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Simultaneous Aortic and Coronary Assessment in Abdominal Aortic Aneurysm Patients by Thoraco-abdominal 64-Detector-row CT Angiography: Estimate of the Impact on Preoperative Management: A Pilot Study

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Abstract *Objectives:* To estimate the influence of information on the coronary arteries obtained from routine thoraco-abdominal CT angiography (CTA) on pre-operative clinical management in abdominal aortic aneurysm (AAA) patients.
Methods: Twenty-eight AAA patients underwent pre-operative thoraco-abdominal electrocardiography (ECG)-gated 64-detector-row CTA to evaluate aortic pulsatility for prosthesis size matching. Retrospectively, the coronaries were reconstructed from the same data set and scored on a per segment basis for stenosis (0%, $\leq$50% or >50%) and grading confidence (poor, adequate or high). An experienced cardiologist was presented information on patient characteristics obtained from patient records and CTA findings. Suggested changes in European Society of Cardiology guidelines based patient management based on CTA information were scored.
Results: On CTA, 17 patients (61%) had significant coronary disease (>50% stenosis) including left main ($n = 4$), single ($n = 7$) and multiple ($n = 6$) vessel disease. Grading confidence was adequate or high in 86% of proximal and middle segments. Based on CTA findings, patient management would have been changed in 4 out of the 28 patients (14%; 95% CI 1–27%) by adding

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coronary angiography ($n = 4$). In five patients who underwent coronary artery bypass grafting previously, CT did not change management but confirmed graft patency.
Conclusions: Information on coronary pathology and coronary bypass graft patency can be readily obtained from thoraco-abdominal CTA and may alter pre-operative patient management, as shown in 14% of AAA patients in our study.

Based on a coronary angiogram study, up to 36% of patients with an abdominal aortic aneurysm (AAA) have severe concomitant coronary artery disease (CAD) which puts them at increased risk for perioperative cardiac complications.[1] Myocardial infarction is the leading cause of peri- and postoperative mortality associated with AAA repair and accounts for up to 37% of early (<30 days) and 39% of late (within 5 years) postoperative deaths.[2]

To stratify pre-operative cardiac risk, the European Society of Cardiology (ESC) guidelines use clinical predictors (angina pectoris, prior myocardial infarction, heart failure, stroke/transient ischaemic attack, renal dysfunction and diabetes mellitus requiring insulin therapy) for initial assessment and only support additional cardiac evaluations in patients with three or more risk factors because of the balance between perioperative benefit, risk and cost.[3]

Multidetector-row CT angiography (MDCTA) is routinely used in the work-up of AAA patients to assess the aorta. In the last decade, MDCTA has also emerged as a promising non-invasive alternative to conventional coronary angiography (CAG) for coronary artery evaluation with high sensitivity and specificity reported for 64-detector row scanners.[4,5]

We routinely perform thoraco-abdominal CTA with retrospective electrocardiography (ECG)-gating in patients prior to AAA repair to exclude thoracic aneurysms and quantify aortic pulsatility for prosthesis size matching.[6] From this same data set, the coronary arteries may be reconstructed as well.[7] Our goal was to estimate how frequently this coronary CTA information would affect clinical management in AAA patients prior to surgery in order to evaluate whether coronary CTA should be routinely performed in these patients.

Materials and Methods

Patient population

In our hospital, pre-operative cardiological consultation is offered to patients prior to AAA repair, based on clinical assessment by the vascular surgeon using an algorithm that is adapted from ESC guidelines. Twenty-eight consecutive patients who underwent ECG-gated thoraco-abdominal CTA prior to AAA repair were included in this study. Eighteen patients were scheduled for endovascular aneurysm repair (EVAR), nine patients for open repair and one for a hybrid approach. Mean aneurysm diameter was 6.5 ± 1.5 cm. Patient records were retrospectively reviewed for patient characteristics including history of angina, coronary revascularisation, chronic obstructive pulmonary disease, diabetes, heart failure, hypertension, intermittent claudication, prior myocardial infraction, renal dysfunction or insufficiency, transient ischaemic attacks or stroke, pre-operative cardiological consultation and patient management.

MDCTA scan protocol

CTA was performed on a 64-detector-row scanner (Brilliance 64-channel, Philips Medical Systems, Best, the Netherlands). No β-blockers were given. The patient was placed in a supine position and an ECG trace was recorded. The imaging volume extended from above the aortic arch to the groin. Subsequently, iodinated non-ionic contrast material (Ultravist, 300 or 370 mg iodine per millilitre; Schering Nederland BV, Weesp, the Netherlands) was continuously injected intravenously. The scanning delay was set with an automatic trigger. A circular region of interest placed in the descending aorta was monitored in real time and as soon as the signal density level reached the predefined threshold of 100 HU, the patient was instructed to maintain a breath-hold. After 6 s, scanning was started and performed in the cranio-caudal direction with simultaneous recording of the ECG trace. Imaging parameters were: slice collimation 64×0.625 mm; gantry rotation time 420 ms; tube voltage, 120 kV; tube current, 300 mAs; matrix size of 512×512 pixels and pitch 0.25.

Image reconstruction

A radiologist reconstructed and scored all CTA examinations using a dedicated workstation and analysis software (Brilliance 3.0, Philips Medical Systems, Best, the Netherlands). He was unaware of the clinical information of the patient regarding pre-, peri- and postoperative treatment and morbidity and mortality.

From the retrospective ECG-gated data set axial images were reconstructed with a slice thickness of 0.9—1.4 mm at eight different phases of the cardiac cycle (each 12.5% of the R—R interval) and used to assess the coronary arteries.

Coronary artery assessment

The coronary arteries were scored in the phase with the best image quality using the 15 segment AHA model:[8] left main coronary artery (segment 5); proximal, middle and distal segments of the right coronary artery (segments 1, 2 and 3), left anterior descending coronary artery (segments 6, 7 and 8) and the left circumflex artery (segments 11, 13 and 15), the RDP (segment 4), the diagonal branches (segment 9 and 10) and the OM branches (segments 12 and 14). Stenosis and image-grading confidence per segment were scored on a three-point scale: (0%, ≤50% or >50% stenosis) and (poor, adequate or high), respectively.

Coronary bypass grafts were reconstructed and scored as patent or non-patent.

Clinical management change

An experienced cardiologist was presented details on cardiac risk factors, previous history, pre-operative cardiological evaluation and patient management of each patient. The cardiologist retrospectively determined the number of clinical risk factors and determined the suggested patient management based on ESC guidelines. Subsequently, cardiac CTA findings were disclosed. The cardiologist scored whether the CTA information would have led to a change in the patient management as was retrospectively determined based on ESC guidelines. The suggested change was scored as: performing additional non-invasive cardiac testing in patients with limited disease; performing additional conventional coronary angiography in case of severe unknown or underestimated coronary disease or defer a specific cardiac test in case of absence of coronary pathology. Additionally, in patients who had previously undergone coronary artery bypass grafting (CABG), the cardiologist scored whether the information on graft patency changed patient management. If no change in patient management was considered based on CT findings, the cardiologist also scored whether or not CT findings provided additional support for the intended management.

Results

Patient characteristics

Patient characteristics are listed in Table 1. Heart rate during scanning was 72 (53–115) (mean and range).

Coronary artery assessment

Out of the total theoretical 420 coronary segments (28 patients $\times$ 15 segments), 303 (72%) were available for analysis on CTA including 104 (93%) of 112 theoretical proximal segments (segments 1, 5, 6 and 11), 77 of 84 (92%) middle segments (segments 2, 7 and 13) and 122 of 224 (54%) other segments (segments 3, 4, 8, 9, 10, 12, 14 and 15). Coronary segment grading confidence score was adequate or high in 87% of proximal and 83% of middle segments. For proximal and middle segments combined 181 of 196 (92%) were visualised on CTA and 168 of 196 (86%) could be graded at least adequately.

A significant ($\geq$50%) stenosis was seen in 74 of 420 (18%) segments including 52 (27%) stenosis in the potential 196 proximal and middle coronary artery segments (Fig. 1). Seventeen patients (61%) were affected: four had left main disease, seven single vessel, three double and three triple vessel disease. Based on stenosis in proximal segments only, the distribution was the same except for one patient who would go from double to single vessel disease.

In five patients, a total of 11 bypass grafts were visualised, one of which was scored 'occluded' and all others as 'patent'.

Clinical management

Retrospectively determined number of clinical risk factors and ESC guidelines-based patient management are listed in Table 1. Based on ESC guidelines, three patients would have had three or more risk factors necessitating additional testing.

Based on CTA information the independent cardiologist would have changed the pre-operative clinical management in 4 of 28 patients (14%; 95% CI 1–27%). The suggested change was performing additional coronary angiography in all four patients. In the five patients who had previously undergone CABG, CT provided additional support for the management, as suggested by the ESC guidelines.

Discussion

The principle findings of this study are (1) >90% of proximal and middle coronary artery segments could be analysed on routine pre-operative 64-detector-row thoraco-abdominal CTA in AAA patients; (2) coronary CTA detects significant coronary disease in >60% of AAA patients; and (3) coronary CTA findings may lead to a change in pre-operative patient management in 14% of patients prior to AAA repair.

Preoperative cardiac evaluation

Open AAA repair is associated with high perioperative mortality (3.5–8.2%) and cardiac morbidity (5.7–12.0%).[9–11] EVAR has a significantly lower early (<30 days) mortality of 1.2–1.7%, but during the next 2–4 years, the initial advantage for EVAR is cancelled out by excess mortality from other (mainly cardiovascular) causes equalling survival for both treatments.[9–11]

Despite the high incidence of CAD, CAG is not used routinely during the pre-operative work-up of AAA patients because of the procedure-related 1.7% incidence of major complications, including a 0.11% mortality rate.[3] Current ESC guidelines recommend additional pre-operative cardiac testing only in patients with three or more clinical predictors and when it will change management in patients prior to non-cardiac surgery.[3] The cardiologist can choose from various functional pre-operative tests (e.g., exercise electrocardiography and dobutamine stress echocardiography). The choice depends on local experience and availability. Most tests provide functional information but no direct anatomical visualisation of the coronary arteries. If direct anatomical visualisation is required CAG will need to be performed. In patients who underwent previous surgical coronary revascularisation, graft patency can only be confirmed by CAG.

In this study, the cardiologist opted to change patient management by adding conventional coronary angiography in four patients with double or triple vessel disease on CT. In cardiac-stable patients, the patient outcome is not necessarily improved by revascularisation of all angiographically stenotic lesions compared to optimal medical treatment.[12] Furthermore, revascularisation prior to AAA surgery should only be performed if there is an indication for revascularisation irrespective of the surgical procedure. This should be kept in mind before a decision to perform CAG is taken.

With thoraco-abdominal CTA being performed routinely in all AAA patients prior to repair, it provides the opportunity to non-invasively obtain anatomical coronary information as well as assess coronary bypass graft patency.

Table 1 Detailed description of the patients enrolled in the study.

Patient #	Age and sex	Patient characteristics and risk factors	Number of ESC risk factors	ESC guidelines based need for pre-operative additional testing	CT-findings	CT induced management change
1	82 M	CVA, HT, IC	1	No	No stenosis	None
2	77 M	COPD, HT	0	No	Single vessel disease	None
3	70 F	—	0	No	Single vessel disease	None
4	66 M	—	0	No	Non diagnostic	None
5	72 M	—	0	No	No stenosis	None
6	70 M	CABG, CVA, DM, HT, IC, MI	3	Yes	2-vessel, LM, Grafts open	None but knowledge of graft patency
7	74 M	CABG, COPD, DM	1	No	3-vessel, Grafts open	None but knowledge of graft patency
8	65 M	CVA, HF, HT, RF	3	Yes	No stenosis	None
9	59 M	—	0	No	No stenosis	None
10	76 F	CABG, HT	0	No	2-vessel, LIMA-LAD open, Venous graft closed	None but knowledge of graft patency
11	77 M	AP, HT	1	No	No stenosis	None
12	63 M	AP, HF, HT, MI PTCA	3	Yes	Single vessel	None
13	83 M	HT	0	No	Single vessel	None
14	76 F	CABG,CVA, HT	1	No	3-vessel, LM, Grafts open	None but knowledge of graft patency
15	86 F	DM	1	No	No stenosis	None
16	75 M	—	0	No	Single vessel	None
17	74 M	AP, HT	1	No	3-vessel	CAG
18	76 M	COPD, HT	0	No	Double vessel	CAG
19	61 M	AP, HT, RF	2	No	Double vessel, LM	CAG
20	66 M	COPD, HT, MI	1	No	Double vessel	None
21	73 M	—	0	No	Single vessel	None
22	63 M	DM, HT, MI	2	No	No stenosis	None
23	85 M	CABG, HT, MI	1	No	Single vessel Grafts open	None but knowledge of graft patency
24	56 M	HT	0	No	No stenosis	None
25	67 M	AP, CABG, HT, MI	2	No	3-vessel, LM CABG post scan	None
26	70 M	HT, IC, MI	1	No	3-vessel	CAG
27	75 F	HT	0	No	No stenosis	None
28	81 M	CVA, DM, HT	2	No	No stenosis	None

Per patient characteristics, ESC risk factors, CT findings and CT induced change of patient management. AP = angina; CABG = coronary artery bypass grafting; CAG = conventional coronary angiography; COPD = chronic obstructive pulmonary disease; CVA = prior transient ischaemic attack or cerebrovascular accident; DM = diabetes mellitus; F = female; HF = heart failure; HT = hypertension; IC = Intermittent claudication; LM = left main coronary artery; M = male; MI = myocardial infarction; PTCA = percutaneous transluminal coronary angioplasty; RF = renal failure.

Although the limited coronary disease (one-vessel or two-vessel disease that did not include the proximal coronary segments) detected by CT may not result in a direct change of perioperative management, the knowledge of the presence of coronary disease can have implications for future patient management in the postoperative period.

Thoraco-abdominal MDCTA

Dedicated cardiac CTA on 64-detector row scanners in patients with symptomatic coronary disease has a reported sensitivity and specificity of 91% and 98% for detection of CAD on based on all segments (pooled data from five studies including 308 patients total).[13]

In the current study, 72% of segments theoretically available for analysis could be evaluated. This is less than commonly reported for dedicated cardiac CT but we feel this is acceptable considering the fact that the information is derived from a routine MDCTA. The scan protocol differs from a dedicated cardiac CT in that we use a lower mAs (300 instead of 500—900) and higher pitch (0.25 instead of 0.2). Furthermore, β-blockers were not administered prior to CT scanning to lower the heart rate. However, 92% of the clinically most important proximal and middle segments could be evaluated and 86% scored at least adequately. Our findings on the number of assessable coronary segments correlate well with those of another group that assessed coronary image quality on ECG-gated thoracic CTA for

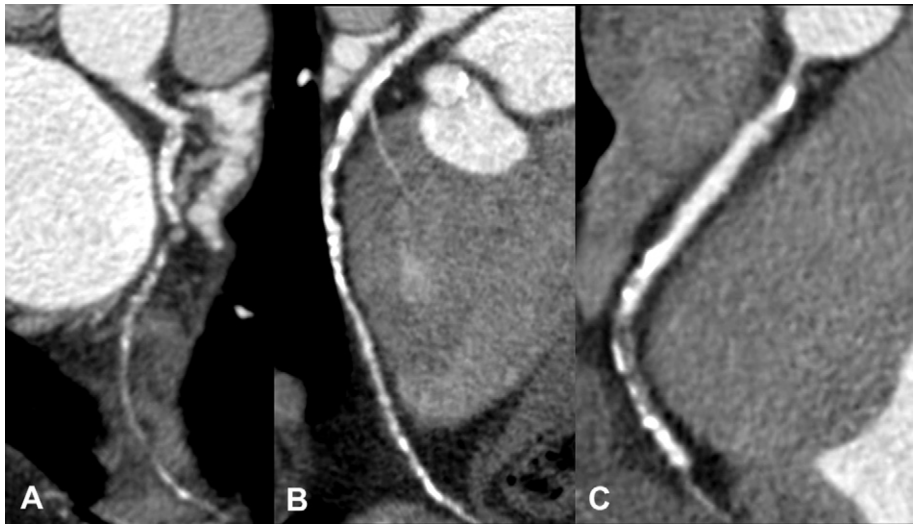

Figure 1 Curved multiplanar reconstructions of the circumflex (A) left anterior descending (B) and right (C) coronary artery (LCx, LAD and RCA, respectively) of patient #26 showing severe coronary atherosclerosis with >50% stenosis in all vessels.

assessment of patients with pulmonary abnormalities (93% of proximal segments assessable).[14]

Recent reports demonstrated the potential use of CT for assessment of cardiac morphology (signs of previous myocardial infarction) and function (wall motion, stroke volume and cardiac output) as well.[7] With further improvements, this may prove a valuable addition and allow a comprehensive cardiac analysis from a single pre-operative scan.

Limitations

No coronary angiography was performed to validate CTA findings of coronary stenosis and determine the precise percentage of coronary segments that were correctly visualised and scored. However, several studies have previously validated MDCT for assessment of coronary arteries in symptomatic patients, generally indicating high sensitivity and particularly high negative predictive value.[4,5] Whether these numbers can be extrapolated to the non-symptomatic population of AAA patients remains to be established.

The study is retrospective, small and changes in clinical management were determined by a single cardiologist. A different cardiologist might have opted for a different change in patient management or a different additional cardiac test in certain patients. Furthermore, in our hospital pre-operative management (and the need for a pre-operative cardiological consultation) is based on an algorithm that is an adapted version of the ESC guidelines. In order to make the findings more widely applicable and comparable we retrospectively determined patient management based on the ESC guidelines. Despite these limitations, however, we feel the findings of this study give an estimate of the magnitude of effect that coronary CTA findings may have on clinical management in AAA patients and provides support for a larger study. Based on these findings we feel first a larger prospective study with strict adherence to the ESC guidelines preoperatively and detailed patient follow-up postoperatively is needed to confirm our findings in a larger cohort and provide an estimate of whether and to what extent postoperative morbidity and mortality can be reduced by including the information on the coronary arteries obtained from the pre-operative CT scan.

Conclusions

Retrospective ECG-gated CTA of the chest and abdomen allows simultaneous assessment of the aorta and coronary arteries in AAA patients and suggests a change in pre-operative management in 14% of AAA patients. Given the high rate of coronary events in AAA patients, such a combined evaluation of the aorta and coronary arteries may be advantageous.

Conflict of Interest

We have no conflicts of interest to disclose.

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