Title: INTRAOPERATIVE DETECTION OF VENOUS EMBOLISM WITH TRANSESOPHAGEAL COLOR DOPPLER IMAGING

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Introduction: Color Doppler imaging is a promising new development in the field of morphological and functional cardiac analysis.[1] This new technology based on the Doppler principle enables the real-time visualization of cardiac blood flow by superimposing colored flow information onto a two-dimensional (2D) echocardiogram. Using the transesophageal approach this new ultrasound method can be applied throughout surgery and allows continuous imaging and quantification of abnormal cardiac flows.[2] The aim of this study was to assess the ability of the transesophageal 2D color Doppler echocardiography (TCDE) to detect embolic events in the right heart during surgery and to compare the color Doppler technique with the conventional black and white transesophageal 2D-echocardiography (TEE) which has proven to be a sensitive and simple monitoring technique for the early intraoperative detection of venous embolisms.[3] Due to the high incidence of pulmonary embolic events during total hip replacement, this surgery is particularly suited for the comparitive evaluation of embolic monitoring equipment.

Methods: We studied 12 patients with transcervical femoral fractures (mean age 77±10, range 53-91 years) undergoing total hip replacement with the Charnly method using methyl methacrylate bone cement (Palacos®). Informed consent was obtained from all patients. General anesthesia was maintained with 66% nitrous oxide in oxigen and enflurane (0.5-1.5%). Ultrasonic monitoring was performed using a Hewlett Packard echo-Doppler unit (model 77020 CF). After induction of anesthesia and endotracheal intubation, the prototype of a new, commercially available (Hewlett Packard) gastroscope tipped with a phased-array transducer (64 elements, focal zone depth 15-80 mm) was introduced into the esophagus and positioned at a level where the right atrium and the inflow tract of the right ventricle could be visualized simultaneously. The color mode was adjusted to such a minute intensity that only the circulating emboli appeared in color during an embolic event whereas the basic background image remained black and white. Alternate use of the color and the black and white mode during an embolic event allowed a comparitive evaluation of both forms of imaging. All images were continuously recorded on videotape and graded by two independent blinded observers. One of the following scores was assigned to each embolic event: 0 = no detection, 1 = sparse, 2 = moderate, 3 = pronounced. When using TEE this assessment was based on the density of the contrasted emboli in the right heart. With the color Doppler mode scoring was based on an estimation of the color area correlating with embolic events. The following parameters were measured simultaneously throughout surgery in all patients: S_aO_2 by pulse oximetry (Novametrix 500®), P_ETCO_2 by capnometry (Normocap®, Datex), mean arterial pressure (MAP) measured noninvasively (Dinamap®, Critikon) and heart rate (ECG). The scores from both methods were statistically compared by means of the chi-square test. A $p<0.05$ was considered significant. Data are presented as mean values ± SD.

Results: During insertion of the acetabulum prosthesis (phase A) as well as during implantation of the femur prosthesis (phase B), we regularly observed transitory color Doppler signals in the form of "colored clouds" in the right atrium and ventricle of all patients. By switching to the black and white TEE mode during this event we observed that the "color clouds" correlated with particles resembling microemboli and varying in density. Statistical analysis showed that both methods were equally sensitive and capable of detecting the higher incidence of severe embolic events (score 2 and 3) occurring in phase B (figure 1). The distribution of the total scores revealed that TEE can distinguish between the severity grades of embolic events more accurately than TCDE ($p<0.001$). Aside from the microembolic events, both techniques also detected "flake"-like structures (up to 5 cm in length) passing through the right heart in 10 patients. As a result of the color, these macroemboli were easier to identify, but not as clearly contoured as in the TEE mode. The transitory hemodynamic and respiratory responses accompanying all embolic events are summarized in table 1.

Discussion. The study demonstrates that this new color flow imaging technique can be used to image embolic events passing the right heart. Intraoperative use of TCDE is a relatively noninvasive and simple method for the early detection of venous embolism during surgery. The two ultrasound methods have an equally high sensitivity, superior to conventional noninvasive monitoring methods. Compared to TEE, the new technique particularly facilitates the qualitative detection of embolism due to the contrasted visualization of the emboli as sudden "color events" on a black and white background. However, a better quantitative assessment of venous embolism is not possible with the color method. The results indicate that a differentiation between the embolic severity grades as well as estimation of the particle dimension is a little more accurate with TEE.

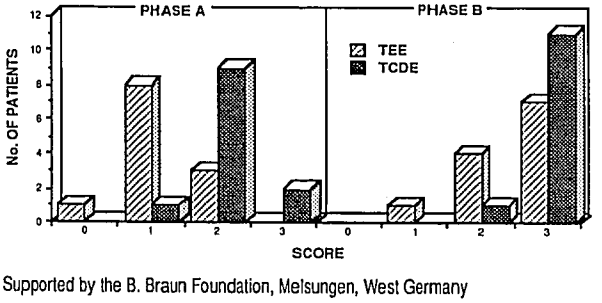
References:

1. Miyatake K et al.: Clinical applications of a new type of real-time two-dimensional Doppler flow imaging system. Am J Cardiol 54:857, 1984
2. Hillel Z et al.: Intraoperative color Doppler imaging of cardiac blood flow. Anesthesiology 65:A169, 1986
3. Roewer N et al.: Detection of venous embolism during intraoperative monitoring by two-dimensional transesophageal echocardiography. Anesthesiology 63: A169, 1985

Table 1 Frequency of hemodynamic and respiratory changes after venous embolism during hip replacement in 12 patients

Changes (Δ)	PHASE A		PHASE B	
MAP ≥ 20 mmHg	n = 6	(103 ±19 → 77±23)	n = 9	(103±18 → 70±15)
HR ≥ 10/min	n = 2	(62 ± 9 → 73± 9)	n = 6	(77±10 → 93± 9)
S_aO_2 ≥ 3%	n = 2	(97 ± 2 → 89± 9)	n = 5	(96± 3 → 88±10)
P_ETCO_2 ≥ 3 mmHg	n = 4	(37± 3 → 32± 4)	n = 4	(36± 2 → 31± 3)
no changes	n = 3		n = 1	

Figure 1 Severity grades of embolic events detected by using TEE and TCDE



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