Editorial Commentary

The role of computed tomography prior to transcatheter aortic valve implantation: preprocedural planning and simultaneous coronary artery assessment

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Introduction

During the last decades, advancements in computed tomography (CT) scanner technology along with multiple clinical studies helped establishing the role of coronary CT angiography (CCTA) for the detection of obstructive coronary artery disease (CAD) (1,2). Currently, CCTA is recognized as a cornerstone for the non-invasive diagnostic work-up of patients with low to intermediate pretest probability of CAD, and its appropriate use is endorsed by several current national and international guidelines (3,4). In this regard, CCTA can identify different stages of the atherosclerotic process, including early atherosclerotic changes of the coronary vessel wall, a quality not met by any other non-invasive modality (5). In addition, CCTA is so far the only diagnostic modality, which can effectively reduce major adverse cardiac events in patients with chronic coronary syndromes, as demonstrated by the randomized controlled Scottish Computed Tomography of the Heart (SCOT-HEART) trial (6). This finding was recently confirmed in a 'real-world' setting, where the implementation of the CCTA in the United Kingdom, as recommended by the National Institute for Health and Care Excellence (NICE) guidelines, was associated with a decline of unnecessary invasive coronary angiography procedures and with significant reductions in cardiovascular mortality rates, without largely affecting average annual healthcare spendings (7,8).

Apart from its usefulness for the assessment of CAD, cardiac CT is nowadays used for a multitude of other applications in clinical routine. These encompass its use prior to transcatheter-delivered interventions for atrioventricular valve disease, offering important information related to the dimension of the corresponding atrioventricular valve ring as well as to the anatomic proximity between the valvular ring and the coronary arteries (9). In particular, it enables various measurements of the mitral and tricuspid valve apparatus with high spatial resolution in any arbitrary plane while offering good visibility of calcifications to allow effective procedural planning as well as patient selection for catheter-based valve therapy (10-12). Furthermore, the usefulness of cardiac CT for accurate planning of transcatheter left atrial appendage occlusion has been suggested (13). In addition, it provides accurate rendering of the left atrium and the pulmonary veins, which has been shown to improve the accuracy of

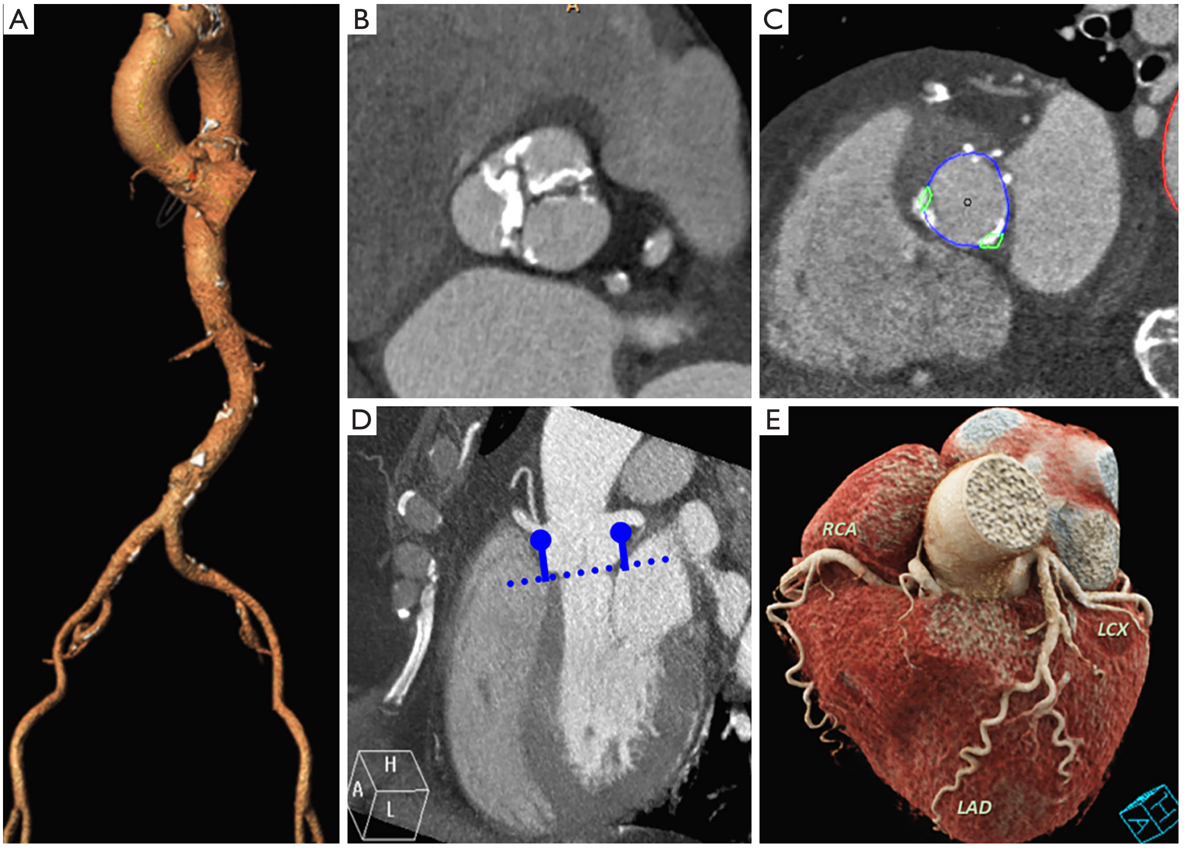

Figure 1 Exemplary TAVI-CT evaluation. Preprocedural CT angiography assessment of peripheral access site (A), aortic valve calcification (B), diameter of the aortic annulus (C) (blue line: annular perimeter; green areas: annular calcifications), distances between the aortic annulus and the coronary ostia (D) (blue dotted line: annulus plane; blue continuous lines: distance from annular plane to coronary artery ostia), and of concomitant coronary artery disease, requiring consideration for revascularization prior to the TAVI procedure (E). RCA, right coronary artery; LAD, left anterior descending coronary artery; LCX, left circumflex coronary artery; TAVI, transcatheter aortic valve implantation; CT, computed tomography.

the pulmonary vein isolation procedure, by providing information related to possible anatomic variations, potentially reducing radiation and contrast agent exposure for the patients (14). In this context, it is relevant to note, that CT is increasingly performed as part of a preoperative work-up in patients scheduled for minimally invasive mitral and aortic valve surgical procedures, as well as complex cardiac surgery, which has been reported to increase the rate of incidental findings (15).

CT has become particularly important for the evaluation of candidates for transcatheter aortic valve implantation (TAVI). In this context, CT angiography of the aorta and the ilio-femoral arteries has become the central preprocedural diagnostic measure and provides information on relevant aspects for clinical decision-making. This involves severity and distribution of aortic valve calcification, anatomy and dimension of the aortic annulus, distance from the annulus plane to the origin of the coronary arteries, presence of porcelain aorta, and visualization of the vascular access route (*Figure 1A-1D*) (16-18). Beyond planning the TAVI procedure, preprocedural exclusion of relevant CAD is recommended by current guidelines (19), which primarily advocate invasive coronary angiography for this purpose. However, CT evaluation prior to TAVI shares system and protocol requirements together with CCTA. Therefore, the value of TAVI-CT for assessing the coronary arteries non-invasively has been previously investigated (20). Three meta-analyses have reported on the diagnostic accuracy of CT prior to TAVI for the diagnosis of concomitant CAD (21-23). The largest and most recent meta-analysis comprised data from 14 studies with 2,533 patients, using a bivariate random-effects model to summarize the diagnostic performance of CT for assessing relevant CAD in the preprocedural setting before TAVI. Per patient, a pooled sensitivity and specificity of 97% and 68% was reported, respectively. This meta-analysis demonstrated that CT has an excellent diagnostic accuracy for the diagnosis of significant CAD in patients scheduled for TAVI and could obviate the need for invasive angiography in 41% (95% confidence interval: 34–47%) cases, assuming a disease prevalence of 40%. In addition, the use of single-heartbeat CT systems was found to significantly improve specificity for CAD detection compared with other CT technology (82% *vs.* 60%, respectively; P<0.0001). The latter finding has been implemented in the expert consensus document, which recommends the use of CT-scanners with high temporal resolution in this patient population (16).

We have read with interest the recently published study by Lecomte *et al.* (24), adding to the data on coronary artery assessment based on TAVI-CT. Although previous studies have investigated the potential value of machine-learning in CT-based fractional flow reserve in this setting (20), artificial intelligence has not played a major role in research activities with TAVI-CT so far. Thus, the present study offers new insights by rigorously implementing deep-learning image reconstruction and motion correction algorithms and improved CT tube technology in this field.

Main methods and results of the commented study

This was a retrospective single-center study including a total of 206 patients with severe symptomatic aortic stenosis (AS), who underwent CT and invasive coronary angiography as part of their diagnostic work-up prior to TAVI. The main exclusion criterion was known CAD, i.e., patients with previous percutaneous coronary intervention (PCI) or coronary artery bypass graft (CABG). The study aimed at assessing the percentage of invasive coronary angiography examinations that could have been avoided by implementation of TAVI-CT. All CT examinations were performed by a single-heartbeat CT system, using state-of-the-art reconstruction algorithms. The CT protocol involved an electrocardiogram synchronized prospectively triggered thoracic scan (RR-interval 30 to 75%), which was followed by a non-synchronized helical image acquisition for peripheral vascular imaging. Relevant CAD on CT as well as on invasive coronary angiography was defined as ≥50% stenosis of the left main coronary artery and ≥70% stenosis of any other coronary artery with >2.5 mm diameter, with invasive coronary angiography serving as the standard reference technique.

Based on TAVI-CT interpretations, invasive coronary angiography would have been recommended in all (51/51; 100%) patients with poor image quality by study protocol, in 33/76 (43%) with moderate and in 25/79 (32%) with good CT image quality. Thus, TAVI-CT ruled out the need for invasive angiography in 97/155 with moderate or good image quality, where indeed no need for coronary revascularization was found by invasive coronary angiography in all these patients. Therefore, the sensitivity and negative predictive value of TAVI-CT for the detection of CAD requiring revascularization was 100%, while specificity, positive predictive value and overall accuracy were 54%, 25% and 60%, respectively. In addition, the mean interpretation time required for the detection of at least one significant coronary artery lesion was relatively low (2.0±1.2 min, range, 1–5 min).

The main result of the study is that CT, using automated motion correction and deep learning reconstruction algorithms, may help potentially avoiding invasive coronary angiography in 47.1% of patients with severe AS who are considered for TAVI. Since this proportion is related to CT image quality, the authors anticipate that it would have been higher (62.6%) in case of good image quality in all patients and may further increase in the future with the implementation of improved imaging and acquisition techniques.

Agreement for the interpretation of the CT image quality was rated as good (kappa values between 0.68 and 0.74) among both experienced and non-experienced operators. Furthermore, observer agreement for classification of patients in those with versus without need for invasive angiography was also high (kappa values between 0.72 and 0.79).

Discussion and critical appraisal

The results of the present study are straight forward and relevant in this field, suggesting that high-quality preprocedural TAVI-CT imaging using state-of-the-art technology allows concomitant evaluation of the coronary arteries and exclusion of significant CAD in a relevant number of patients with severe AS. This agrees with the current literature, demonstrating the usefulness of the noninvasive CT-based evaluation of coronary arteries in TAVI candidates, obviating the need for invasive angiography in a large number of such patients.

This is an important message for the daily clinical practice in many cardiac centers. However, some points need to be considered in this context. Of note, the studied population did not consist of all-comer TAVI patients. Thus, the exclusion criteria *per se* introduce some selection biases. Altogether, only 206 (62.6%) of the initially screened patients were included in the main analysis, mainly due to exclusion of patients with prior PCI or CABG and of patients who did ultimately not undergo TAVI for clinical reasons. The authors justified the exclusion of patients with prior PCI or CABG, because the diagnostic yield of TAVI-CT is expected to be lower in this subset, which was similarly carried out in previous studies (20). Thus, the diagnostic yield of CT may have been lower in an all-comer TAVI-CT cohort since false-positive findings and non-evaluable coronary artery segments may have been more frequent in such patients.

In the same direction, the percentage of patients ultimately requiring coronary revascularization was surprisingly low (6.3%), which indicates an overall low risk TAVI patient cohort and may limit the extrapolation of the current findings to TAVI patients at higher risk for relevant CAD. Moreover, as only patients with CT and invasive coronary angiography were included, it is not completely clear why invasive coronary angiography was not deferred in patients without evidence of relevant CAD by TAVI-CT, as recommended by current guidelines (19,25).

In addition, CT image quality was low in a relatively large number of patients (24.8%), which triggered a high percentage of patients, where invasive coronary angiography would have been recommended despite the absence of CAD. This was intentionally chosen by the authors based on the study protocol to securely avoid false negative findings, thus overlooking significant coronary lesions, which may require revascularization prior to the TAVI procedure. Furthermore, it is stated in material and methods of the commented study, that a reader with limited experience in cardiac imaging performed the image quality rating. The authors emphasize the importance of reaching a perfect negative predictive value of 100% in the population of TAVI patients due to the perceived risk of severe periprocedural myocardial ischemia. However, evidence to establish the relevance of revascularization in the context of TAVI is also scarce. Of note, CAD is often an incidental finding during the work-up of patients with the indication for TAVI due to symptomatic AS. Based on expert consensus and in the absence of randomized controlled trial data, it has been suggested to consider PCI in case of >70% diameter stenosis of the proximal coronary artery segments in patients scheduled for TAVI (19). Nevertheless, the clinical value of systematic revascularization in TAVI candidates is still not completely understood and merits further investigation in future studies. The same applies for the optimal timing of coronary revascularization either prior or after the TAVI procedure, which also remains unclear. In absence of indicatory data from randomized clinical trials, it is important to note that decisions should be made on an individual basis and preferably in a multidisciplinary heart-team setting weighing the risk of bleeding with that of myocardial ischemia. Nevertheless, on the basis of our experiential knowledge, it is safe to proceed with TAVI first in absence of high-risk characteristics (e.g., significant left main disease or >70% disease of a proximal segment of a dominant coronary artery with anticipation of difficult coronary re-access after TAVI). Elective PCI of stable CAD should then be scheduled as a two-staged procedure following TAVI. This is in line with available evidence favoring this strategy over PCI pre-TAVI and PCI concomitant with TAVI due to improved clinical outcomes (26).

Although invasive fractional flow reserve and the resting pressure ratios are not well established in this specific group of patients, their usefulness prior to TAVI has been previously reported (27), indicating that such techniques usefully guide coronary revascularization procedures in this context. However, such indices should be interpreted with caution in the presence of hemodynamically relevant AS since increased end-systolic and end-diastolic pressures may have confounding effects on coronary physiology (28).

Outlook into the future

Further prospective randomized controlled studies are now warranted to evaluate the role of TAVI-CT for the diagnosis of concomitant CAD. In this context, the implementation of a diagnostic algorithm, primarily centered on a non-invasive evaluation of the coronary arteries in TAVI candidates needs to be examined. Within this proposed diagnostic pathway, all patients presenting for further evaluation of AS and interventional treatment planning will undergo (I) echocardiography for the verification of severe AS; (II) combined CT coronary artery evaluation and TAVI planning with referral to invasive coronary angiography only in case relevant CAD is suspected (*Figure 1*). Finally, it would be interesting to understand the potential role of CT-based fractional flow reserve for assessing CAD in patients prior to TAVI. A small number of studies have addressed this unresolved issue with promising initial results (20).

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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