ESC European Society of Cardiology

European Heart Journal - Case Reports (2023) **7**, 1–5
https://doi.org/10.1093/ehjcr/ytad507

CASE REPORT
Coronary intervention

A case report of virtual reality-guided percutaneous coronary intervention for anomalous origin of right coronary artery chronic total occlusion

Hirooki Higami [1]*, Hiroki Saito[2], Hideaki Endo[2], Hitoshi Matsuo[1], and Etsuo Tsuchikane[3]

[1]Department of Cardiovascular Medicine, Gifu Heart Center, 4-14-4 Yabutaminami, Gifu city, Gifu 500-8384, Japan; [2]Department of Cardiovascular Medicine, Iwate Prefectural Central Hospital, Morioka, Japan; and [3]Department of Cardiology, Toyohashi Heart Center, Toyohashi, Japan

Received 23 March 2023; revised 28 September 2023; accepted 9 October 2023; online publish-ahead-of-print 11 October 2023

Background Engagement of the guiding catheter (GC) for the coronary artery is sometimes difficult, depending on the patient's anatomy. The most suitable GC before percutaneous coronary intervention (PCI) in individual cases has not been determined yet.

Case summary An 81-year-old woman who had a right coronary artery chronic total occlusion had difficulty to engage the catheter for the right coronary artery in the first examination. Virtual reality (VR)-guided GC simulation before PCI using cardiac computed tomography (CT) could overcome the difficulty of GC engagement for the coronary artery and achieve procedure success.

Discussion VR-guided GC simulation has the potential to solve the catheter approach difficulty for any cardiovascular intervention.

Keywords Percutaneous coronary intervention • Guiding catheter • Virtual reality • Case report

ESC Curriculum 3.1 Coronary artery disease • 2.4 Cardiac computed tomography

Learning points

- This study described our management of an 81-year-old woman with chronic total occlusion of the right coronary artery of anomalous origin.
- The virtual reality (VR)-guided guiding catheter simulation makes a significant contribution to the procedure.
- We believe that VR could be beneficial in cases where guided catheter engagement has proven difficult, or as an educational tool to help train inexperienced percutaneous coronary intervention (PCI) operators.
- In addition, VR simulation before the procedure has expectations in PCI after transcatheter valve implantation and other structural interventions.

Introduction

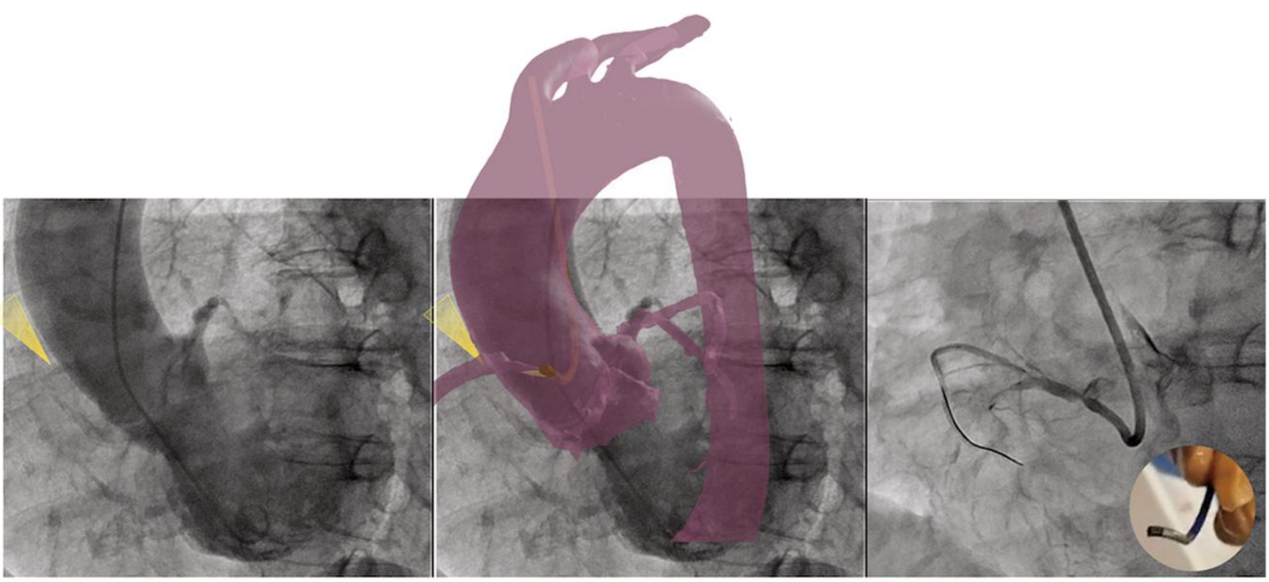
Recent improvements in cardiac computed tomography (CT) before complex percutaneous coronary intervention (PCI) have made effective evaluation of coronary disease easier, including chronic total occlusion (CTO) and severely calcified lesions. However, accurate prediction of guiding catheter (GC) engagement for the coronary artery before PCI remains a challenge, even with the utilization of cardiac CT. Approximately 0.2–1.2% of patients undergoing PCI have the uncommon origin of the coronary artery.[1,2]

* Corresponding author. Tel: +81-58-227-2277, Email: hhigami@kuhp.kyoto-u.ac.jp
Handling Editor: Dimitrios Vrachatis
Peer-reviewers: Ivan Ilic; Arif Anis Khan; Milenko Zoran Cankovic; Julio Echarte
Compliance Editor: Nicholas Weight

To address this issue, the authors developed a novel approach called virtual reality (VR)-guided catheter engagement simulation using cardiac CT. The simulation involved utilizing actual size solid data of the GC, including predictive deformation [all types of Hyperion (Asahi Intecc, Aichi, Japan) and Launcher (Medtronic, Minneapolis, MN)] models. These data were generated using Fusion 360 (Autodesk, San Francisco, CA), while the solid aortic data from cardiac CT were displayed in a virtual space using the VR application 'Gravity Sketch' (Gravity Sketch, London, UK). In the virtual space, an operator exists in the same space as the patient's aortic solid model and the actual size of the GC, allowing us to visualize the behaviour of the GC depending on the approach site. Therefore, we can select the most suitable type of GC and simulate how to fit the GC into the patient's sinus of Valsalva intuitively (see Supplementary material online, *Video S1*).

This study represents the first successful report of PCI using VR-guided GC simulation.

Summary figure



Anormalous origin of total occluded right coronary artery was overcome by guiding catheter simulation in the virtual reality space constructed with cardiac CT. The most suitable guiding catheter was the modified SAL0.75 (Hyperion) approach from the right upper limb.

Case report

An 81-year-old woman presented with chest pain, which was diagnosed as angina caused by total occlusion of the right coronary artery (RCA) on cardiac CT findings. The lesion difficulty was assessed using the j-CTO score (1 point) and CT rector score (1 point). Physical examination revealed normal findings, and transthoracic echocardiography showed normal left ventricular wall motion. Coronary angiography was attempted via the left radial artery. However, it was difficult to engage the catheter in the RCA. Unsuccessful attempts using three different types of catheters (JR4.0, AL1.0, and AL2.0) were performed before finally achieving successful RCA angiography using a JR5.0 catheter with a hand-made curve. The procedure lasted 65 min, using 150 mL contrast medium and involved a 1390 mGy exposure dose (air kerma). The angiography showed total occlusion of the RCA #1 and poor collateral channels via septal and epicardial atrial circumflex branches (*Figure 1*). The inferior wall seemed to be viable from echocardiography and electrocardiogram; therefore, revascularization for the RCA was planned.

Regarding the difficulty of catheter engagement for RCA in initial coronary angiography, VR-guided GC simulation was performed before PCI of the RCA. Analysing the cardiac CT using a DICOM proved challenging in demonstrating the difficulty of catheter engagement due to the nearly normal height of the RCA (15 mm) and its origin from the right coronary cusp. However, the simulation identified the acute angle between the axis of the ostial RCA and the ascending aorta as the primary reason for the difficulty in catheter engagement. This distinction played a critical role in determining the appropriate tip direction of the GC, including JR and AL types, concerning the nearest position for ostial RCA and its axis. Initially, attempts were made with JR3.5, JR4.0, and IM catheters, but none of them successfully engaged the ostial RCA (*Figure 2A, 2B*). However, the AL type catheter exhibited a similar trend, and it was the modified SAL0.75 (Hyperion) approach from the right upper limb that proved to be the most suitable (*Figure 2C, 2D*, Supplementary material online, *Video S1*). The tip of the GC was bent by heating it with a flame for a second and then shaping the tip (*Figure 3A*). During the PCI procedure, the time from inserting the GC via the sheath to GC engagement in the RCA using the modified SAL0.75 was 2 min, and 6 mL of contrast was used. The procedure was successfully performed using the antegrade approach, lasting 152 min and requiring 175 mL of contrast and 1550 mGy of exposure (*Figure 3*). Following the procedure, the patient's angina symptoms improved.

Discussion

VR has been used in several medical fields.[3] However, the contribution of GC simulation before PCI is not established. To the best of our knowledge, this is the first report suggesting the effectiveness of

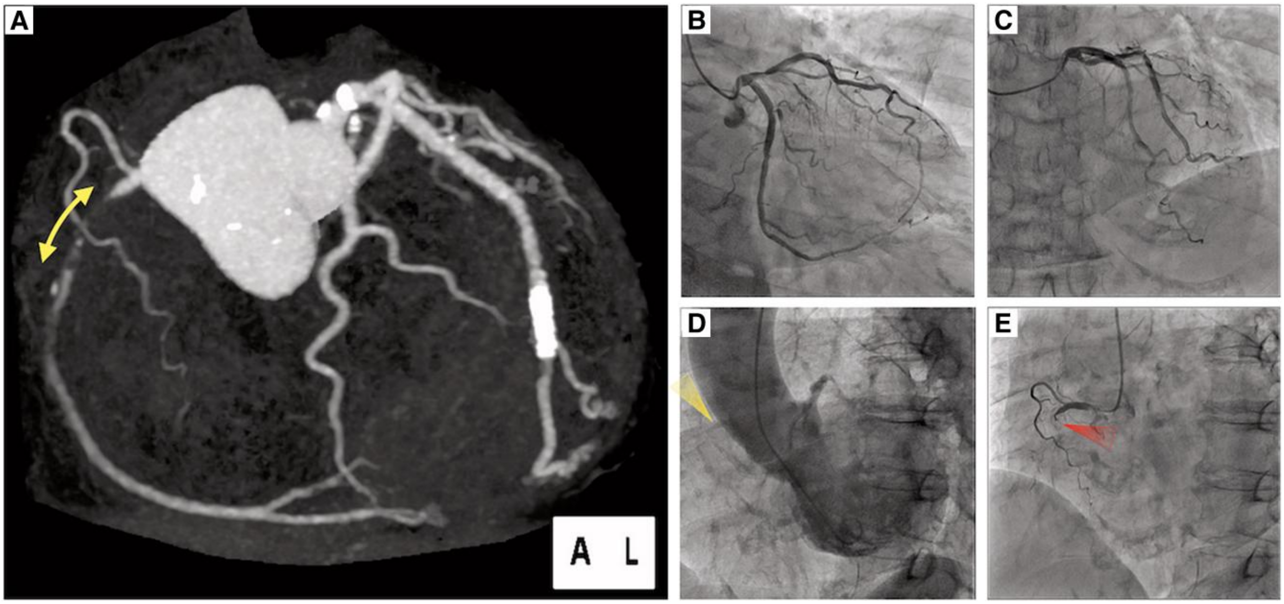


Figure 1 Previous procedure information. (*A*) Cardiac computed tomography (CT) suggesting a total occlusion of 10 mm in the right coronary artery (RCA) #2 (yellow arrow). (*B*) Left coronary angiography (RAO 30°/CAU 30°). (*C*) Left coronary angiography (CRA 30°). (*D*) RCA is confirmed using left ventricular angiography (yellow arrow). (*E*) RCA angiography was successfully performed using a hand-made curved JR5.0. The total occluded lesion was confirmed (red arrow).

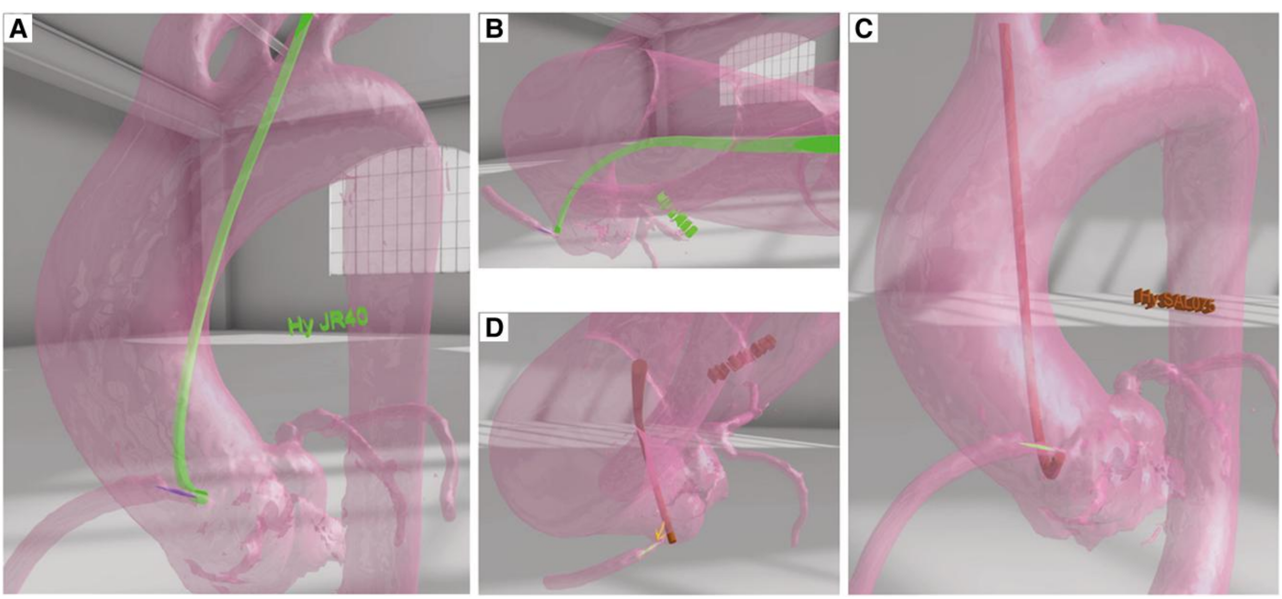


Figure 2 Guided catheter (GC) engagement simulation by virtual reality (VR). (*A*, *B*) The simulation of Hyperion JR40 from the left upper limb approach [*A*: left anterior oblique (LAO) view, *B*: from overhead view]. (*C*, *D*) The simulation of Hyperion SAL0.75 from the right upper limb approach (*C*: LAO view, *D*: from overhead view). This suggested the tip of GC should be bent in the direction of the yellow arrow.

VR-guided GC simulation for a difficult GC engagement case. As described, the selection of the GC was determined by manipulating the GC within the virtual space of the aortic solid model. If the GC model did not fit into the aorta model when the tip of the GC model was positioned at the coronary ostium, it indicated unsuitability for the patient. Therefore, the VR-guided GC simulation requires some imagination of catheter movement, but experienced PCI operators can simulate and identify the most suitable GC for the patient within 5–10 min.

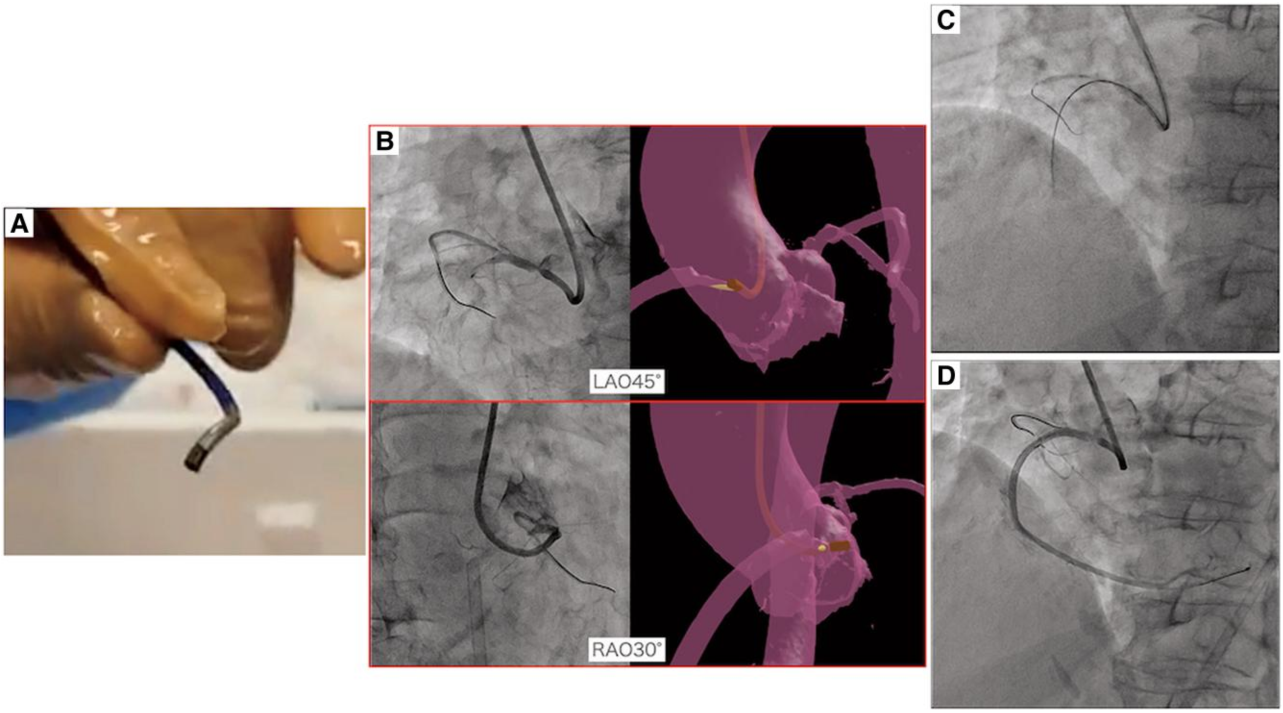


Figure 3 Percutaneous coronary intervention. (*A*) Tip bent SAL0.75 (Hyperion 7 Fr.). (*B*) Comparison between real catheter engagement and simulation. The yellow line in the simulation picture suggests a bent tip. (*C*) Antegrade wiring was successful. (*D*) Final angiography.

On clinical analysis, VR-guided GC simulation before PCI may be effective for patients undergoing PCI for ostial CTO lesions or after transcatheter aortic valve implantation (TAVI). The coaxiality of GC for the ostial coronary artery is an important factor in the ostial CTO PCI procedure that could decide the difficulty of the antegrade approach. In cases where post-TAVI PCI is performed, GC engagement is one of the most serious problems, particularly in the patients in whom the Evolut series (Medtronic, Minneapolis, MN) has been implanted.[4,5] VR-guided GC simulation has the potential to overcome the problem. The authors are currently exploring the application of VR simulation for left atrial appendage closure and embolization procedures involving the inferior mesenteric artery/lumber artery before endovascular aortic repair. The scope of virtual simulation may expand to other interventional fields. The potential benefits of VR-guided simulation in interventional cardiology include increased procedure success rates, reduced contrast and procedure time, cost-effective device utilization, medical staff education, and more. Therefore, conducting clinical research to investigate the effectiveness of VR simulation in guiding cardiovascular interventions is essential.

Regarding the modification of the GC through heating, we observed that the tip was bent at an approximate angle of 45° from its original 10 mm position. It is important to note that this slight modification did not have any adverse effects on the delivery of the device or the torque response of the catheter. However, it is crucial to avoid exposing the catheter to excessive temperatures as it can result in the melting of the tip and the hydrophilic coating. Therefore, it is recommended to carry out the catheter modification process within a temperature range of 150–200°C for a duration of 1–1.5 min to ensure optimal results while preventing any potential damage to the catheter.

The limitation of the method is the requirement for cardiac CT prior to PCI and its limited universal usage. We aim to develop a user-friendly application that would facilitate VR-guided catheter simulation for all cardiovascular interventions in the future.

Lead author biography

Hirooki Higami is a coronary interventionalist at Gifu Heart Center in Gifu, Japan and is focusing on virtual reality-guided endovascular intervention including coronary, aortic, and structural heart disease.

Supplementary material

Supplementary material is available at *European Heart Journal – Case Reports* online.

Acknowledgements

The authors thank paramedical assistants of the catheterization laboratory in Iwate Prefectural Central Hospital, Asahi INTECC, Medtronic, and YES Foundation.

Slide sets: A fully edited slide set detailing these cases and suitable for local presentation is available online as Supplementary data.

Consent: The authors confirm that written consent for submission and publication of this case report including images and associated text has been obtained from the patient in line with COPE guidance.

Conflict of interest: E.T. is a member consultant of Asahi Intecc, KANEKA medics, and Boston Scientific. The other authors declare no conflict of interest.

Funding: This study has received no financial support.

Ethics approval: The present study has ethical approval in Iwate Prefectural Central Hospital.

Data availability

A fully edited slide set detailing these cases and suitable for local presentation is available online as Supplementary data.

References

1. Kimbiris D, Iskandrian AS, Segal BL, Bemis CE. Anomalous aortic origin of coronary arteries. *Circulation* 1978;**58**:606–615.
2. Click RL, Holmes DR, Vlietstra RE, Kosinski AS, Kronmal RA. Anomalous coronary arteries: location, degree of atherosclerosis and effect on survival – a report from the coronary artery surgery study. *J Am Coll Cardiol* 1989;**13**:531–537.
3. Izard SG, Juanes JA, García Peñalvo FJ, Estella JMG, Ledesma MJS, Ruisoto P. Virtual reality as an educational and training tool for medicine. *J Med Syst* 2018;**42**:50.
4. Perrin N, Fassa A, Baroz A, Frangos C, Mock S, Frei A, *et al.* Complexity assessment and technical aspect of coronary angiogram and percutaneous coronary intervention following transcatheter aortic valve implantation. *Cardiol J* 2022;**29**:197–204.
5. Yudi MB, Sharma SK, Tang GHL, Kini A. Coronary angiography and percutaneous coronary intervention after transcatheter aortic valve replacement. *J Am Coll Cardiol* 2018;**71**:1360–1378.