SURGERY FOR CONGENITAL HEART DISEASE

EFFECT OF TRENDLENBURG HEAD POSITION DURING CARDIAC DEAIRING ON CEREBRAL MICROEMBOLI IN CHILDREN: A RANDOMIZED CONTROLLED TRIAL

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Objectives: We prospectively evaluated the effects of head position during cardiac deairing on the Doppler ultrasonography-detected cerebral microemboli in children and the association between the embolic counts and the clinical assessment of deairing.

Methods: Children requiring exposure of the systemic ventricle under cardiopulmonary bypass were randomized to Trendelenburg (-15°) and horizontal (0°) head positions during and after standard surgical deairing. Complexity of repair was categorized as follows: group I consisted of single simple lesions, and group II consisted of multiple complex lesions. Transcranial Doppler ultrasonography identified high-intensity transient signals in the right middle cerebral artery within the first 5 minutes after aortic declamping (release) and from this ending period until cardiopulmonary bypass termination (residual). Electrocardiographic alterations after deairing were documented. A predefined 5-point scale was used by the surgeon for blinded assessment of deairing.

Results: High-intensity transient signals were identified in 97% of 128 patients (aged 5 days to 17 years). The median total high-intensity transient signal count was 60 (25th-75th quartiles, 14-189). Head position or surgeon did not affect the rate of high-intensity transient signals ($P > .20$). During the residual interval, occurrence of HITS in group I was less than that in group II ($P < .05$), but there was no difference at release. The incidence of high-intensity transient signals and electrocardiographic alterations correlated with the clinical assessment of deairing ($P < .01$).

Conclusions: Trendelenburg head position as a complement of cardiac deairing in children does not decrease the cerebral microembolic load compared with the horizontal head position. The cerebral microembolic count and the occurrence of electrocardiographic alterations usually increases when the surgeon is less confident in the efficacy of deairing. (J Thorac Cardiovasc Surg 2001;121:3-9)

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This work was partially funded by a grant-in-aid from the Children's Hospital of Eastern Ontario Foundation.

Portions of this study were presented at the International Neurosonology meeting, Winston Salem, NC, 1997, and at the Canadian Cardiovascular Society meeting, Winnipeg, MB, Canada, 1997.

Received for publication April 4, 2000; revisions requested July 18, 2000; revisions received July 29, 2000; accepted for publication August 30, 2000.

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0022-5223/2001 \$35.00 + 0 12/1/111177

doi:10.1067/mtc.2001.111177

During cardiac operations in children, air may be introduced into the systemic ventricle. In an attempt to minimize air emboli into the systemic circulation, the surgeon performs cardiac deairing.¹ These emboli may be detected by using Doppler techniques in the carotid or middle cerebral artery during cardiopulmonary bypass (CPB) in children.^{2,3} Remarkably, these Doppler signals have been found to occur more frequently after aortic declamping and seem to be associated with residual intracardiac air.² Although the clinical implications of microemboli on the child's postoperative brain and myocardial function are not fully defined, cardiac deairing is important because residual air represents a source of cerebral and coronary artery microembolization and potential injury.

Methods that optimize cardiac deairing in children are desirable. In an attempt to maximize cardiac deairing, positioning of the patient's head in the Trendelenburg position has been suggested for use before aortic declamping.¹ It is proposed that the buoyancy during this position will cause bubbles to rise from dependent regions of the body and minimize the number of arterial bubbles going to the brain.^{4,5} This assumption is controversial because other reports^{6,7} have indicated that during heart ejection with normal cardiac output, the forces of buoyancy may be less than the force of blood flow. Consequently, the Trendelenburg head position (THP) may not preclude the distribution of arterial gas bubbles into the brain.

In this study we used a randomized controlled trial to test the hypothesis that THP during cardiac deairing in children would reduce Doppler ultrasonography-detected cerebral microemboli compared with the horizontal head position (HHP) after aortic declamping. Additionally, we evaluated the potential association between cerebral microemboli and the surgeon's assessment of deairing according to predefined criteria.

Methods

Design and population. After approval by our institutional ethics review committee, children undergoing cardiac operations and requiring exposure of the systemic ventricle were enrolled in this randomized controlled trial at our tertiary care center. Patients had standard deairing procedures performed by one of 2 surgeons and were randomized only to the position of the surgical table.

Randomization and allocation concealment. With the use of computer-generated random sequences prepared in advance, patients were randomly assigned to THP or HHP stratified by surgeon (A or B). Before the operation, the surgical table was calibrated with the use of a protractor system to 2 head positions: 0° (HHP) and -15° (THP). Surgeons remained blinded to the table position until 2 minutes before deairing. At 2 minutes before deairing, the experimental posi-

tion was maintained (HHP) or adopted (THP), followed by deairing. The experimental position was maintained until 5 minutes after aortic clamp release.

Transcranial Doppler ultrasonography. After intubation and before surgical incision, a unilateral 2 MHz Doppler probe (Medasonics, Inc, Fremont, Calif) was secured on the temporal window to continuously monitor blood flow velocities at the right middle cerebral artery. The Doppler waveforms were acquired (high band-pass filter, 150 Hz) through a Neuroguard-Plus system (Medasonics, Inc), and the composite video signal was transferred for storage through a hyperconverter system (PC Video Conversion Corporation, San Jose, Calif) into a VHS tape. High-intensity transient signals (HITS) were counted and identified on the stored waveforms by using their distinctive high-pitch chirping sound associated with a unidirectional disturbance of the Doppler waveform (time resolution, <300 ms; intensity, >3 dB), according to the guidelines of the International Consensus on Emboli Detection.⁸ Surgeons were unaware of the presence of HITS because the sound volume of the monitor was maintained at a low level. There was no difficulty in distinguishing acoustic artifacts (eg, electrocautery or tapping) from embolic signals because artifacts of this type usually generate bidirectional signals of large amplitude and higher frequency spectra or bidirectional, brief, low-pitch disturbances.⁹ If signals were difficult to identify because of an embolic burst, the HITS count was calculated as the quotient of dividing the duration of the burst by 50 ms.

Measurements. HITS were measured at 2 intervals: (1) release, or the HITS count within the first 5 minutes after the release of the aortic crossclamp, and (2) residual, which represents the count from the end of this 5-minute period until CPB termination. Subsequently, the total count of HITS was obtained by adding the results from these 2 measurements.

Surgical deairing. Air was evacuated from the aortic root through the cardioplegia cannula (DLP, Inc, Walker, Mich), which was located at or close to the highest point of the aorta. If the right side of the heart was closed, one of the caval snares was released, and ventilation was initiated. If a left atrial vent was present, it was temporarily turned off. Subsequently, the heart was gently compressed, and air was allowed to escape from the cardioplegia cannula. The patient's thorax was gently shaken to displace air from the pulmonary veins and continued until no further air was seen to escape from the cardioplegia needle. Then the final dose of cardioplegic solution was given (warm), and the left atrial venting was resumed at a low level (if used). A final check for air was usually made before aortic clamp removal, but handling of the heart was kept to a minimum at this stage.

If the right side of the heart was opened, the left atrial appendage was gently compressed, ventilation was initiated, and the cardioplegia site at the aorta was left actively bleeding until the heart started ejecting. Closure of the right atrium was often done after the release of the aortic crossclamp, and the left atrial vent (if used) and caval snares were removed after completion of right atrial closure.

Study subgroups. To account for differences in surgical complexity,³ we stratified the surgical procedures into group I (single simple lesions) and group II (multiple complex lesions). Group I included single septal defects (ventricular and atrial), aortic valvotomies, and mitral or aortic valve repairs, and group II accounted for mitral or aortic valve replacements, arterial switches, atrioventricular canal operations, redo operations, or the combination of atrial and ventricular septal defect repairs.

CPB management. Extracorporeal circulation was achieved with the use of a nonpulsatile pump flow (Stockert-Shiley, Toronto, Ontario, Canada) with a membrane oxygenator and an arterial filter. The pump priming solution was composed of an electrolyte solution (Ringer's lactate), albumin (25% or 5%), heparin (1000-5000 units), mannitol (0.5 g/kg), and sodium bicarbonate (15-25 mEq/L). Packed red blood cells or autologous blood and fresh-frozen plasma were added to the priming solution for most infants under 10 kg. The arterial PCO_2 during CPB was maintained between 30 and 40 mm Hg uncorrected for body temperature (ie, alpha-stat). Hypothermia was achieved by core cooling with cooled perfusates administered through the CPB machine. The perfusate temperature decreased by 5°C to 10°C below the patient's rectal temperature, and cooling was stopped when the target temperature was reached. During rewarming, the water temperature of the heat exchanger was maintained at 5°C to 10°C above the patient's rectal temperature until a maximum perfusate temperature of 38°C was achieved. In this study full pump flow at normothermia varied between 120 to 140 mL·kg⁻¹·min⁻¹ and 80 to 100 mL·kg⁻¹·min⁻¹ at moderate hypothermia (28°C-30°C).

Anesthetic management. When premedication was indicated, it consisted of oral midazolam (0.5 mg/kg). Induction was intravenous with sufentanil (0.5 µg/kg) plus propofol (0.5-1.5 mg/kg) or halothane. Anesthetic maintenance consisted of isoflurane (0.2%-0.8%) and sufentanil (0.2 µg·kg⁻¹·h⁻¹). During CPB, isoflurane was replaced by propofol (5-10 mg·kg⁻¹·h⁻¹) in a continuous infusion. Muscle relaxants were used as required. The electrocardiogram was continuously monitored. Electrocardiographic changes were documented only when these alterations were a cause of concern for the surgical team, when they persisted for 4 minutes or more, or when their duration was shorter but repeated at least twice during the time of heart ejection. The heart ejection was defined as the time at which a noticeable pulse was detected in the arterial line waveform after the release of the aortic crossclamp. ST alterations were characterized by a minimum 2-mm shift of the electrocardiogram ST segment. Ventricular fibrillation was only noted when rapid spontaneous conversion did not occur. In addition, end-tidal carbon dioxide, central venous pressure, transcutaneous oxygen saturation, inspired oxygen fraction, rectal body temperature, pump blood flow, mean arterial pressure (MAP), arterial blood gases, and hematocrit levels were all documented.

Clinical evolution. The patients were observed in the intensive care unit for neurologic complications (eg, seizures or prolonged unconsciousness). In case of any abnormal neurologic event, this was also documented by means of cranial

ultrasonography, electroencephalography, or computed tomographic scanning. The clinical chart of each patient was also reviewed to document these and other complications.

Assessment of deairing. Before the beginning of the trial, a consensus was obtained between the participating surgeons to design a 5-point scale for assessing the surgeon's confidence in cardiac deairing (see Appendix). Input for category definitions relied on their surgical experience and visualization of air in particular areas of the heart. At the end of the operation, the surgeon was asked to assess his confidence using this scale.

Statistical analysis. Patient demographics and physiologic parameters were summarized according to the complexity of repair (group I vs II) and the randomized head positions (THP vs HHP). We verified the absence of differences in the distribution of any patient's characteristics across the 4 subgroups by using a Kruskal-Wallis test for continuous variables (ie, age, pump flow and MAP). Similarly, a χ^2 test of no association between the 4 subgroups and a categorical variable (ie, electrocardiographic alteration) was used. The effects of complexity of repair and head position were evaluated by analysis of variance models (SPSS/PC; SPSS, Inc, Chicago, Ill),¹⁰ including factors for complexity, head position, surgeon (A or B), and the interaction between complexity and head position. The marginal effects of complexity and head position were derived after checking for interaction between these 2 factors (ie, least-square estimates and their 95% confidence intervals derived from the fitted analysis of variance models).

Results

Demographics. There were 128 cardiac deairing procedures performed between the 2 surgeons. Because children were randomized to the head position stratified by surgeon, this resulted in the following distribution of patients with respect to the complexity of repair: group I, 25 patients to THP and 33 to HHP; group II, 39 to THP and 31 to HHP. Table I summarizes the demographics and physiologic parameters for the 4 subgroups defined by complexity of repair and head position. In these subgroups the differences among patients' ages and weights, case distribution between surgeons, or the frequency of using blood as a component of the priming solution were trivial ($P > .25$).

Physiologic monitoring parameters. After surgical deairing, HITS were detected in 97% of all patients (age range, 5 days to 17 years). The median of the total count of HITS was 60 (25th-75th quartiles, 14-189). The majority of HITS occurred during the residual measurement (median, 30; 25th-75th quartiles, 7-135), but only 30% of the total count were identified during the release interval (median, 10; 25th-75th quartiles, 1-43). As expected, aortic crossclamp times and CPB duration were longer for more complex surgeries of group II compared with those in group I ($P < .001$). No

Table I. Demographics and physiologic parameters

	Group I (n = 58)		Group II (n = 70)		P value*
	THP (n = 25)	HHP (n = 33)	THP (n = 39)	HHP (n = 31)	
Age (mo)	40 (24-114)	21 (8-66)	12 (4-84)	24 (6-102)	.31
Weight (kg)	14 (10-26)	11 (6-18)	10 (5-21)	14 (5-27)	.31
HITS count, release	4 (1-17)	12 (1-40)	8 (2-49)	14 (3-72)	.65
HITS count, residual	23 (13-110)	14 (4-63)	44 (17-180)	37 (11-276)	.11
HITS count, total	83 (17-133)	45 (8-101)	53 (22-217)	80 (12-290)	.27
MAP (mm Hg), release	39 (37-52)	43 (37-50)	38 (32-45)	39 (36-48)	.42
MAP (mm Hg), residual	49 (41-55)	52 (45-57)	47 (40-53)	49 (38-55)	.27
Pump flow (L/min), release	1.7 (1-2.9)	1.4 (0.8-1.8)	1.2 (0.7-2.0)	1.3 (0.9-2.5)	.41
Pump flow (L/min), residual	1.5 (1-1.9)	1.3 (0.8-2.0)	1.3 (0.8-1.9)	1.5 (0.8-2.4)	.76
Temperature (°C), lowest	30 (28-32)	29 (26-32)	27 (25-28)	26 (25-28)	.001
Temperature (°C), release	32 (30-34)	31 (29-34)	30 (28-32)	30 (27-33)	.03
Temperature (°C), residual	35 (35-36)	35 (35-35)	35 (35-36)	35 (35-36)	.42
Surgeon A, patients (%)	10 (40)	13 (39)	22 (56)	19 (61)	.20†
Surgeon B, patients (%)	15 (60)	20 (61)	17 (44)	12 (39)	.20†
Electrocardiographic changes, patients (%)	6 (18)	4 (16)	9 (29)	12 (31)	.41†
Deaths, patients (%)	2 (6)	0 (0)	3 (10)	1 (3)	.32†

Values are median (25th-75th quartiles) or number of patients (percentage).

*Kruskal-Wallis test of equal effect across the 4 subgroups defined by complexity of repair and head position.

† χ^2 Test of no association between the 4 subgroups.

Table II. Effect of complexity of repair and head position on physiologic parameters and HITS

	Group I (n = 58)		Group II (n = 70)		Effect of complexity	Effect of head position	Interaction P value
	THP (n = 25)	HHP (n = 33)	THP (n = 39)	HHP (n = 31)			
HITS, release	32 (0-67)	34 (3-64)	40 (11-68)	65 (33-96)	20 (-13 to 52)	14 (-18 to 45)	.47
HITS, residual	86 (0-179)	71 (0-152)	131 (57-205)	208 (125-292)	90 (7-175)*	31 (-51 to 114)	.27
HITS, total	117 (4-231)	105 (6-204)	170 (79-261)	273 (171-375)	110 (7-213)*	45 (-56 to 147)	.26
MAP (mm Hg), release	42 (38-46)	44 (40-47)	40 (36-43)	41 (37-45)	-2 (-6 to 2)	1 (-2 to 5)	.85
MAP (mm Hg), residual	48 (45-52)	51 (48-54)	47 (44-50)	48 (45-51)	-2 (-5 to 1)	2 (-2 to 5)	.55
Deairing score	4.0 (3.7-4.2)	4.0 (3.8-4.3)	3.7 (3.5-3.9)	3.6 (3.5-3.8)	0.3 (-0.5 to -0.1)†	0.1 (-0.1 to 0.3)	.99
Temperature (°C), release	32 (31-33)	31 (30-32)	30 (29-31)	30 (29-31)	-2 (-0.4 to -2.5)†	-0.3 (-1.3 to 0.7)	.52
Temperature (°C), residual	35 (35-36)	35 (34-35)	35 (35-36)	35 (35-36)	0.1 (-0.2 to 0.4)	-0.1 (-0.5 to 0.2)	.71

Values are estimates (95% confidence intervals); least-square estimates from analysis of variance models include complexity of repair (group I or II), head position (THP or HHP), and surgeon (A or B) and an interaction term between the complexity and head position. The marginal effects of the complexity of repair and head position were meaningful because there was no significant interaction between these 2 factors (see last column of the table). Complexity of repair: group I, single simple lesions; group II, multiple complex lesions.

* $P < .05$.

† $P < .01$.

intergroup differences (defined by complexity of repair and head position) were identified as regarding pump flows, PCO_2 management, hematocrit value, or MAPs at either of the 2 measurements ($P > .20$, Table II).

Head position and complexity of repair. Table II illustrates the effects and interactions of the complexity of repair and head position on HITS counts and several of the monitoring parameters. The body temperature before rewarming and at the time of the release of the aortic crossclamp was lower in group II than in group I ($P < .05$). Additionally, subjects in group II usually had a significantly higher total count of HITS ($P = .04$). The increased HITS counts were only noted during the residual measurement ($P = .03$). There were no intergroup differences at the time of release

($P = .23$). Also, between-surgeon differences in deairing techniques as reflected on HITS counts were not observed ($P > .15$). There were no effects of the head position on the total or partial counts of HITS, MAP, pump blood flow, or deairing scores ($P > .20$).

Electrocardiographic alterations. Transient electrocardiographic alterations after cardiac deairing were detected in 27% of all cases. Although transient ST changes accounted for 61% of all electrocardiographic alterations, cardiac arrhythmias, such as ventricular fibrillations (25%) or atrioventricular blocks (14%), were also identified. Most of these electrocardiographic alterations spontaneously resolved during heart ejection (51%), but 29% persisted as cardiac rhythm disturbances (ie, varying degrees of atrioventricular

blocks), and 20% were followed by clinical signs of low cardiac output and myocardial ischemia. In 90% of the patients who manifested varying degrees of atrioventricular block, temporary sequential atrioventricular pacing was indicated. In contrast, in those children without declamping-related electrocardiographic alterations ($n = 93$), we found a 9% rate of subsequent cardiac arrhythmias that did not require sequential atrioventricular pacing. Although the rate of intraoperative electrocardiographic disturbances was identified to be equal ($P = .41$) between the 2 experimental table positions (THP, 25%; HHP, 23%), surgical procedures in group I were usually associated with a slightly higher rate (30%) of altered electrocardiography compared with those in group II (16%, $P = .09$).

Assessment of deairing. The median score of the assessment of cardiac deairing was 4 (25th-75th quartiles, 3-5). The complexity of surgical repair affected the clinical evaluation of cardiac deairing ($P = .01$). For example, deairing for patients corresponding to group II (see Table II) was usually scored lower compared with that of patients in group I ($P = .01$). A significant correlation was found between the clinical assessment of deairing and the total count of HITS ($\rho = -0.57$, $P = .001$). Moreover, an increased rate of electrocardiographic alterations was found in those patients in whom cardiac deairing was believed to be insufficient ($P = .01$). For example, deairing scores of 5, 4, or the combination of 3 and 2 were followed respectively by a 7%, 15%, and 51% rate of temporary intraoperative electrocardiographic changes. No association was found between pacemaker use and the clinical assessment of deairing ($P > .22$).

Clinical evolution. The average hospital stay for all survivors was 8 days (25th-75th quartiles, 4-9 days). Six patients died postoperatively as a result of myocardial ischemia and low cardiac output ($n = 4$), sepsis ($n = 1$), and renal insufficiency ($n = 1$). The most common complication in survivors was the presence of cardiac rhythm disturbances (16%), followed by pleural and pericardial effusions (5%), low cardiac output (3%), neurologic complications (3%), and otitis media (2%). Neurologic complications were associated with stroke ($n = 1$), seizures ($n = 2$), and phrenic nerve palsy ($n = 1$). One 3-month old infant with previous repair of a complete atrioventricular canal underwent a subsequent operation for repair of the left atrioventricular valve. During the operation, the total microembolic count was 145 (deairing, 4), and the postoperative evolution was followed by clinical and electroencephalography seizures. A computed tomographic scan was suggestive of multiple focal parieto-occipital areas of stroke. A 12-month-old infant with a previous Blalock-

Taussig shunt underwent repair of a ventricular septal defect and left pulmonary artery stenosis (total HITS count, 44). This child's evolution was followed by tonic-clonic movements, but the electroencephalogram only showed a global diffuse electrocortical slowing.

Discussion

Residual intracardiac air and extracorporeal circuits are believed to be the 2 most common sources of cerebral air microembolization during cardiac operations in children.^{2,3,11,12} Previous investigations^{2,3} have confirmed that children undergoing repair of congenital heart defects usually have the highest detection rate of cerebral microemboli after the release of the aortic crossclamp. This phenomenon is assumed to be related to the presence of residual intracardiac air.²

On the basis of our present findings, Doppler-detected microemboli after deairing of the heart in children were identified in 97% of our patients. In this study the use of THP as a means of maximizing cardiac deairing did not reduce the rate of cerebral microemboli compared with the use of HHP. Experimental studies^{6,7} indicate that under conditions of normal cardiac output, the forces of buoyancy are insufficient to counterbalance the forces of blood flow. Moreover, in vitro models suggest that during THP, the speed of bubbles increases in proportion to the diameter of the bubble in the direction of the blood flow.⁷ Consequently, it appears that THP does not preclude scattering of intracardiac microemboli.

Surgical deairing is believed to accomplish enough displacement of air bubbles from the inside cavities of the heart.¹ However, despite the best technically possible deairing, our study suggests that procedures free of microemboli were rare. We speculate 2 possible explanations for this phenomenon: either that a complete surgical deairing of the heart was difficult to achieve or that other embolic sources may also contribute to this rate of microembolization. Since their inception, extracorporeal circuits have been believed to constitute a potential source of microemboli.^{13,14} This situation has been suspected because small capillary and arteriolar dilatations have been identified in the brains of dogs undergoing CPB but not in those that have not been under extracorporeal circulation.¹⁵ Additionally, Doppler ultrasonography-detected microemboli during CPB in children have been found at the time the aorta was clamped, a maneuver that presumably minimizes those emboli originated from intracardiac sources.¹²

In our study individual techniques for deairing were comparable, as suggested by the absence of differences in the microembolic load found in patients operated on by the 2 surgeons. Moreover, repair of complex defects

appears to result in higher counts of microemboli after deairing when compared with simple single lesions. These findings support previous results³ suggesting that repair of multiple complex lesions may be associated with a higher count of microemboli during CPB. We speculate that the longer CPB times and the length and complexity of the operation usually associated with repair of multiple complex lesions may have a role on the higher rates of circulating microemboli. A striking finding in this investigation was the association between the assessment of cardiac deairing and the rates of microemboli or electrocardiographic alterations. The high incidence of temporary electrocardiographic alterations in patients with low deairing scores is intriguing because the presence of air in the coronary arteries was suspected. Although we believe that some electrocardiographic findings influenced the surgeon to assess his deairing score as low, a cause relationship with intracoronary air macroembolization was difficult to establish because other factors, such as surgical manipulation, myocardial reserve, temperature, and particularly the length or complexity of the procedure, have a role on these myocardial alterations during rewarming.^{16,17}

Limitations

Transcranial Doppler ultrasonography is sensitive to the presence of nonblood elements within the vascular lumen of major intracranial vessels.¹⁸ The higher reflectance of these elements is used to distinguish their signals from the blood spectra.¹⁹ Because the composition of emboli is relevant to the understanding of the mechanisms of brain injury,^{20,21} a limitation of this technique is that current Doppler systems are unable to distinguish among the nature or size of these signals.^{19,22}

We recognize that our stratification for the complexity of repair is subjective. It was expected to allocate complex and multiple defects, as well as redo cases, into a single group. This was based on the assumption that the presence of these defects or redo operations would make for more difficult deairing of the heart, as well as extending the duration of CPB. Moreover, the absence of a previous validation of our assessment of cardiac deairing may limit the strength of our associations.²³ In the absence of a previously established measure of deairing, creating a scale to assess subjective attributes requires us to relate the scale scores with some other marker, such as systemic air microembolization. Transesophageal echocardiography has been used to assess residual intracardiac air,²⁴ but it is invasive and expensive, and the system for quantifying microbubbles is complicated.^{21,24} We selected transcranial Doppler ultrasonography because it is noninvasive,

and the detection of microemboli is more precise, but it quantifies a small proportion of the total air microemboli ejected from the heart into the systemic circulation.^{18,21} Notwithstanding this argument, it is worth noting that our clinical scale for assessment of deairing has not been validated with other techniques. Although the selection of items included in the scale was derived from proper consensus between the participating surgeons, its scoring scheme is nonetheless arbitrary.

Microembolization of air and particulate debris into the cerebral circulation has been postulated as a potential cause of neurologic injury in adults,^{20,25} but the clinical significance of this phenomenon in children is not clearly established.² Although no detailed cognitive follow-up was done in our patients, the rate of gross neurologic deficits was low. The count of microemboli in cases with cerebral complications was not excessively high compared with that of other patients with even higher rates (>2000) who did not show any gross neurologic deterioration. A careful postoperative cognitive assessment in a more homogeneous surgical group would help to determine the clinical significance of these signals in children. In addition, the preference by our team to maintain the child's head slightly rotated limited our access for positioning a Doppler probe that would allow us to identify events on the contralateral side.

In summary, the THP as a complement of cardiac deairing in children does not decrease the cerebral microembolic rate compared with HHP. A surgical procedure free of cerebral microemboli after aortic declamping was rarely achieved. Our observations suggest that the microembolic count and the rate of electrocardiographic alterations increase for those cases in which the surgeon is less confident in the efficacy of deairing.

We appreciate the cooperation of our colleagues in the operating room and thank Carlos D. and David Rodriguez for clerical work.

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Appendix. Clinical assessment of cardiac deairing

Score	Description
5	Minimal possibility of air. Left side of heart kept full of blood at all times; no bubbles ever seen.
4	Air was in the heart but easily removed; no residual bubbles seen.
3	Considerable time to deair (longer than 5 minutes); large left atrium or pulmonary veins.
2	Considerable time to deair and small bubbles persisting; visible small amounts of coronary air seen after deairing is completed.
1	Obvious air in aortic root after declamping or massive entry of air into the circulation.