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Evaluation of Transesophageal Echocardiography for Diagnosis of Traumatic Aortic Injury

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Background: **Traumatic aortic injury is a frequent cause of death after blunt trauma, but few patients survive to reach a trauma center. The role of transesophageal echocardiography (TEE) in the diagnosis of traumatic aortic injury remains debated.**

Methods: **Over a 9-yr period, 209 blunt trauma patients (mean age, 34 ± 13 yr) were suspected of having traumatic aortic injury because of enlarged mediastinum and/or sudden deceleration, and underwent TEE and angiography (aortography and/or contrast-enhanced computed tomography.**

Results: **Traumatic aortic injury was diagnosed in 42 patients (20%). Angiography (aortography and/or contrast-enhanced computed tomography) was less accurate (sensitivity, 83%; specificity, 100%) than TEE (sensitivity, 98%; specificity, 100%) for the diagnosis of aortic injury because it failed to diagnose most minor injuries (intramural hematoma or limited intimal flap, n = 7). However, when considering only patients with major aortic injury (n = 33; *i.e.*, those who might need surgery), angiography (sensitivity, 97%; specificity, 100%) and TEE (sensitivity, 97%; specificity, 100%) were equivalent.**

Conclusion: **Transesophageal echocardiography is an accurate method for diagnosis of traumatic aortic injury. Nevertheless, the clinical implications of limited aortic injuries diagnosed by the technique have yet to be determined. (Key words: Aorta; aortic rupture; trauma.)**

TRAUMATIC aortic injury (TAI) occurs in patients sustaining blunt trauma with sudden deceleration, usually because of a high-speed motor vehicle accident or a fall from a height.[1] In patients with aortic rupture, survival depends on early and accurate diagnosis.[2] For diagnosis of TAI, aortography has been considered as the gold standard method, although contrast-enhanced spiral computed tomography (CT) seems to be as accurate.[3] Transesophageal echocardiography (TEE) has been more recently advocated and has many advantages. It can be performed quickly at the bedside without contrast-material injection, and it provides useful information on volume status, cardiac function, and injury.[4] Few studies have evaluated the accuracy of TEE.[5–8] Nevertheless, the role of TEE in the diagnosis of TAI remains debated for several reasons. First, because TAI does not occur frequently, most of these studies included few patients with TAI. Second, the echocardiographic signs of TAI are complex and have been only recently described.[9,10] Third, important discrepancies occurred in these initial studies because the sensitivity was found to be between 57% and 91% and the specificity between 84% and 100%.[5–8] In the multicenter prospective study of blunt aortic injury in the United States,[11] TEE was performed in few patients (11%), suggesting that TEE is not widely used presently or that it has not been presently recognized as an accurate diagnostic tool, in contrast with the experience of some European and US trauma centers.[7,9,11]

Therapeutic management of TAI has recently changed. There is increasing evidence that limited aortic lesions (intramural hematoma, limited intimal flap) can benefit only from medical treatment and that some patients with subadventitial rupture can benefit from delayed surgery.[12] The decision-making process requires a precise assessment of the severity of aortic lesions. Therefore, the evaluation of a diagnostic procedure should also consider the degree of severity of TAI.

Thus, we evaluated prospectively the efficacy of TEE in a large population of blunt trauma patients in whom TAI was suspected. Moreover, we distinguished between major TAIs that indicate emergency or delayed surgery and minor TAIs without any evidence of rupture that may indicate only medical treatment and close follow-up, as previously reported.[9,11]

Methods

This study was approved by the hospital's ethics committee (CCPPRB Pitié-Salpêtrière). All blunt trauma patients in whom TAI was suspected were prospectively included over a 9-yr period, ending in June 1999. Criteria for inclusion were either enlarged mediastinum on the chest radiograph or sudden deceleration. All of these patients underwent TEE for the assessment of aorta, volume status, and cardiac function. Moreover, whenever possible, either aortography or a contrast-enhanced spiral CT scan (since 1996) was performed to diagnose TAI, and all such examinations were reviewed by one of

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Table 1. Grading of the Severity of Traumatic Aortic Injury (TAI)

Severity	Characteristics	Therapeutics
Grade 1	Intramural hematoma or limited intimal flap	Medical follow-up
Grade 2	Subadventitial rupture or modification of the geometric shape of the aorta	Emergency or delayed surgery
Grade 3	Aortic transsection with active bleeding or aortic obstruction with ischemia	Immediate surgery

Grade 1 corresponds to minor TAI; grades 2 and 3 correspond to major TAI.

the authors (P. C.). Nevertheless, in few patients with hemodynamic instability, emergency surgery was decided only after TEE.

Transesophageal echocardiography was performed on arrival in the trauma center with a 5-MHz phased array probe (HP1500; Hewlett-Packard, Andover, MA). The probe was a single-plane probe at the beginning of the study and a multiplane probe since 1992. Standard TEE examination included visualization of the ascending aorta, aortic arch, and descending thoracic aorta, as well as based short-axis, four-chamber, and transgastric short-axis cardiac view, which permitted the assessment of volume status, cardiac function, pericardium, and mediastinum. These data were recorded and analyzed on a real-time basis by anesthesiologists fully trained in echocardiography. All recorded data were reviewed by two of the authors (J. P. G. and M. G.). As previously described, TAI was diagnosed when direct, specific signs were observed,[9] including thick medial flaps, false aneurysm, aortic dissection, free-edge intimal flap, aortic wall hematoma, fusiform aneurysm, and aortic obstruction.[9] When indirect, nonspecific, signs of TAI were observed, examination was carefully continued to exclude the possibility of TAI. Indirect signs included hemomediastinum,[13] minor increases in aortic diameter, and impairment of Doppler color flow.[9]

Traumatic aortic injuries were graded according to therapeutic implication (table 1). Grade 1 corresponds to minor TAI when isolated intimal flap or intramural hematoma were observed without any evidence of hemomediastinum or modification of the geometry of aorta. Minor TAIs do not indicate surgery but warrant close medical follow-up.[9,11] Grade 3 corresponds to major TAI requiring immediate emergency surgery because of either aortic transsection, and thus active bleeding, or complete aortic obstruction, inducing ischemia.[2,9] Grade 2 corresponds to other TAIs with subadventitial rupture in which medial injury or modification of the geometry of the aorta were observed, with or without hemomediastinum, thus indicating potential need for either immediate or delayed surgery.[1,2] Consequently, for assessing the accuracy of TEE, patients with TAI were divided into two groups: major TAI (grades 2 and 3) and minor TAI (grade 1).

Data are expressed as mean ± SD or percentage. Comparison of two means was performed using the Student *t* test, and comparison of two percentages was performed using the Fisher exact method. The sensitivity, specificity, and negative and positive predictive values of TEE and angiography (aortography or contrast-enhanced spiral CT scan) were calculated for the diagnosis of minor TAI, major TAI, and all TAI. Although major TAI were confirmed by surgery, it should be pointed out that most minor TAI were diagnosed only by TEE, and thus that TEE was actually considered as a gold standard technique in the present study. All *P* values were two-sided, and a *P* value less than 0.05 was considered significant.

Results

During the study period, 1,890 trauma patients were admitted into our trauma center, and 209 (11%) blunt trauma patients (mean age, 34 ± 13 yr; 155 men and 54 women) were suspected of having TAI because of enlargement of mediastinum (n = 120, 57%) or sudden deceleration. The cause of trauma was a motor vehicle accident in 142 cases (68%) and a fall (13 ± 5 m) in 67 cases (32%). All but one patient underwent TEE. In this patient, emergency aortic surgery was performed without any imaging except chest radiograph because of cardiac arrest. TAI was confirmed at surgery, but the patient died. Aortography was performed in 165 cases (79%), and contrast-enhanced spiral CT scan was performed in 111 cases (53%), the two examinations being performed in 70 cases. Only two patients underwent TEE only because of hemodynamic instability, and TAI was confirmed in all cases either by emergency surgery (n = 1) or autopsy (n = 1). TAI was diagnosed in 42 cases (20% of patients suspected of having TAI, and 2% of all trauma patients) and located at the isthmus in 41 cases and at the origin of the left subclavian artery in one case.

Transesophageal echocardiography was analyzed in 208 patients, in whom TAI was diagnosed in 41 cases. A single-plane probe was used in eight cases, and a multiplanar probe was used in the remaining 33 cases. Table 2 depicts the comparison between patients with and without TAI. TAI was minor in seven patients who did not undergo surgery but only follow-up. Major TAI was diagnosed in 33 patients (grade 2, 17 cases; grade 3, 16 cases), 30 of whom underwent immediate or delayed surgery. In two patients, death occurred before surgery because of head trauma or multiple organ failure. Another patient refused surgery and left the hospital, and follow-up information could not be obtained.

Table 2. Comparison of Patients with or without Traumatic Aortic Injury (TAI)

Characteristic	TAI (n = 42)	No TAI (n = 167)
Age (yr)	33 ± 10	35 ± 13
Sex		
Male	34 (81%)	121 (72%)
Female	8 (19%)	46 (28%)
Mechanism of injury		
Vehicle accident	32 (76%)	110 (65%)
Fall	10 (24%)	57 (34%)
Trauma lesions		
Head and cervical trauma	27 (64%)	127 (76%)
Thoracic trauma	42 (100%)*	144 (86%)
Abdominal trauma	21 (50%)*	60 (36%)
Pelvic trauma	10 (24%)	47 (28%)
Limb trauma	24 (57%)	114 (68%)
ISS	43 ± 15*	32 ± 13
Widened mediastinum	31 (74%)*	89 (53%)
Death	10 (24%)*	18 (11%)

* $P < 0.05$ *versus* patients without TAI.

ISS = Injury Severity Score.

Table 3 depicts the diagnostic value of TEE compared with angiography. Angiography was less accurate than TEE for the diagnosis of TAI because it failed to diagnose most minor TAIs. However, when considering only patients with major TAIs, angiography and TEE were equivalent (table 3). TEE was negative in one patient whose angiography was positive, and angiography was negative in another patient whose TEE was positive.

Among the seven patients with minor TAIs, two died because of severe head trauma or multiple organ failure, and two were lost to follow-up. Three patients underwent TEE several years later (range, 17 months to 6 yr). In two patients, TEE showed an almost complete regression with only a localized (> 1 cm) thickening of the aortic wall or an irregular intimal layer at the isthmic portion of the aorta. In the third case, TEE was performed again 17 months after trauma and showed the same lesion observed during the initial examination: significant intramural hematoma (extended on 4 cm) without aortic dilation or modification of aortic external layers, without any color Doppler flow abnormalities. An annual follow-up examination was decided for this patient.

Table 3. Accuracy of Transesophageal Echocardiography (TEE) and Angiography (Aortography or Contrast-enhanced Spiral CT) in the Diagnosis of Minor TAI, Major TAI, and All TAI

	Sensitivity	Specificity	NPV	PPV
All TAI (n = 41)				
TEE (n = 208)	98%	100%	99%	100%
Angiography (n = 206)	83%	100%	96%	100%
Major TAI (n = 33)				
TEE (n = 208)	97%	100%	99%	100%
Angiography (n = 206)	97%	100%	99%	100%
Minor TAI (n = 7)				
TEE (n = 208)	100%	100%	100%	100%
Angiography (n = 206)	14%	100%	97%	100%

CT = computed tomography; TAI = traumatic aortic injury; NPV = negative predictive value; PPV = positive predictive value.

Discussion

In this study, we selected prospectively a population of trauma patients at high risk for TAI. Indeed, all patients underwent rapid deceleration during trauma, and most showed a widened mediastinum on chest radiograph. A widened mediastinum was not the only criterion for inclusion because it has been demonstrated that TAI can occur in trauma patients without widened mediastinum.[14] In the same manner, external chest trauma lesions were not considered as potential criteria for inclusion because they do not correlate with TAI occurrence.[15] The incidence of TAI (20%) in our selected population of trauma patients was greater than those previously reported (4–17%)[5–7] but comparable to that reported by Minard *et al.* (26%).[8]

The apparent high number of publications dealing with TEE and TAI may be confusing. Indeed, most of these publications were only case reports, and some of the series published included the same patients,[6,7,10,16,17] potentially providing a misleading impression of the number of patients studied and the value of TEE. Although our previous report only analyzed the TEE signs, 16 of our 42 patients were previously described.[9] Thus, only four teams have evaluated the accuracy of TEE in the diagnosis of TAI[5–8] but provided conflicting results concerning sensitivity (57–91%) and specificity (84–100%). Because TAI does not occur frequently, most of these studies included few patients with TAI (n = 8–25).[5–8] The echocardiographic signs of TAI are complex and have been only recently described.[9,11] Obviously, the low sensitivity reported by two studies[5,8] may be partly explained by numerous inconclusive TEE. Some of these inconclusive investigations were probably related to minor aortic injuries that were not fully recognized at the time.[5,8] Moreover, the study by Saletta *et al.*[6] was retrospective. Our study showed that TEE has a high sensitivity and specificity, as previously suggested.[7] When considering only patients with major TAIs who required either immediate or delayed surgery, TEE and angiography seemed equivalent. Our study suggests that no diagnostic procedure is perfectly sensitive because a false-negative result was observed both with TEE and angiography. However, no false-positive results were reported with TEE, and TEE enabled us to not indicate surgery in a patient with a false-positive angiography.

Transesophageal echocardiography has allowed the description of limited traumatic lesions of the aorta, including small intimal lesions and intramural hematomas (fig. 1).[9,11] These lesions are not associated with hemomediastinum or any modification of the geometric

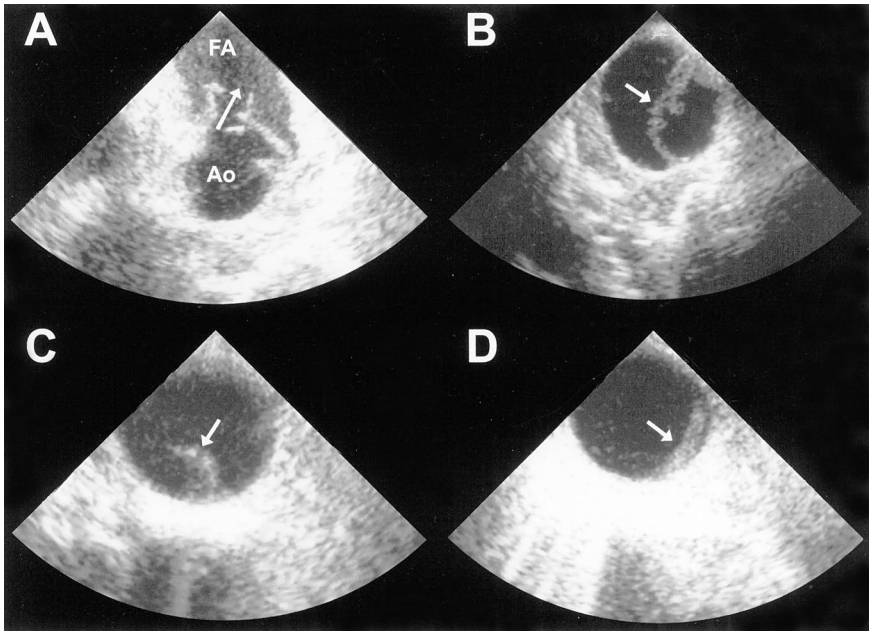

Fig. 1. Transesophageal echographic aspect of main categories of traumatic aortic injury. (*A*) Traumatic aortic rupture (grade 3) with false aneurysm (FA) communicating (arrow) with the aortic lumen (Ao); (*B*) Traumatic aortic rupture (grade 2) with a large medial flap; (*C*) Intimal flap without hemomediastinum or modification in the aorta geometry; (*D*) Intramural hematoma (arrow) without haemomediastinum; (*C*) and (*D*) correspond to minor aortic injury (grade 1).

shape of the aorta. Consequently, these limited lesions are usually missed by angiography, as confirmed in the present study (table 3). The clinical implications of these minor aortic injuries remain presently unknown. Although most of the cases reported did not undergo surgery and seemed to have complete healing of the lesions during follow-up,[9,11] careful follow-up or medical treatment may be required.[2] Indeed, limited spontaneous nontraumatic aortic lesions (intramural hematoma and perforating atheromatous ulcer) are thought to have the same bad prognosis as spontaneous aortic dissection.[18] The further development of posttraumatic false aneurysm cannot be presently excluded in patients with these limited traumatic aortic lesions. Long-term follow-up was available in only three patients with minor TAIs and was uneventful, although the lesions were stable in one patient after 17 months. Further study including a larger group of patients with minor TAIs and a longer follow-up period is mandatory to answer this important question concerning the prognosis of minor TAIs. Because of the scarcity of minor TAIs, this study should involve many trauma centers.

Transesophageal echocardiography provides useful information in patients with subadventitial rupture and severe multisystem trauma. For some of these patients, aortic surgery was intentionally postponed. Anatomic type of parietal lesions, size of false aneurysm, and presence of hemomediastinum all play a part in the decision-making process. TEE provides some useful information that is not provided by aortography or CT scan. Indeed, TEE can assess volume status and cardiac function and is very accurate in diagnosing other thoracic traumatic lesions such as hemopericardium, myocardial contusion, and rare valvular lesions.[19] Moreover, TEE is a rapid bedside examination, enabling emergency decisions to be made in case of complete aortic transection or complete aortic obstruction.[9] In contrast, TEE can miss supraaortic vessel lesions that are diagnosed by angiography,[2,20] but these lesions are far more rare than aortic isthmus injury.[2] Expertise in performing TEE may be of paramount importance to obtain a high level of accuracy, as previously emphasized.[7] It should be pointed out that all TEE examinations were carefully reviewed by echographists highly trained in treating trauma patients and with much experience with TAI. Vignon *et al.* demonstrated that a learning period is required to improve the accuracy of TEE in the diagnosis of TAI. It is thus not surprising that the less favorable results were from reported series that included few patients with TAI ($n = 8–9$).[6,8]

Some remarks must be included to assess the relevance of our results. First, from a methodologic point of view, investigators were not blinded, and some variations in the diagnostic techniques used occurred during the study period (single plane *vs.* multiplane probe for TEE, addition of spiral CT scan). Nevertheless, a multiplane probe was introduced very early in the present study, and the accuracy of contrast-enhanced spiral CT scan is thought to be equivalent to that of arteriography. Second, no gold standard method exists for the diagnosis of TAI, which may represent a weakness of our analysis. For patients with severe TAI, the results were confirmed by surgery or autopsy, and for patients without TAI, at least two negative examination results were obtained (TEE and arteriography or CT scan), which presently represents an acceptable manner to rule out severe TAI. Nevertheless, most patients with minor TAI were only diagnosed by TEE, which was the technique evaluated in the present study.

In conclusion, in a large prospective study in the same trauma center, we observed that TEE was more accurate than angiography for the diagnosis of TAI, mainly because angiography failed to evidence minor aortic injury. However, when considering only major TAI, TEE and angiography seemed equivalent.

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