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The REVOLUTION project: planning and performing surgical revascularization based solely on coronary computed tomography angiography

Leonardo Bolognese *, Matteo Rocco Reccia, and Marco Chioccioli

Cardiovascular Department, Azienda Ospedaliera Toscana Sudest, San Donato Hospital, Via Pietro Nenni 22, Arezzo, Italy

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Coronary computed tomography angiography (CCTA) is a non-invasive diagnostic tool that is increasingly being used as an alternative to invasive coronary angiography (ICA) in patients with suspected coronary artery disease (CAD), providing important information on the extent and severity of CAD. Furthermore, stress CT myocardial perfusion imaging (CT-MPI) and fractional flow reserve derived from CCTA (CT-FFR) have been recently introduced in clinical practice as new tools for evaluating the functional relevance of coronary stenoses. ICA has been the preferred diagnostic method to guide the decision-making process between coronary artery bypass grafting (CABG) and percutaneous coronary intervention (PCI). Recently, two studies have investigated the feasibility of using CCTA rather than ICA to plan CABG. In patients with three-vessel disease and/or left main CAD, the SYNTAX III REVOLUTION trial concluded that clinical decision-making between CABG and PCI using CCTA had a high level of agreement with treatment decisions based on ICA. In the FASTTRACK study, CABG procedures were planned based on CCTA without knowledge of ICA. CABG guided by CCTA showed to be feasible with an acceptable safety profile in a selected population of complex CAD. These intriguing findings should be confirmed in a large randomized trial on the revascularization outcome by comparing patients who underwent a novel non-invasive vs. a traditional invasive roadmap.

To diagnose obstructive coronary artery disease (CAD) and consequently determine appropriate treatment is not a trivial task. Invasive coronary angiography (ICA) is considered the reference standard, particularly when combined with haemodynamic interrogation by fractional flow reserve (FFR). This effective invasive procedure, however, carries inherent risks of potential serious complications and is accompanied by considerable costs, relatively high radiation exposure, and patient discomfort. Furthermore, this strategy has not been without challenges since a substantial percentage of patients (~60%) who are referred for angiography have no haemodynamically significant coronary artery stenosis.[1]

Over the past 20 years, coronary computed tomography angiography (CCTA) has undergone rapid growth from a technique that can estimate the amount and severity of CAD,[2,3] to a test that provides important prognostic information and has a direct impact on subsequent patient management decisions.[4,5] Moreover, as the yield of ICA to detect CAD is low, CCTA has become a gatekeeper to the catheterization laboratory as a negative CTA of sufficient quality virtually rules out obstructive CAD and significantly reduces unnecessary invasive procedures. Consequently, 2024 ESC guidelines for the diagnosis and management of chronic coronary syndromes now include coronary CTA among the routine testing options for evaluating patients with stable chest pain[6] when there is a low-to-moderate (>5–50%) pre-test likelihood of obstructive CAD (Class I/Level of Evidence: A).

CCTA is also increasingly being used as an alternative to ICA to potentially improve outcomes in patients with CAD independent from their revascularization needs. In the

*Corresponding author. Email: leonardobolognese@hotmail.com

recent Diagnostic Imaging Strategies for Patients with Stable Chest Pain and Intermediate Risk of Coronary Artery Disease (DISCHARGE) trial[7] that randomized 3561 patients with stable chest pain and intermediate pre-test probability of obstructive CAD to CCTA or ICA as the initial diagnostic test, the risk of major procedure-related complications was significantly lower in patients undergoing CCTA (0.5 vs. 1.9%, hazard ratio 0.26, 95% CI 0.13–0.55). Furthermore, stress CT myocardial perfusion imaging (CT-MPI) and fractional flow reserve derived from CCTA (CT-FFR) have been recently introduced in clinical practice as new tools for evaluating the functional relevance of coronary stenoses, with the possibility to overcome the main CCTA drawback, i.e. anatomical assessment only.[8,9] Finally, with its three-dimensional nature and physiological assessment, CCTA allows also to accurately assess Syntax Score and Syntax Score II, enhancing the potential role of CCTA in Heart Team discussion for decision-making regarding the mode of revascularization (PCI or CABG) for patients with complex disease.[10]

Building on this evidence, attention has turned towards combining anatomy and physiology not only to guide decisions regarding ICA but also to help revascularization planning. This new paradigm is supported by the unique opportunity of having anatomy and lesion-specific physiology, a combined information that is not provided by other non-invasive imaging modalities.[11] This concept has been tested in two recent, elegant and relevant trials.

The Syntax III Revolution trial

The potential role of CCTA in Heart Team discussion for decision-making between PCI and coronary artery bypass (CABG) was investigated in the Syntax III Revolution trial, which enrolled patients known for having three-vessel disease (VD) with or without left main (LM) disease diagnosed by ICA. The agreement on treatment decision (surgery or PCI) of two heart teams was measured. The heart teams received, in order to make their decision, either a conventional ICA or CCTA of cases with 3VD with or without LM disease.[12] The decision-making of 'CABG only', 'PCI only', or 'equipoise CABG-PCI' was concordant between the two heart teams in 86% of the cases, with a Cohen's kappa of 0.82, qualifying the agreement as almost perfect according to the statistical Cohen's kappa categorization.[12]

Of note, this randomized trial was virtual in nature since the concordance or discordance in decision-making between ICA and CCTA was unveiled to the operators (surgeon or interventional cardiologist) prior to the final definitive decision regarding percutaneous or surgical revascularization. Nevertheless, it is worth mentioning that vital prognosis at 5-year follow-up, using either ICA or CCTA, was comparable.[13]

Although these findings are encouraging, some concerns remain on CCTA capability to be used for decision-making in patients with a high calcific burden of the coronary arteries, a frequent condition in complex and diffuse CAD, particularly in elderly and diabetic patients. The issue was addressed by a sub-analysis of the SYNTAX III Revolution trial.[14] As expected, the sub-analysis showed that heavy coronary calcifications moderately affect CCTA capability to assess accurately the anatomical SYNTAX score, with a significantly higher difference between the CCTA-derived and ICA-derived anatomical SYNTAX score. However, despite the discrepancy in the anatomical SYNTAX score assessment, agreement on the heart team treatment decision did not differ in patients with (Cohen's kappa 0.79) or without heavy calcifications (Cohen's kappa 0.84). Similarly, agreement on treatment planning, defined as the coronary vessels to be revascularized, was high and similar between the two groups of patients.[14]

The SYNTAX III Revolution study findings prompted the hypothesis that CCTA might provide sufficient, or even superior, information to ICA in planning and performing CABG and raised the question if a cardiac surgeon might be confident in using only the non-invasive coronary information provided by CCTA to plan CABG. The intriguing hypothesis was tested first in a theoretical feasibility survey study among surgeons involved in the Syntax III trial.[15] Six surgeons reviewed 20 CCTA of 20 patients who underwent CABG performed previously by them during the course of the SYNTAX III trial. Each surgeon had to declare for himself whether the planning and the execution of surgery would be feasible. In 84% of the cases, they declared that patients would be eligible for surgery without prior conventional ICA.

The logical next step could have been to plan a trial truly randomizing patients between CCTA and ICA in a blinded fashion. However, for ethical reasons, an intermediate step was felt to be mandatory, and this is the essence of the FASTTRACK CABG trial: to assess the feasibility and safety of using CCTA and FFRCT as guidance for planning and performing CABG in patients with 3VD and/or LM CAD.[16]

The FASTTRACK CABG trial

The study *Safety and Feasibility Evaluation of Planning and Execution of Surgical Revascularization Solely Based on Coronary CTA and FFRCT in Patient with Complex Coronary Artery Diseases* (FASTTRACK CABG) is an investigator-initiated, single-arm, multicentre, prospective, proof-of-concept trial in patients with 3VD and/or LM CAD referred for CABG to investigate the feasibility of using CCTA rather than ICA to plan CABG in 114 patients with chronic coronary syndrome at low surgical risk.[17] All patients had previously undergone ICA and were referred to CABG by a Heart Team. They subsequently underwent CCTA, and a separate Heart Team blinded to the ICA was provided only with the CCTA results to guide CABG planning. The key finding of this first-in-human study is the 99.1% feasibility (unblinding of the ICA occurred only in one case), which was driven by the relatively good diagnostic concordance between CCTA and ICA.[17] The agreement in revascularization planning between the angiography and CCTA Heart Teams was 82.9% (a kappa of 0.58, 95% CI 0.50–0.66), and the agreement between the CCTA Heart Team and the treatment received was 83.7% (a kappa of 0.61, 95% CI 0.53–0.68). At 30 days, the incidence of major adverse cardiac and cerebrovascular events (for which the trial was not powered) was 7.2%, and in the 102 patients who received follow-up CCTA, anastomotic patency was 92.6% (another outcome that was not powered). The mean CCTA-anatomical SYNTAX score (aSS) 43.6 (15.3) was

higher than the ICA-aSS 33.7 (12.5), which may relate on the one hand to slightly different methodologies of assessment of the ICA and CCTA scores and on the other hand to calcium blooming artefact on CCTA causing lesion severity to be overestimated, thereby increasing the number of stenoses visually ≥50%.

These results suggest that CABG may be performed without the need for ICA (although no conclusion of the efficacy and safety of CCTA-based CABG can be drawn from the study) and have the potential to change CABG practice. Furthermore, using CCTA rather than ICA for coronary visualization in patients with CAD may lead to a wider adoption of the Heart Team approach and ultimately benefit patients. Infact, these data increase the interest in a planned revascularization approach and bolster the Heart Team role for pre-procedural decision-making in a way similar to that used for structural heart disease.

Although providing exceptionally interesting and promising data, the study should only be seen as hypothesis-generating, and several limitations must be acknowledged.

First, the sample size ($n = 114$) is too small to extrapolate the results to the general population of chronic coronary syndrome patients. The enrolled patients represent only 12% of the total CABG population at participating institutions during the study period, and the baseline characteristics and the very low mean Society of Thoracic Surgeons risk score (0.8, 95% CI 0.68–0.81) clearly show that this is a very low-risk population, which is not representative of current practice.[18]

Second, in this highly selected population, the concordance between coronary angiography and CCTA is only moderate, and there are a non-insignificant number of patients in whom the CABG decision is different when based on CCTA rather than on ICA.

Third, the participating surgeons were highly experienced and dedicated to the research question, and it remains to be demonstrated whether their expertise can be conveyed to other surgical centres.

FASTTRACK CABG was a single-arm study and was not formally powered for clinical outcomes.

Finally, coronary CTA examinations of optimal quality with experienced interpretations are not a universal guarantee. While these attributes might be ‘normal’ in highly experienced environments, we do not know what will happen in ‘real-life’ scenarios especially if one considers that in the FASTTRACK CABG trial, only one type of CT scanner (256-slice GE Healthcare REVOLUTION CT) was used, and this may raise the potential issue of generalizability of the study results to clinical practices with less multi-slice CT expertise and usage of lower-quality CT scanners.

Conclusions

These studies open new perspectives on CCTA use as a tool to provide interventionalists and cardiac surgeons with a non-invasive roadmap for planning myocardial revascularization strategies. Moreover, using CCTA rather than ICA for coronary visualization in patients with CAD may lead to a wider adoption of the Heart Team approach and ultimately benefit patients.

This intriguing hypothesis was tested first in a theoretical feasibility survey study and then in a ‘first-in-man’, proof-of-concept feasibility and safety trial. The further step must be a large, international, prospective, and randomized trial on the revascularization outcome by comparing patients who underwent a novel non-invasive vs. a traditional invasive roadmap. The generalizability of the study results to clinical practices awaits for the implementations of such trials. In the meantime, CT technology continues to advance, allowing improved characterization of disease with new technologies such as photon counting CT detectors and applications of artificial intelligence.

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Data availability

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Disclaimer

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References

1. Patel MR, Peterson ED, Dai D, Brennan JM, Redberg RF, Anderson HV *et al.* Low diagnostic yield of elective coronary angiography. *N Engl J Med* 2010;**362**:886–889.
2. Miller JM, Rochitte CE, Dewey M, Arbab-Zadeh A, Niinuma H, Gottlieb I *et al.* Diagnostic performance of coronary angiography by 64-row CT. *N Engl J Med* 2008;**359**:2324–2336.
3. Budoff MJ, Dowe D, Jollis JG, Gitter M, Sutherland J, Halamert E *et al.* Diagnostic performance of 64-multidetector row coronary computed tomographic angiography for evaluation of coronary artery stenosis in individuals without known coronary artery disease: results from the prospective multicenter ACCURACY (Assessment by Coronary Computed Tomographic Angiography of Individuals Undergoing Invasive Coronary Angiography) trial. *J Am Coll Cardiol* 2008;**52**:1724–1732.
4. Bittencourt MS, Hulten E, Ghoshhajra B, O’Leary D, Christman MP, Montana P *et al.* Prognostic value of nonobstructive and obstructive coronary artery disease detected by coronary computed tomography angiography to identify cardiovascular events. *Circ Cardiovasc Imaging* 2014;**7**:282–291.
5. Nurmohamed NS, van Rosendael AR, Danad I, Ngo-Metzger Q, Taub PR, Ray KK *et al.* Atherosclerosis evaluation and cardiovascular risk estimation using coronary computed tomography angiography. *Eur Heart J* 2024;**45**:1783–1800.
6. ESC guidelines for the management of chronic coronary syndromes: developed by the task force for the management of chronic coronary syndromes of the European Society of Cardiology (ESC) endorsed by the European Association for Cardio-Thoracic Surgery (EACTS). *Eur Heart J* 2024;**45**:3415–3537.

7. The DISCHARGE Trial Group. CT or invasive coronary angiography in stable chest pain. *N Engl J Med* 2022;**386**:1591–1602.
8. Conte E, Sonck J, Mushtaq S, Collet C, Mizukami T, Barbato E *et al*. CT-FFR and CT perfusion: a review on the evaluation of functional impact of coronary artery stenosis by cardiac CT. *Int J Cardiol* 2020; **300**:289–296.
9. Yang S, Koo B-K. Noninvasive coronary physiological assessment derived from computed tomography. *J Soc Cardiovasc Angiogr Interv* 2024;**3**:101304.
10. Papadopoulou SL, Girasis C, Dharampal A, Farooq V, Onuma Y, Rossi A *et al*. CT-SYNTAX score: a feasibility and reproducibility study. *JACC Cardiovasc Imaging* 2013;**6**:413–415.
11. Collet C, Miyazaki Y, Ryan N, Asano T, Tenekecioglu E, Sonck J *et al*. Fractional flow reserve derived from computed tomographic angiography in patients with multivessel CAD. *J Am Coll Cardiol* 2018; **71**:2756–2769.
12. Collet C, Onuma Y, Andreini D, Sonck J, Pompilio G, Mushtaq S *et al*. Coronary computed tomography angiography for heart team decision-making in multivessel coronary artery disease. *Eur Heart J* 2018;**39**:3689–3698.
13. Masuda S, Serruys PW, Mustaq S, Tanaka K, Mandry D, Buechel RR *et al*. Predictive ability of five-year mortality based on computed tomography angiography in the SYNTAX III REVOLUTION trial. *J Cardiovasc Comput Tomogr* 2023;**17**:318–325.
14. Andreini D, Takahashi K, Mushtaq S, Conte E, Modolo R, Sonck J *et al*. Impact of coronary calcification assessed by coronary CT angiography on treatment decision in patients with three-vessel CAD: insights from SYNTAX III trial. *Interact CardioVasc Thorac Surg* 2022;**34**:176–184.
15. Sonck J, Miyazaki Y, Collet C, Onuma Y, Asano T, Takahashi K *et al*. Feasibility of planning coronary artery bypass grafting based only on coronary computed tomography angiography and CT derived fractional flow reserve: a pilot survey of the surgeons involved in the randomized SYNTAX III revolution trial. *Interact Cardiovasc Thorac Surg* 2019;**29**:209–216.
16. Kawashima H, Pompilio G, Andreini D, Bartorelli AL, Mushtaq S, Ferrari E *et al*. Safety and feasibility evaluation of planning and execution of surgical revascularisation solely based on coronary CTA and FFRCT in patients with complex coronary artery disease: study protocol of the FASTTRACK CABG study. *BMJ Open* 2020;**10**:e038152.
17. Serruys PW, Kageyama S, Pompilio G, Andreini D, Pontone G, Mushtaq S *et al*. Coronary bypass surgery guided by computed tomography in a low-risk population. *Eur Heart J* 2024;**45**:1804–1815.
18. Harik L, Gaudino M. Coronary angiography and bypass surgery: born together and now going separate ways? *Eur Heart J* 2024;**45**:1816–1818.