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CASE REPORT
Structural intervention

Appropriate assessment using virtual reality simulation for a novel reshaped curve sheath during percutaneous left atrial appendage closure: a follow-up case report

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Background We previously reported a case of successful percutaneous left atrial appendage closure (LAAC) for complex left atrial appendage (LAA) morphology using a handmade double-curve delivery sheath (DS) reshaped by a heat gun. However, whether the reshaped curve was appropriately adjusted as an optimal configuration for this patient's anatomy remained uncertain.

Case summary We established the LAAC procedural simulation model supported by virtual reality (VR) technology. With this VR simulator, the patient's whole heart model with venous access route and atrial septal puncture point of foramen ovale (FO) could be replicated based on the pre-procedural computed tomography image. Multiple views of the VR image provided a deep understanding of the patient-specific anatomy. Additionally, the operators were enabled to perform the virtual LAAC procedure using VR-derived LAAC devices, including various DS types. In the VR simulator, the manually reshaped DS showed better co-axiality from the FO to the LAA orifice than the conventional double-curve DS, resulting in the successful deployment inside the LAA of the VR simulator. However, the perpendicularity of the device towards the LAA orifice of the handmade reshaped DS remained insufficient. The VR simulator suggested that the ideal curve of the DS needed to change relatively posteriorly and have a more aggressive inferior slide than the previously reshaped DS.

Discussion The post-procedural review of the VR simulator confirmed that the sheath reshaping technique helped ensure successful LAAC. Pre-procedural VR simulation may be useful for procedural planning that includes DS reshaping for patients with challenging anatomy undergoing LAAC.

Keywords Percutaneous left atrial appendage closure • Complex left atrial appendage morphology • Virtual reality simulator • Reshaped delivery sheath • Case report

ESC Curriculum 2.1 Imaging modalities • 2.4 Cardiac computed tomography • 5.3 Atrial fibrillation

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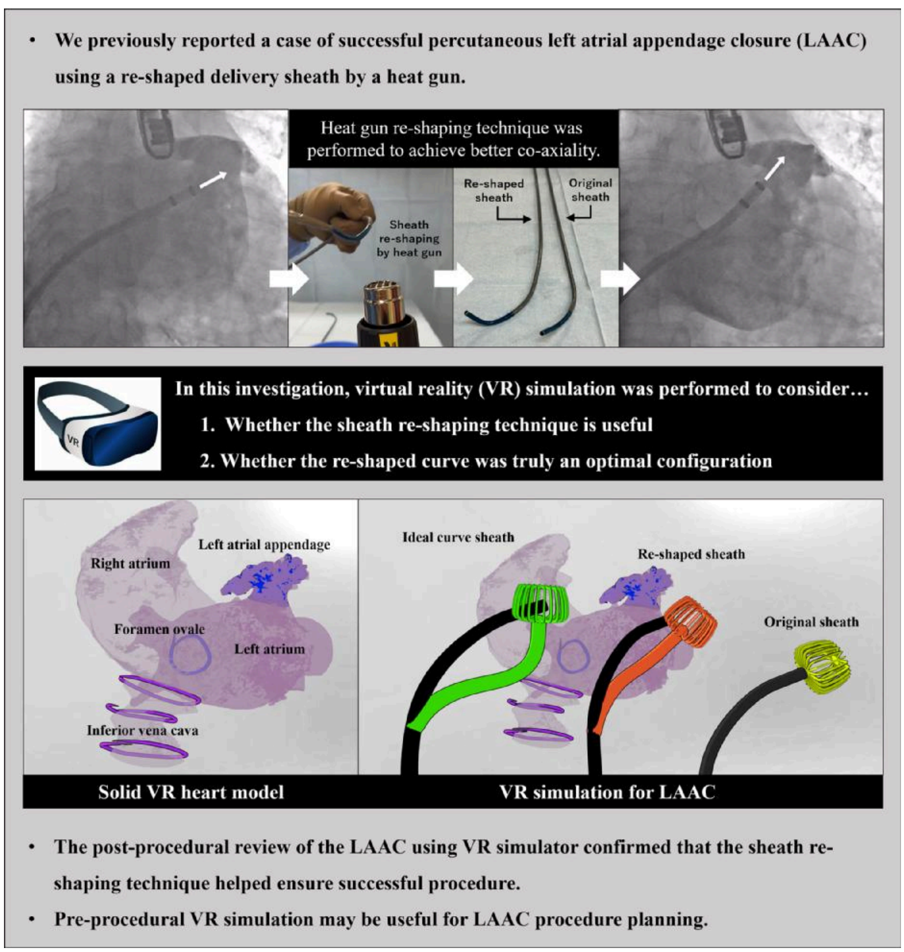
Learning points

- Virtual reality simulation system for percutaneous left atrial appendage closure provides a deep understanding of anatomical structures and enables the evaluation of patient specific anatomy.
- Pre-procedural assessment for complex percutaneous left atrial appendage closure case may be beneficial for procedural planning and leads to successful procedure.

Case recap

We previously reported a case of successful percutaneous left atrial appendage closure (LAAC) with complex morphology using a double-curve WATCHMAN™ TruSeal™ Access System sheath (Boston Scientific, Inc., Marlborough, MA, USA) reshaped by a heat gun (Makita HG6031VK®, Makita Corporation, Aichi, Japan).[1] Pre-procedural computed tomography (CT) revealed a reverse chicken-wing morphology of the left atrial appendage (LAA). The procedure was initiated using an original double-curve delivery sheath (DS). However, an inadequate co-axiality of the WATCHMAN-FLX™ device towards the LAA orifice made the procedure difficult. Reshaping the DS using the heat gun resolved this problem. Ultimately, a 27 mm WATCHMAN-FLX™ device was successfully implanted without complications, and no adverse events were observed during follow-up. However, there is room for consideration of whether the DS reshaping technique is useful and whether the reshaped curve was truly an optimal configuration for this complex LAA anatomy.

Summary figure



Further follow-up

The current investigation applied virtual reality (VR) technology to assess (i) how DS reshaping contributed to this procedure and (ii) whether an effective DS shape could be considered before the procedure in cases with complex LAA anatomy.

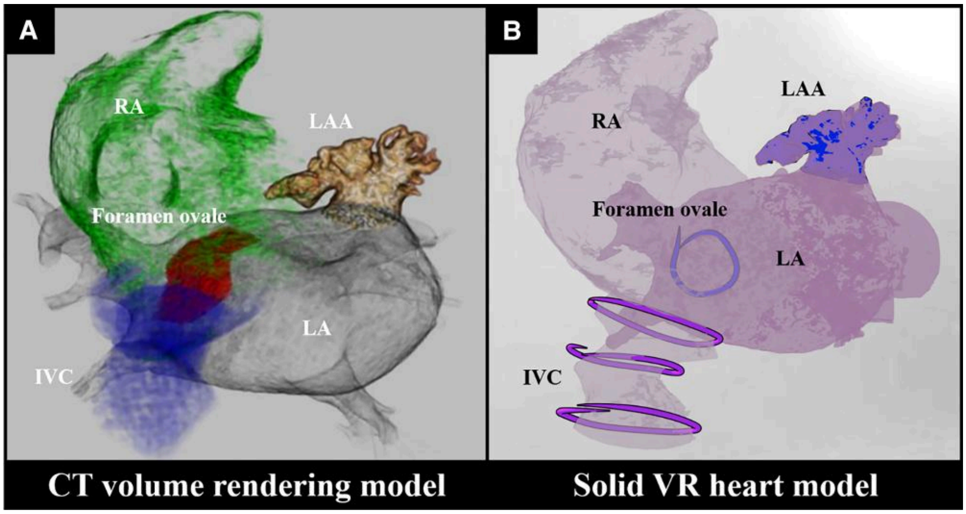


Figure 1 Volume-rendering image created from computed tomography data (panel *A*) and a solid heart model created in virtual reality (VR) (panel *B*). The areas matching the inferior vena cava and foramen ovale are marked on the VR heart model. LA, left atrium; LAA, left atrial appendage; RA, right atrium; IVC, inferior vena cava.

Three-dimensional solid VR heart model constructed from cardiac-CT data using the Gravity Sketch application (Gravity Sketch, London, England, UK) was displayed at Meta Quest 2 VR headsets (Meta Platforms, Menlo Park, CA, USA). Constructed by pre-procedural CT findings, the VR simulation model could provide a patient's whole heart image, including information on the inferior vena cava (IVC) as an access route and the position of the foramen ovale (FO) as a septal puncture point. The Fusion 360 application (Autodesk, San Francisco, CA, USA) was enabled to represent the exact sizing data for the 27 mm WATCHMAN-FLX™ LAAC device, original double-curve DS, and currently used reshaped DS. The ideal device alignment from the FO to the LAA orifice was also simulated by creating a VR-defined ideal curve DS (VR-iDS). These device data were also uploaded to the Gravity Sketch application and displayed in VR headsets. Operators could perform the virtual LAAC and contemplate an appropriate procedural preparation for the patient by combining the equipment mentioned above in the virtual space. Positions of the IVC and FO were marked based on the volume-rendering cardiac-CT model (*Figure 1A* and *B*). Next, the device alignment of the double-curve and reshaped DSs towards the LAA through the marked IVC and FO (see Supplementary material online, *Video S1*) was compared. On the angiogram, the double-curve DS was not co-axially oriented towards the LAA (*Figure 2A*). The device was implanted almost horizontally in caudal and cranial views (*Figure 2B* and *C*). The reshaped DS was positioned with its tip facing the LAA orifice on the angiogram (*Figure 2D*) and confirmed a better orientation than the original double-curve DS (*Figure 2E* and *F*). However, the VR-iDS proposed by the VR simulation showed a relatively different specific shape than previous DSs (*Figure 2G*). Using the VR-iDS, the LAAC device could be implanted almost perpendicular to the LAA orifice, which was determined as the best shape for device implantation in caudal and cranial views (*Figure 2H* and *I* and Supplementary material online, *Video S2*).

Discussion

Virtual reality technology is a well-known tool that is a computer-generated representation of a different universe or reality that allows the creation of realistic simulations implemented in educational settings and is known to help improve learning outcomes.[2,3] Based on the case analysis, the potential benefit of VR technology could be considered for pre-procedural planning. Multiple views of VR images provided a deep understanding of anatomical structures and enabled the evaluation of the patient-specific anatomy. These features are not fully visualized using conventional imaging modalities such as transoesophageal echocardiography and cardiac CT. Although the three-dimensional printing technology or angiographic simulator may provide a detailed procedure image, these are expensive and time-consuming compared to VR simulation. Virtual reality simulation only requires a few minutes for constructing VR heart model from CT data and only needs costs for VR headsets and gloves. Virtual reality simulation can support physicians with a better understanding of procedural planning that may shorten the learning curve in many institutions.

This study examined DS behaviour in VR according to patient-specific anatomy. Comparing three types of DSs, the alignment of the DS from FO to LAA orifice was crucial for a successful procedure. The results of the retrospective review by the VR simulator supported the feasibility of the sheath reshaping technique during LAAC. However, the VR-iDS indicated that reshaped DS should be bent more aggressively in both first and second curves (*Figure 3A–C*) without anterior curving (*Figure 3D–F*).

Previous studies have shown that the success rate of LAAC with complex morphology is significantly lower than that of LAAC with normal morphology.[4] In the complex anatomy of LAA cases, pre-procedural planning using VR would be beneficial for anatomical understanding and procedure planning including DS selection. However, further investigations are required to clarify the feasibility of VR simulation in patients undergoing LAAC.

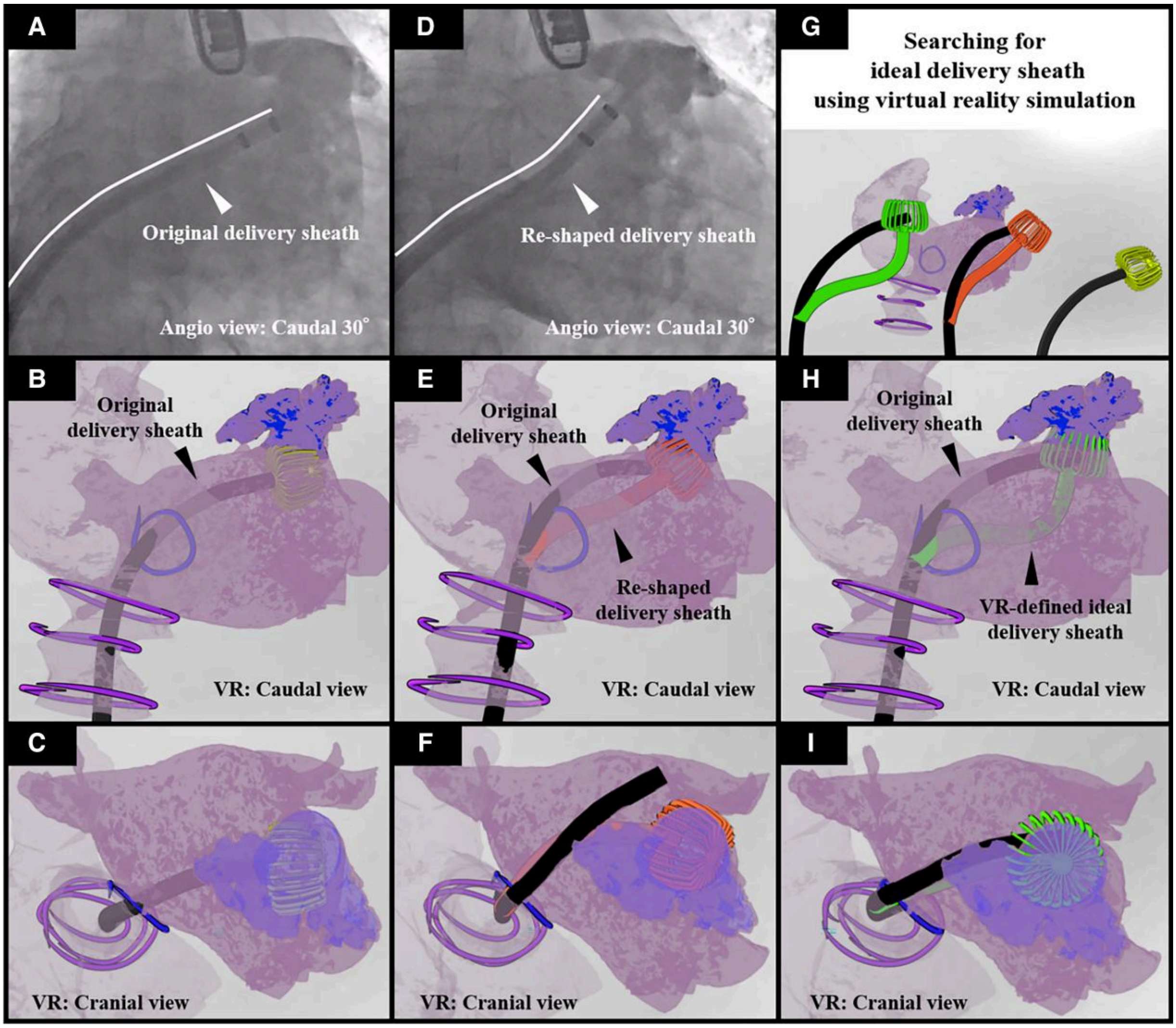


Figure 2 Procedure by using the original double-curve delivery sheath (DS), the sheath tip was oriented horizontally to the left atrial appendage (LAA), as seen on the angiogram (panel *A*). This orientation was confirmed by both caudal and cranial views using virtual reality (VR) simulation (panels *B* and *C*). Procedure using the reshaped DS, the sheath tip was oriented towards the LAA with more co-axiality compared to the procedure by using an original DS, as seen on the angiogram (panel *D*). This sheath co-axiality was also confirmed by both caudal and cranial views using VR simulation (panels *E* and *F*). The VR-defined ideal curve DS (VR-iDS) was created based on the solid heart model and compared with the other two double-curve sheaths (panel *G*). This VR-iDS showed best co-axiality for device implantation, as visualized in both caudal and cranial VR simulation views (panels *H* and *I*).

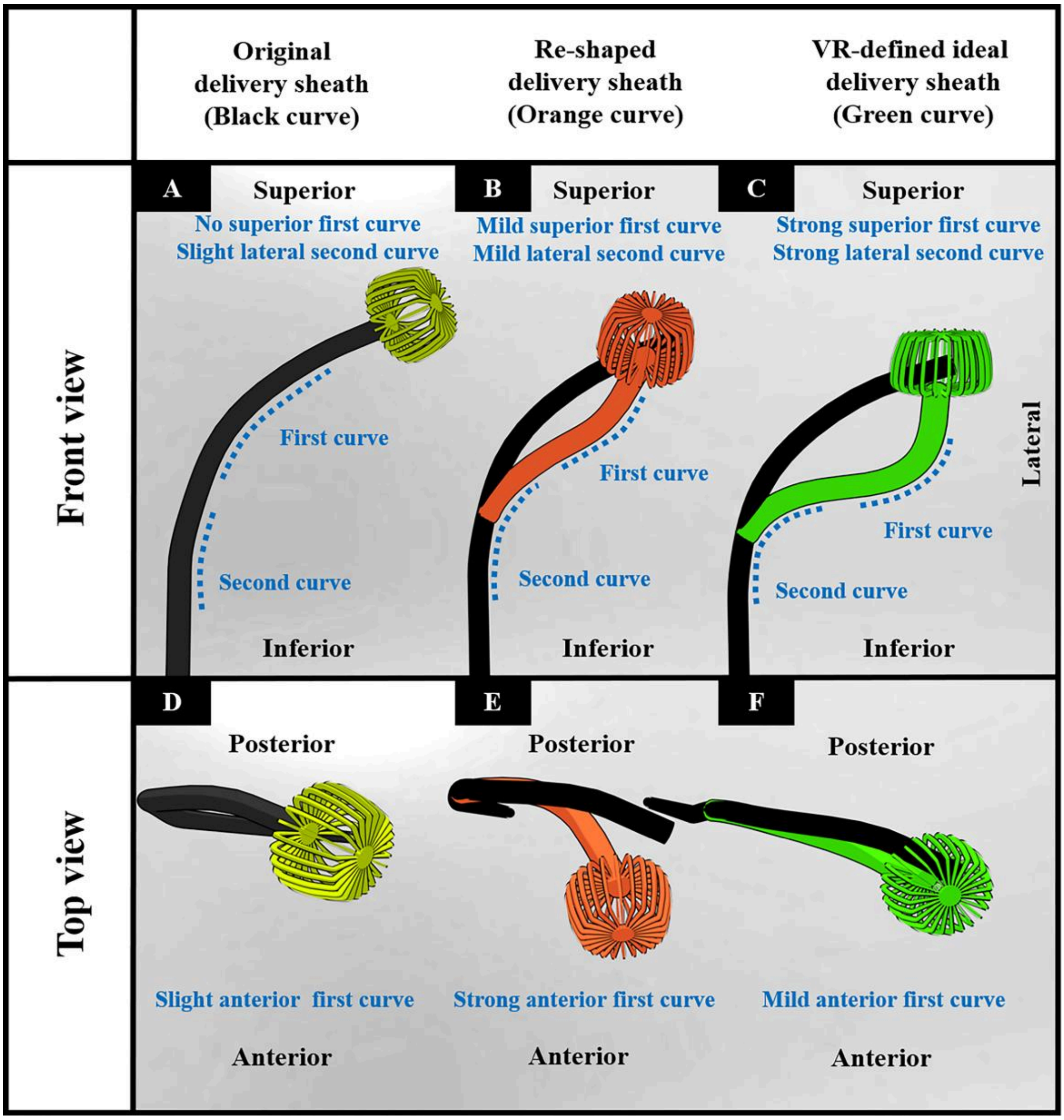


Figure 3 The three virtual reality (VR) sheath models are shown from the front and top views (panels *A–F*). The original double-curve delivery sheath (DS) showed slight anterior first and slight lateral curves (panels *A* and *D*). Compared to the original DS, the reshaped DS showed strong anterior mild superior first and mild lateral second curves (panels *B* and *E*). Virtual reality-defined ideal DS showed mild anterior strong superior first curve and strong lateral second curve (panels *C* and *F*).

Lead author biography

Tetsuro Shimura is a general cardiologist who graduated from Nippon Medical School, Tokyo, Japan, in 2009. Since 2022, he has worked at Gifu Heart Center (Gifu, Japan) as a chief of structural heart disease intervention.

Supplementary material

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

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Data availability

The data underlying this article cannot be shared publicly due to privacy and ethical reasons of individuals that participated in the study.

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