al. reported a requirement of 2 external ventricular drains and 4 episodes of intracranial hypotension.⁵ Coselli et al. reported 2 catheter occlusions/dislodgements.¹¹ Svensson et al. reported a persistent CSF leak requiring an epidural blood patch.⁴⁷

Publication Bias and Heterogeneity

Publication bias was assessed graphically using funnel plots. As shown in Fig. 3 there is a paucity of studies in the right lower quadrant. This quadrant represents small studies that showed an increase in SCI following TAAA repair using CSFD, indicating that publication bias may exist. Minimal heterogeneity was detected as evidenced by the I^2 statistics and correlating p values.

Discussion

Spinal cord injuries following TAAA repair are significant complications to patients, their families, providers, and the overall health care system. The cardiothoracic literature is mixed when evaluating adjuncts such as CSFD in preventing SCI. Some studies show a benefit, while others do not. This study focuses on nontraumatic SCI in the setting of TAAA repair.

A systematic review performed in 2004 by Cina et al. demonstrated a protective benefit when using CSFD. This study contained 8 included articles and 2 of their studies may have overlapping patient recruitment periods from the same groups of authors.^{18,39} The article by Safi, et al. in 2003 in our study contains the same group of patients as these 2 studies with longer follow-up durations and larger sample sizes.⁴⁰ Thus, our review contains 4 unique articles not presented in their review after more than a decade has elapsed. A Cochrane review in 2012 by Khan et al. looked

FIG. 3. Funnel plot for evaluating all studies for overall SCI. The absence of studies in the right lower quadrant indicates a lack of small studies that showed increased rates of SCI. SE = standard error.

FIG. 4. Forest plot of all studies with their respective RRs and 95% CIs, events (early SCI), and overall RR.

only at RCTs and found 3 included articles^{11,13,47} that are also included in the current study. Khan et al. concluded that there is limited data supporting the role of CSFD in thoracic and TAAA surgery and further studies are needed.³¹ Two of the 3 RCTs of open aortic aneurysm repair included in this study showed benefit when using CSFD.^{11,47} The study by Svensson et al. in 1998 was stopped early by the institutional review board because the interim results show a significant benefit in favor of CSFD and intrathecal papaverine, thus limiting the size of their trial.⁴⁷ In the second trial by Coselli et al. in 2002¹¹ the rates of SCI significantly decreased from 12.2% to 2.7% ($p = 0.03$), although the observers rating neurological deficit were not blinded. The RCT by Crawford et al. in 1991 did not show a benefit in preventing SCI in those who received CSFD compared with those who did not.¹³ The Crawford study had several important shortcomings. The amount of CSF drained was limited to 50 ml and the CSFD pressure was only reduced to less than 10 mm Hg in less than half of the participants. Thus, this trial may not have adequately increased spinal cord perfusion pressure to prevent neurological deficit and answer the hypothesis posed by their study.¹³ Our subgroup fixed-effects meta-analysis shows the same results as described by the Cochrane Review in 2012.³¹

Our study contains 7 articles pertaining to open aortic aneurysmal repair and 3 newer endovascular studies. In the overall analysis we showed a significant protective benefit with moderate but not significant heterogeneity. The overall NNT was 14 with an absolute risk reduction of 7%, which is slightly more modest than the systematic review performed over a decade ago by Cinà et al. that

showed an NNT of 11 with an absolute risk reduction of 9%.⁸ This benefit continued when analyzing early SCI but did not continue when analyzing late SCI. Late neurological deficits may be more a manifestation of a reperfusion type injury and not as directly responsive to increasing spinal cord perfusion pressure by CSFD.

The literature is heterogeneous when evaluating the 3 included endovascular studies. The study by Bisdas et al. showed no improvement in SCI following endovascular repair when prophylactically performing CSFD. However, their protocol for prophylactic versus selective CSFD placement was not uniform and the validity of their results is questionable.⁵ Arnaoutakis et al. did not show a difference when placing a CSF drain compared with the control group, however, both patients who developed SCI responded to CSFD and the authors concluded that the “use of adjunctive procedures for TEVAR [thoracic endovascular aortic repair] demonstrated better SCI results compared with prior reports.”³⁴ Hnath et al. showed a statistically significant benefit when using prophylactic CSFD despite having higher rates of prior TAAA repair, left subclavian artery coverage, increased aortic coverage, and perioperative vasopressors in the CSFD group.²⁷ Additional higher quality studies will be needed prior to making any formal recommendations on the use of CSFD in endovascular repair of aortic aneurysms.

The rate of complications related to CSFD was marginal in the included studies. There were reports of non-clinically significant subdural hematoma and external ventricular drain placement. However, there are a multitude of case reports^{9,14,24,25,29,33,34} in the literature citing CSFD

FIG. 5. Forest plot of all studies with their respective RRs and 95% CIs, events (late SCI), and overall RR.

FIG. 6. Forest plot of RCTs with their respective RRs and 95% CIs, events (SCI), and overall RR.

linked to the development of subdural hematoma following aortic aneurysm repair; 1 report even directly links this complication to the death of the affected patient.³³ A study by Youngblood et al. looking at a series of 504 patients over 5 years receiving CSFD for TAAA repair reported that the rate of intracranial hemorrhage was 2.8%, with the majority being subdural hematomas (72%), and the postprocedural headache rate was 9.7%.⁵¹ At our own institution we follow a protocol of CSF pressure targeting to 10 mm Hg but do not allow greater than 30 ml of CSF to be drained in a single hour to prevent these types of complications.

Limitations and Strengths

Limitations of our meta-analysis are related to the quality of the included studies. A systematic review and meta-analysis is only as robust as the articles of which it is composed. With only 3 RCTs, the majority of the included data are based on combining prospective and retrospective cohort studies. The quality of the evidence was moderate using objective grading scales. Any selection bias inherent to these nonrandomized studies would be perpetuated in the current analysis. Authors defined neurological deficit heterogeneously. Some authors used sensitive grading scales that likely identified more subtle deficits while others did not. Surgical technique and approach was heterogeneous. To account for heterogeneity in the overall analysis we used a random, instead of a fixed-effects, meta-analysis and formal statistical testing found minimal overall heterogeneity among studies in the outcome of interest. While publication bias may exist, the Cochrane Collaboration recommends against testing for it when a meta-analysis is composed of 10 or fewer studies because when there are fewer studies the power of the tests is too low to distinguish chance from real asymmetry. Until a large, multiinstitutional, prospective RCT is performed, the current meta-analysis represents the highest level of evidence supporting CSFD in TAAA repair.

Conclusions

Neurosurgeons are often asked to perform CSFD for other consulting services at their discretion. It is prudent for the neurosurgical community to understand the risks, benefits, and indications of this procedure as it relates to the natural history of this disease. Based on moderate quality evidence, the use of CSFD in open TAAA repair may be beneficial with appropriate spinal cord perfusion

pressure targeting and appropriate neurological monitoring, but care should be taken to prevent complications related to overdrainage. No firm conclusions can be drawn on the endovascular population at the current time.

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Disclosures

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Author Contributions

Conception and design: Khan. Acquisition of data: Michael, Khan, Smalley, Nesvick. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: Michael, Khan, Lee. Approved the final version of the manuscript on behalf of all authors: Michael. Statistical analysis: Khan. Study supervision: Michael.

Correspondence

L. Madison Michael II, Semmes-Murphey Neurologic & Spine Clinic, 847 Monroe Ave., Ste. 427, Memphis, TN 38120. email: mmichael@semmes-murphey.com.