

Intraluminal Projection of Descending Thoracic Aorta and Intraaortic Balloon Pump Catheter Examined by Transesophageal Echocardiography in Patients Undergoing Coronary Artery Bypass Surgery

Kazumasa ORIHASHI¹⁾ and Yasu OKA²⁾

1) *The First Department of Surgery, Hiroshima University School of Medicine, 1-2-3 Kasumi, Minami-ku, Hiroshima 734, Japan*

2) *Department of Anesthesiology, Albert Einstein College of Medicine/Montefiore Medical Center, 1300 Morris Park Avenue, Bronx, New York, U.S.A. 10461*

ABSTRACT

The thoracic descending aorta (DTA) was examined in 57 patients undergoing coronary artery bypass grafting (41 men and 16 women: 63.0 ± 10.6 years old) using two-dimensional transesophageal echocardiography. An intraaortic balloon pump (IABP) was instituted in ten patients. A short-axis view of DTA was examined for intraluminal projection from the diaphragm level to the aortic arch level. In a frozen-frame image, the area and the height of the projection at each clockwise direction was measured. Four patients with preoperative insertion of an IABP catheter were excluded from the analysis. Seventy projections were found in 40 of 53 patients (75.5%), most frequently found at the 3 to 6 o'clock position. The tip of the IABP catheter was also located in the area between 3 and 6 o'clock of the aortic lumen in 6 of 10 patients. In one case, the area of projection was reduced from 1.1 cm^2 to 0.7 cm^2 . In two of four patients with preoperative institution of an IABP catheter, projections were found near the catheter tip.

Both intraluminal projections and IABP catheter tip were most commonly located in the same region of the DTA, suggesting a possible dislodging of the projection while advancing the catheter. This was demonstrated in one case. The catheter tip may damage the aortic intima and/or cause a formation of abnormal projection. We conclude that intraoperative examination of DTA in addition to routine monitoring can provide useful information which is helpful for minimizing complications at the time of insertion of an IABP catheter.

Key words: *Aorta, Transesophageal echocardiography (TEE), Intraaortic balloon pump (IABP)*

An increasing number of high risk patients are now undergoing coronary artery bypass grafting (CABG), and the use of the intraaortic balloon pump (IABP) is relatively common. However, complications related to insertion of an IABP catheter are not uncommon, including ischemia of the lower extremities, thrombotic embolism, and aortic dissection^{3,8)}.

We have routinely used two-dimensional transesophageal echocardiography (TEE) during cardiac surgery for decision-making and monitoring of cardiac function, because it provides useful information of cardiovascular events. In addition, TEE depicts the descending thoracic aorta clearly and can be used to examine aortic dissection or aortic aneurysm^{4,5,14)}. In CABG patients, we have often found abnormal intraluminal projections in the descending aorta ("projection"), possibly indicating atheromatous change and/or mural thrombus, but not detected prior to surgery. Moreover, we recently reported that the IABP catheter can be visual-

ized clearly with TEE and the insertion technique can be evaluated intraoperatively¹⁰⁾. The purpose of this study is therefore: 1) to find out the incidence of intraaortic projections in CABG patients and 2) to examine the clinical relevance of those findings at insertion of the IABP catheter.

SUBJECTS AND METHODS

1. Subjects

After approval from an institutional research committee, informed consent was obtained from all patients. Upper gastrointestinal disease was not present in any patients. Examination was carried out with routine monitoring of cardiac function during surgery. TEE was performed in 57 consecutive patients (#1 to #57) undergoing CABG (41 males and 16 females, age; 63.0 ± 10.6 years, mean \pm SD). The number of diseased coronary arteries (stenosis in more than 70%) was one in 9 patients, two in 28 patients, and three in 20 patients. Thirty-four patients (59.6%) had a history of hypertension; ten

patients (13.5%) had diabetes mellitus; six patients (10.5%) suffered cerebrovascular attack; and carotid bruit was heard in three patients (5.3%). IABP was instituted in ten of 57 patients. In four patients, the catheter was inserted preoperatively and in six patients it was inserted intraoperatively in the post-bypass period.

2. TEE technique

After induction of anesthesia and endotracheal intubation, a TEE probe (ESB-37LR, 3.75MHz, Toshiba, Tokyo, Japan) was inserted into the esophagus and connected to an echocardiographic system (SSH-65A, Toshiba). The gain setting in B mode was determined in each patient to optimize the image of the heart and aorta. All TEE images were recorded with a VHS videotape recorder (AG-6300, Panasonic, Osaka, Japan) for subsequent image analysis.

A short-axis view of the descending thoracic aorta was obtained by rotating the TEE probe counter-clockwise from the three-chamber view, which was usually visualized with the probe tip positioned at 30 to 35 cm from the incisors (Fig.1). At this level, the vertebral body appeared at the right side of the aorta on the screen, depicted as an arch of strong echo with acoustic shadow. First, the probe was advanced to the level of the diaphragm where the aorta shifted rightward and downward on the screen. This usually occurred with the probe tip located at 40 to 45 cm from the incisors. The probe was then slowly withdrawn until the aorta gradually shifted leftward (returning to the original direction) at about the level of diaphragm. It then shifted rightward on the screen with the appearance of the long-axis view of aortic arch. The latter occurred at 20 to 25 cm from the incisors. The left pulmonary veins were depicted adjacent to the aorta on the 7 to 8 o'clock position: the left lower pulmonary vein at the level of the three-chamber view and the left upper pulmonary vein at the level of the left atrial appendage¹¹. The descending thoracic aorta was subdivided into three portions by its relation to the pulmonary veins: 1) proximal portion: between the levels of aortic arch and the left upper pulmonary vein; 2) pulmonary vein portion: between the levels of the left upper and left lower pulmonary veins; 3) distal portion: between the levels of the left lower pulmonary vein and diaphragm (Fig.2). The distance from the incisors to the probe tip was not used because it varied depending upon the habitus of the patient¹². The abdominal aorta and aortic arch were excluded from the analysis since the extent of visualization varied among individuals.

3. Interpretation of intraaortic projection detected by TEE

The intraluminal projection was defined as a protrusion into the aortic lumen from the bright layer of the aortic wall which is presumed to be smooth and circular. When a protrusion was found, a

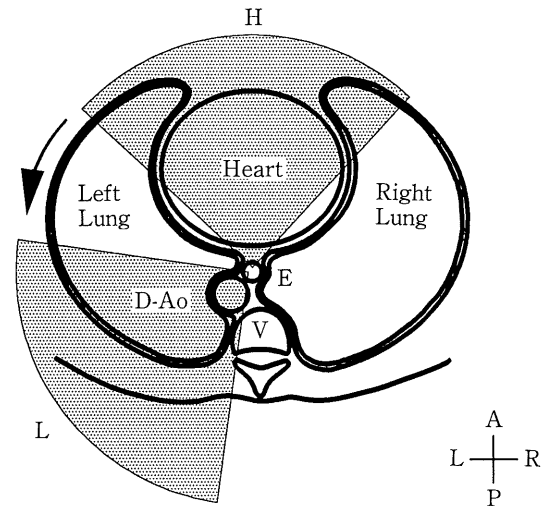


Fig. 1. Schematic illustration of images obtained by TEE, with special reference to technique for visualizing the descending thoracic aorta. H: area for the heart; L: area for the left pleural cavity and descending aorta; E: esophagus; V: vertebra; D-Ao: descending thoracic aorta.

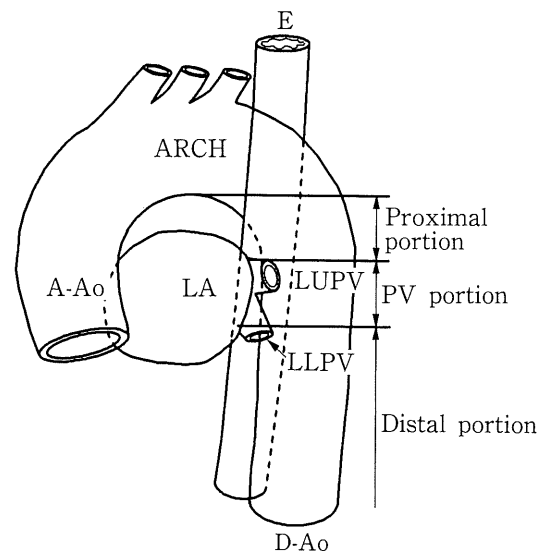


Fig. 2. Schematic illustration of three portions of the descending thoracic aorta, subdivided by its relation to the pulmonary veins. E: esophagus; A-Ao: ascending aorta; LA: left atrium; LUPV: left upper pulmonary vein; LLPV: left lower pulmonary vein; D-Ao: descending aorta.

frozen-frame image was selected which depicted the largest cross-sectional area of the protrusion. The area (cm^2) was measured using the on-line computer of the echocardiographic system (Fig.3), manually tracing the projection along its contour and the inner border of the bright echogenic layer of the aorta. Occasionally, a less echogenic thin layer of about 1 mm thick was seen along the inner side of the bright echogenic layer. The bright echogenic layer was used for measurement because the less echogenic layer was not always visualized with the

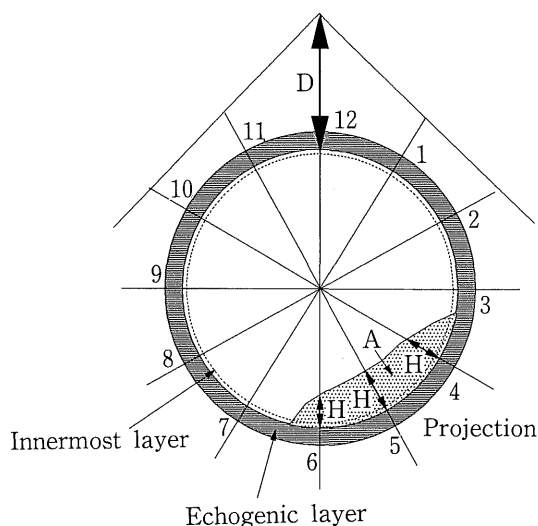


Fig. 3. Schematic illustration of the portion of projection in the descending aorta. H: height of the projection at each clockwise direction; A: cross area of the projection; D: distance from the transducer to the inner border of the bright echogenic layer of the aorta.

3.75MHz transducer. The height of the protrusion (mm) into the aortic lumen was measured at each clockwise direction from the top of the projection to the inner edge of the bright echogenic layer of the aortic wall (Fig.3). Since the image is not clearly obtained adjacent to the transducer (top of the screen), the distance between the transducer and the object is important. The distance (mm) from the top of the screen to the inner edge of the echogenic layer at 12 o'clock position (Fig.3) was measured. All these measurements were taken by a single investigator in order to minimize technical variation.

4. IABP catheter

The IABP catheter was used in 10 patients. The chamber portion of the catheter was usually depicted at the level of the three-chamber view¹⁰, as a scattered echo in the aortic lumen during inflation of the balloon and as a dot of strong echo accompanied by side lobes and acoustic shadow during deflation of the chamber. As the probe was gradually withdrawn, the shaft portion near the catheter tip was seen in the proximal portion of the descending thoracic aorta before the aortic arch appeared. The position of the catheter tip in the cross-sectional image of the aorta was examined.

5. Statistical analysis

Statistical analysis was carried out by means of an unpaired t-test comparing the means of two groups, and a chi-square test to analyze the nominal data between two groups. Statistical significance was determined when the P value was smaller than 0.05.

RESULTS

1. TEE findings of intraluminal projections in the descending thoracic aorta

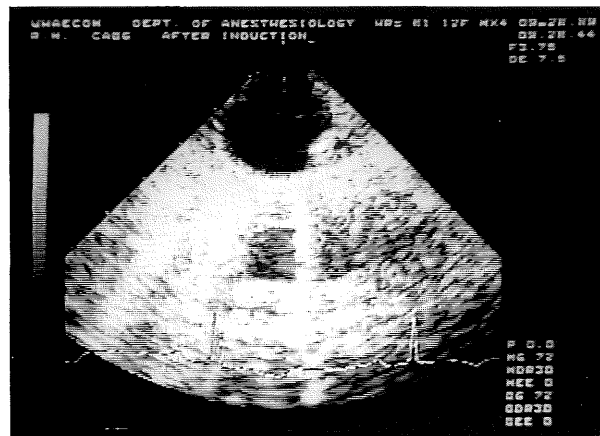


Fig. 4. Transesophageal echocardiogram showing small projection with strong echo, accompanying side lobes.

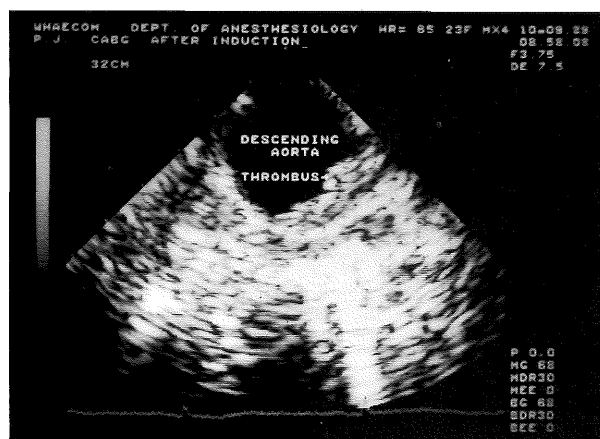


Fig. 5. Transesophageal echocardiogram showing large projection: less echogenic than the aortic wall but containing echogenic portions.

No complications related to the manipulation of the TEE probe were encountered during the study. The descending thoracic aorta was depicted clearly in all cases except four, where the IABP catheter had been inserted preoperatively. Thus, the TEE findings were analyzed in 53 patients.

A total of 70 projections were found in 40 of 53 patients (75.5%): one projection in 18 patients, two projections in 17 patients, three projections in 2 patients, and four projections in 3 patients. The projections were depicted as strongly echogenic (Fig.4) or weakly echogenic (Fig.5), narrow (Fig.4) or broad (Fig.5). In 70 projections, sixteen were larger than 0.5cm² and six were larger than 1.0 cm². The largest one was 3.1 cm², reducing the arterial lumen area by 45%.

Height distribution of the projections at each clockwise direction is summarized in Fig.6. Projections were mostly located in the area between 3 and 6 o'clock. At the 4 o'clock position, thirty-two projections were detected in 53 patients, and four projections were higher than 7mm in height.

Fig.7 shows the incidence of projections higher

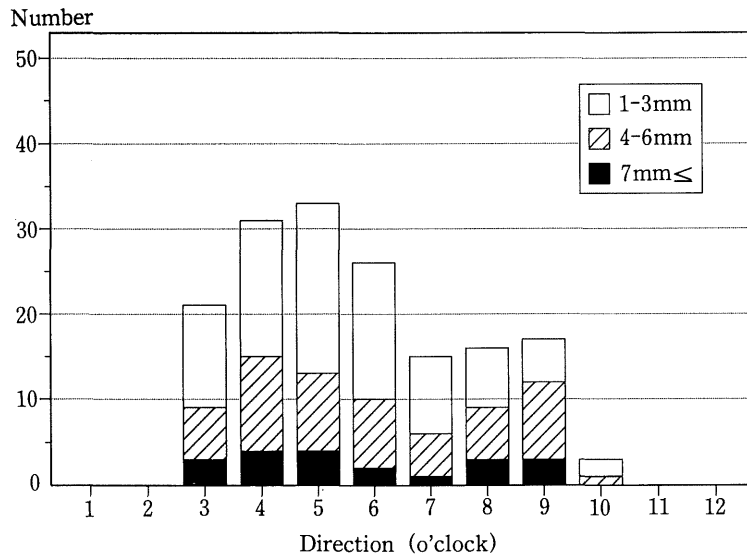


Fig. 6. Number of intraaortic projections at each clockwise direction in 53 patients according to the height of the projections.

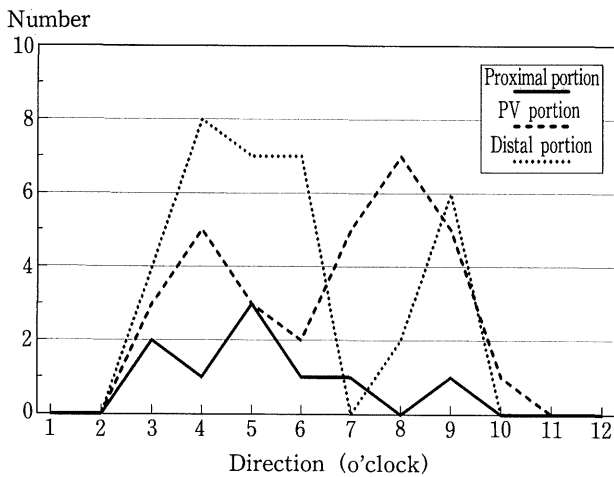


Fig. 7. Number of intraaortic projections at each clockwise direction in three portions of the descending thoracic aorta.

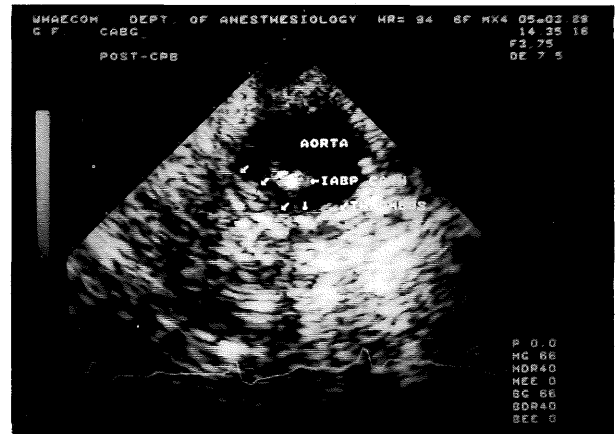


Fig. 8. Transesophageal echocardiogram showing projection (arrows) found near the catheter tip in a patient in whom IABP had been instituted preoperatively.

than 4mm in each of the three portions of the descending thoracic aorta. In the proximal and distal portions, projections were most frequently found at the 3 to 6 o'clock position. At the pulmonary vein portion, projections were mostly found at the 7 to 9 o'clock position, next to the pulmonary vein.

The distance between the transducer and the innermost layer of the aortic wall (less echogenic layer) was measured in all of the 70 views where projections were visualized (Fig.3D). This was less than 5mm in 15 views, between 6 and 10mm in 38 views, and larger than 11mm in 17 views.

2. TEE findings in IABP cases

The tip of the IABP catheter was located in the right lower quadrant (the area between 3 and 6 o'clock) of the aortic lumen in 6 of 10 patients and in the upper half area (between 9 and 3 o'clock)

in 4 of 10 patients. The tip was often seen periodically touching the aortic wall while the IABP was operated. Inflation of the chamber disturbed the image of the aortic wall at 3 to 9 o'clock. The catheter tip was not observed at the aortic arch level in any case.

Projections were found near the catheter tip in two of 4 patients in whom IABP had been instituted preoperatively (case #2 and #13; Fig.8). In both patients, the tip of the catheter was located in the right lower quadrant of the aortic lumen and the projections were also found in that area. However, in the six patients with intraoperative insertion of the IABP catheter, no projection was found around the catheter tip.

In case #9, IABP had been temporarily instituted. This patient was admitted to the hospital twelve

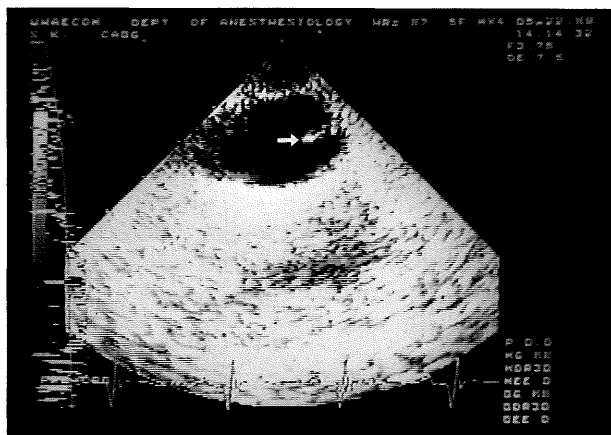


Fig. 9. Transesophageal echocardiogram showing flail intima (arrow) in the aorta at the level near the aortic arch.

days before surgery due to cardiogenic shock following acute myocardial infarction of the anterolateral left ventricular wall. A flail movement of a small segment of intima was found at 3 o'clock in the aortic lumen at the level near the aortic arch (Fig.9). Neither dissection nor aneurysmal change was present and no projection was found around this flap.

In case #19, an IABP catheter was inserted intraoperatively. A projection of 1.1 cm² in area was found adjacent to the pulmonary vein at the depth of 30 cm from the incisor prior to insertion of an IABP catheter (Fig.10A). However, after insertion of the catheter, the area of the projection was reduced to 0.7 cm² (Fig.10B). The portion of the projection at the 6 o'clock position disappeared.

3. Projections and patient profiles

The relationship between the projections and the

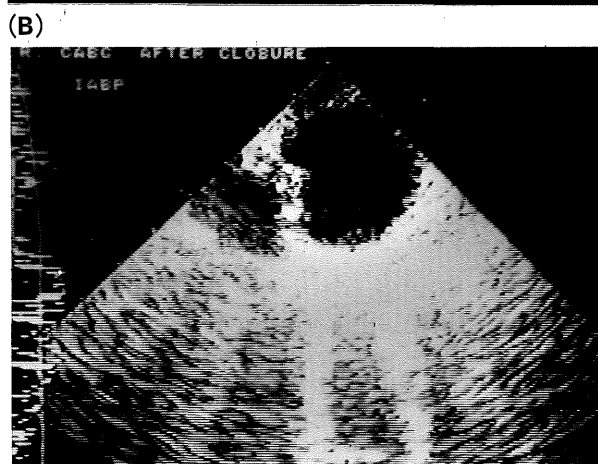
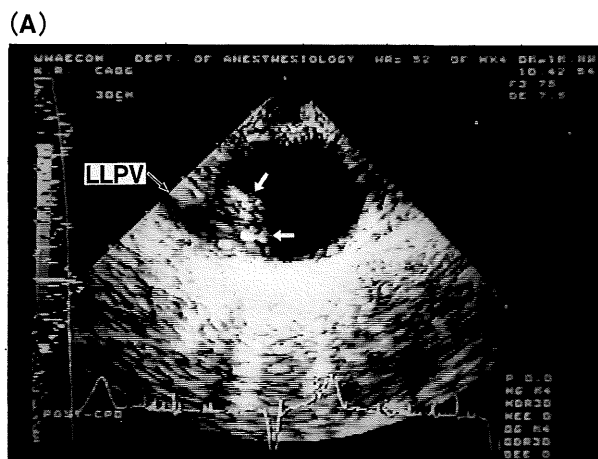


Fig. 10. Transesophageal echocardiogram showing projection (arrows) detected at the depth of 30cm: (A) prior to insertion of an IABP catheter, (B) after insertion of the catheter. The area of the projection was reduced from 1.1cm² to 0.7cm². LLPV: left lower pulmonary vein.

Table 1. Projections and associated diseases

		Projections (-)	Projections (+)	Statistical significance
Number		13	40	
Age (mean ± SD)		56.4 ± 9.3	64.7 ± 10.5	P < 0.05
Sex	men	11	26	NS
	women	2	14	
CAD	1	2	6	NS
	2	7	19	
	3	4	15	
TIA or	(-)	12	36	NS
CVA	(+)	1	4	
Carotid	(-)	13	37	NS
	Bruit	(+)	0	
DM	(-)	13	31	NS
	(+)	0	9	
HT	(-)	6	14	NS
	(+)	7	26	

SD: standard deviation, CAD: number of diseased coronary arteries, TIA: transient ischemic attack, CVA: cerebrovascular attack, DM: diabetes mellitus, HT: hypertension, NS: not significant (P ≥ 0.05).

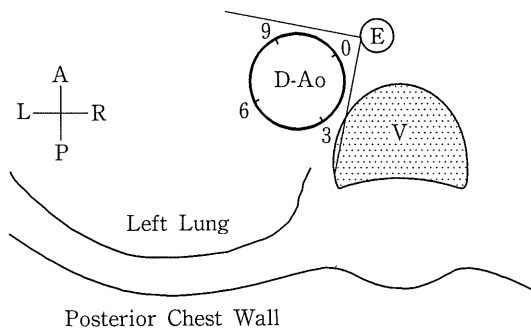


Fig. 11. Schematic illustration of a tomography of the thorax. The aorta of the 3 to 6 o'clock on the screen corresponds to the posterior aspect of the aorta anatomically. E: esophagus, D-Ao: descending aorta, V: vertebra.

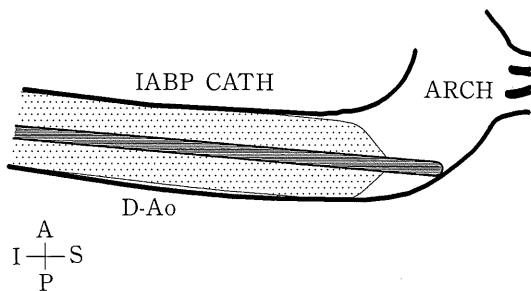


Fig. 12. Schematic illustration of an IABP catheter in the aorta. the catheter tip touches the posterior side of the aorta due to the curved course of the aorta. D-Ao: descending aorta.

patients' profiles are summarized in Table 1. The ages were significantly higher in patients in whom projections were found ($p < 0.05$, *t*-test). In other factors, no statistically significant difference was detected between two groups with chi-square analysis of contingency table, although projections were found in all of the 9 cases of patients with diabetes mellitus and in all of the three cases of patients with carotid bruit.

DISCUSSION

1. Clinical implications of TEE in CABG

This study showed that intraluminal projections are common in the descending thoracic aorta, detected in as many as 75.5% of CABG patients. Those projections were most frequently found at the 3 to 6 o'clock position of the aorta. Anatomically, this portion of the aortic wall corresponds to the posterior aspect of the aorta, since the descending thoracic aorta is situated on the left-posterior side of the esophagus (Fig.11). This result is in accord with the pathological study that determined that atheromatous change of the descending thoracic aorta is most commonly found at the posterior side of the aorta¹⁾. However, at the pulmonary vein level, a different distribution of projections were seen; it was found predominantly at the 7 to 9 o'clock position adjacent to the pulmonary vein.

These pathological changes cannot be observed by routine preoperative examinations or at the time of insertion of an IABP catheter unless TEE is not used. We demonstrated that the tip of the IABP catheter was also located in the 3 to 6 o'clock area. Fig.12 indicates a possible mechanism of the predominant position of the catheter tip in the 3 to 6 o'clock area. The descending thoracic aorta shows a slightly curved course convex to the left posterior, and the catheter tip is located at the left posterior side in the aortic lumen which corresponds to the 3 to 6 o'clock area on the TEE screen.

These findings suggest that the catheter tip may dislodge the projection or damage the aortic intima while being advanced in the descending aorta.

A reduction of the size of the projection area in case #19 indicates a dislodging of the projection. The flail intima in case #9 indicates a traumatic tear of the aortic intima, possibly by the tip of an IABP catheter reaching the aortic arch at insertion or by a guidewire or catheter at the time of coronary angiography.

Whenever IABP is used, preventive measures should be taken against related complications such as arterial embolism. The use of TEE can detect a projection and prevent its dislodging. When the projection is located at the proximal portion of the descending thoracic aorta, guidance by TEE is helpful to stop the catheter tip below the site of projection while being advanced. This is accomplished in the following manner: the TEE probe is advanced about 5 cm from the level at which a projection in the aortic lumen is detected on the screen. The IABP catheter is then slowly advanced until the TEE probe detects the catheter tip in the aorta. (The catheter tip is placed 5cm below the projection). This position is lower than usual but acceptable if the diastolic augmentation by IABP is sufficient and the renal blood flow is maintained. However, when the projection is located at the distal level, this technique is not useful because the location of the tip is too distal and the renal blood flow will be reduced. It is difficult to steer the straight catheter to avoid the projection as it approaches, but a slightly curved catheter may solve this problem. Even if the catheter is advanced safely without touching the projection, pumping the balloon may irritate it. This cannot be documented, however, since the balloon portion markedly disturbs the TEE image of the aortic wall of 3 to 9 o'clock area. TEE findings suggest a higher risk of arterial embolism, such as mesenteric arterial embolism.

Other unfavorable situations observed in this series include: 1) the catheter tip touching the aortic wall during pumping and 2) an abnormal projection seen around the catheter tip in a case where IABP was instituted preoperatively. These findings strongly suggest that a continuous irritation of the

aortic intima by the tip of the indwelled IABP catheter may cause pathological changes to the aortic wall.

2. Limitations of this study

No significant embolic episodes were detected in case #19 in spite of the fact that a reduction in the size of the projection was noted after the insertion of IABP. This does not imply that the presence of projection in the aortic lumen has no clinical relevance. Manifestation of embolism can vary according to site, size, and characteristics. It is best to minimize the chance of this complication as much as possible.

In this study, the projection was not found in the area between 11 to 2 o'clock. The echo image is generally unclear within 1 cm from the transducer. Thus, the incidence of projections around the 12 o'clock position can be missed or underestimated. However, the distance between the transducer and the aorta was found to be larger than 6 mm in 55 of 70 views (78.6%), and thus projections higher than 5mm in this area could have been visualized. (The top of the projection is located at more than 10 mm from the transducer.) Therefore, we believe that the incidence of large projections in this area is low.

The pathological analysis of the projection was not feasible because there was no mortality in this series. The intraluminal projection might be identified as 1) atherosclerotic changes including plaque, calcification, or intraplaque hemorrhage or 2) mural thrombus. The former can be commonly present at the aorta in patients with ischemic heart disease. Atherosclerotic plaques are identified as irregular or smooth and rounded protuberances¹³⁾, and calcification appears as thick, high-amplitude, non-linear echoes, often with acoustic shadowing⁶⁾. Mural thrombus shows similar echocardiographic findings to some of the intraluminal projections found in this series, depicted as low level echoes surrounding the translucent lumen⁷⁾. However, experience in the surgery of aortic aneurysm informs us that irregular projections due to atheromatous changes and mural thrombus are fragile and can be easily dislodged. In the intraoperative monitoring, the presence and location of the projections is of primary importance. By contrast, tissue characterization of the projections is important in the long-term management of patients with systemic atherosclerosis.

Although it is difficult to know the presence of projection without use of TEE, it should be kept in mind that presence of projection is more likely in the aged group of CABG patients, as shown in this study. In addition, attention should be paid to that group of patients with diabetes mellitus or carotid bruit, although this is not statistically significant.

Although the atheromatous changes of the aorta are more remarkable in the abdominal aorta than

in the thoracic aorta²⁾, it is difficult to examine the abdominal aorta with TEE alone. This portion of the aorta can be examined better with surface echocardiography than with TEE. Nakatani et al⁹⁾ reported a case in which an IABP catheter was successfully inserted into the true lumen of the dissected aorta using both surface and transesophageal echocardiography.

In this study, we used a 3.75 MHz transducer, which was practically sufficient examination of the presence of large projections. But the innermost, less echogenic layer of the aorta could not always be visualized. A 5 MHz transducer provides better images with higher resolution.

It is impractical to examine the descending thoracic aorta with TEE in all CABG patients before surgery. However, we believe that routine intraoperative examination of the aorta in coronary artery patients provides useful information with minimal time and effort, especially in high-risk patients.

(Received August 6, 1991)

(Accepted November 15, 1991)

REFERENCES

1. Crawford, T. 1966. Atherosclerosis (Chap 3), p.94-105. In G.P. Wright and W.St.C. Symmers (eds.), Systemic Pathology Vol.1. Longmans, London.
2. Crawford, T. 1977. Blood and lymphatic vessels (Chap 21), p.879-927. In W.A.D. Anderson and J.M. Kissane (eds.), Pathology, 7th ed. CV Mosby Co., Saint Louis.
3. Daily, E.K. and Tilkian, A.G. 1986. Intra-aortic balloon pumping, p.257-73. In A.G. Tilkian and E.K. Daily (eds.), Cardiovascular Procedures-Diagnostic Techniques and Therapeutic Procedures. CV Mosby Co., St. Louis.
4. Engberding, R., Bender, F., Grosse-Heitmeyer, W., Most, E., Müller, U.S., Bramann, H.U. and Schneider, D. 1987. Identification of dissection of aneurysm of the descending thoracic aorta by conventional and transesophageal two-dimensional echocardiography. *Am. J. Cardiol.* 59: 717-719.
5. Erbel, R., Börner, N., Steller, D., Brunier, J., Thelen, M., Pfeiffer, C., Mohr-Kahaly, S., Iversen, S., Oelert, H. and Meyer, J. 1987. Detection of aortic dissection by transesophageal echocardiography. *Br. Heart J.* 58: 45-51.
6. Goldstone, J. 1989. Vascular imaging techniques (Chapter 7), p.119-128. In R.B. Rutherford (ed.), Vascular Surgery, 3rd ed. W.B. Saunders Co., Philadelphia.
7. Harter, L.P., Gross, B.H., Callen, P.W. and Barth, R.A. 1982. Ultrasonic evaluation of abdominal aortic thrombus. *J. Ultrasound Med.* 1: 315-318.
8. McEnany, M.T., Kay, H.R., Buckley, M.J., Daggett, W.M., Erdmann, A.J., Mundth, E.D., Rao, R.S., Detoef, J. and Austen, W.G. 1978. Clinical experience with intraaortic balloon pump support in 728 patients. *Circulation* 58 (Suppl.I): 124-132.
9. Nakatani, S., Beppu, S., Tanaka, N., Andoh, M.,

- Miyatake, K. and Nimura, Y.** 1989. Application of abdominal and transesophageal echocardiography as a guide for insertion of intraaortic balloon pump in aortic dissection. *Am. J. Cardiol.* **64**: 1082-1083.
10. **Orihashi, K., Hong, Y.W., Chung, G., Sisto, D., Goldiner, P.L. and Oka, Y.** 1990. New applications of two-dimensional transesophageal echocardiography in cardiac surgery. *J. Cardiothorac. Vascular Anesth.* **5**: 33-39.
 11. **Orihashi, K., Goldiner, P.L. and Oka, Y.** 1990. Intraoperative assessment of pulmonary vein flow. *Echocardiography: J CV Ultrasound & Allied Tech.* **7**: 261-271.
 12. **Orihashi, K., Hong, Y., Sisto, D.A., Goldiner, P.L. and Oka, Y.** 1990. The anatomical location of the transesophageal echocardiographic transducer during a short-axis view of the left ventricle. *J. Cardiothorac. Anesth.* **4**: 726-730.
 13. **Pop, G., Sutherland, G.R., Koudstaal, P.J., Sit, T.W., de Jong, G. and Roelandt, J.R.T.C.** 1990. Transesophageal echocardiography in the detection of intracardiac embolic sources in patients with transient ischemic attacks. *Stroke* **21**: 560-565.
 14. **Takamoto, S. and Omoto, R.** 1987. Visualization of thoracic dissecting aortic aneurysm by transesophageal Doppler color flow mapping. *Herz* **12**: 187-193.