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Intraoperative Transesophageal Echocardiography in High Risk Patients Undergoing Noncardiac Surgery: A Brief Overview and A Case Presentation.

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The value of transesophageal echocardiography (TEE) in cardiac surgery is well proven[1]. TEE is evolving as a perioperative monitoring and diagnostic tool in noncardiac surgery as well, especially for the treatment of high-risk cardiovascular patients. Its significance lies in that it is the only direct method for imaging and evaluating heart function. Calculation of ventricular volumes and ejection fraction of the left ventricle (LV), evaluation of contractility, assessment of valvular anatomy and function, and inspection of extracardiac structures are feasible through TEE[2-5]. This is of particular importance in haemodynamically compromised patients, when an efficient, relatively safe and fast approach is required.

A variety of pathological conditions can now be diagnosed intraoperatively, thanks to the application of perioperative TEE. Infective endocarditis affecting the valvular and perivalvular structures and leading to abrupt hemodynamic changes or embolic events may be accurately diagnosed through TEE[6]. Patients with a high suspicion of endocarditis presenting for noncardiac surgery may be diagnosed using the Duke criteria, and the potential risk for complications (abscess, cusp rupture, perforation, fistulae) can be estimated[7]. TEE can diagnose pulmonary embolism, either directly, when a significant number of emboli or thrombi is visualized in the pulmonary artery system, or indirectly, when the signs of right ventricular overload or dysfunction are demonstrated[8]. This is very useful during orthopedic surgery, when during the phase of reamming of the bone, a massive embolic load is introduced into the circulation[9]. Cardiac tamponade may be diagnosed when TEE imaging of the pericardial cavity shows the presence of fluid, blood or thrombi. In addition, TEE reveals any compromise of the cardiac function, and aids in the therapeutic aspiration of the pericardial collection. The safety of the transcutaneous pericardiocentesis is increased by continuously visualizing the position of the instruments used in relation to the heart. Postoperatively, possible relapses are easy to detect10]. Aortic dissection or aneurysm, especially in trauma patients with multiple injuries, can be rapidly diagnosed by intraoperative TEE, while the patient is otherwise stabilized. The dimensions of the aorta and the anatomy of its lumen (presence of flailing formations after a dissection) are most accurately shown with two-dimensional TEE, and the false or true lumen of the dissection are easily differentiated with Doppler ultrasound[11]. The endovascular repair of aneurysms of the ascending, descending aorta and of the arch may become much easier and associated with signi-

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ficantly less radiation for the patient and the medical personnel, with the use of intraoperative TEE. The positioning of the endovascular device is continuously visualized, and potential postoperative complications, such as leaks, are easy to diagnose and accurately follow-up[12]. The presence of atheromatous plaques in the major vessels, and especially in the aorta, is a signifycant problem, which may cause embolism[13]. The risk of emboli from atheromatic plaques may be assessed in vascular patients undergoing noncardiac surgery using intraoperative TEE. The potential use of anticoagulant or other therapeutic strategies, are based on the position, size and characteristics of the atheromatous lesion [14]. Pleural effusions and hemothorax are life threatening conditions and are usually detected in trauma patients, or postoperatively. The use of TEE will assist in the early diagnosis and treatment. An infrequent but useful application of TEE is the intraoperative monitoring of the hepatic veins and the inferior vena cava during the removal of infiltrating renal tumors that extend up to the liver[15]. TEE has also been used during liver surgery (transplantation) for the hemodynamic monitoring of patients.

COMPLICATIONS OF TEE

Although TEE is considered a noninvasive diagnostic and monitoring tool, it is not free from complications ranging from minor to life threatening. The overall morbidity is 0.2%, whereas mortality is around 0-0.004%, with no difference between patients receiving sedation or general anesthesia. The complications may be divided according to system affected: cardiopulmonary (mostly in patients under sedation) and gastrointestinal. The cardiopulmonary events account for 0.03-0.16% of the complications and are mostly hypoxia (due to oversedation or inadvertent endobronchial intubation if the patient is under general anaesthesia), bronchospasm, acute respiratory distress (often leading to death), non-sustained ventricular ectopy and tachycardia, atrioventricular block, angina pectoris and transient atrial fibrillation. The gastrointestinal events account for 0.2% of the complications and are the most common ones. These include odynophagia after TEE examination, dental injury, upper gastro-intestinal bleeding which may lead to death, esophageal lacerations and esophageal perforation resulting in pneumothorax, hydropneumothorax, subcutaneous emphysema or appearance of the probe in the surgical field[16-18].

Another important issue when referring to conscious patients is intolerance, which may lead to study interruption and ranges from 0.1 - 2.0 % of the patients.

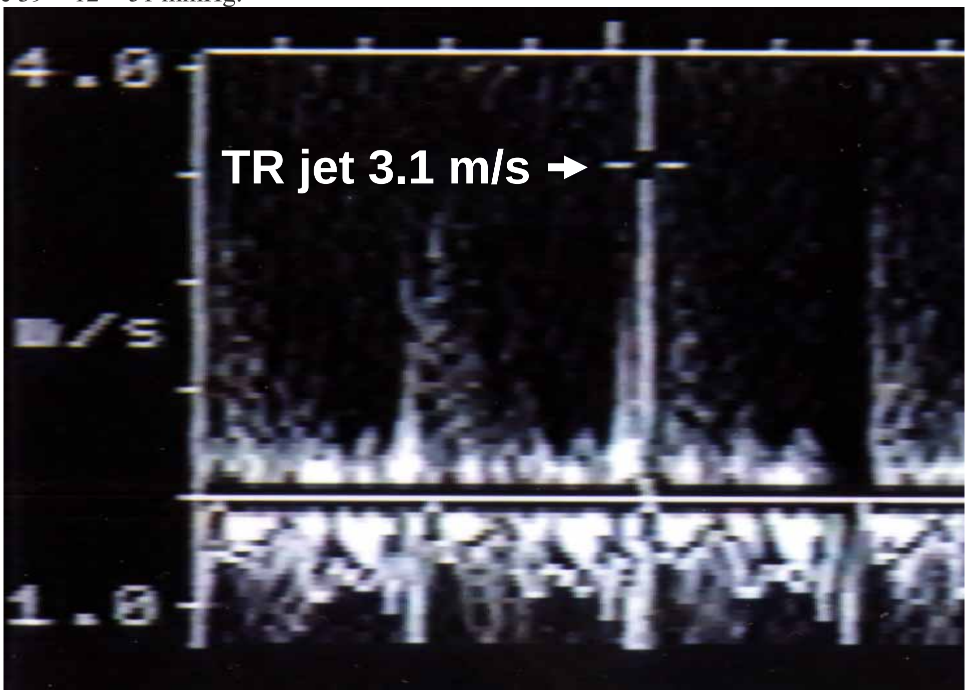
There are a number of issues referring to the intraoperative use of TEE. It is proven that the cost/effect balance favors its use for cardiac surgery, and actually there is a lack of trained personnel to cover the needs of cardiac surgical procedures. The use of TEE has not yet been proven to be cost effective in non-cardiac surgery, even in high risk patients. However, there are definite data showing that whenever TEE has been used by trained personnel, it has changed the treatment plan effectively. Another unresolved issue is that of training, and whether someone dedicated to it should perform all the TEE examinations. Although this would be ideal, it has been shown that the learning curve is rather steep and the training effective. The variability of the results between different observers is higher among anesthesiologists, in comparison with cardiologists, but this probably represents only lack of training. Some are concerned about the decreased vigilance and attention of the anesthesiologists in the operation room, but this has not been proven[19-20].

The motivation of anesthesiologists to use TEE intraoperatively is high, not because of the probable reimbursement, but of the new possibilities it offers for diagnosis and treatment.

CASE PRESENTATION

A 24 year old gravida 4, para 3 woman, 31 weeks pregnant, was admitted for worsening

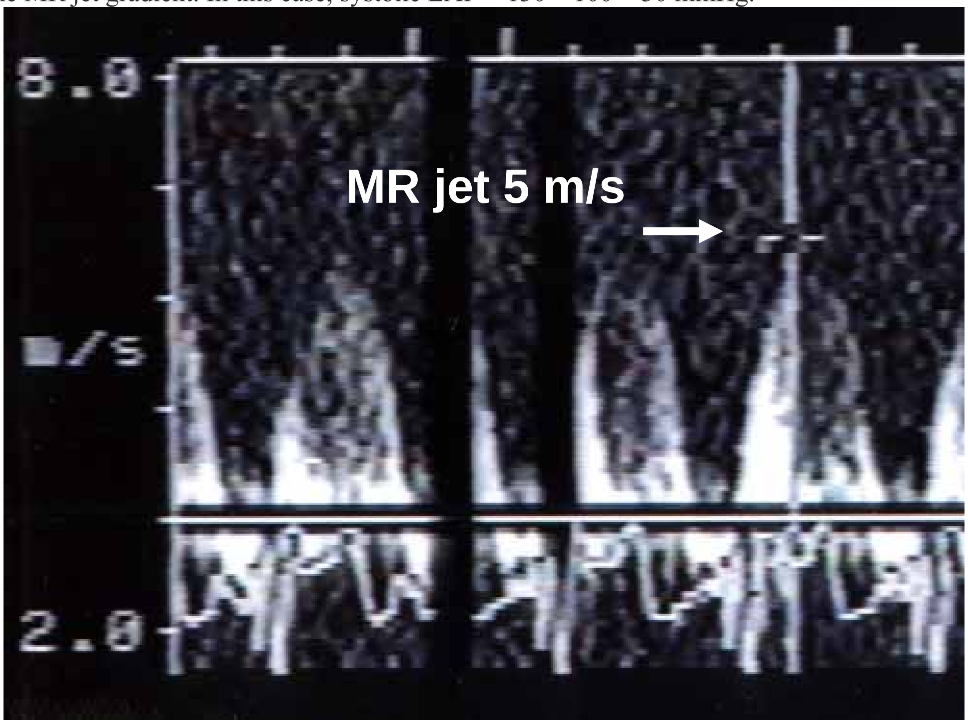
Figure 1. Continuous-wave Doppler recording of the TR jet. According to the Bernoulli equation (pressure gradient (PG) = 4 × velocity^2), there is a pressure gradient of $4 \times 3.1^2 = 39$ mmHg across the tricuspid valve at systole. Therefore, the RV systolic pressure is equal to the sum of RA pressure and the PG of TR. Assuming there is no pulmonary artery stenosis, and knowing that the RA pressure was measured to be 12 mmHg, the PA systolic pressure is calculated to be 39 + 12 = 51 mmHg.



heart failure. Five months after the birth of her last child, two years before this admission, she was diagnosed with post-partum cardiomyopathy. Her past medical history was also significant for mild asthma. Her ECG showed complete LBBB. Her current medications included furosemide and aspirin. Apart from a brief admission for medication adjustment at the start of this pregnancy, she continued to work.

At the time of admission, a trans-thoracic echocardiograph (TTE) showed a dilated left ventricle (LV) with an ejection fraction of approximately 21%, global severe hypokinesis, and preserved right heart function. Four weeks later, at 35 weeks gestation, the heart function had deteriorated further. Repeat TTE demonstrated further dilation of LV, with an EF of 11% and "4++ mitral regurgitation" (MR). She was scheduled for an elective cesarean section. The pre-anesthetic evaluation revealed a Malampati class III airway, free range of motion and normal thyromental distance in an orthopneic (3 pillows) patient. Chest auscultation revealed normal lung sounds, and a loud holosytolic murmur over the cardiac apex. Her vital signs were: blood pressure 90/65 mmHg, pulse rate 100 bpm, SpO_2 94% on room air. The primary cardiologist suggested a regional anesthetic technique with invasive hemodynamic monitoring (arterial and pulmonary artery catheters). The obstetric anesthetist considered the potential for a difficult airway, along with the existing precarious hemodynamic status (dilated cardiomyopathy with poor LV function, as documented by the TTE and vital signs) and opted for a general endotracheal anesthetic with an arterial pressure line. The potentially detrimental complications associated with the insertion and presence of a pulmonary artery catheter in an orthopneic patient with an existing LBBB prompted the use of intraoperative transesophageal echocardiography (TEE) for monitoring of heart function and hemodynamics.

Figure 2. Continuous-wave Doppler recording of the MR jet. There is a pressure gradient of 100 mmHg between the LV and LA at systole (4×5^2). If the systolic arterial pressure is known (from the arterial line: 130 mmHg), and assuming the absence of any aortic valve stenosis, the LA pressure is the difference between the arterial systolic pressure and the MR jet gradient. In this case, systolic LAP = 130 – 100 = 30 mmHg.



The patient was brought to the operating room and a lumbar epidural catheter was placed for postoperative pain management. An arterial line was placed in the left radial artery. Immediately after endotracheal intubation, a TEE probe was placed in the esophagus and a 9 French introducer was inserted in the right internal jugular vein. The general anesthetic was maintained with isoflurane in oxygen until delivery of the baby. TEE examination confirmed the presence of severe, global LV hypokinesis with an EF of 10%, 3+ central MR, and moderately decreased right atrial (RA) and ventricular (RV) function, with 2+ tricuspid regurgitation (TR). The central venous pressure was calculated as 12 mmHg. The systolic pulmonary artery pressure (SPAP) was estimated to be 51mmHg (figure 1), and the mean systolic left atrial pressure 30 mmHg (figure 2). The Doppler examination of the LV filling revealed an elevated diastolic LV pressure (figures 3 and 4). No major improvements in heart function were noted after delivery of the baby: the MR remained at 2-3+ and SPAP decreased to 40mmHg. The LV function remained unchanged. Upon completion of surgery patient was extubated in the OR and was transported on monitor to the coronary care unit. There, a right heart catheter was placed without incident, for post-operative management.

The above brief case presentation illustrates the invaluable contribution of the intraoperative TEE in the hemodynamic evaluation and management of a patient with significant cardiac disease[21] undergoing non-cardiac surgery. While a regional anesthetic might have been equally effective, and as safe to perform, one should not disregard the potential complications of the hemodynamic monitors (pulmonary artery catheter) that would have been required. It was obvious to us, that the preoperative placement of a pulmonary artery catheter in an orthopneic patient, with a potentially difficult airway and an existing LBBB, might have exposed our patient to unnecessary risks.

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Figure 3. Evaluation of LV diastolic function.

The transmitral pressure gradient during diastole (the difference between LA and LV pressures) determines the LV filling pattern. Pulsed-wave Doppler recording of the transmitral flow (TMF) demonstrates an early (E) velocity, corresponding to the rapid filling phase, and a late (A) velocity, corresponding to LV filling during atrial contraction. Faster relaxation results in an increased gradient and filling in early diastole. With normal aging there is slowing of LV relaxation, and E and A become equal (E/A ratio ~ 0.75-1.5) around the sixth decade of life. In disease states, relaxation abnormalities occur early, and the inability of LV to fill in early diastole significantly affects the rapid filling phase, resulting in a compensatory increase in filling with atrial contraction (impaired relaxation, E/A <0.75 – panel A). These patients depend on a relatively slow, sinus rhythm and adequate preload to maintain normal cardiac output. When the chamber compliance is decreased (stiff myocardium, increased pericardial restraint, increased volume), the associated increased LA pressure results in proportionally greater filling in early diastole, resulting in a "normal" E/A pattern (pseudonormal pattern – panel B). With disease progression, there is severe decrease in compliance, which leads to a further increased LA pressure, and results in a very high E/A ratio (restrictive pattern – panel C). These patients become more sensitive to alterations in filling volume, with marked increases in filling pressures with relatively small increases in volume.

Pulmonary venous flow (PVF) Doppler echocardiography provides additional information for the evaluation of diastolic function. The flow from the pulmonary veins to the LA occurs during systole (LA relaxation, and downward motion of the mitral annulus produce a systolic [S] velocity), and diastole (an early filling phase velocity [D] and a retrograde (rA) velocity during atrial contraction). When the LA pressure is normal, LA filling occurs primarily in systole (S/D >1 – panel A). However, with increasing LA pressure, the LA filling occurs during diastole (S/D <1 – panels B and C). Both TMF and PVF flow parameters are volume dependent and follow a parabolic pattern. Comparison of the atrial contraction events (A and rA waves) provide additional information: rA >35 cm/s, rA duration >30 ms of A duration, or rA duration > A duration predict an LA pressure >15 mmHg, usually found in moderate and severe diastolic dysfunction.(Ref: [Rossvoll O, Hatle LK. Pulmonary venous flow velocities recorded by transthoracic Doppler ultrasound: relation to left ventricular diastolic pressures. J Am Coll Cardiol 1993;21:1687-96)

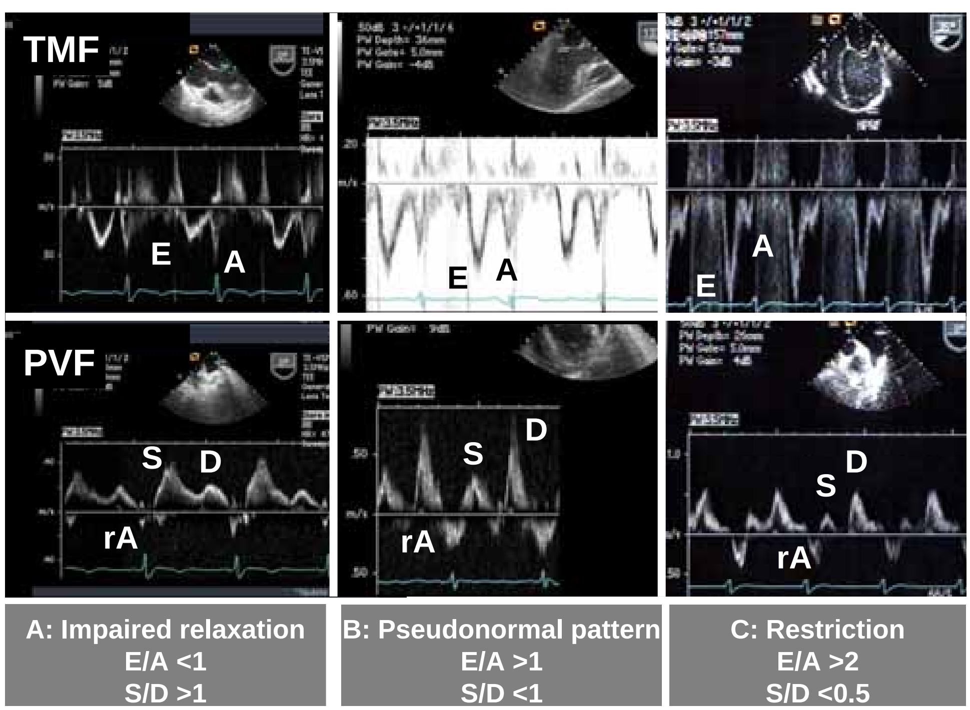

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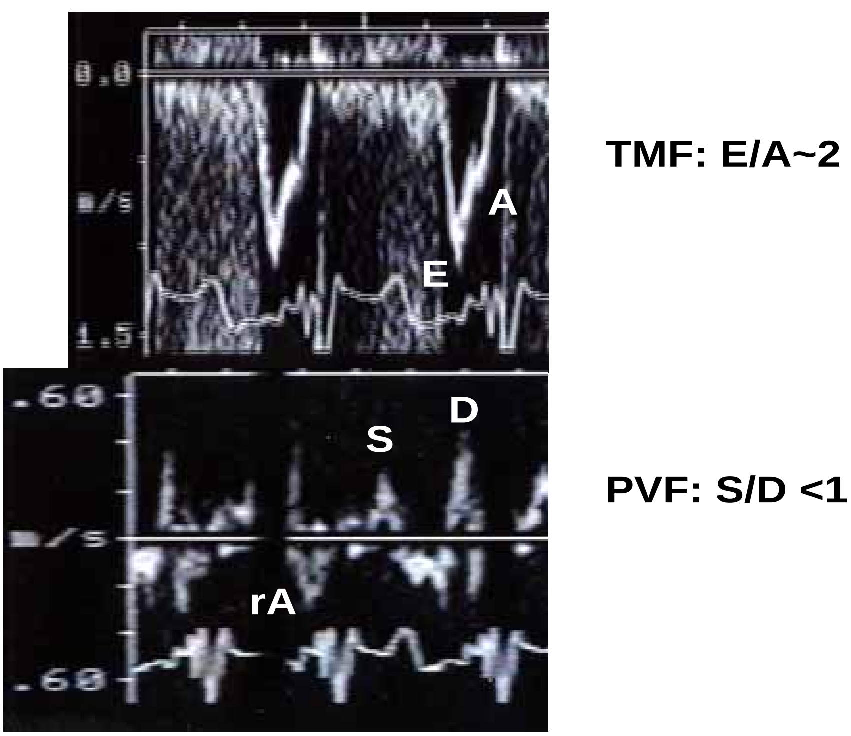
Figure 4. The recorded TMF and PVF velocities were consistent with a restrictive pattern, as was expected from the preoperative evaluation of LV function. The PVF rA velocity was around 30 cm/s with a longer duration than of TMF-A wave. The estimated LA pressure was >15 mmHg.



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