Interactive CardioVascular and Thoracic Surgery 15 (2012) 702–708
doi:10.1093/icvts/ivs284 Advance Access publication 3 July 2012

Is cerebrospinal fluid drainage of benefit to neuroprotection in patients undergoing surgery on the descending thoracic aorta or thoracoabdominal aorta?

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Received 27 February 2012; received in revised form 5 May 2012; accepted 16 May 2012

Abstract

A best evidence topic in cardiac surgery was written according to a structured protocol. The question addressed was 'Is cerebrospinal fluid (CSF) drainage of benefit in patients undergoing surgery on the descending thoracic aorta or thoracoabdominal aorta?' Altogether 1177 papers were found using the reported search, of which 17 represented the best evidence to answer the clinical question. The authors, journal, date and country of publication, patient group studied, study type, relevant outcomes and results of these papers are tabulated. Ten of 13 studies demonstrate significant neurological protection from CSF drainage (±additional adjuncts), with two further papers showing no significant difference between patients who had or had not had CSF drainage and one study unable to provide any conclusions. For patients having surgery on the thoracic aorta or thoracoabdominal aorta CSF drainage, maintaining pressures <10 mmHg ($P < 0.03$), in conjunction with other neuroprotective strategies, minimizes the risk of neurological sequelae when compared with patients treated with similar adjuncts but without CSF drainage. The majority of studies used additional neuroprotective strategies, including cooling and reattachment of the intercostal arteries as adjuncts to CSF drainage. Logistic regression curves demonstrated that the longer the ischaemia time, the greater the benefit from CSF drainage ($P < 0.04$). Four papers observed complications of CSF drainage, of which the main complications were: catheter occlusion or dislodgement, headache, meningitis and subdural haematoma. Overall, CSF drainage does offer a neuroprotective benefit; preventing paraplegia if CSF pressures are maintained <10 mmHg.

Keywords: Cerebrospinal fluid • Thoracic aortic • Cardiac • Thoracoabdominal

INTRODUCTION

A best evidence topic was constructed according to a structured protocol. This is fully described in the ICVTS [1].

THREE-PART QUESTION

In [patients undergoing thoracic aortic or thoracoabdominal aortic surgery] is [cerebrospinal fluid drainage] of [benefit to neuroprotection]?

CLINICAL SCENARIO

You have a 63-year old patient listed for repair of an extensive aneurysm to the descending thoracic and thoracoabdominal aorta. You wonder whether to use cerebrospinal fluid (CSF) drainage in this patient.

SEARCH STRATEGY

An English language literature review was performed on MEDLINE 1948 to July 2011 using the Ovid interface: ['Cerebrospinal Fluid drainage'] AND ['Thoracic aortic' OR 'Thoracoabdominal aortic'].

SEARCH OUTCOME

The search returned 1177 papers. From these, 21 papers were identified as answering our question. Duplicated and nonrandomized studies containing fewer than 40 patients who had undergone CSF drainage were removed. Seventeen papers provided the best evidence to answer the question: These are presented in Table 1.

RESULTS

The studies examined the effects of CSF drainage (CSFDr) in descending thoracic aortic aneurysms (TAAs) or Type I, II or III thoracoabdominal aortic aneurysms (TAAAs).

Table 1: Best evidence papers

Author (date), Journal and country Study type (level of evidence)	Patient group	Outcomes	Key results	Comments, study weaknesses
Cina *et al.* (2004), J Vasc Surg, Canada [2] Meta-analysis (level 1a)	Fourteen studies were identified that used CSF drainage (CSFDr) of patients undergoing elective or emergent surgery to treat dissecting and nondissecting TAAs and TAAAs Three were RCTs (n = 289), five cohort studies with a control group, and six were cohort studies without a control group	Paraplegia (randomized and non-randomized studies with a control group)	OR 0.30 in patients undergoing CSFDr (95% CI 0.17–0.54, P = 0.0001). ARR = 9% (95% CI 5–13%, P = 0.0001). NNT = 11 (95% CI 8–20)	A number of small, poorer quality studies were included in the meta-analysis. Authors concluded that CSF drainage should be used in high-risk TAAA and dissection patients, although further research is required Distal atriofemoral bypass and re-anastomosis (re-connection) of intercostal and lumbar vessels were used in controls and cases
		Paraplegia (randomized studies)	OR 0.35 in patients undergoing CSFDr (95% CI 0.12–0.99, P = 0.05)	
		Paraplegia (five cohort studies with control group)	ARR 9% (95% CI 3–13%)	
		In-hospital mortality (randomized studies) Lower limb neurological deficit (randomized studies)	No difference between CSFDr and control (P = 0.56) 12% in CSFDr, vs 33% in control. NNT = 9 (95% CI 5–50)	
		CSFDr complications	3 of 1486: 2 subdural haematoma requiring surgical decompression, 1 fatal meningitis	
Khan and Stansby (2008), Cochrane Database Syst Rev, UK [3] Meta- analysis (level 1a)	Three RCTs (n = 289) examining the neurological sequelae ± CSFDr were included in the analysis	Neurological deficit (for patients undergoing CSFDr)	OR 0.57 (95% CI 0.28–0.17)	Authors performed meta-analysis on just three RCTs (some of which used adjuncts to CSFDr). Authors concluded that more research is required Distal atriofemoral bypass and re-anastomosis (re-connection) of intercostal and lumbar vessels were used in controls and cases
Crawford *et al.* (1991), J Vasc Surg, USA [4] Prospective RCT (level 1b)	Ninety-eight patients due to undergo repair of Type I and II TAA randomized to CSFDr (n = 46) and control (n = 520)	Number of patients with neurological deficit in patients who became hypotensive (<100 mmHg systolic)	CSFDr, 2 of 16; Control, 6 of 15 (P = 0.08)	Authors concluded that there was no benefit in CSFDr but they did not control CSF pressures evenly Intercostal and lumbar arteries were reattached where possible in both groups. Additionally moderate heparinization, permissive mild hypothermia and left heart bypass were used for neuroprotection
		Neurological scores of patients with immediate neurological deficits (CSFDr n = 10, Control n = 11)	No significant difference at discharge/death (P = 1.0), cumulative follow-up/death (P = 0.8) or survivor score at 86 days–17 months (P = 0.9)	
		Number of patients with delayed neurological deficits	CSFDr, 3 of 3; control, 6 of 41 (P = 0.6)	
Svensson *et al.* (1998), Ann Thorac Surg, USA [5] Prospective RCT (level 1b)	Thirty-three Type I and II TAAA patients were randomized to CSFDr + IP (n = 17) or control (n = 16) CSFDr patients were administered treated with IP and drainage was commenced prior to surgery and for 2–60 h postoperatively. CSF pressure maintained ≤10 mmHg	Neurological injury	CSFDr + IP, 2 of 17; control, 7 of 16 (P = 0.0392, Pearsons χ^2)	This study had a small population size. This was due to interim analysis stopping the study following just a third of total patient recruitment due to the significant increase in paraplegia in the control group CSFDr was in conjunction with administration of IP. Other neurological protection techniques in both groups included active cooling
		Lowest mean motor score	CSFDr + IP, 3.88; control, 3.25 (P = 0.034 t-test, P = 0.17 Kruskall–Wallis)	
		Neurological injury risk	OR for CSFDr + IP = 0.02 (95% CI 0.00–0.68, P = 0.039) Adjusted for active cooling	

Continued

BEST EVIDENCE TOPIC

Table 1: Continued

Author (date), Journal and country Study type (level of evidence)	Patient group	Outcomes	Key results	Comments, study weaknesses
			(*P* = 0.037) and aortic clamp time (*P* = 0.029)	(29–31°C), sequential cross clamping of aortic segments and preservation where possible of intercostals and lumbar arteries
Coselli *et al.* (2002), J Vasc Surg USA [6] Prospective RCT (level 1b)	One hundred and fifty-six patients undergoing Type I or II TAAA repairs were randomized to CSFDr (*n* = 82) or control (*n* = 74) CSFDr was initiated intraoperatively and continued for 2 days postoperatively, with CSF pressure maintained ≤10 mmHg	Mortality rate In hospital: 30 day Paraplegia or paraparesis CSF drainage complications	 CSFDr, 6 of 82, control, 5 of 74 (*P* = 1.0) CSFDr, 4 of 82, control, 2 of 74 (*P* = 0.68) CSFDr, 2 of 82, control, 9 of 74 (*P* = 0.03) Logistic regression curves demonstrated increasing benefit from CSF drainage the longer the ischaemia time (*P* < 0.04) Two catheters became occluded, one catheter dislodged. They were not replaced	The study demonstrated an 80% reduction in relative risk in patients with CSFDr The operative mortality for patients with neurological deficit was significantly higher at 45% than those without at 4.5% (*P* = 0.0003) Additional neuroprotection was afforded in both groups by left heart bypass, moderate heparinization, permissive hypothermia (32–33°C) and reattachment of the intercostals
Hollier *et al.* (1992), J Vasc Surg, USA [7] Retrospective cohort with control (level 2b)	One hundred and fifty patients undergoing thoracoabdominal replacement between June 1980 and June 1991 In 1989, a protocol of CSFDr was introduced. Patients were compared preprotocol (*n* = 101) and postprotocol with CSFDr (*n* = 42). CSF pressure maintained ≤10 mmHg	Incidence of neurological deficit	Lower incidence (*P* < 0.01) in CSFDr (0 of 42) compared with preprotocol control (6 of 101, 3 patients had no CSF drainage, 3 had no intercostal arteries reimplanted)	Although CSF drainage became protocol in 1989, some preprotocol patients still had CSF drainage on an individual basis, the extent of CSF drainage and use of other neuroprotective mechanisms preprotocol are not clear. The protocol after 1989 for neuroprotection also included: tight glucose control (insulin started if glucose >220 mg/dl), an increase is systolic blood pressure to 15–20% above baseline during aortic occlusion, passive cooling to 32–34°C, thiopental sodium, mannitol, nimodipine and steroids and reimplantation of intercostals arteries
Murray *et al.* (1993), J Cardiothorac Vasc Anesth, USA [8] Retrospective cohort study with control (level 2b)	CSF drainage (maintained <15 mmHg) for thoracic aortic aneurysm and Type I, II and III TAAA surgery was introduced as protocol in 1986. Preprotocol control patients (*n* = 49) were compared with protocol patients receiving CSFDr (*n* = 50)	Spinal deficit	Comparable between control (4 of 45) and CSFDr (4 of 47)	Control patients were more aggressively cooled than the CSFDr patients There was more thoracic (descending and Type I) aneurysms in the control compared with CSFDr (*P* < 0.05). Six of 49 patients in the CSFDr group did not achieve CSF pressures <15 mmHg. Additional protective strategies included the use of shunts and mild hypothermia (34°C)
Safi *et al.* (1998), Ann Thorac Surg, USA [9] Retrospective cohort study with control (level 2b)	Two hundred and seventy-one patients with TAAA or descending TAA undergoing cross-clamp times >30 min, with CSF drainage (pressures <10 mmHg) and distal aortic perfusion (CSF + DAP, *n* = 159) or without adjunct (*n* = 112)	Neurological deficit (in patients undergoing CSFDr + DAP) cross-clamp >30 min cross-clamp >60 min (*n* = 87)	 OR 0.28 (95% CI 0.11–0.70, *P* = 0.004) if OR = 0.20 (*P* = 0.009)	Study used CSFDr in conjunction with distal aortic perfusion. Temperature drifts to ∼33°C

Continued

Table 1: Continued

Author (date), Journal and country Study type (level of evidence)	Patient group	Outcomes	Key results	Comments, study weaknesses
Safi *et al.* (2003), Ann Surg, USA [10] Retrospective cohort study with control (level 2b)	Thousand and four patients undergoing descending thoracic or thoracoabdominal aortic graft replacement over a 12-year period receiving either an adjunct of CSF drainage + DAP (n = 741) or without (n = 263)	Early neurological deficit	Univariate analysis. OR of 0.33 (95% CI 0.17–0.66, P = 0.0009) in CSFDr + DAP patients CSFDr + DAP prevented 1 of 20 cases of neurological deficit in all patients, at 1 of 5 in the high-risk TAAA Type II patients Number needed to treat to prevent paraplegia was 23 (all patients) and 5 (Type II TAAA)	Study used CSFDr in conjunction with DAP CSF pressure <10 mmHg. Core temperature is maintained between 32 and 33°C and, kidney temperature <20°C
		Long-term mortality	*Multiple Cox regression* adjusted hazard ratio for CSFDr + DAP = 0.80 (P = 0.053, 95% CI 0.64–1.00) *Univariate/Multivariate analysis* Increased survival in Type II patients undergoing CSFDr + DAP (univariate P < 0.0001, multivariate P < 0.002) Increased survival in none Type II patients undergoing CSFDr + DAP (univariate P = 0.0001, multivariate P = 0.0001)	
Estrera *et al.* (2005), Ann Thorac Surg, USA [11] Retrospective cohort study with control (level 2b)	Three hundred and fifty-five patients undergoing descending TAA repair (55 excluded from analysis due to the use of DHCA or aortic rupture) Patients either received neuroprotection from CSF drainage for 3 days + DAP (pressures <10 mmHg, n = 238) or no protection (n = 62)	Neurological deficit	Lower incidence of deficit in CSFDr + DAP (2 of 238) compared with control (4 of 62) (P < 0.02) Univariate analysis: OR = 0.19 (P < 0.02) in CSFDr + DAP patients	Study used CSFDr in conjunction with DAP. Reimplantation of the intercostals arteries was performed where possible
Acher *et al.* (1998), J Vasc Surg, USA [12] Prospective cohort study with control (level 2b)	Two hundred and seventeen patients who underwent thoracoabdominal (n = 176) and descending thoracic (n = 41) aneurysm surgery and, consequently multivariate and univariate analyses of perioperative variables. CSF drainage was performed in conjunction with naloxone administration in 147 patients, and without in 58	Paraplegia or paraparesis	Five of 147 CSFDr + naloxone (expected = 31) and 12 of 58 (expected = 13) in none CSF drainage Univariate analysis: OR 0.025 (P < 0.03) for patients undergoing CSFDr + naloxone	Reduced paraplegia incidence with the use of CSF drainage Study used CSFDr in conjunction with naloxone. No intercostal reimplantation was performed
Cheung *et al.* (2002), Ann Thorac Surg, USA [13] Prospective observational cohort study (level 2b)	Ninety-nine patients who underwent surgical repair of Type I, II or II TAAA or TAA repair with CSF drainage (pressures <12 mmHg)	Paraplegia or paraparesis	Eleven of 99 patients (8 cases were delayed onset). Lumbar CSF pressure at diagnosis was higher (14 ± 3 (SD)) than at the time of recovery (10 ± 3 mmHg) (P < 0.001)	Patients did not consistently undergo CSF drainage at the same time and it is unclear how many did undergo perioperative CSF drainage. Hypothermic circulatory arrest, 'total body' retrograde cerebral perfusion and intercostal artery re-attachment were also used for neuroprotection
Hnath *et al.* (2008), J Vasc Surg, USA [14]	One hundred and twenty-one patients undergoing TEVAR with	Spinal cord ischaemia	One of 56 patients in the CSFDr group due to a faulty CSF drain (full recovery	Fewer incidences of spinal cord ischaemia with CSF drainage. Patients in CSFDr and control

Continued

BEST EVIDENCE TOPIC

Table 1: Continued

Author (date), Journal and country Study type (level of evidence)	Patient group	Outcomes	Key results	Comments, study weaknesses
Observational cohort study (level 2b)	(*n* = 56) or without (*n* = 65) CSF drainage		following insertion of new drain). Four of 65 patients in the control group (following CSF drain insertion 2 had a full recovery, 1 patient a partial recovery and 1 patients did not recover)	groups had differing numbers previous AAA and subclavian artery coverage ($P < 0.05$). No additional neuroprotection was noted to be used
Weaver *et al.* (2001), J Vasc Surg, USA [15] Observational cohort study (level 2b)	Sixty-five patients undergoing TAAA repair, of which 62 had CSF drainage for a mean of 2.4 days (range = 1–6 days)	Complications of CSF drainage	Two cases (of 62 patients) of intradural haematoma at site	Small observational group for complications. Intercostal artery reattachment was attempted in some patients
Cheung *et al.* (2003), Ann Thorac Surg, USA [16] Observational cohort study (level 2b)	Four hundred and thirty-two patients undergoing TAA or TAAA repair over a 9-year period, of which 162 used lumbar CSF drainage (pressures >12 mmHg intraoperatively and 10–12 mmHg for up to 24 h postoperatively)	Complications of CSF drainage	Occurred in 6 (of 162 patients): 1 temporary abducens nerve palsy, 1 meningitis after drain removal, 1 meningitis associated with a retained lumbar CSF catheter fragment, 2 additional patients had retained catheter fragments due to fracture of the catheter during removal, and 1 patient had a post-lumbar puncture spinal headache. All patients recovered with no sequelae No haemorrhagic complications, no epidural haematomas, no spinal haematomas	Mean ± SD time between catheter insertion and heparin administration was 153 ± 60. Hypothermia used if there was distal arch aneurysm. Intercostal arteries were reimplanted, distal perfusion and mild hypothermia or deep hypothermia were used
		Immediate postoperative paraplegia	Four of 162 patients. No recovery in any	
		Delayed onset paraplegia	Fifteen of 162 patients. Eleven of 15 of these patients recovered with further CSF drainage	
		Mortality	23 of 162	
Wynn *et al.* (2009), J Vasc Surg, USA [17] Observational cohort study (level 2b)	Four hundred and eighty-six patients undergoing TAA and TAAA repair with cerebrospinal fluid drainage (<10 mmHg) continued for 24–48 h postoperatively over an 11-year period Three hundred and eleven patients had a small drain and 174 had a large	Drain failure Small drain vs large drain Post dural headache Small drain vs large drain Spinal infection Bloody CSF	7.8%, 24 of 308 vs 1.7%, 3 of 174 ($P = 0.0054$) 2 of 308 vs 4 of 174. All treated with epidural blood patch Nil Twenty-four of 482 patients. All had CT which showed: no haematoma formation in any patient but intracranial bleeding in 17 of 24 patients (3 of 17 of which had neurological deficit but were noted to have had preoperative cerebral atrophy with brain volume loss.) Higher volume of CSF drained correlated with an increased	Risk of complications of CSF drainage may be higher in patients with unrecognized chronic subdural haematoma or cerebral atrophy. It is not clear which neurological protective adjuncts were used

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Table 1: Continued

Author (date), Journal and country Study type (level of evidence)	Patient group	Outcomes	Key results	Comments, study weaknesses
			risk of bloody CSF (mean 178 vs 124 ml, $P < 0.0001$) and higher CVP preaortic occlusion (mean 16 vs 13 mmHg, $P = 0.0012$)	
		Neurological deficits	Three of 17 bloody CSFs (although they all also had pre-existing cerebral atrophy, 1 of 3 died) Two patients developed deficits on Day 5, due to cerebral subdural haematomas following anticoagulation (2 of 2 died)	
Leyvi *et al.* (2005), J Cardiothorac Vasc Anesth, USA [18] Retrospecitive cohort study (level 2b)	Ninety-one patients who underwent TAAA repair with CSF drainage ($n = 54$) or without ($n = 37$)	Neurological events (CSFDr vs control)	Stroke (5.5 vs 5.4%) Cerebral haemorrhage (5.5 vs 0%) Paraplegia (5.5 vs 0%) Seizures (1.8 vs 0%) Death (11 vs 0%)	Hypothesized that too fast a removal if too large a volumes of CSF may result in subdural haematoma due to tearing of the vessels. Additional neurological protection was afforded in both groups by one or more of permissive hypothermia (32°C), left atrial–femoral artery bypass, femoral–femoral bypass, atrial–distal bypass, permissive hypothermia or DCHA

ARR: absolute risk reduction; CSF: cerebrospinal fluid; CVP: central venous pressure; ECC: extracorporeal circulation; LHB: left heart bypass; CPB: cardiopulmonary bypass; DAP: distal aortic perfusion; DHCA: deep hypothermic circulatory arrest; CSFDr: cerebrospinal fluid drainage; IP: intrathecal papaverine; OR: odds ratio; NNT: number needed to treat; TAA: thoracic aortic aneurysm; TAAA: thoracoabdominal aortic aneurysm; TEVAR: thoracic endovascular aortic repair; DAP: distal aortic perfusion; MAP: mean arterial pressure.

The two meta-analyses included the three randomized control trials (RCTs) (described below) looking at CSFDr in Type I and II TAAAs.

Cina *et al.*'s [2] meta-analysis, of 14 studies (including results from both TAAs and TAAAs), found a pooled odds ratio (OR) from all studies of 0.3 for postoperative paraplegia in patients undergoing CSF drainage (95% confidence interval [CI] 0.17–0.54, $P = 0.0001$).

Khan and Stansby's [3] meta-analysis, of the three RCTs only (all Type I or II TAAAs), reported a higher OR for postoperative paraplegia of 0.57 (95% CI 0.28–0.17) in patients undergoing CSF drainage.

Crawford *et al.* [4] conducted a RCT (98 patients) looking at CSF drainage (various CSF pressures) in Type I and II TAAA, and concluded that CSF drainage did not prevent paraplegia.

Svensson *et al.* [5] conducted a RCT (33 patients) assessing the effects of CSFDr and intrathecal papaverine (IP) (CSFDr + IP, pressures maintained <10 mmHg) compared with a control group in preventing neurological injury. Neurological injury occurred in 2 of 17 CSFDr + IP patients and 7 of 16 patients in the control ($P = 0.0392$). Active cooling in combination with CSFDr + IP was used in 8 patients, none of whom experienced neurological injury. The OR for neurological injury was 0.02, using CSFDr + IP (adjusted for active cooling and aortic clamp time).

Coselli *et al.* [6] found that CSF drainage (pressures maintained <10 mmHg) during the intraoperative and 48 h postoperative period reduced the rate of paraplegia after repair of Type I and II TAAAs ($P = 0.03$). Logistic regression curves demonstrated that the longer the ischaemia time, the greater the benefit from CSF drainage ($P < 0.04$).

Hollier *et al.* [7] found a lower incidence of neurological deficit ($P < 0.01$) once CSF drainage was introduced as a routine protocol.

Murray *et al.* [8] conducted a retrospective cohort study of 99 patients undergoing descending thoracic aorta or TAAA (I, II, III) ± CSFDr. They found no significant difference in spinal deficit between the two groups.

Safi *et al.* [9] demonstrated a reduced risk of neurological deficit in patients with TAAA or descending TAA undergoing cross-clamp times >30 min (OR: 0.28, 95% CI 0.11–0.70, $P = 0.004$) if CSFDr is used with distal aortic perfusion (CSFDr + DAP). A further study from Safi *et al.* [10] demonstrated that CSFDr + DAP conferred the greatest benefit in high-risk Type II TAAA patients in preventing neurological deficits (NNT all cases = 23, NNT Type II TAAA = 5). Improved long-term survival was seen in CSFDr + DAP patients ($P < 0.002$). Estrera *et al.* [11] found a lower incidence of neurological deficit in CSFDr + DAP patients (2 of 238) compared with controls (4 of 62) undergoing descending TAA repairs ($P < 0.02$).

Acher *et al.* [12] found that CSF drainage (plus naloxone) was a significant factor in reducing paraplegia and paralysis post-TAAA or descending TAA surgery ($P < 0.03$).

Cheung *et al.* [13] observed an incidence of 11 with paraplegia in 99 patients who underwent CSF drainage (pressure aim <12 mmHg) during TAAA and TAA repairs. Higher lumbar CSF pressures were demonstrated in patients with paraplegia compared with pressures when patients had recovered ($P < 0.001$).

Hnath *et al.* [14] observed an increased incidence of spinal cord ischaemia following thoracic endovascular aortic repair without ($n = 65$), compared with, ($n = 56$) CSF drainage.

Weaver *et al.* [15] conducted an observational study ($n = 65$) of complications following CSF drainage during TAAA repairs. Two of 62 patients undergoing CSF drainage developed intradural haemotomas at the site of CSF catheter insertion.

Cheung *et al.* [16] found that 23 of 162 patients died (14.1% mortality). Nineteen patients developed immediate or delayed paraplegia or paraparesis, which was permanent in 8 patients. They also observed temporary abducens nerve palsy, meningitis, retained catheter fragments due to catheter fracture during removal and post-lumbar puncture spinal headache. All patients recovered with no sequelae.

Wynn *et al.* [17] demonstrated mortality from CSF drainage of 0.6%. The most common side effect was drain failure, the rate of which declined when using a larger drain ($P = 0.0054$).

Leyvi *et al.* [18] reported higher incidences of neurological events in the CSFDr groups compared with controls.

CLINICAL BOTTOM LINE

Ten of 13 studies demonstrate significant neurological protection from CSF drainage (±additional adjuncts, two papers showed no significant difference between controls and one study was unable to provide any conclusions). In the studies that demonstrated no significant difference, CSF pressures were not infrequently >15 mmHg, and it does appear from the remaining studies that benefit is obtained through the maintenance of CSF pressures <10 mmHg. Unfortunately, many of these studies did also use an additional adjunct, which makes the analysis of the effects of CSF drainage alone harder.

Despite the observed complications (catheter occlusion or dislodgement, headache, meningitis and subdural haematoma being the most noted), CSF drainage (maintaining pressures <10 mmHg) in patients undergoing thoracic and/or thoracoabdominal aortic surgery is an effective neuroprotective adjunct.

Conflict of interest: none declared.

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