Selective shunting with eversion carotid endarterectomy

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Purpose: **The consensus is that eversion carotid endarterectomy (CEA) is a safe, effective, and durable surgical technique. Concern remains, however, regarding insertion of a shunt during the procedure. We studied the advisability of shunting with eversion CEA by comparing patients who underwent eversion CEA with and without shunting.**

Methods: **Over 9 years, 624 primary eversion CEAs were performed in 580 selected patients to treat symptomatic (n = 398, 63.8%) and asymptomatic (n = 226, 36.2%) carotid lesions. All eversion CEAs were performed by the same surgeon (E.B.), with the patient under deep general anesthesia, with continuous electroencephalographic (EEG) monitoring for selective shunting, based exclusively on EEG changes consistent with cerebral ischemia. A Pruitt-Inahara shunt was used in 43 eversion CEAs (6.9%). All patients underwent postoperative duplex ultrasound scanning and clinical follow-up at 1, 6, and 12 months and once a year thereafter. Mean follow-up was 52 months (range, 3-91 months). The main end points were perioperative (30-day) stroke and death, and recurrent stenosis.**

Results: **No perioperative death occurred in this series. Overall, ischemic perioperative stroke occurred in 4 of 624 patients (0.6%). Two strokes were minor and two were major. Only one (major) stroke occurred in the group with shunt insertion (1 of 43, 2.3%; *P* = not significant); the everted internal carotid artery was patent. Long-term follow-up was performed in all living patients. There was no late recurrent stenosis (>50%), and one late asymptomatic occlusive event occurred in the group without shunt insertion.**

Conclusions: **Shunt insertion can be safely performed during eversion CEA. Perioperative mortality and morbidity after eversion CEA are not statistically modified with shunting. (J Vasc Surg 2003;38:1045-50.)**

Eversion carotid endarterectomy (CEA) was initially reported by DeBakey et al,[1] later described by Etheredge,[2] and finally adapted by Kasprzak and Raithel[3] as the simplified version used today, which involves complete oblique transection of the internal carotid artery (ICA) at the bulb. Although it is generally agreed that this technique is safe, effective, and a reasonable alternative to traditional CEA with primary or patched longitudinal arteriotomy closure,[4-18] some concern remains regarding the technical aspects of inserting an indwelling shunt.

We assessed the advisability of shunting during eversion CEA by reviewing our experience with this technique and comparing outcome in patients who did or did not receive a shunt.

PATIENTS AND METHODS

Over 9 years, 624 consecutive primary eversion CEAs were performed in 580 patients with symptomatic (>70%) and asymptomatic (>60%) ICA lesions, according to the recommendations of the North American Symptomatic Carotid Endarterectomy Trial[19] and the Asymptomatic Carotid Atherosclerosis Study.[20] This group included 43 eversion CEAs (6.9%) performed in 38 patients in whom an intraluminal shunt was inserted. Patients scheduled for CEA with concomitant coronary artery bypass grafting and patients with associated supra-aortic trunk lesions requiring concurrent surgery were excluded from the analysis. No eversion CEA was aborted or incomplete, and no patients were refused eversion CEA because of clinical or technical reasons. The records of all patients were reviewed. Information was collected retrospectively before July 1, 1994, and prospectively for all patients operated on thereafter. Information on demographic and clinical variables, operation details, and hospital stay was collected from hospital and office charts, radiology records, vascular laboratory records, and operating room records. In patients with an indication at admission for bilateral CEA, the second operation was scheduled a mean 7 ± 2 weeks after the first operation. Preoperative arteriography was standard practice during the earlier part of this experience, whereas duplex ultrasound (US) scanning was the only preoperative ICA imaging study performed in most patients from mid-1998 and after. The radiologist's estimate of carotid bulb or ICA stenosis from the final angiography report was recorded. If arteriography was not performed, estimated stenosis was based on the findings at preoperative duplex US scanning performed in our vascular laboratory.[21] Clinical presentation was always classified by the same consultant neurologist, as transient ischemic attack (TIA; ie, temporary hemispheric symptoms lasting no more than 24 hours, with complete recovery), amaurosis fugax (transient monocular visual loss), or stroke (neurologic deficit persisting for more than 24 hours, regardless of the mechanism, and related to either cerebral hemisphere). Patients who had nonhemispheric symptoms, such as dizzy spells or vertigo, were included in the asymptomatic group.

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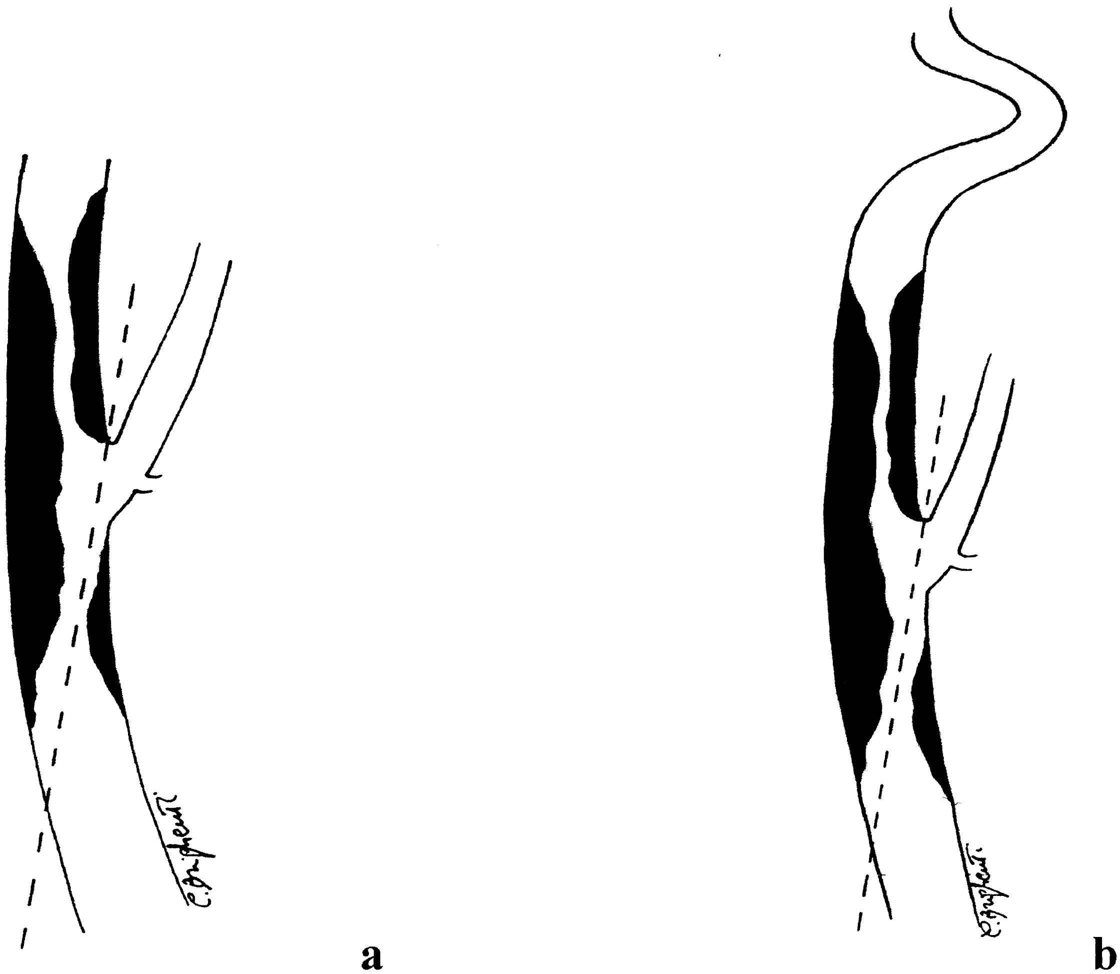

Fig 1. Both a normal **(A)** and an elongated internal carotid artery **(B)** are transected at the bulb with an incision *(broken line)* almost longitudinal to the common carotid artery, taking a large patch and leaving a large hole in the common carotid artery.

Preoperative patient preparation was standardized. Antiplatelet therapy (aspirin or dipyridamole, and ticlopidine) was suspended at least 1 week before the operation, and was not resumed until the patient was discharged from the hospital.

Surveillance protocol. After discharge, visiting nurses monitored the patients' blood pressure and neurologic status. Follow-up clinical evaluation and duplex US scanning were performed systematically by a consultant neurologist and two experienced technologists in all surviving patients at 1, 6, and 12 months, and once every year thereafter, to assess any residual ICA stenosis, recurrent ICA disease, or occlusion. Residual stenosis was recorded when a stenotic area was noted at the proximal or distal end of the endarterectomized site at 30-day follow-up. A diagnosis of recurrent ICA disease (peak systolic velocity >125 cm/s) was made only if the abnormality was apparent at 6 or 12 months but not at 1 month. It was defined as greater than 50% narrowing of the lumen diameter. Angiography was performed if there was noninvasive evidence of restenosis exceeding 70%.

The end points of the study were perioperative (30-day) stroke and death, and recurrent stenosis, and were prospectively recorded according to the guidelines of the Ad Hoc Committee on Reporting Standards for Cerebrovascular Disease, Society for Vascular Surgery/North American Chapter of the International Society for Cardiovascular Surgery.[22] Minor stroke was defined as minimal and stabilized focal neurologic deficit of acute onset and persisting for more than 24 hours but not leading to handicap or significant impairment in activities of daily living. Major stroke was defined as deficit that lasted more than 30 days and caused a change in lifestyle. TIA and other neurologic deficits lasting less than 24 hours, cervical and cranial nerve injury, or medically controlled angina were not stratified as end points. Since each perioperative outcome was correlated with the surgical procedure, and patients who underwent bilateral CEA were exposed to twice

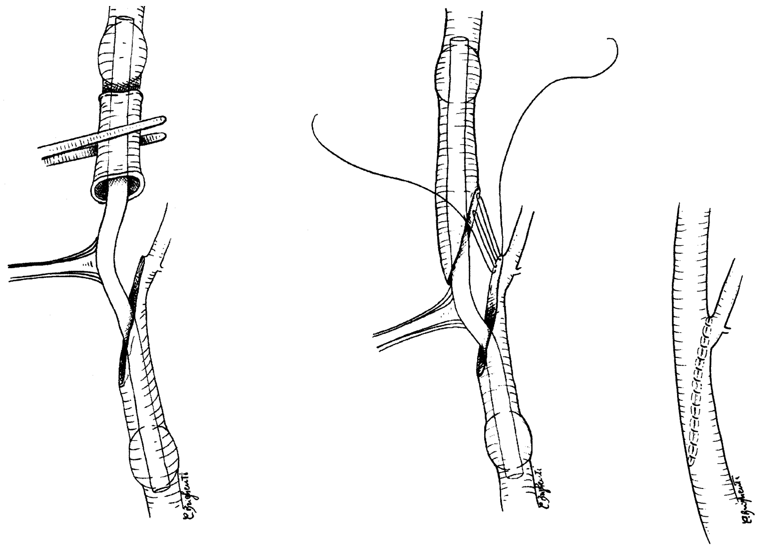

Fig 2. A, First the shunt distal arm is pulled gently downward into the normal internal carotid artery lumen, passing beyond the end point. Then the proximal arm is inserted in the large hole of the common carotid artery. **B,** The eversion is then reduced, and the internal carotid artery is reanastomosed to the common carotid artery with a running "parachute" suture. **C,** Shunt is removed before completing the suture line, arteries are clamped briefly, and suture line is completed.

the risk for stroke, many data were analyzed in terms of CEA, rather than patients.

Statistical analysis. All values are expressed as mean ± SD. Univariate analysis was performed on all clinical, morphologic, and procedural variables, with the Student *t* test (two-tailed) for continuous variables, and χ^2 analysis or the Fisher exact test (two-tailed), as appropriate, for categorical variables. Significance was assumed at $P < .05$.

Operating procedure. All eversion CEAs were performed by the same surgeon (E.B.), with the patient under deep general anesthesia, with cerebral protection involving continuous perioperative electroencephalographic (EEG) monitoring for selective shunting. Shunting criteria were based exclusively on EEG changes suggestive of cerebral ischemia. A Pruitt-Inahara shunt (Ideas for Medicine, Clearwater, Fla) was chosen in all cases, because it ensures adequate cerebral perfusion during the procedure and is easy and safe to anchor to the arterial walls by means of balloon pressure alone, with no need for clamps or vessel loops. In all CEA procedures, intravenous heparin (5000 U) was administered before carotid cross-clamping; blood pressure was maintained at average preoperative levels or slightly higher. Heparinization was never reversed with protamine. A drain was routinely placed, inserted through a separate stab wound. Completion imaging was not performed. All patients undergoing CEA remained in the recovery room for 2 to 4 hours, until blood pressure and neurologic status were considered acceptable, and then were transferred to the hospital ward. All patients with severe headache were observed for hyperperfusion syndrome, and hypertension was treated aggressively. Most patients were discharged 48 to 72 hours after CEA.

Eversion carotid endarterectomy. Standard exposure of the carotid bifurcation was achieved through a longitudinal neck incision paralleling the anterior border of the sternocleidomastoid muscle. After cross-clamping, the ICA was transected at the bulb (Fig 1). The external elastic membrane was then separated from the plaque circumferentially and everted in a cephalad direction. After removing the gross plaque, the distal aspect of the endarterectomy was directly visualized in a 360-degree view, and residual circumferential debris was addressed with fine forceps. The eversion was maintained until the endarterectomized surface had been freed of all medial fibers and loose fragments, leaving adherent distal intima, with no need for endpoint tacking sutures; the distal ICA lumen had been widened by means of a right-angled instrument; and the ICA had been dilated cephalad with graduated olive-type metal dilators, after removing the distal vascular clamp. It is only at this point that shunt placement is recommended in the event of EEG abnormalities consistent with cerebral ischemia. The eversion is then reduced, and the ICA is reanastomosed to the common carotid artery (CCA) by means of a running "parachute" 5-0 Prolene suture (Ethicon, Sommerville, NJ; Fig 2). If the ICA is redundant, as is often the case, this must be routinely corrected; the transected vessel is not reanastomosed in situ to the CCA, but is reimplanted end-to-side caudad on the lateral wall of the CCA, after cutting a large matching elliptic longitudinal window in the arterial wall (Fig 3). Extensive CCA disease may be man-

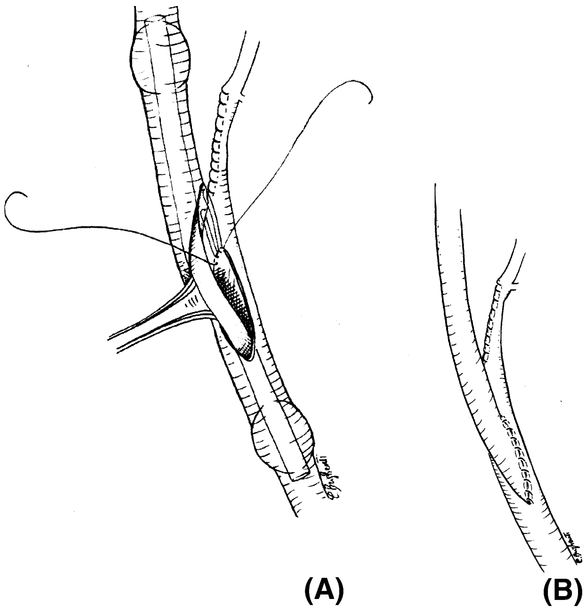

Fig 3. **A,** If the internal carotid artery (ICA) is redundant and a shunt is required, it is inserted in much the same way as in a nonredundant ICA, the only difference being that the proximal arm of the shunt is placed in the large new elliptic window in the common carotid artery (CCA; see text). The defect in the CCA is closed with a running over-and-over suture while the shunt is still inserted. **B,** The ICA is then reimplanted end-to-side on the lateral wall of the CCA.

aged through this opening or by further extending the longitudinal arteriotomy caudad (inasmuch as it is usually impossible to evert the CCA end point completely, the proximal plaque is transected sharply), then separately closing the CCA arteriotomy as far as the site of ICA reanastomosis or reimplantation on the CCA. The endarterectomy at the orifice of the external carotid artery is sharply transected flush with its ostium, with no attempt to blindly extend the endarterectomy more distal into the vessel. Patency is assessed by backbleeding.

RESULTS

Patient demographics and risk factors for atherosclerosis are summarized in Table I. In the shunt group, incidence of peripheral atherosclerotic disease or abdominal aortic aneurysm was statistically lower than in the no shunt group (31.5% vs 52.6%; $P = .01$). The indications for surgery in the two groups are presented in Table II. Incidence of stroke was significantly higher in the shunt group (34.1% vs 14.1%; $P = .003$), whereas incidence of amaurosis fugax, as an indication for surgery, revealed a trend toward a significant difference in the no shunt group (18.4% vs 7.3%; $P = .06$). Perioperative end points and early complications are listed in Table III. There was no perioperative death in this series. Overall, there were four ischemic perioperative strokes (4 of 624 patients, 0.6%), one in the shunt group (2.3% vs 0.5%; $P = .24$). All strokes, two major and two minor, developed in patients with symptoms and involved the anterior circulation, two in the hemisphere ipsilateral to the everted ICA. All patients awoke from anesthesia neurologically intact; the stroke occurred within the first 12 hours after surgery,

Table I. Patient demographics data

	With shunt		*Whithout shunt*		
	n	%	*n*	%	P
Patients	38	6.5	542	93.5	
Procedures	43	6.9	581	93.1	
Age (y)					
Average	71		71		
Range	54-88		43-93		
Male	24	63.1	389	71.8	.26
Hypertension*	25	65.8	321	59.2	.49
CAD	16	42.1	233	42.9	1.0
Smoking†	27	71.0	344	63.5	.38
Diabetes mellitus	13	34.2	180	33.2	.86
Hyperlipidemia‡	18	47.4	244	45.0	.86
POAD/AAA	12	31.5	285	52.6	.01

CAD, coronary artery disease; POAD, peripheral obliterative atherosclerotic disease; AAA, abdominal aortic aneurysm.
*Elevated blood pressure treated with medication.
†Defined by patient history.
‡Elevated cholesterol or triglyceride concentration treated with medication.

Table II. Indications for eversion CEA

	With shunt		*Without shunt*		
	n	%	*n*	%	P
Symptoms	29	67.4	369	63.5	.74
Transient ischemic attack	12	29.3	191	32.9	.61
Amaurosis fugax	3	7.3	107	18.4	.06
Stroke	14	34.1	82	14.1	.003
No symptoms	14	32.6	212	36.5	.74

Table III. End points and other complications

	With shunt (n = 43)		*Without shunt (n = 581)*		
	n	%	*n*	%	P
Early outcome					
Stroke	1	2.3	3	0.5	.24
Occluded internal carotid artery	0		0		
Patent internal carotid artery	1		3		
Death	0		0		
Cardiac complications	0		5	0.9	1.0
Respiratory complications	0		3	0.5	1.0
Nerve injury	2	4.6	31	5.3	1.0
Wound hematoma	1	2.3	7	1.2	.43
Late complications					
Recurrent stenosis	0		0		
Occlusion	0		1		1

while the patient was in the recovery room, where duplex US scans immediately demonstrated ICA patency. Contrast angiography of the carotid vessels, performed within 1 hour of urgent duplex US scanning, confirmed the noninvasive finding. Both major strokes, one in the shunted group, occurred in patients with a slightly diseased contralateral ICA and were probably related to peripheral embolization, because CT scans demonstrated an ischemic cerebral infarction in the territory of the middle cerebral artery. Both minor strokes were most likely due to hemodynamic reasons; one developed in the hemisphere contralateral to the ICA operated on ipsilateral to an occluded ICA. No significant difference was found in other complication rates between procedures with or without shunt insertion.

Mean follow-up was 52 months (range, 3-91 months) and was performed in all living patients. There was no recurrent stenosis in this series. One asymptomatic ICA occlusion was identified in the no shunt group, however, which is difficult to explain, inasmuch as the vessel appeared normal on previous duplex US scans.

DISCUSSION

For CEA to be beneficial in selected patients with and without symptoms, a low incidence of perioperative stroke is necessary.[23] Because technical errors still account for a large percentage of perioperative neurologic complications, and durability of CEA is affected by recurrent stenosis, due more to technical or local factors than to systemic factors,[24-27] the already low perioperative stroke rate and incidence of recurrent stenosis can clearly be further reduced by improving technical aspects of the surgical procedure. Although encouraging results, in terms of perioperative outcome and recurrent stenosis rate, have been reported with eversion CEA, many surgeons are still reluctant to consider this technique among their treatment options, especially because use of the shunt is presumed to be more cumbersome than with traditional CEA. The attitude toward shunting of many authors dealing with the eversion CEA procedure is controversial, and surprisingly little information is available in the medical literature on this crucial issue. While some recommend shunting to simplify the eversion, especially in cases of long-running plaque (downward traction on the shunt, serving as a mandrel, could facilitate the management of the distal endpoint[3,11,12]), others find shunt placement extremely awkward, preferring alternative means of cerebral protection and discouraging eversion CEA in patients in whom a shunt is required.[5,6,9,16] Finally, some reported a lesser need for shunting during eversion CEA, compared with standard CEA and primary or patched longitudinal closure, justifying the difference with the shorter cross-clamping time in the case of eversion CEA.[10,13,15,17] None of these investigators mentioned, however, whether and to what degree shunting affected perioperative morbidity in their series.

The present study shows that shunting with the eversion CEA procedure is feasible, and perioperative mortality and morbidity did not differ statistically in patients undergoing eversion CEA with and without shunting. These findings are consistent with those reported by Chang et al[14] in the only study in the recent medical literature specifically dealing with shunt use during eversion CEA. In an impressive series of 2724 eversion CEAs performed in 2233 patients over 5 years at Albany Medical College, the shunt was used in 112 procedures (4.1%), mainly in patients under cervical block anesthesia (103 of 112, 92%) and because of neurologic deterioration during cross-clamping (99 of 112, 88.4%). The combined stroke and death incidence for the shunt group was 2.7%, compared with 1.1% in the no shunt group. No death or stroke occurred intraoperatively in the shunt group. In addition, prolonged cross-clamping or shunting did not correlate with occurrence of neurologic complications, nor was there any correlation between ischemic time before shunting and postoperative neurologic deficits. No information was available, however, on patency or occlusion of the shunted vessels in patients with stroke.

Because eversion CEA is a rapid surgical procedure, when the onset of EEG changes consistent with cerebral ischemia are not immediate and the procedure is nearing completion, insertion of the shunt becomes superfluous, and this accounts for a lesser need to resort to shunting in this series (6.9%), despite the incidence of perioperative EEG abnormalities consistent with cerebral ischemia being higher.

When we started using eversion CEA at our institution in 1992, shunt placement appeared theoretically more difficult than with conventional CEA. With time, and as we gained experience with the eversion technique, shunt placement posed no particular problems. When EEG changes occur, we suggest inserting the shunt in the open ICA lumen, under direct vision, but only after the end point has been managed and the distal endarterectomy completed. These maneuvers usually take no more than 2 to 3 minutes, and are performed in the same fashion for long-running plaque, especially in the event of a redundant ICA. Moreover, because routine correction of concomitant ICA elongation (a common finding at the end of the plaque that becomes more evident once the plaque has been extracted) is essential to any carotid revascularization, to standardize the technique, even when shunting is needed, we preserve the entire length of the ICA with its original ostium and reimplant the vessel on a more caudad new side, unlike those authors who open the longitudinally ICA along its medial side or shorten the elongated vessel before reanastomosing it to the original hole on the CCA.[4-17]

That no recurrent stenosis was recorded in the present series shows that eversion CEA is a durable procedure, confirming the trend toward a statistically significant decrease in risk for recurrence observed during follow-up in comparison with conventional CEA.[7,10,12,17,18] Reanastomosis or reimplantation of the ICA in the CCA (two large arteries that serve to patch each other) simplifies the arteriotomy closure and prevents potential distal ICA narrowing (caused by a longitudinal primary or patched closure through or just beyond the critical end point), which seems to be the main cause of recurrent carotid disease.

Limitations of the study. The present study has the inherent drawbacks of a nonrandomized protocol. Because event rates were low (overall, 4 of 624 patients [2.3%]; 1 of 43 patients [2.3%] in the shunt group; 3 of 581 patients [0.5%] in the no shunt group), the relative lack of power did not permit definitive analysis. *P* values that failed to reach statistical significance for perioperative death and stroke, and recurrent stenosis between the two groups represent a type II statistical error, which might be overcome by increasing the sample size.

In conclusion, the perioperative stroke and death rates after eversion CEA were not modified by shunting in this series. Despite the natural initial perplexity prompted by a new maneuver that was seen as particularly cumbersome, shunt insertion during eversion CEA is now a standard aspect of our surgical procedure. Although we prefer selective shunting, the method described would, in our opinion, be equally suitable for routine shunting if the surgeon chooses to do so.

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