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Preoperative Computed Tomography or Intraoperative Epiaortic Ultrasound for the Diagnosis of Atherosclerosis of the Ascending Aorta?

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ABSTRACT

Background: Extensive atherosclerotic disease, usually first diagnosed intraoperatively, is the most important risk factor for postoperative stroke after cardiac surgery. The aim of this study was to investigate if preoperative computed tomography (CT) is comparable with intraoperative epiaortic ultrasound to diagnose severe atherosclerosis in the ascending aorta.

Methods: The study included 20 consecutive patients who underwent elective coronary artery bypass surgery. Preoperative CT evaluation of the ascending aorta was compared with intraoperative epiaortic ultrasound findings. The ascending aorta was divided into 12 segments per patient, giving 240 segments to compare.

Results: Epiaortic ultrasound detected atherosclerosis in 16.7% ± 2.4% of the segments, a rate significantly higher than with CT ($P \leq .03$). There was a low reliability between the 2 methods, indicated by kappa coefficients of 0.45 or lower.

Conclusions: The CT method is inferior to epiaortic ultrasound, today's gold standard, in diagnosing the extent and location of atherosclerosis of the ascending aorta. Other methods, possibly magnetic resonance imaging, should be considered.

INTRODUCTION

Postoperative stroke is one of the most (if not the most) dreaded complications in cardiac surgery. It is therefore hardly surprising that great efforts have been made to identify its risk factors. Clearly, such factors could be used as warning signals. Some investigators hold that age is the key factor for developing stroke [John 2000]. If this hypothesis were correct, matters would be simplified considerably, because age is a variable about which any patient can give the most accurate information one can desire. Unfortunately, other findings point in a different direction. Extensive atherosclerotic disease of the ascending aorta of 50% or more was found to be associated with a 31% incidence of postoperative stroke [Bergman in press], whereas other studies reported incidences of postoperative cerebral complications between 6% and 33% [Roach 1996, van der Linden 2001]. If atherosclerosis of the aorta is the key factor, we are dealing with a variable about which, in contrast to age, accurate data are very difficult to come by. In that case, we are in dire need of a simple method that can give reliable preoperative information about the presence, extent, and location of atherosclerotic changes in the ascending aorta. We stress that such a method should ideally be able to supply us with the required data preoperatively. Intraoperative epiaortic ultrasound, today's gold standard for detecting atherosclerotic changes in the ascending aorta, suffers from the drawback that it can only do so during the operation. This fact means that if the information given by this diagnostic tool is not anticipated, changes that could have been made much more easily preoperatively have to be made during the operation. The aim of the present study was to investigate if preoperative computed tomography (CT) scanning can evaluate severe atherosclerosis in the ascending aorta as equally well as intraoperative epiaortic ultrasound.

MATERIALS AND METHODS

The hospital ethical committee approved the study, and informed consent was obtained from all patients. We included 20 consecutive patients who were aged 70 years or older and who were to undergo elective coronary artery bypass grafting surgery. A preoperative CT scan of the thorax was performed with a multislice CT scan (Siemens Volume Zoom; Siemens, Munich, Germany) 1 to 3 days before surgery. A senior radiologist graded the atherosclerosis of the ascending aorta without communicating the findings to the surgical team. The ascending aorta was divided into 3 equal transverse segments (proximal, middle, and distal thirds) and 4 equal longitudinal segments (anterior, posterior, lateral, and medial), thus giving 240 (12 × 20) segments to compare. The CT investigation was

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Table 1. Patient Characteristics (n = 20)*

Mean age ± SD, y	76.5 ± 4.02
Male sex	70% (14/20)
Hypertension	75% (15/20)
Non–insulin-dependent diabetes mellitus	10% (2/20)
Insulin-dependent diabetes mellitus	15% (3/20)
Hypercholesterolemia	85% (17/20)
Intermittent claudication	10% (2/20)
Previous cerebral embolism	15% (3/20)
Carotid disease	10% (2/20)
Atherosclerosis of the aortic arch (TEE)	75% (15/20)
Atherosclerosis of descending aorta (TEE)	90% (18/20)
Atherosclerosis of ascending aorta (EPI)	60% (12/20)
Atherosclerosis of ascending aorta (CT)	45% (9/20)
Calcification in the ascending aorta (EPI)	35% (7/20)
New stroke	0% (0/20)

*TEE indicates transesophageal echocardiography; EPI, epiaortic ultrasound; CT, computed tomography.

performed with and without intravenous contrast (100 mL of 300 mg/mL iodine [Optiray]; Tyco Healthcare Deutschland, Neustadt/Donau, Germany). Each measurement was done with 3-, 5-, and 10-mm sections.

After induction of anesthesia, an experienced anesthetist evaluated all patients with transesophageal echocardiography (TEE) using a multiplane probe (Sono 1500 [Hewlett-Packard, Andover, MA, USA] or System V [GE Vingmed Ultrasound, Horten, Norway]) according to a standard protocol. Apart from studying the heart, we paid special attention to the ascending aorta, the aortic arch, and the descending aorta with regard to atherosclerotic changes. After a median sternotomy was carried out, the surgeon carefully examined the ascending aorta by digital palpation with the index finger and by epiaortic ultrasound. Epiaortic ultrasound was performed with an ultrasound scanner (Site-Rite II, 9.0 MHz; Dymax, Pittsburgh, PA, USA). Two assessors, the surgeon and the anesthetist, interpreted the epiaortic ultrasound findings. In the case of disagreement, the opinion was requested of a third assessor, who had no information about the conclusions of the first 2 assessors. The mapping of the atherosclerotic disease of the ascending aorta was performed by dividing the ascending aorta into 3 equal transverse (proximal, middle, and distal thirds) and 4 equal longitudinal segments (anterior, posterior, lateral, and medial). The presence of atheroma of the ascending aorta (intimal thickening ≥0.5 mm) and calcification were recorded for every segment. Extent of disease was defined as the number of segments concomitantly involved. Extensive atherosclerosis in the ascending aorta was defined as ≥6 segments with epiaortic signs of atherosclerosis out of a total of 12 segments. Clinical demographic data were prospectively recorded. Carotid artery disease was defined as either an asymptomatic carotid stenosis or bruit or a carotid stenosis associated with a transient ischemic attack and/or a history of stroke.

Table 2. Percentages of Segments with Atherosclerosis of the Ascending Aorta Detected in 240 Segments by Intraoperative Epiaortic Ultrasound and by Preoperative Computed Tomography (CT)*

	Segment Percentage (n)	*P*
Epiaortic ultrasound	16.7% ± 2.4% (40)†	
CT: 3-mm sections, contrast (0)	8.8% ± 1.8% (21)	.01
CT: 3-mm sections, contrast (1)	5.8% ± 1.5% (14)	<.0002
CT: 5-mm sections, contrast (0)	9.6% ± 1.9% (23)	<.03
CT: 5-mm sections, contrast (1)	5.4% ± 1.5% (13)	<.0001
CT: 10-mm sections, contrast (0)	5.0% ± 1.4% (12)	<.0001
CT: 10-mm sections, contrast (1)	3.8% ± 1.2% (9)	<.0001

*Data are presented as the mean ± SEM.
†99% Confidence interval, 11.4%-23.8%.

Statistical Analysis

Data were analyzed with SAS software, version 8.2 (SAS Institute, Cary, NC, USA), and with confidence interval analysis (Newcombe, version 2.0.0, by Trevor Bryant, University of Southampton, UK). To test the agreement of preoperative CT and intraoperative epiaortic ultrasound, we used the Cohen simple kappa coefficient [Kraemer 1980]. Generally, a kappa coefficient >0.7 is considered satisfactory. The Cohen kappa coefficient is the usual way to analyze interobserver agreement for nominally coded data and to correct for the proportion of agreement that might occur by chance. To test whether the kappa coefficient was >0.7, we used a normal application to compute confidence intervals. The Student *t* test was also used to test the proportions of findings determined by the 2 methods (n = 240).

RESULTS

The preoperative patient characteristics, the intraoperative epiaortic ultrasound findings, the TEE data, and the preoperative CT data are summarized in Table 1. The mean age was 76.5 years. Most patients were men with hypertension and hypercholesterolemia. Intraoperative epiaortic ultrasound detected atherosclerotic disease of the ascending aorta in 60% (12/20) of the patients and calcified plaques in 35% (7/20), whereas CT detected atherosclerotic disease in 45% (9/20) of the patients. TEE detected atherosclerotic disease in the aortic arch in 75% (15/20) and in the descending aorta in 90% (18/20) of the patients, with positive TEE findings being more frequent than positive epiaortic ultrasound findings of the ascending aorta ($P < .05$; 95% confidence limits, 0.51-0.06).

The percentages of the 240 (20 patients with 12 segments each) segments with detected atherosclerosis of the ascending aorta according to intraoperative epiaortic ultrasound and preoperative CT analyses are presented in Table 2. With epiaortic scanning, atherosclerosis was detected in 16.7% of segments (SEM, ±2.4%; 99% confidence interval, 23.8%-11.4%), which was significantly higher than with CT. This result was independent of the

Table 3. Detection of Atherosclerosis in the Ascending Aorta with Intraoperative Epiaortic Ultrasound (EPI) and Preoperative Computed Tomography (CT) (n = 240)*

	3-mm Sections (n)		5-mm Sections (n)		10-mm Sections (n)	
Atherosclerosis	IV contrast (0)	IV contrast (1)	IV contrast (0)	IV contrast (1)	IV contrast (0)	IV contrast (1)
EPI (–), CT (–)	79.2% (190)	81.2% (195)	78.8% (189)	81.7% (196)	80.8% (194)	82.1% (197)
EPI (+), CT (–)	12.1% (29)	12.9% (31)	11.7% (28)	12.9% (31)	14.2% (34)	14.2% (34)
EPI (–), CT (+)	4.2% (10)	2.1% (5)	4.6% (11)	1.7% (4)	2.5% (6)	1.2% (3)
EPI (+), CT (+)	4.6% (11)	3.8% (9)	5% (12)	3.8% (9)	2.5% (6)	2.5% (6)

*The ascending aorta for the 20 patients was divided into 12 segments per patient. The CT analysis was made with section thicknesses of 3 mm, 5 mm, and 10 mm, as well as before (0) and after (1) the intravenous (IV) injection of contrast medium.

thickness of the sections (3 mm, 5 mm, or 10 mm) and whether contrast was used ($P \leq .03$).

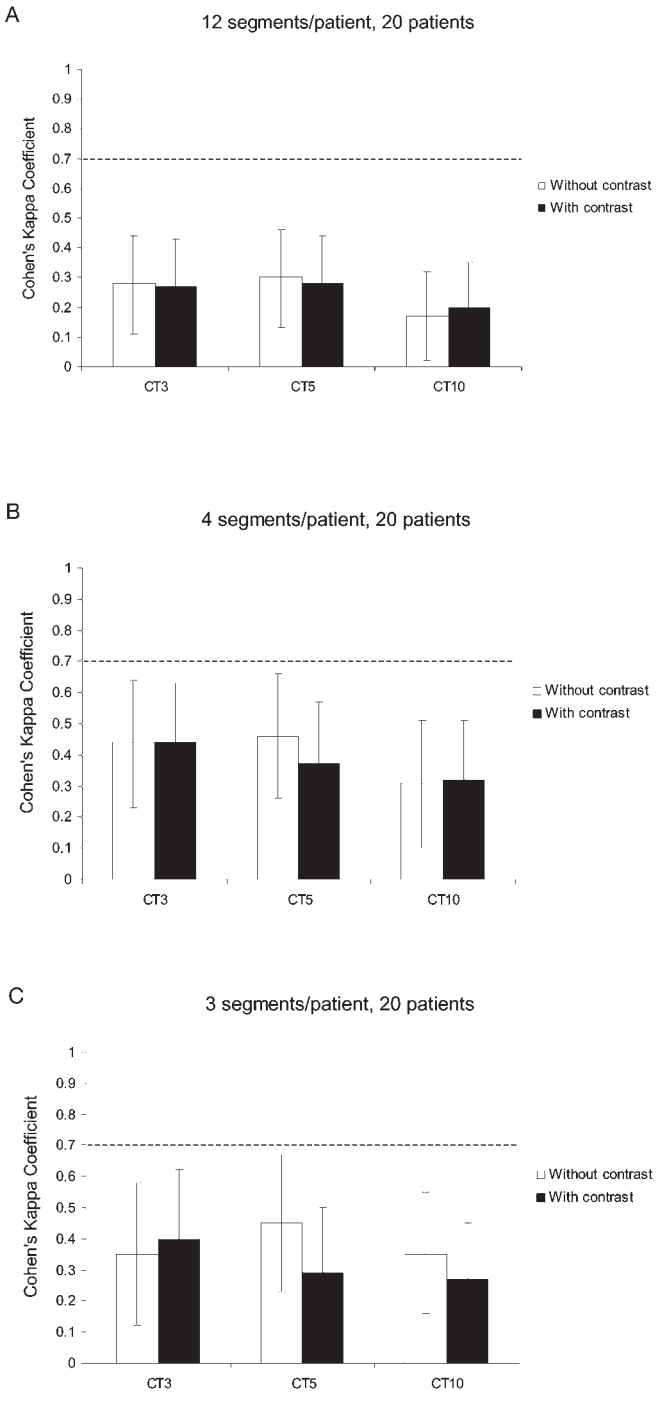
The differences between the 2 diagnostic tests are summarized in Table 3. This table presents the number of segments with atherosclerosis detected with epiaortic scanning and with CT when the aorta is divided into the different segments.

When we compared each segment of the ascending aorta, we found a low reliability (kappa coefficients of 0.45 or lower) between the 2 methods that was independent of the thickness of the sections (3 mm, 5 mm, or 10 mm) or whether contrast was used. All coefficients were significantly lower than 0.7 at the 95% level (Figure).

DISCUSSION

The fact that during the last 15 years the incidence of postoperative stroke has not shown the slightest sign of declining can only be regarded as proof that the search for its risk factors has failed. If we had known those factors, we would have had at least some success in avoiding them, and the incidence of stroke would have decreased. The earlier view that age, carotid disease, and atrial fibrillation were the 3 main risk factors [Demopoulos 1995, Stroke Prevention in Atrial Fibrillation Investigators Committee on Echocardiography 1998] has now been abandoned. So, what is the state of our knowledge at present? It is perhaps a bit less dismal than the previous discussion suggests, for although opinions differ about the relative importance of the various risk factors, there is a rather high degree of consensus about the role of atherosclerosis of the ascending aorta. Admittedly, John et al [2000] in a large multicenter study recognized not atherosclerosis but age as the key risk factor; however, they nevertheless awarded atherosclerosis of the ascending aorta second place. By contrast, in our clinical study involving 921 consecutive patients who underwent cardiac surgery, logistic regression identified atherosclerosis as the most important risk factor by far for postoperative stroke [van der Linden 2001], whereas it deemed the roles of many other commonly reported risk factors, including age, as insignificant. Several other studies [Davila-Roman 1994, Blauth 1995, Roach 1996, Hogue 1999] also pointed to atherosclerosis of the ascending aorta as the main risk factor. The probable reason for the divergence among the various studies is the way in which the presence of atherosclerosis was ascertained. In our study, we diagnosed and mapped the extent of the disease with intraoperative epiaortic ultrasound, and we found that simple digital palpation, a technique used by others, identified only 39.6% of the patients with disease of the ascending aorta. However, whatever the reason for the differences among the studies, the present consensus is that atherosclerosis of the ascending aorta is either the most important or the second most important risk factor for stroke. Consequently, accurate beforehand knowledge of the condition of the ascending aorta is of the utmost importance for the cardiac surgeon.

What diagnostic methods do we have for evaluating the presence, extent, and location of atherosclerosis in the ascending aorta? As is apparent from a number of studies [Konstadt 1995, Davila-Roman 1996, Sylivris 1997, van der Linden 2001], epiaortic ultrasound is superior to both simple palpation and TEE as a diagnostic method. Its drawback, however, is that the examination has to be performed intraoperatively. As pointed out in the "Introduction," the ideal method should be able to provide accurate information before the start of the operation. What preoperative methods are being used to diagnose atherosclerosis of the ascending aorta? Apart from magnetic resonance imaging, which is not widely applied because of the expense, there are only 2 methods in common use, ie, the ordinary chest radiograph and the CT scan. Because it visualizes only calcified areas of a certain size, the chest radiograph tends to seriously underestimate the extent of the disease. The same does not hold true for CT scanning, which has been shown to accurately detect the presence of calcifications in the wall of the thoracic and abdominal aorta as well as in coronary vessels [Raskin 1978, Stanford 1999]. It also has the advantage of being relatively cheap and fast. The question that now arises is how can these techniques be compared. The mere identification by CT of the presence of atherosclerosis is not enough. Only if CT were able to classify the extent and location of atherosclerosis with the same accuracy as intraoperative epiaortic ultrasound would it become a clinically useful method to preoperatively identify patients with a high risk of stroke. In the present study, CT sections of the ascending aorta were therefore divided into the same 12 segments as with epiaortic scanning. Thus, the primary comparison of the methods involved 240 segments, which should be a sufficiently large number of segments for an extensive statistical analysis. However, one may argue that the distinction between the segments may vary between the methods. Such variations



Detection of atherosclerosis in the ascending aorta with intraoperative epiaortic ultrasound (EPI) versus preoperative computed tomography (CT) in 20 patients for whom the ascending aortas were divided into 12 (A), 4 (B), and 3 (C) segments per patient. The CT analysis was made with section thicknesses of 3 mm, 5 mm, and 10 mm, as well as before (0) and after (1) the intravenous injection of contrast medium. The agreement of preoperative CT scans and intraoperative epiaortic ultrasound are expressed as the Cohen simple kappa coefficient ± 95% confidence limits. Generally, a kappa coefficient >0.7 is considered satisfactory.

may be due, for instance, to the deviation of the ultrasound probe from the vertical line. For this reason, comparisons were also made when the ascending aorta of each patient was divided into only 4 longitudinal and 3 transversal sections. Thus, the comparison of the techniques would gain in validity if the outcomes were roughly the same with many segments or with few segments. Furthermore, for the same reason we also studied whether the thickness of the CT sections and the presence of contrast influenced the results.

The present study included only patients with coronary artery disease who were aged 70 years or older. This selection criterion explains the high incidence of atherosclerosis among our patients. The incidences were 60% and 45% as diagnosed with epiaortic ultrasound and CT scanning, respectively, and are more than twice as high as those of unselected patients who undergo cardiac surgery [van der Linden 2001].

As shown in Table 2, epiaortic ultrasound was clearly superior to CT scanning for detecting the extent and location of atherosclerosis of the ascending aorta. The difference between the methods remained significant at the 1% level and was independent of the choice of section thickness and of whether contrast was used for the CT analysis. This finding was verified by the extended statistical analysis, which consistently showed a low reliability between the 2 methods. As can be seen in the Figure, the 95% confidence limits of the Cohen simple kappa coefficients were uniformly below the 0.7 limit with tests involving 240, 80, and 60 segments.

In conclusion, the CT method is clearly inferior to epiaortic ultrasound, today's gold standard, for detecting the extent and location of atherosclerosis in the ascending aorta. Because there clearly is a need for a preoperative diagnosis of extensive disease, other methods, possibly magnetic resonance imaging, should be considered.

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REVIEW AND COMMENTARY

Invited Commentary from Johannes Bonatti, MD, Innsbruck Medical University Department of Cardiac Surgery, Innsbruck, Austria:

In this paper, Bergman and coworkers present another important study in which the superiority of epiaortic scanning compared with other methods of diagnosing ascending aortic atherosclerosis is pointed out. Their intention to evaluate the CT scan as a preoperative means of diagnosing ascending aortic disease needs to be recognized because an adequate preoperative method to determine the extent of pathology is highly desirable.

It was not surprising to see a 60% rate of diseased ascending aortas after epiaortic scanning, and this rate was only 45% for CT scans. The poor sensitivity of palpation for the detection of the disease has been repeatedly described and was again demonstrated in this report. The group's findings are in accordance with our own experience [Hangler 2003].

Because intraoperative detection of ascending aortic atherosclerosis often causes intense and sometimes confusing discussions about surgical management, the search for adequate preoperative diagnostics should continue. The authors suggest magnetic resonance imaging, which has been shown to be of significant value in diagnosing ascending aortic atherosclerosis in patients with homozygous familial hypercholesterolemia [Summers 1998].

One point of discussion concerning CT scans could be the fact that more and more patients are receiving ultrafast CT scans for the evaluation of calcium scores in their coronary arteries. Could these examinations be a source of preoperative information for coronary artery bypass grafting patients, at least for detection of calcifications in the ascending aorta? Overall, the authors should be congratulated for a very interesting and valuable study.

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