reported cases being managed in this manner. In one case, lobectomy was performed after bleeding was first controlled by transcatheter embolization.⁸

We have stressed that incidentally detected mediastinal bronchial artery aneurysms of any cause cannot be assumed to be stable, and in the light of the collected case histories wherein spontaneous rupture led to life-threatening bleeding, intervention should be favored, regardless of the presence or absence of symptoms. In addition, because of the variety of clinical pictures of ruptured bronchial artery aneurysms mimicking other vascular entities and the various mediastinal vessels causing confusion, the identification of the vascular nature of a mediastinal mass in hemodynamically stable patients should be mandatory to better guide the type of therapeutic approach.

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CEREBRAL EMBOLIZATION DURING TRANSMYOCARDIAL LASER REVASCULARIZATION

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Transmyocardial laser revascularization (TMLR) is a relatively new procedure used to treat patients with severe inoperable coronary artery disease.¹ During the course of the procedure, an epicardial carbon dioxide laser is placed on the heart. Discharges from the laser create transmural myocardial channels permitting the flow of oxygenated intraventricular blood into the ischemic myocardium. Laser penetration can be observed at the surface of the heart

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Table I. Results

Patient	TMLR pulses	Total emboli	Emboli/ pulse	Percent $CerSO_2$		
				Before	During	After
1	27	716	27			
2	44	*	*			
3	29	954	33			
4	44	1509	34			
5	15	159	11	65	65	67
6	22	238	11	66	65	68
7	18	637	35			
8	13	96	7			
9	16	350	22			
10	22	316	14	66	66	66
11	21	394	19	63	63	64
Median	23	350	22	65	65	66
Range	13-44	96-1509	7-35			

TMLR, Transmyocardial laser revascularization; $CerSO_2$, cerebral regional oxygen saturation measured by near-infrared spectroscopy (NIRS).

*TCD tape malfunction (no recorded signal could be reviewed); only patients 5, 6, 10, and 11 had NIRS performed.

Fig. 1. TEE image after a single TMLR pulse. The TEE shows opacification of the left ventricle with emboli after the TMLR pulse.

Fig. 2. TCD after a single TMLR pulse. The vertical deflections on the TCD record are the emboli flowing through the left middle cerebral artery after having been ejected from the left ventricle.

by intraventricular blood spurting out of the newly created channels, as well as by transesophageal echocardiographic (TEE) imaging of emboli within the left ventricle. Although their origin is not completely clear, these emboli are likely due to vaporization of myocardium and blood, as the laser pulse passes through the myocardium.² The effect on the brain of these emboli is largely unknown, although a recent report describes no effect on jugular

venous oxygen saturation during TMLR.³ The purpose of this study was to quantitate the amount of cerebral embolization and its effects on cerebral oxygenation as assessed by near-infrared spectroscopy (NIRS).

Methods. As part of a multicenter trial of TMLR efficacy, patients were studied after institutional review board approval and informed consent. After routine preoperative care including placement of standard invasive

monitors, general anesthesia was induced. After double-lumen endotracheal intubation, a TEE probe was positioned to allow imaging of the left ventricle and detection of intraventricular emboli as confirmation of the transmyocardial penetration of each laser pulse. Images were obtained with the use of a TEE Omniplane probe and Sonos 1500 echocardiography machine (Hewlett-Packard Company, Andover, Mass.). Images were recorded on videotape and analyzed on-line for the presence of intraventricular emboli produced by TMLR pulses. The laser used during the study was The Heart Laser (PLC Medical Systems, Inc., Milford, Mass.), an 800-watt carbon dioxide laser. Transcranial Doppler (TCD) assessment of the left middle cerebral artery was obtained (2 mHz pulsed-wave probe; 18 mm sample length, gated at depths of 45 to 55 mm) with the use of an automated emboli counter, with images recorded on videotape (Neurogard; Medasonics Inc., Fremont, Calif.). Off-line analysis by one of the authors (H.P.G.), using audio and video methods, confirmed the automated emboli count on the TCD videotape.

When equipment was available, cerebral regional oxygenation was determined by NIRS (Critikon 2020; Johnson & Johnson, New Brunswick, N.J.) With the use of a probe placed on the patient's left forehead.

No formal neurologic or neuropsychologic testing was performed, although, as part of the study protocol, patients were closely observed in the postoperative period by a research nurse who noted any deficits.

Results. Eleven patients (6 men and 5 women, aged 48 to 69 years) having TMLR were studied with TCD and TEE (Table I). The median number of TMLR pulses was 23 (range 13 to 44 pulses) with a median of 22 (7 to 35) emboli per pulse. Four patients also had continuous measurements of cerebral regional oxygenation by NIRS, which ranged from 63% to 68% and were not influenced by emboli count. The TCD recording and corresponding TEE frame after a TMLR pulse are shown in Figs. 1 and 2. No patients had any apparent neurologic sequelae from the procedure.

Comments. This study demonstrates that cerebral embolization occurs during TMLR and that the quantity of emboli is significant. During standard coronary artery bypass graft operations, TCD-detectable emboli (gaseous and particulate) number in the hundreds.⁴ Emboli during bypass grafting have been associated with cognitive deficits.⁴ However, NIRS failed to show any adverse effects of emboli on cerebral regional oxygenation during our TMLR study. Although these are preliminary data and the number of patients studied is small, the study confirms a previous report³ that describes no change in jugular venous oxygen saturation with embolization during TMLR. Inasmuch as cerebral regional oxygenation has been shown to correlate well with jugular venous oxygen saturation,⁵

our findings provide further supporting evidence that cerebral oxygenation is not affected during TMLR.

The reasons for there being a lack of change in NIRS measurements may be related to the regional sampling of this device. During a shower of emboli, it is possible that the region of the brain interrogated by NIRS may not receive sufficient emboli to affect cerebral regional oxygenation, or it may not be receiving any emboli at all. Another explanation may be the transient existence of gaseous emboli. Absorption may occur so rapidly that cerebral blood flow is preserved with no subsequent significant effect on brain oxygenation. This may be related to the gaseous² rather than particulate composition of the emboli, although even transient gaseous emboli are known to cause cerebral injury.⁶ It is possible that gaseous emboli are relatively benign in this setting of cardiac surgery not requiring cardiopulmonary bypass. However, gaseous emboli in the setting of standard cardiac operations in which cardiopulmonary bypass is used may be more significant. This difference may be related to the inflammatory response to cardiopulmonary bypass that predisposes the cerebral blood vessels to the harmful effects of air microembolism.⁷

Prospective neurologic (focal and cognitive) evaluation of patients subjected to TMLR is needed to reach definitive conclusions regarding the neurologic sequelae of this embolization.

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