Acute diastolic dysfunction in thoracoabdominal aortic aneurysm surgery

[Dysfonction diastolique aiguë pendant l'opération d'un anévrysme aortique thoraco-abdominal]

Ashraf Fayad MD,* Homer Yang MD,* Howard Nathan MD,* Gregory L. Bryson MD,* Claudio S. Cina MD†

Purpose: To report transesophageal echocardiographic (TEE) findings consistent with intraoperative acute diastolic dysfunction in a series of patients undergoing thoracoabdominal aortic aneurysm (TAAA) repair.

Methods: A series of nine consecutive patients underwent TAAA repair with intraoperative TEE monitoring. Surgical repair was performed with the adjunct of a left atrio-femoral bypass. Invasive arterial and venous pressures were monitored. Intraoperative TEE was utilized to assess the diastolic function before, and during aortic cross clamping. Diastolic dysfunction was defined as a mitral inflow pulsed wave Doppler (E: A ratio) < 1.

Results: All patients demonstrated an E: A ratio > 1 (1.3 ± 0.08) before aortic cross clamping. During cross clamp, the E: A ratio decreased to < 1 (0.75 ± 0.05) in six of nine patients consistent with diastolic dysfunction. The three patients who did not develop E: A changes were receiving ß-blockers preoperatively. Patients with diastolic dysfunction were treated with nitroglycerin infusions, which resulted in restoration of their E: A ratios > 1 (1.2 ± 0.09). Three of the patients with intraoperative diastolic dysfunction developed postoperative myocardial infarction.

Conclusions: Chronic diastolic dysfunction is a well-known entity. This report describes acute diastolic dysfunction, which was observed frequently in patients undergoing TAAA during aortic cross clamp. Further research is required to confirm this phenomenon and determine its possible association with increased postoperative cardiac morbidity.

Objectif *: Présenter les résultats de l'échocardiographie transœsophagienne (ETO) compatibles avec une dysfonction peropératoire diastolique aiguë chez une série de patients opérés pour un anévrysme aortique thoraco-abdominal (AATA).*

Méthode *: Neuf patients consécutifs ont subi la réparation d'un AATA sous monitorage peropératoire avec ETO. Une dérivation auriculo-fémorale gauche et un monitorage endovasculaire des pressions artérielle et veineuse ont été utilisés. L'ETO peropératoire a servi à évaluer la fonction diastolique avant et pendant le clampage de la crosse aortique. La dysfonction diastolique était une onde Doppler pulsée d'entrée mitrale (ratio E : A) < 1.*

Résultats *: Tous les patients ont démontré un ratio E : A > 1 ($1,3 \pm 0,08$) avant le clampage de la crosse aortique. Pendant le clampage, le ratio E : A a baissé à < 1 ($0,75 \pm 0,05$) chez six des neuf patients, indiquant une dysfonction diastolique. Les trois autres patients avaient reçu des ß bloquants préopératoires. La dysfonction diastolique a été traitée avec une perfusion de nitroglycérine, ce qui a restauré le ratio E : A > 1 ($1,2 \pm 0,09$). Trois des patients qui ont présenté une dysfonction diastolique peropératoire ont subi un infarctus du myocarde postopératoire.*

Conclusion *: La dysfonction diastolique chronique est bien connue. Nous avons décrit une dysfonction diastolique aiguë observée souvent pendant le clampage de la crosse aortique chez des patients opérés pour un AATA. Il faut encore confirmer ce phénomène et déterminer son lien possible avec la hausse de la morbidité cardiaque postopératoire.*

From the Department of Anesthesia,* University of Ottawa; and the Department of Surgery,† McMaster University, Hamilton, Ontario, Canada.

Address correspondence to: Dr. Ashraf Fayad, Department of Anesthesia, University of Ottawa, B309, 1053 Carling Avenue, Ottawa, Ontario K1Y 4E9, Canada. Phone: 613-761-4940; Fax: 613-761-5209; E-mail: afayad@ottawahospital.on.ca

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DIASTOLIC dysfunction is the inability of the left ventricle (LV) to relax, an energy-requiring step which is related to intracellular calcium metabolism.[1] It is a well-recognized problem in patients with high afterload, e.g., hypertension or aortic stenosis. "Diastolic dysfunction is present in virtually all patients with systolic dysfunction; however, diastolic dysfunction can be present without systolic dysfunction."[2] Nearly half of patients with congestive heart failure have diastolic dysfunction despite a normal ejection fraction,[3] suggesting that the left ventricular systolic and diastolic function may be uncoupled.[4,5] As a result, many traditional monitors of cardiac systolic function may not reflect the extent of diastolic dysfunction. In thoracoabdominal aortic aneurysm (TAAA) repair, there is a significant increase in the afterload upon application of the aortic cross clamp. The acute impact of the aortic cross clamp on the left ventricular diastolic function has not been described previously.

Echocardiography plays a unique role in allowing the non-invasive measurement of intracardiac flows and velocities to assess diastolic function. An analysis of echocardiographic Doppler mitral inflow (E: A ratio), pulmonary venous flow, deceleration time (DT) and isovolumic relaxation time allows assessment of the severity of diastolic dysfunction.[6] Intraoperative measurement of diastolic function during TAAA repair using transesophageal echocardiography (TEE) is a challenging task. This is due to the patient's position, the busy and limited environment at the head of the patient, and the rapid resuscitation maneuvers required at the time of aortic clamping. In this study, a simplified approach was used to assess diastolic function by measuring the mitral inflow waves (E: A ratio) before, and immediately after application of the aortic cross clamp.

The purpose of this study was to document the possible occurrence of acute diastolic dysfunction secondary to aortic cross clamping, identified by TEE in patients undergoing TAAA repair.

Methods

This was a prospective cohort study of consecutive patients undergoing TAAA repair in a tertiary vascular centre with TEE monitoring between March 2003 and June 2004. After obtaining Research Ethics Board approval and patient consent for publication of personal health information, demographics, characteristics, medications, type of aneurysm (Crawford Classification),[7] comorbid diseases and the preoperative cardiac investigations were recorded. Intraoperative changes in systolic and diastolic function, as assessed by TEE, were documented during aortic cross clamping.

There were two anesthesiologists for each case, one performing the intraoperative TEE, the other attending to the anesthetic. All patients received a standard volatile anesthetic technique supplemented by sufentanil 3 to 5 $\mu g \cdot kg^{-1}$ *iv*. Hemodynamic measurements included pulmonary arterial pressure (PAP), pulmonary capillary wedge pressure (PCWP), central venous pressure (CVP), right radial artery (proximal) pressure, right femoral artery (distal) pressure, and intracranial pressure measured through a lumbar cerebrospinal fluid drainage catheter.

Patients were positioned in the right lateral decubitus position. A left bronchial blocker was inserted to facilitate one-lung ventilation. Surgical exposure was achieved through a posterolateral thoracoabdominal incision and excision of the fifth rib. The left atrium was cannulated through the left upper pulmonary vein while the left femoral artery was cannulated with a femoral cannula to complete the left atrio-femoral bypass (LAFB) circuit. The normothermic LAFB flow was adjusted to maintain a proximal mean pressure of 60 mmHg. Details of the sequential repair with the LAFB, anesthesia, transfusion technique and cooling procedure for renal preservation have been reported elsewhere.[8–11]

A Vivid 3® echocardiography device (GE Medical Systems, Mississauga, ON, Canada) was used in this study. The TEE probe was inserted in the supine position after induction of anesthesia. Midesophageal and transgastric views were obtained in the right decubitus position. A transgastric short axis view was used to monitor the LV volume status and to detect any wall motion abnormalities. Mitral inflow waves were measured in the midesophageal four-chamber view using the conventional pulsed wave Doppler, by sampling at the level of the open mitral leaflets in diastole. The E: A ratio was measured manually before aortic cross clamping, at the time of application of the cross clamp, and every three minutes for 15 min, thereafter. The colour flow Doppler was used to help align the sample. The sweep speed was 50 $mm \cdot sec^{-1}$. A valsalva maneuver up to 30 cm H_2O was applied whenever E: A ratio was > 1 to rule out a "pseudonormal" pattern. In keeping with the Canadian consensus guidelines,[12] diastolic dysfunction in this study was defined as the inversion of the E: A ratio (E: A ratio < 1). Patients with impaired LV relaxation were treated with nitroglycerin infusion started at 2 $\mu g \cdot kg^{-1} \cdot min^{-1}$ and titrated to maintain the proximal mean arterial pressure > 60 mmHg. All patients were followed during the course of their stay in the intensive care unit (ICU).

TABLE I Demographics and comorbidities of patients with acute diastolic dysfunction

Patient	*Age (yr)*	*Sex*	*Aneurysm type*	*Medications*	*Comorbidities*	*2-D ECHO*	*Stress test*	*Coronary angiogram*
1	58	M	Type II	Ramipril	HPT, DM	NLV	N	N
2	71	M	Type II	Furosemide	HPT, PVD	NLV	N	N
3	66	F	Type I	HCT	HPT	NLV	N	N
4	74	F	Type II	Atenolol	Angina, HPT	LV II	N	N
5	66	M	Type I	Ramipril	Angina, HPT	NLV	N	N
6	65	F	Type I	Ramipril	HPT, DM	NLV	N	N
7	58	M	Type II	Metoprolol	HPT, PVD	NLV	N	N
8	79	F	Type II	Furosemide	HPT	LV II	N	N
9	69	M	Type II	Metoprolol	HPT, DM	NLV	N	N

M = male; F = female; HCT = hydrochlorothiazide; HPT = hypertension; DM = diabetes mellitus; PVD = peripheral vascular disease; LV = left ventricle; 2D-ECHO = assessment of LV function on two dimensional echocardiogram; N = normal; NLV = normal ventricular function; LV II = grade II ventricular function.

TABLE II Measurement of intraoperative hemodynamics and outcomes

Patient	*MAP mmHg*		*CVP cm H_2O*		*MPAP mmHg*		*PCWP mmHg*		*ADD*	*MI*
	PRE	*AXC*	*PRE*	*AXC*	*PRE*	*AXC*	*PRE*	*AXC*		
1	68	62	17	18	26	27	19	19	Yes	Yes
2	74	66	19	18	29	29	21	20	Yes	Yes
3	68	60	19	19	29	30	17	19	Yes	No
4	68	66	18	18	25	26	17	17	No	No
5	70	64	21	22	27	26	19	17	Yes	Yes
6	62	68	17	17	25	25	16	15	Yes	No
7	64	60	17	16	30	29	19	21	No	No
8	64	68	19	21	26	27	22	19	Yes	No
9	70	62	20	19	30	30	23	22	No	No

MAP = mean arterial pressure measured in the right radial artery; CVP = central venous pressure; MPAP = mean pulmonary artery pressure; PCWP = pulmonary artery pressure; PRE = pressure following institution of one lung ventilation and prior to aortic cross clamp; AXC = pressure following application of aortic cross clamp; ADD = E: A ratio < 1.0 following application of aortic cross clamp; MI = tropinin T > 0.5 $\mu g \cdot L^{-1}$.

A 12-lead electrocardiogram was preformed on arrival at the ICU and repeated as required if ischemia was suspected. Troponin-T levels were measured immediately after ICU admission and every six hours for 48 hr, thereafter. A myocardial infraction was diagnosed when troponin-T levels exceeded 0.5 $\mu g \cdot L^{-1}$.

Continuous variables were described with mean and standard deviation. Dichotomous variables were described as proportions.

Results

Data from the nine consecutive patients who underwent TAAA repair with TEE monitoring are reported. There were five males and four females, aged 58 to 79 yr (mean 67 ± 5). Three had a type I aneurysm (involving the descending thoracic aorta) and six had a type II aneurysm (involving the entire descending aorta). Three patients were on ß-blockers, three were taking angiotensin converting enzyme inhibitors, and three were receiving diuretics. Preoperatively, all patients had LV function grade I (ejection fraction > 60%) or II (40–59%) with no significant coronary artery disease as determined by echocardiography and coronary angiography (Table I). With intraoperative TEE, it was possible to confirm the correct position of the left atrial cannula and measure mitral inflow E: A ratios in all patients. No technical difficulty was encountered in obtaining midesophageal or transgastric echocardiography views. However, some manipulations were required to obtain the relative views due to the lateral decubitus position.

Before aortic cross clamping, all patients demonstrated a normal pattern of mitral inflow with an E: A ratio > 1 in the four-chamber and the two-chamber midesophageal views (mean 1.3 ± 0.08). The E: A ratio remained unchanged with the application of the valsalva maneuver. Three to ten minutes after application of the aortic cross clamp, six patients (three females and three males; three with type I and three with type II TAAA) experienced a decrease in their E:

FIGURE 1 Mitral inflow pulsed wave Doppler midesophageal four-chamber view in a patient who underwent thoracoabdominal aortic aneurysm repair and developed diastolic dysfunction during cross clamping.

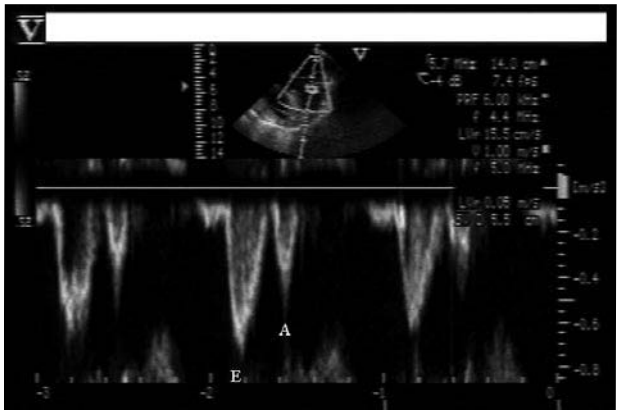

FIGURE 1A Normal mitral inflow pulsed wave Doppler (E: A ratio > 1) before aortic cross clamping.

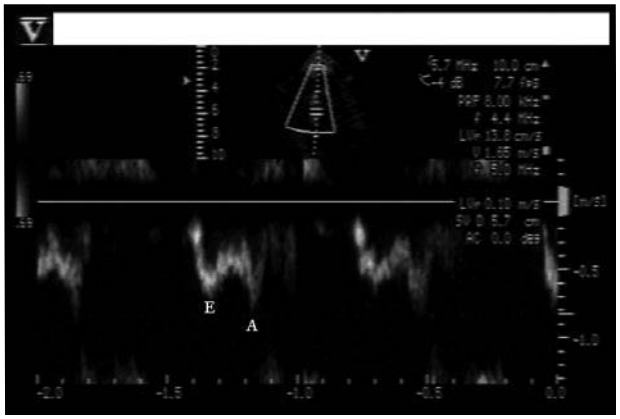

FIGURE 1B Decreased mitral inflow pulsed wave Doppler (E: A ratio < 1) during cross clamping.

A ratio (0.75 ± 0.05) consistent with acute impairment of LV relaxation. There were no changes on PAP, CVP, or PCWP during the episodes of diastolic dysfunction (Table II). In addition, no wall motion abnormalities were detected during the acute diastolic dysfunction. Figure 1 provides an example of acute diastolic dysfunction occurring during aortic clamping.

Patients with impaired LV relaxation were treated with nitroglycerin infusions, which resulted in normalization of the E: A ratio (1.2 ± 0.09) within two to seven minutes after initiation of the infusion. A graphical summary of E: A ratio changes is displayed in Figure 2.

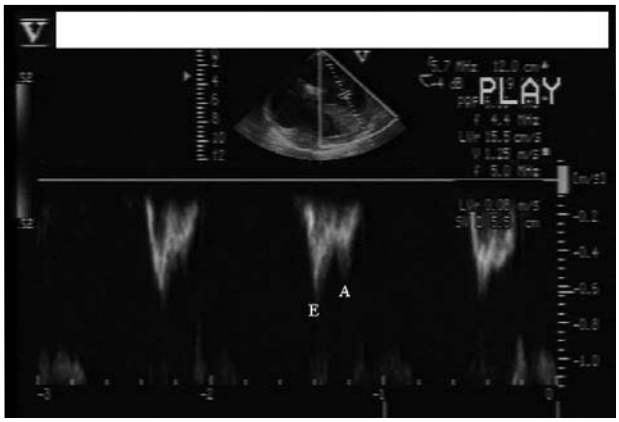

FIGURE 1C Restoration of mitral inflow pulsed wave Doppler (E: A ratio) with a nitroglycerin infusion during cross clamping.

Three of the patients with intraoperative diastolic dysfunction developed postoperative myocardial infarction based on increased serum troponin-T levels > 0.5 $\mu g \cdot L^{-1}$. None of the three patients who were receiving ß-blockers preoperatively developed intraoperative diastolic dysfunction or postoperative myocardial infarction.

Discussion

In this cohort study, six of nine consecutive patients undergoing TAAA repair had a decrease of mitral inflow E: A ratio to < 1 during aortic cross clamp, consistent with acute diastolic dysfunction. This phenomenon was sudden in onset and reversible with nitroglycerin infusion. There were no changes in systolic function according to the echocardiographic LV transgastric images. In an animal study, diastolic LV dysfunction was induced by the application of the aortic cross clamp resulting in an elevated afterload in healthy hearts. This was determined by an elevation of the LV end-diastolic pressure and alteration in the LV pressure – internal diameter relationship.[13]

Diastolic function is assessed with Doppler echocardiography by measuring several parameters including mitral inflow waves, pulmonary venous flow, isovolumetric relaxation time (IVRT) and the DT. A typical Doppler transmitral blood flow velocity profile has a biphasic pattern. An initial peak velocity (E-

wave) occurs during early diastolic filling, and a later peak flow velocity (A-wave) occurs during atrial systole. Normally, the flow velocity during early diastole is greater than that during atrial systole (E: A ratio is greater than 1). In patients undergoing TAAA repair with LAFB, the mitral inflow pattern was maintained while the pulmonary venous flow Doppler pattern was disturbed. Turbulent flow resulting from cannulation of the left atrium or one of the pulmonary veins renders measurements of pulmonary venous flow invalid. Because of the busy environment at the patient's head and the amount of time required to manipulate the TEE probe to obtain the respective diastolic parameters in such a short period, IVRT and DT were not measured in this study. We chose to simplify our approach and measure the transmitral flow (E: A) ratio as an indicator of diastolic function.

Recently, colour M-mode and Doppler tissue imaging have emerged as new modalities to provide a complementary role in the assessment of diastolic function. However, Doppler mitral inflow velocity derived variables remain the cornerstone of the evaluation of diastolic function.[14]

In patients with diastolic dysfunction, a previous study demonstrated four abnormal filling patterns based on E: A ratio and other diastolic parameters:[15] mild or impaired relaxation pattern (E: A ratio < 1), moderate or pseudo normal pattern (E: A ratio > 1 < 1.5), reversible severe or reversible restrictive pattern (E: A ratio > 1.5) and fixed severe or fixed restrictive pattern (E: A ratio > 1.5). Diastolic dysfunction seen in this study was either a mild or impaired relaxation pattern in response to aortic cross clamping.

Previous echocardiography studies have suggested that diastolic dysfunction may contribute to perioperative hemodynamic instability and adverse outcome following cardiac surgery.[16] In this series, three of six patients with intraoperative diastolic dysfunction developed postoperative myocardial infarction, suggesting that the new onset of diastolic dysfunction may predict adverse outcome. It is unclear if the resolution of diastolic dysfunction associated with nitroglycerin infusion represents improved coronary blood flow or changes in ventricular loading conditions.

Preoperative diastolic dysfunction is prevalent among cardiovascular surgical patients[17] and identifying high-risk vascular patients preoperatively may allow for the institution of prophylactic therapeutic strategies. It is of interest that acute diastolic dysfunction was absent in all three patients taking ß-blockers in the present study. Further research is required to determine a possible association between ß-blockade and the absence of diastolic dysfunction.

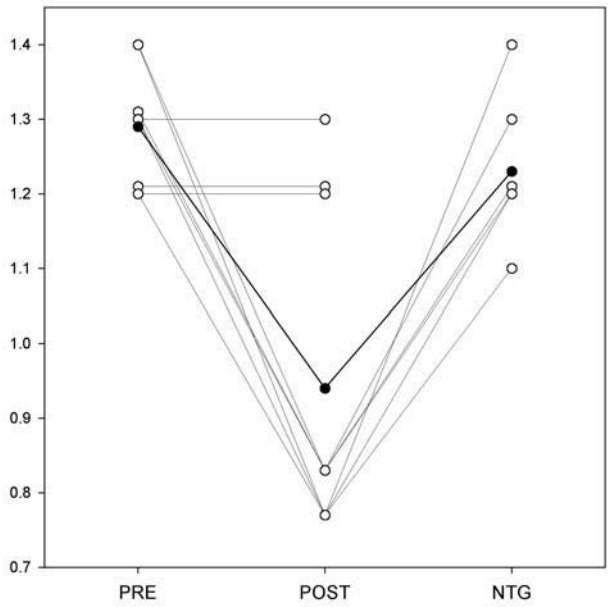

FIGURE 2 Changes in the mitral inflow pulsed wave Doppler (E: A ratio) in the nine patients who underwent thoracoabdominal aortic aneurysm (TAAA) repair. Pre: before aortic cross clamping, post: during aortic cross clamping and NTG = with the nitroglycerin infusion. The dark dots represent the mean of the E: A ratios in patients with diastolic dysfunction during cross clamping.

While chronic diastolic dysfunction is a well-known entity, limited information is available regarding acute diastolic dysfunction. In this study, conventional Doppler mitral inflow velocities were used to measure diastolic function. This is the first report of a new onset, reversible E: A ratio < 1, identified by TEE during aortic clamping in TAAA repair. Further studies using all diastolic parameters in addition to the newer Doppler techniques, which are less sensitive to intraoperative preload changes, will be needed to confirm this phenomenon. The prognostic significance of intraoperative acute diastolic dysfunction and the potential influence of perioperative ß-blockade are intriguing, and warrant further observational and interventional research.

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