

## Case Report

# Selective Deep Spinal Hypothermia with Vacuum-Assisted Cerebral Spinal Fluid Drainage for Thoracoabdominal Aortic Surgery

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**Abstract:** Recent experiences from several centers indicate that the overall risk of spinal cord ischemia during thoracoabdominal aortic aneurysm repair has decreased to 5–8%. The results from these centers are rather consistent, despite the use of a variety of spinal protection strategies. An alternative to the various distal aortic perfusion techniques is selective spinal cooling by cold saline lavage. The principle advantage of selective hypothermia is the avoidance systemic heparinization and extracorporeal bypasses, while affording comparable spinal protection. The primary method of spinal cooling was pioneered by Cambria et al.

at Massachusetts General Hospital. In their experience, paraplegia or paresis occurred in 6.9% of patients (5-year period, 170 cases). An alternative to the Cambria method utilizes readily available perfusion supplies and offers the potential advantages of lower cerebral spinal fluid-systemic blood pressure differences, more expedient cooling, and deeper spinal hypothermia. This report describes this method and the clinical course of a patient treated with it. **Keywords:** spinal cooling, thoracoabdominal aneurysm. *JECT. 2003;35:152–155*

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Spinal cord protection during thoracoabdominal surgery is required to avoid the devastating complication of paraplegia. Various strategies to provide ischemic protection to the spinal cord have evolved, although none has been shown to be completely reliable in avoiding ischemic injury (1–3). The strategies commonly used can be broadly divided into two categories—those that attempt to reduce the ischemic *time*, and those that attempt to reduce the ischemic *impact*. Although such a division is useful, it is important to realize that neither category is mutually exclusive. For example, strategies utilizing extracorporeal blood flow are used to reduce the duration of spinal ischemia. However, the use of hypothermia in conjunction with extracorporeal flow is an attempt to reduce ischemic impact while concurrently reducing ischemic time (4). This

report focuses on a technique to reduce ischemic impact via the delivery of regional hypothermia to the spinal cord.

The selective delivery of hypothermia to the spinal cord has received a moderate amount of interest since 1993, when Marsala, Vanicky, Galik, et al. established that moderate levels of cord hypothermia (26–28°C) could be effective in preventing damage associated with double thoracic aortic clamping (5). Cambria and Davison rapidly translated this experimental experience into clinical practice, utilizing local hypothermia in over 200 patients from 1993 to date (6). The technique described in this report differs from Cambria's in two key points. The perfusionist operates the cooling system (in lieu of the anesthesiologist), and cerebral spinal fluid (CSF) is actively drained. Our institution previously reported the early experience using this technique, although it has been modified since then to include the incorporation of vacuum-assisted CSF drainage (7).

The rationale for the use of regional spinal cord hypothermia to replace distal aortic perfusion methods is mul-

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tifaceted. First is the avoidance of systemic hypothermia, systemic heparinization, and the risks associated with extracorporeal blood flow. Second, and more significantly, distal perfusion methods provide only limited ischemic reduction. The use of these techniques only “saves” the ischemic time required to complete the proximal aortic anastomosis. In Cambria and Davison (6) and in our experience, this has been a minimal portion of the total cross clamp exposure. Because of this limitation, distal perfusion techniques are used only when the proximal aortic reconstruction is likely to be time consuming (i.e., anastomosis is carried out in the distal aortic arch).

In this report, the clinical course of one patient who underwent spinal cooling with vacuum-assisted cerebral spinal fluid (CSF) drainage is discussed.

**DESCRIPTION**

A 67-year-old, 58 kg woman, initially admitted for retinal hemorrhage, was found to have a large thoracoabdominal aortic aneurysm. The aneurysm was believed to originate from a chronic dissection, and progressed from the left subclavian artery to the bifurcation of the aorta. The area of potential rupture began above the diaphragm and extended to the bifurcation, involving all abdominal vessels, the superior mesenteric artery, the celiac artery, and both renal arteries. Aside from a history of atrial fibrillation and chronic hypertension, the patient’s history was noncontributory. The patient’s aneurysm was scheduled to be resected with the use of selective spinal cooling because of the anatomy of the lesion and previous success with the technique at our institution (7). The spinal cooling protocol was modified from the previous report by incorporating assisted drainage of the CSF.

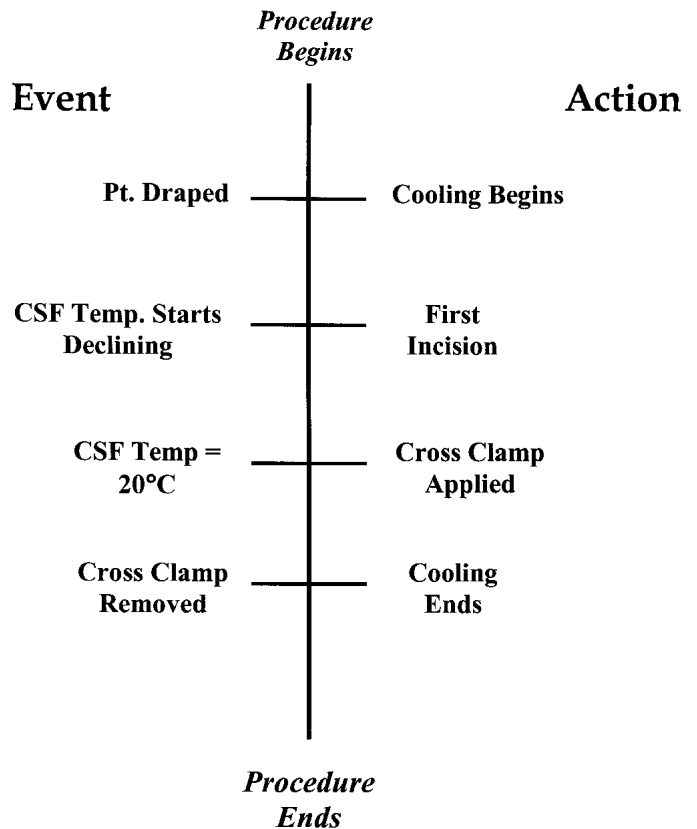
Before surgery, the patient was taken to the angiographic suite where an invasive radiologist placed three catheters into the subarachnoid space (between the arachnoid and pia mater, contains the CSF). With the patient sedated on a fluoroscopic table, the subarachnoid space was entered with a 20 ga spinal needle at the L3-4 level. A guide wire (Cook Incorporated, Bloomington, IN) was then advanced. The dilating catheter was positioned on the ventral side within the subarachnoid space, followed by a 0.035 Tad wire (Advanced Cardiovascular Systems, Inc., Santa Clara, CA). A 5F straight flush catheter was placed over the wire and positioned above T3, ventral to the spinal cord.

The same procedure was used to place a second 5F catheter at the conus medullaris level (L1, inferior end of spinal cord), with two changes. First, five additional holes were placed at the conus medullaris catheter tip before insertion, and second, the entrance was through L4-5. A 4F catheter was placed at the next inferior level, with the tip placed in the lumbar region. All three catheters were su-

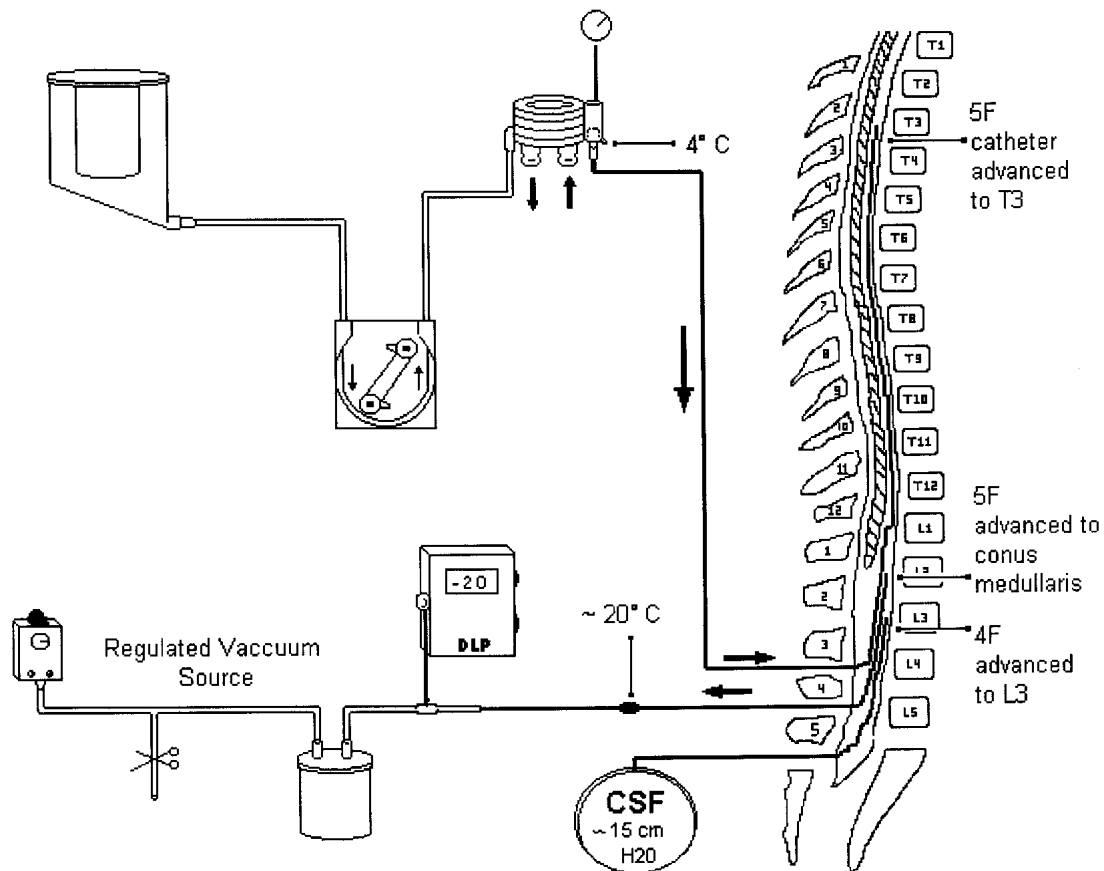
tured into place and covered with a Tegaderm transdermal patch (3M, St. Paul, MN). The catheter placed at the T3 position was used as the infusion line, the catheter at the conus medullaris was the effusion catheter, and the 4F line was the pressure-monitoring catheter. The patient was then transported to the operating room, where she was placed in the semilateral position, prepped, and draped per hospital protocol.

After induction of general anesthesia, but before the first incision, the cooling process began (Figure 1). The cooling system used readily available perfusion supplies, and consisted of (Figure 2): a Cobe cardiotomy reservoir (Cobe Cardiovascular, Arvada, CO), a Sarns S10K roller pump (Terumo, Ann Arbor, MI), a heat exchanger (Medtronic, Parker, CO), a Sarns heater cooler (Terumo, Ann Arbor, MI), a DLP pressure display set (Medtronic, Parker, CO), and a Swan-Ganz temperature monitoring port (Baxter, Deerfield, IL).

Three cooling system pressures were measured, including line pressure at the distal end of the heat exchanger, the CSF pressure via the 4F catheter, and the negative pressure on the effluent line via a DLP pressure module. Three cooling system temperatures were monitored, including water temperature of the heater cooler unit, infu-



**Figure 1.** Order of events. An *Event* dictated when an *Action* took place. For example, the cross clamp was not applied until the cerebral spinal fluid temperature reached 20°C.



**Figure 2.** Spinal cooling circuit.

sion solution temperature, and effluent temperature via a Swan–Ganz temperature set.

Cooling was accomplished by infusing 4°C 0.9% NaCl into the T3 catheter at approximately 15–20 mL min<sup>-1</sup>, depending on the CSF pressure. Cerebral spinal fluid pressure was maintained at 15 mmHg, never exceeding 18 mmHg. To maintain CSP pressure while increasing flow, drainage from the conus medullaris catheter was placed on -20-mmHg vacuum.

Additional hemodynamic and physiological parameters were monitored throughout the procedure, including radial and femoral artery pressures, pulmonary artery pressure, central venous pressure, cardiac output, nasopharyngeal temperature, blood gas status, and thromboelastograph profile (Hemoscope, Skokie, IL).

After the CSF effluent temperature began to decline (>2°C change), an incision was made from the seventh intercostal space, through the costal arch to the midline of the abdomen (Figure 1). The patient was in the semilateral position and on right lung ventilation. The temperature of the effluent line was maintained at 20°C before cross clamping the aorta (Figure 1). The aneurysm was resected from the left subclavian artery to the bifurcation of the aorta, with attachment of the celiac, superior mesenteric, both renal, and intercostal arteries to a #28 Hemashield

graft. In addition, two #8 Hemashield grafts were used to reconstruct the right renal artery and the intercostal artery. Cooling was discontinued after the cross clamps were removed. Total cross clamp time was 47 min, and the total duration of spinal cooling was 195 min.

At the end of the procedure, no hemostatic defects were apparent visually or by thromboelastographic analysis (Figure 3). In addition, the patient was hemodynamically stable with good urine output (2.5 mL/kg<sup>-1</sup>/h<sup>-1</sup>), and no evidence of compromised bowel flow. All three subarachnoid catheters were removed 48 hours postoperation by the radiologist.

The patient's postoperative stay was complicated by temporary, reversible spinal shock at sensory level T10. However, this resolved after postoperative day 3. A thoracic spinal cord MRI was performed on postoperative day 1, with no evidence of ischemia, edema, enlargement, hemorrhage, or cord compression. The patient was discharged in an ambulatory state on postoperative day 5.

## DISCUSSION

Selective cooling of the spinal cord using a continuous lavage of cold 0.9% NaCl can be safely performed in humans, and the low temperatures used do not cause an

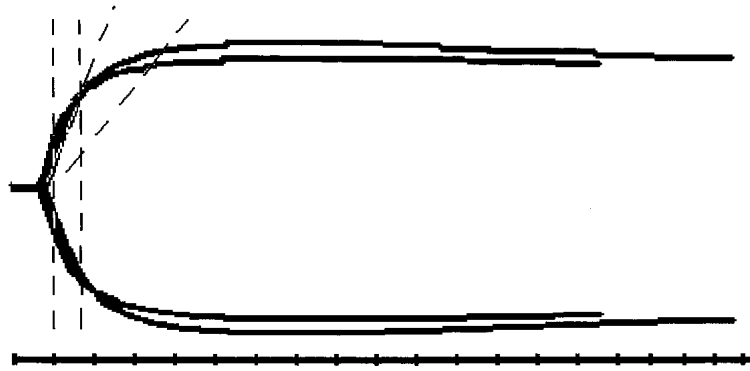


Figure 3. Thromboelastograph tracing. CI = Coagulation index.

	SP	R	K	ANG	MA	TMA	G	EPL	CL30
	min	min	min	deg	mm	min	d/sc	%	%
Preop	3.8	4.1	1.8	68.0	69.0	25.3	11129.0	1.0	95.7
Postop	3.1	3.4	1.4	70.0	61.5	22.9	7987.0	0.0	100.0
Normal		5-7	1-3	53-67	59-68		7195-10625		
	Preoperative			Postoperative					
	CI = +2.48			CI = +2.32					

adverse neurological outcome (7). It should be noted that the catheters at our institution were placed by an experienced radiologist. The introduction of cold 0.9% NaCl effectively reduced the temperature of the CSF to 20°C. The speed and maintenance of cooling may be enhanced by using a low degree of vacuum ( $\geq 20$  mmHg) on the effluent line, which enabled higher flow (+5 to +10 mL/min<sup>-1</sup>) through the infusion catheter. Perhaps more significantly, CSF drainage allowed optimization of spinal cord perfusion pressure (SCPP = Mean Arterial Pressure – CSF Pressure) and the flexibility to adjust for the patient’s dynamic arterial pressures. An alternative to vacuum assistance would be active drawing with a syringe. However, this may be undesirable because the negative pressure created cannot be reliably measured or controlled.

Selective spinal cooling may be advantageous over other strategies in that it avoids the complications associated with systemic hypothermia and various bypass strategies, while offering a level of ischemic protection versus the “clamp and sew” technique. However, the placement of the catheters and the conduct of spinal cooling must be done with care because both activities may cause damage to the spinal cord. Therefore, it is advisable to have a radiologist place the catheters and, perhaps more critical, have a perfusionist operate the cooling system.

Future investigation with this method is warranted. Although a large-scale, prospective clinical study would be ideal, several adjunctive areas remain poorly understood.

Identifying flush solutions that mimic the physiological CSF environment, while offering suitable viscosity characteristics, could improve the procedure. Likewise, pharmacological interventions tailored to mediate the effects of ischemia and hypothermia could potentially be incorporated into the delivery of selective hypothermic solutions. Indeed, the cooling apparatus could eventually contain multiple configurations, incorporating servo regulation to the CSF pressure, recirculation of CSF, and optimization of CSF drainage.

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