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Novel apical-to-femoral rail technique for horizontal aorta in transcatheter aortic valve replacement

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Transcatheter aortic valve replacement (TAVR) has emerged as a viable treatment option for patients with severe aortic stenosis regardless of its surgical risk stratification (Otto et al., 2021). Aortic angulation is usually measured as the angle between the horizontal and the aortic annulus planes based on preprocedural multidetector computed tomography (MDCT) (Al-Lamee et al., 2011). Extremely horizontal aorta, defined as an aortic angulation greater than 70°, is an unfavorable anatomic structure that poses particular technical challenges for TAVR. Abramowitz et al. (2016) have proved that an extremely horizontal aorta increased the risk of procedural complications, such as lower device success rates, more moderate or even severe perivalvular leakage (PVL), and the need for second valve implantation. Because of the long stent frame, inflexibility, and non-steerability, it is challenging to pass the delivery system of self-expanding valves (SEVs) through an extremely horizontal aorta. As a result, patients with an extremely horizontal aorta have always been excluded from the clinical trials of TAVR, and transfemoral (TF)-TAVR with SEV is considered as an "off-label" use of TAVR (Adams et al., 2014; Kaneko et al., 2020). Herein, we present a technically difficult case, in which a patient with an extremely horizontal aorta underwent TF-TAVR with SEV by applying a unique apical-to-femoral rail strategy.

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An 84-year-old woman was presented with progressive exertional dyspnea for two months, classified as New York Heart Association (NYHA) class III. She had a history of refractory hypertension and diabetes mellitus, which were managed with medication. The transthoracic echocardiography revealed severe aortic stenosis with left ventricular ejection fraction of 69.2%. The patient's Society of Thoracic Surgeons Score was 5.534%, classifying her as an intermediate-risk patient for the surgical procedure. The preprocedural MDCT assessment revealed an extremely aortic angulation of around 84°. A small left ventricular type 0 bicuspid aortic valve and a short and dilated ascending aorta were also found in MDCT (Fig. 1). Considering the advanced age of the patient, she and her family members pushed for minimally invasive surgery. After a careful review of her anatomy and repeated discussion by the multidisciplinary heart team, TF-TAVR was performed with a 21-mm VitaFlow (Microport, Shanghai, China) due to the lack of available commercial balloon-expanding valves (BEVs).

The TAVR procedure was performed in our hybrid catheter lab as previously reported (Fan et al., 2021). Because of the aorta's extreme angulation, the tips of the straight guidewire and super-stiff wire were difficult to align with the valve orifice, resulting in a situation that these guidewires could not be introduced smoothly into left ventricle. A loop snare catheter was pushed into the ascending aorta from an ipsilateral femoral approach to assist the straight guidewire, and a Lunderquist super-stiff guidewire was barely inserted into the left ventricle (Video S1). The super-stiff guidewire could be hardly located in the left ventricle stably when attempting to convey the

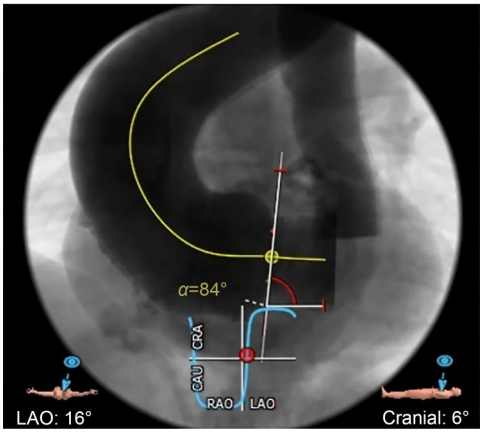

Fig. 1 An extreme aortic angulation. Preprocedural multidetector computed tomography (MDCT) shows an extreme aortic angulation. CRA: cranial; CAU: caudal; LAO: left anterior oblique; RAO: right anterior oblique.

pre-dilatation balloon. This step took several hours, and all attempts were unsuccessful.

After much deliberation, our heart team decided to pursue a novel therapeutic strategy of making a micro-thoracotomy at the apex to connect it with the femoral artery pathway, and establish the apical-to-femoral rail. A 2.6-inch super-slip guidewire was threaded through the ipsilateral femoral artery and looped by a snare inserted from the apex with a 6-Fr (6-French, 1 Fr=1/3 mm) sheath (Video S2). The angle between the delivery system and the aortic annulus was precisely controlled by concurrently pulling or loosening the wire ends. The technique improved the maneuverability of the delivery system by increasing the tension of the wire. The delivery system was progressed slowly across the aortic arch in order to avoid contact with the aortic lumen. Coordinated manipulation resulted in successful balloon dilatation and coaxial valve implantation under rapid ventricular pacing (Video S3). Nevertheless, during deployment, the valve migrated downward slightly more than intended. Intraprocedural digital subtraction angiography (DSA) confirmed the prosthesis's coaxial but relatively deep valve position, resulting in moderate-to-severe PVL (Video S4). Subsequently, a second 21-mm VitaFlow prosthesis was implanted at a relatively higher position to reduce PVL. The final intraoperative DSA confirmed that the valve was in an appropriate position with trace PVL, and a maximum aortic gradient was 4 mmHg (1 mmHg=0.133 kPa) (Video S5). At the end of the procedure, aortography was performed to confirm aortic injury or dissection.

The patient was transferred to the intensive care unit after the procedure, where her symptoms relieved soon and then she was moved to the general ward within one day. Cardiac computed tomography (CT) revealed that the prosthetic valve was in an appropriate position with good coaxiality. Transthoracic echocardiography showed normal valve function and a mean aortic gradient of 7 mmHg. The patient was discharged without any periprocedural complications, she remained asymptomatic afterwards, and her cardiac function was graded II. Following 30 d of follow-up, the mean aortic gradient was 4 mmHg without PVL.

This is the first reported case of the novel apical-to-femoral rail technique applied successfully in SE-TAVR for a frail elderly patient with a pronounced angulated aorta. After reviewing this case, the following technical difficulties were identified: (1) Extreme aortic angulation would significantly weaken the tension of the guidewire, making it difficult for the system to pass smoothly through the aortic arch; (2) The guidewire tip lacked enough cushioning to adjust the direction due to the short dilated ascending aorta, which increased the difficulty in aligning the guidewire tip with the aortic orifice; (3) Because of the small left ventricular cavity, the guidewire was difficult to be anchored in place and was prone to shifting into the aortic sinus.

The following benefits of the apical-to-femoral rail were highlighted: (1) This technique can enhance the rigid guidewire's maneuverability, assist the delivery system with passing through the aortic arch and coaxial valve implantation, and minimize the risk of aortic dissection and cerebral infarction. (2) A pronounced angulated aorta is one of the risk factors for left ventricular perforation, especially if combined with aortic-left ventricle misalignment and small hypertrophic left ventricle (Ancona et al., 2018). This technique prevents the guidewire tip from being exposed to the ventricular cavity and lowers the risk of left ventricular perforation. (3) Compared to the incision required by the transapical approach, the apical-to-femoral rail technique requires a tiny incision, which can minimize the procedural trauma and is conducive to rapid rehabilitation.

The horizontal aorta has been excluded from well-designed prospective clinical trials due to its negative anatomic features. To date, the influence of aortic angulation on SE-TAVR remains debatable. Compared to balloon-expanding TAVR, patients with an aortic

angulation of ⩾48° had lower device success rates but similar mortality in SE-TAVR (Abramowitz et al., 2016). The causes of device failure include valve embolization, increased demand for a second valve, and mild or more severe PVL. Nevertheless, Kaneko et al. (2020) expatiated that TF-TAVR with Medtronic Evolut R and Evolut PRO (Medtronic, Minneapolis, Minnesota, USA) SEV in an extremely horizontal aorta was feasible and effective with a high device success rate. It seems that the performance of SEV degrades in patients with unfavorable anatomic features because of inflexibility and long stent frame. Compared to SEV, the shorter valve stent frame and adjustable delivery system of BEV contribute to more accurate and satisfactory coaxial valve alignment in patients with an extremely horizontal aorta (Abramowitz et al., 2016). In addition, the super-stiff wire can be used to provide more support. "The buddy-balloon technique" and "the buddy-wire technique" assist the operator in dealing with these unfavorable anatomical features by adjusting the direction of the delivery catheter and facilitating its retrograde aortic valve crossing (Noble and Roffi, 2014). Espinoza Rueda et al. (2021) described the successful use of a snare catheter in five patients with horizontal aorta via the contralateral femoral artery or the radial artery. In general, operators should weigh all factors carefully when developing procedural strategies for patients with an extremely horizontal aorta.

The TF approach is the first-line choice of vascular access route for TAVR, accounting for 75% of TAVR, which is associated with favorable clinical outcomes (Leon et al., 2010). Although transapical and transaortic access can avoid the undesirable effect of aortic angulation in SE-TAVR, and these are considered as alternative access routes for patients not suitable for TF-TAVR, their mortality rate is statistically higher than that of TF access (Arai et al., 2016). Being an experienced center, our multidisciplinary heart valve team deemed the TF approach as the least invasive access for this case to reduce the incidence of procedural complications. However, underlying complications such as failing to pass through the aortic arch, aortic dissection, and ventricular perforation are not uncommon during TF-TAVR with a horizontal aorta. Our successful case enlightened us that when encountering a situation of inability to pass through the aortic arch during the TAVR procedure, establishing the apical-to-femoral rail might be an effective emergency strategy to avoid converting to open surgery.

Our case study described the successful use of the apical-to-femoral rail technique during TF-TAVR in a patient with bicuspid aortic stenosis and an extremely horizontal aorta. This case prompts us to devise dependable and effective procedural strategies for patients based on their distinct anatomical characteristics.

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Author contributions

Xianbao LIU and Hanyi DAI checked the literature and wrote the first draft of the paper. Lihan WANG and Jiaqi FAN collected data of the case. Jian'an WANG revised and checked the final manuscript. All authors have read and approved the final manuscript, and therefore, have full access to all the data in the study and take responsibility for the integrity and security of the data.

Compliance with ethics guidelines

Xianbao LIU, Hanyi DAI, Lihan WANG, Jiaqi FAN, and Jian'an WANG declare that they have no conflict of interest.

This procedure followed was in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5). Informed consent was obtained from the patient for being included in the report.

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Supplementary information

Videos S1–S5