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Alignment of Transcatheter Aortic-Valve Neo-Commissures (ALIGN TAVR)

Impact on Final Valve Orientation and Coronary Artery Overlap

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ABSTRACT

OBJECTIVES The aim of this study was to evaluate the impact of initial deployment orientation of SAPIEN 3, Evolut, and ACURATE-neo transcatheter heart valves on their final orientation and neocommissural overlap with coronary arteries.

BACKGROUND Coronary artery access and redo transcatheter aortic valve replacement (TAVR) following initial TAVR may be influenced by transcatheter heart valve orientation. In this study the impact of transcatheter heart valve deployment orientation on commissural alignment was evaluated.

METHODS Pre-TAVR computed tomography and procedural fluoroscopy were analyzed in 828 patients who underwent TAVR (483 SAPIEN 3, 245 Evolut, and 100 ACURATE-neo valves) from March 2016 to September 2019 at 5 centers. Coplanar fluoroscopic views were coregistered to pre-TAVR computed tomography to determine commissural alignment. Severe overlap between neocommissural posts and coronary arteries was defined as 0° to 20° apart. The SAPIEN 3 had 1 commissural post crimped at 3, 6, 9, and 12 o'clock. The Evolut "Hat" marker and ACURATE-neo commissural post at deployment were classified as center back (CB), inner curve (IC), outer curve (OC), or center front (CF) and matched with final orientation.

RESULTS Initial SAPIEN 3 crimped orientation had no impact on commissural alignment. Evolut "Hat" at OC or CF at initial deployment had less severe overlap than IC or CB ($p < 0.001$) against the left main (15.7% vs. 66.0%) and right coronary (7.1% vs. 51.1%) arteries. Tracking Evolut "Hat" at OC of the descending aorta ($n = 107$) improved OC at deployment from 70.2% to 91.6% ($p = 0.002$) and reduced coronary artery overlap by 36% to 60% ($p < 0.05$). ACURATE-neo commissural post at CB or IC during deployment had less coronary artery overlap compared to CF or OC ($p < 0.001$), with intentional alignment successful in 5 of 7 cases.

CONCLUSIONS This is the first systematic evaluation of commissural alignment in TAVR. More than 30% to 50% of cases had overlap with 1 or both coronary arteries. Initial SAPIEN 3 orientation had no impact on alignment, but specific initial orientations of Evolut and ACURATE improved alignment. Optimizing valve alignment to avoid coronary artery overlap will be important in coronary artery access and redo TAVR. (J Am Coll Cardiol Intv 2020;■:■–■) © 2020 by the American College of Cardiology Foundation.

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ABBREVIATIONS AND ACRONYMS

CB = center back

CF = center front

CT = computed tomography

IC = inner curve

LM = left main coronary artery

OC = outer curve

RCA = right coronary artery

TAVR = transcatheter aortic valve replacement

THV = transcatheter heart valve

Transcatheter aortic valve replacement (TAVR) is now approved in patients across all surgical risk categories. As TAVR expands to patients with longer life expectancy, issues of access to the coronary arteries for diagnostic and therapeutic management, valve durability, and repeat valve intervention with TAVR in failing transcatheter heart valves (THVs) (i.e., redo TAVR) become important (1,2). In addition, computational modeling has suggested that commissural alignment may reduce THV leaflet stress, particularly in the setting of elliptical annuli (3). Previous studies demonstrated that the relationship between THV neocommissures and coronary artery orifices appeared random and that certain initial deployment positions of the Evolut THV (Medtronic, Minneapolis, Minnesota) improved commissural alignment with native commissures and reduced severe coronary artery overlap (4-6). The aim of this study was to evaluate the impact of initial deployment orientation of the SAPIEN 3 (Edwards Lifesciences, Irvine, California), Evolut, and ACURATE-neo (Boston Scientific, Marlborough, Massachusetts) THVs on their final orientation and neocommissural overlap with coronary arteries.

METHODS

PATIENT POPULATION. Pre-TAVR multidetector row computed tomography (CT) and procedural fluoroscopic images were retrospectively analyzed from 828 patients who underwent TAVR with the SAPIEN 3 (n = 483), Evolut (n = 245), and ACURATE-neo (n = 100) THVs for aortic stenosis from March 2016 to September 2019. Given that this was a pilot imaging study, patient outcomes were not systematically collected. Our study was approved at respective Institutional Review Boards, and the requirement to obtain patient consent was waived.

COREGISTRATION OF MULTIDETECTOR COMPUTED TOMOGRAPHY AND FLUOROSCOPY. THV orientation visualized on the 3-cusp coplanar fluoroscopic view was coregistered with pre-TAVR multidetector row CT to determine THV commissural alignment and overlap with the coronary arteries, as previously described for the Evolut THV (Figure 1) (6). THV orientation on the fluoroscopic view was identified by the neocommissures as follows: 3 "double lines" between the hexagonal crowns at the top cells on the SAPIEN 3, C-tab on the Evolut, and 3 commissural posts on the ACURATE-neo (Figure 1). Positions of the THV neocommissures on fluoroscopy in the same coplanar view as the initial aortogram were coregistered with multidetector CT axial images of the aortic annulus and sinus of Valsalva using 3mensio Valves version 9.1 (Pie Medical Imaging, Maastricht, the Netherlands).

Our coregistration technique was as follows. First, aortographic and final THV orientation images were obtained at the 3-cusp coplanar view on fluoroscopy. Second, the 3-cusp view was identified on 3mensio. Third, an orange circle with spokes (12 for the SAPIEN 3 representing the connecting hinge points, 12 or 15 for the Evolut representing 15 crowns including the C-tab [12 for the 23-mm Evolut and 15 for the 26-, 29-, and 34-mm Evolut THVs], and 3 for the ACURATE-neo) was projected onto CT axial images, with THV

received speaking fees from Boston Scientific, Baylis Medical, Edwards Lifesciences, and Medtronic; is a consultant for Abbott Structural, Edwards Lifesciences, W. L. Gore & Associates, Medtronic, Navigate, and Philips Healthcare; has received nonfinancial support from 3mensio; holds equity in Navigate; and is the chief scientific officer for the Echocardiography Core Laboratory at the Cardiovascular Research Foundation for multiple industry-sponsored trials, for which she receives no direct industry compensation. Dr. Khalique has served on the Speakers Bureaus for Edwards Lifesciences and Boston Scientific; and has served as a reader for a core laboratory that has contracts with Edwards Lifesciences. Dr. Kaneko has served as a proctor and an educator for Edwards Lifesciences. Dr. Kovacic has received research support from the National Institutes of Health (grants R01HL130423 and R01HL135093). Dr. Shah is a proctor and an educator for Edwards Lifesciences; and is an educator for St. Jude Medical. Dr. Adams has served as the national co-principal investigator of the Medtronic APOLLO Pivotal Trial and the Medtronic CoreValve US Pivotal Trial. In addition, the Icahn School of Medicine at Mount Sinai receives royalty payments from Edwards Lifesciences and Medtronic for intellectual property related to development of valve repair rings. Dr. Leon has served as a nonpaid member of the scientific advisory board of Edwards Lifesciences; and has served as a consultant for Abbott Vascular and Boston Scientific. Dr. Kodali is on the steering committee for Edwards Lifesciences; is a consultant for Medtronic and Claret Medical; and is on the scientific advisory board for Thubrikar Aortic Valve. Dr. George is a consultant for Edwards Lifesciences and Medtronic. Dr. Tang is a physician proctor for Edwards Lifesciences and Medtronic; and is a consultant for Medtronic. Dr. Bapat has served as a consultant for Medtronic, Edwards Lifesciences, 4C, and Boston Scientific. Dr. Søndergaard has received consulting fees and institutional research grants from Abbott, Boston Scientific, Edwards Lifesciences, Medtronic, and Symetis. Dr. De Backer has received consulting fees and institutional grants from Abbott and Boston Scientific. Dr. Dangas is on the advisory board and is a consultant for Boston Scientific; and has common stock with Medtronic that is fully divested. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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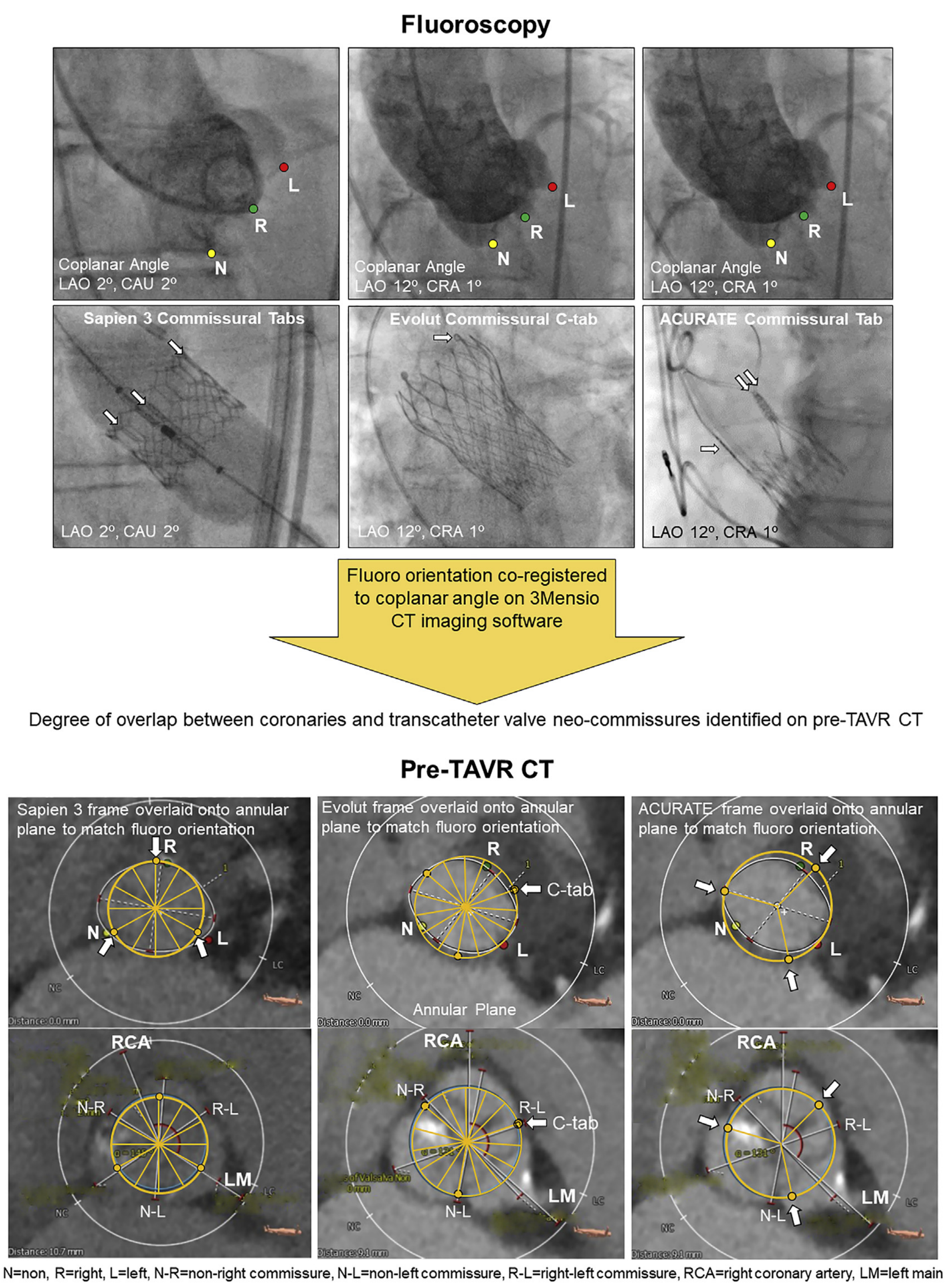
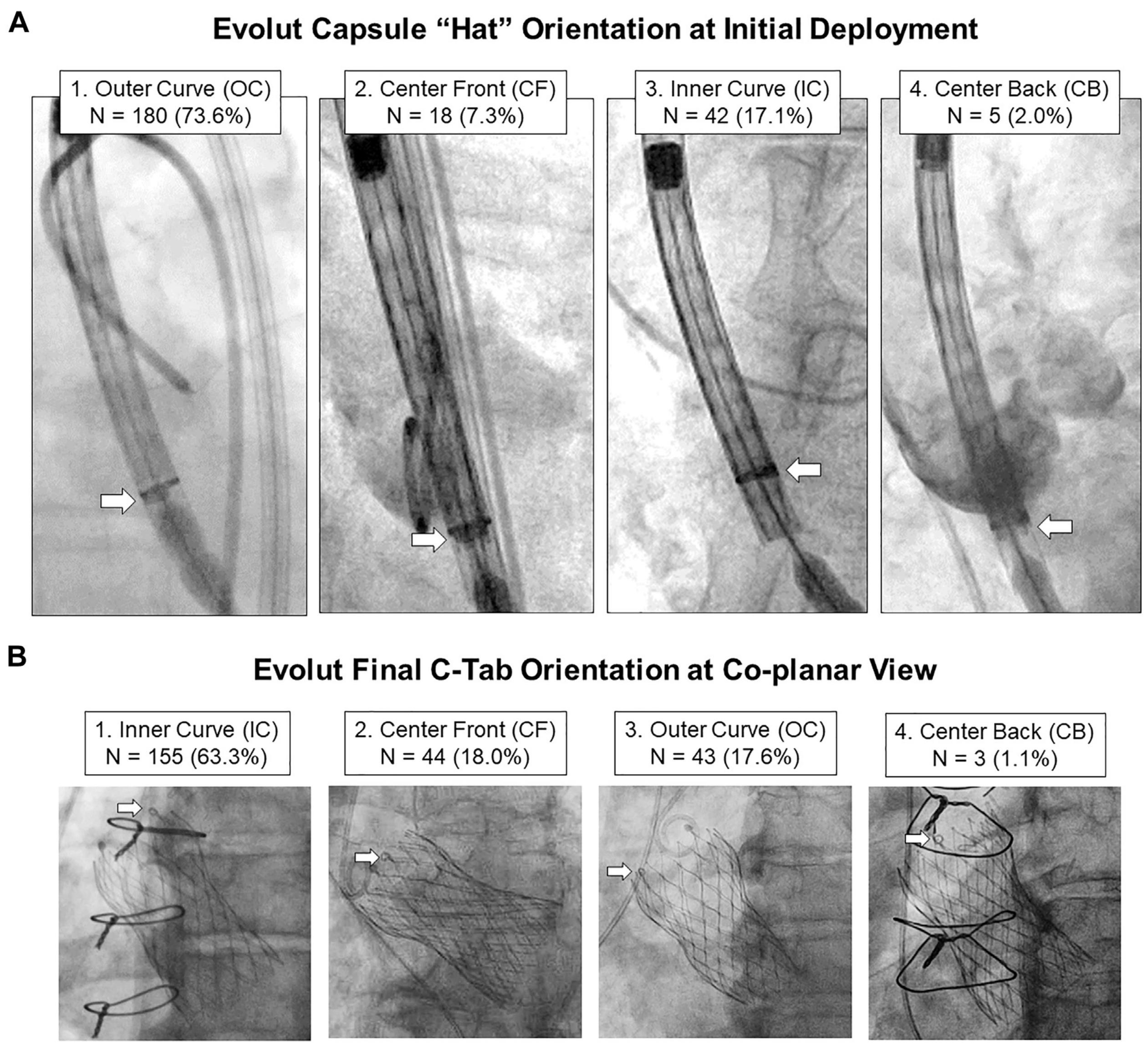
FIGURE 1 **Fluoroscopic-CT Coregistration to Determine Commissural Alignment in TAVR**



Three-cusp coplanar fluoroscopic view was taken prior to and after transcatheter aortic valve replacement (TAVR) with the SAPIEN 3, Evolut, and ACURATE-neo transcatheter heart valves (THVs). Commissural posts **(white arrows)** indicated respective THV orientation, which was then coregistered onto pre-TAVR computed tomography (CT) imaging using 3mensio Valves software. Positions of the THV neocommissures were then compared with the coronary orifices and native aortic valve commissures to determine commissural alignment and severity of coronary artery overlap. CAU = caudal; CRA = cranial; LAO = left anterior oblique.

FIGURE 2 Categorization of Evolut "Hat" Marker Orientation During Initial Valve Deployment and Final C-Tab Orientation



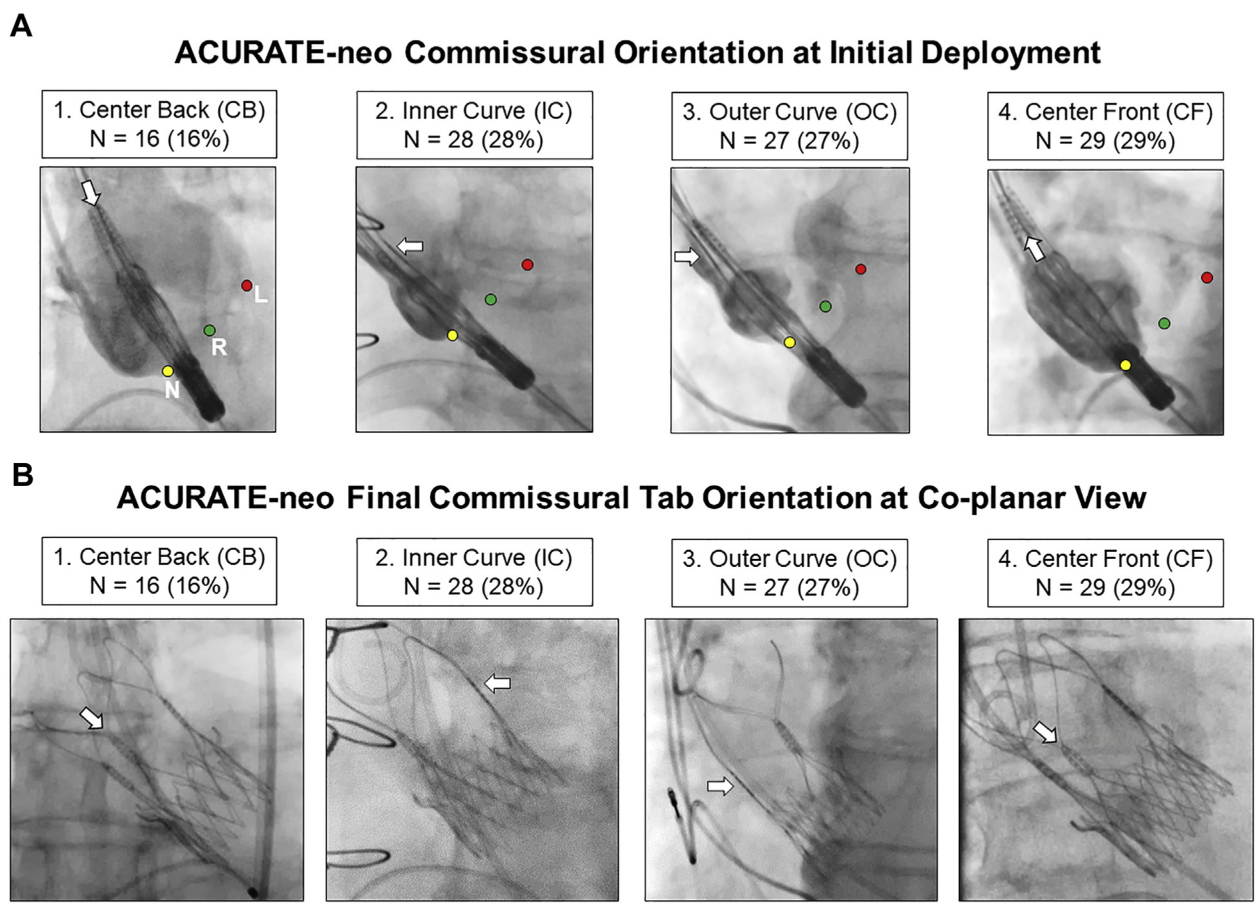
Distribution of the 4 possible Evolut "Hat" marker **(white arrow)** orientations at the initial deployment **(A)** and the respective final C-tab **(white arrow)** orientation at the 3-cusp coplanar fluoroscopic view **(B)**. C-tab represents 1 of the Evolut transcatheter valve commissures.

neocommissural orientation on CT images matching the fluoroscopic image (coregistration). THV neo-commissural alignment with native commissures and relationship to coronary orifices could therefore be identified.

Our technique of using CT-fluoroscopic coregistration to determine THV orientation was validated in 77 patients across the 3 valve types by matching THV orientations using our coregistration technique respectively with those derived from post-TAVR multidetector row CT (Supplemental Figure 1, Supplemental Table 1).

CHARACTERIZATION OF INITIAL THV DEPLOYMENT ORIENTATION. To track initial deployment orientation, SAPIEN 3 cases had 1 commissure crimped at 3, 6, 9, or 12 o'clock orientation relative to the delivery catheter with the "Edwards" logo facing up at 12 o'clock. Evolut "Hat" marker and ACURATE-neo commissural tab position during initial deployment

FIGURE 3 **ACURATE-neo Commissure Position Before and After Valve Deployment**



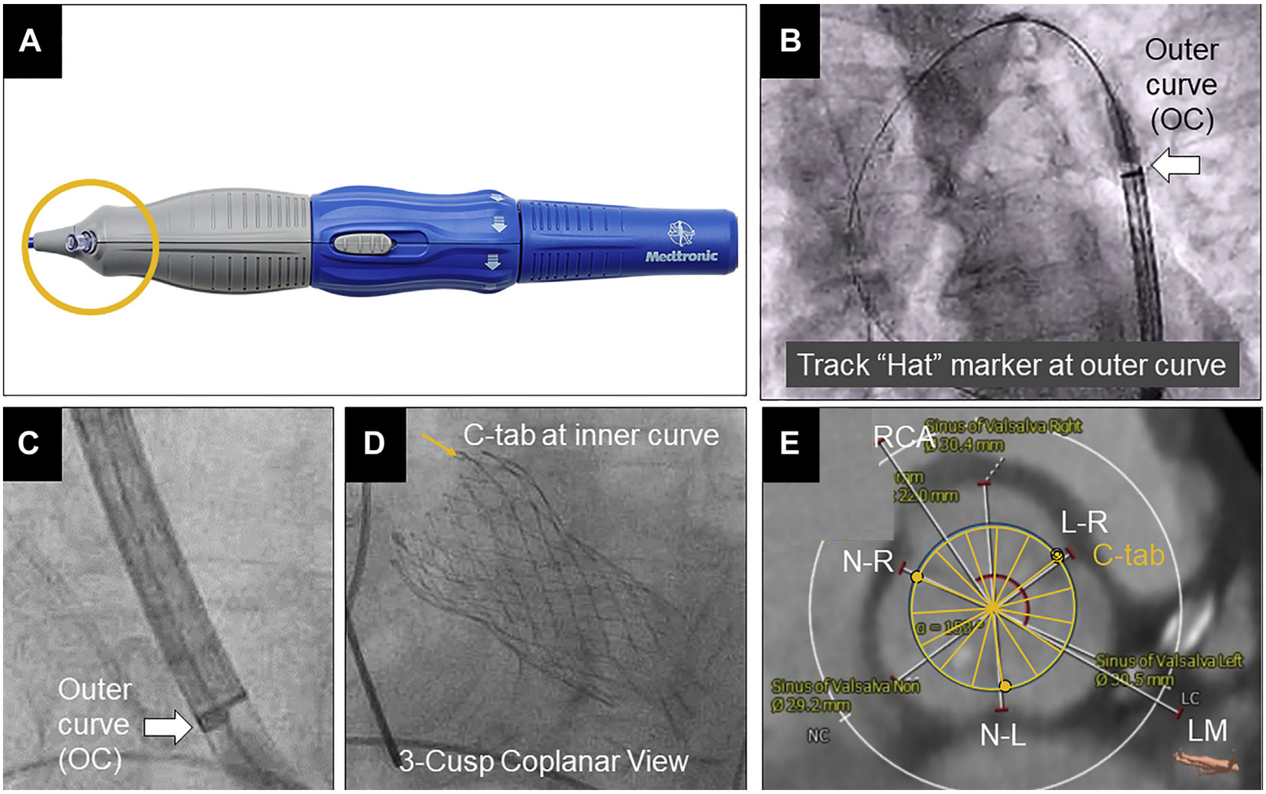
Distribution of the 4 possible orientations of an ACURATE-neo commissural post before **(A)** and after **(B)** valve deployment.

were categorized as center back (CB), inner curve (IC), outer curve (OC), or center front (CF) and matched with final valve orientation (Figures 2 and 3) (6).

DETERMINATION OF COMMISSURAL ALIGNMENT AND CORONARY ARTERY OVERLAP. Commissural alignment between the THV and native aortic valve was determined by CT-fluoroscopic coregistration on the basis of the CT axial image at the sinus of Valsalva level reconstructed using 3mensio. Coronary artery overlap with the left main coronary artery (LM) and right coronary artery (RCA) was deemed severe if a neocommissure and coronary orifice were 0° to 20° apart (5,6).

CONTROLLING INITIAL THV DEPLOYMENT ORIENTATION TO IMPROVE COMMISSURAL ALIGNMENT. In 107 consecutive Evolut TAVR cases, we aimed to have the “Hat” marker oriented to the OC of the descending aorta, by inserting the delivery catheter with the flush port facing the 3 o’clock position (i.e., away from the operator), to get the “Hat” marker positioned at the OC of the annulus at the time of Evolut deployment (Figure 4). The Evolut THV was then deployed in the standard manner. In 7 consecutive ACURATE-neo cases, the delivery catheter was inserted into the introducer sheath with its flush port facing the 12 o’clock position. After crossing the aortic arch and native annulus, the handle of the delivery catheter was torqued clockwise until 1 of the ACURATE-neo commissural posts faced the IC of the aortic root. The ACURATE-neo THV was then deployed in the standard fashion. Final THV orientation was determined using the CT-fluoroscopic coregistration technique.

FIGURE 4 Flush Port Orientation and Impact of Initial "Hat" Marker Orientation in Evolut Deployment



Pointing the flush port **(orange circle)** at 3 o'clock when inserting the Evolut delivery catheter into the patient **(A)** improved the "Hat" marker orientation to the outer curve **(white arrow)** in the descending aorta **(B)** and during initial valve deployment **(C)**, resulting in C-tab **(orange arrow)** at the inner curve of the aortic root **(D)** and better commissural alignment **(E)**. LM = left main coronary artery; L-R = left coronary cusp-right coronary cusp; N-L = noncoronary cusp-left coronary cusp; N-R = noncoronary cusp-right coronary cusp; RCA = right coronary artery.

STATISTICAL ANALYSIS. We compared the incidence of severe coronary artery overlap with LM, RCA, both coronary arteries, and 1 or both coronary arteries among the initial crimped orientations with the SAPIEN 3 (3, 6, 9, and 12 o'clock), the "Hat" marker positions with the Evolut (OC, CF, IC, and CB groups), and the initial commissure post positions with the ACURATE-neo (CB, IC, CF, and OC groups). In addition, we compared the incidence of severe versus nonsevere coronary artery overlap on the basis of the clockface-designated orientations of the interatrial septum, base of the right coronary sinus, LM and RCA orifice, and the 3 native commissures on CT axial images reconstructed using 3mensio Valves software.

Continuous variables are reported as mean $\pm$ SD, and categorical variables are reported as proportions. Differences were detected using Student's *t*-test for continuous variables and the chi-square or Fisher exact test for categorical variables. All statistical tests were 2 tailed, with p values <0.05 considered to indicate statistical significance. Statistical analyses were performed using SPSS version 24.0 (IBM, Armonk, New York).

RESULTS

Patient characteristics are listed in Table 1.

SAPIEN 3 THV. Crimping orientation among the 483 SAPIEN 3 cases was distributed as follows: 104 (21.5%) at 3 o'clock, 126 (26.1%) at 6 o'clock, 136 (28.2%) at 9 o'clock, and 117 (24.2%) at 12 o'clock. Initial SAPIEN 3 crimping orientation had no impact on final commissural alignment (Figure 5). The overall incidences of severe coronary artery overlap were 36.9% with the LM, 38.7% with the RCA, 23.6% with both coronary arteries, and 51.3% with 1 or both coronary arteries. There were no differences in SAPIEN 3

TABLE 1 Patient Characteristics (N = 828)

Age, yrs	80.2 ± 8.3
Female	359 (43.4)
STS score (%)	4.8 ± 3.5
Coronary artery disease	457 (55.2)
Diabetes	266 (32.1)
TIA or stroke	84 (10.1)
Peripheral vascular disease	159 (19.2)
Moderate/severe COPD	163 (19.7)
Atrial fibrillation	230 (27.8)
Chronic kidney disease	320 (38.6)
Pulmonary hypertension	364 (44.0)
Prior permanent pacemaker	104 (12.6)
Prior cardiac surgery	151 (18.2)
Prior PCI	244 (29.5)
NYHA functional class III/IV	544 (65.7)
LVEF <35%	87 (10.5)

Values are mean ± SD or n (%).

COPD = chronic obstructive pulmonary disease; LVEF = left ventricular ejection fraction; NYHA = New York Heart Association; PCI = percutaneous coronary intervention; STS = Society of Thoracic Surgeons; TIA = transient ischemic attack.

crimping on the incidence of severe coronary artery overlap with the LM ($p = 0.71$), both coronary arteries ($p = 0.19$), and 1 or both coronary arteries ($p = 0.10$), but there was a higher incidence of severe overlap with the RCA when a SAPIEN 3 THV commissure was crimped at 6 o'clock (51.6% vs. 28.8% at 3 o'clock, 36.8% at 9 o'clock, and 35.9% at 12 o'clock; $p = 0.003$).

EVOLUT THV. With the 245 Evolut cases, the overall incidence of severe coronary artery overlap was 25.3% with the LM, 15.5% with the RCA, 9.8% with both coronary arteries, and 31.0% with 1 or both coronary arteries. We grouped the cases with "Hat" at OC and CF together (198 [80.8%]) and those with "Hat" at IC and CB together (47 [19.2%]) (Figure 2). The overall incidence of severe overlap was 25.3% with the LM, 15.5% with the RCA, 9.8% with both coronary arteries, and 31.0% with 1 or both coronary arteries (Figure 6). Compared with patients who had "Hat" at IC or CB during initial deployment, those with "Hat" at OC or CF had improved commissural alignment and lower incidence of coronary artery overlap ($p < 0.001$ for all) with the LM (15.7% vs. 66.0%), RCA (7.1% vs. 51.1%), both coronary arteries (2.5% vs. 40.4%), and 1 or both coronary arteries (20.2% vs. 76.6%).

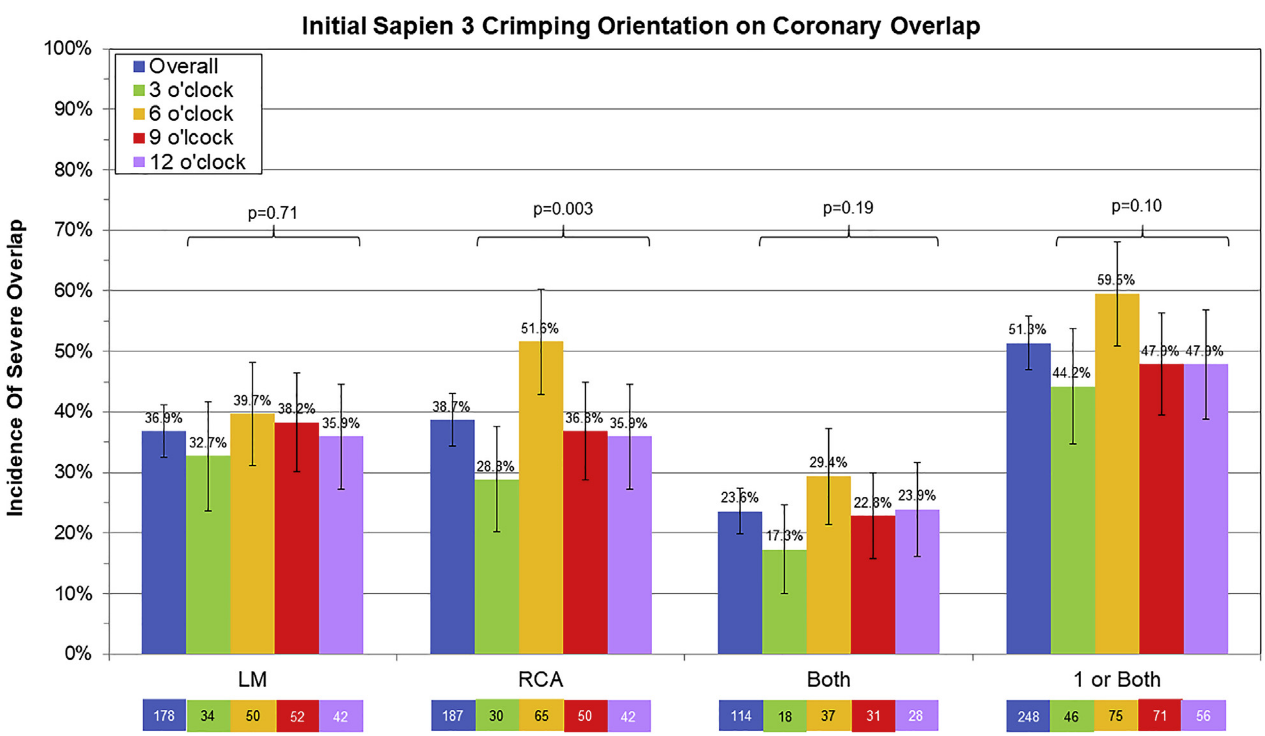
Beginning in March 2019 at 1 institution, 107 consecutive patients had the flush port of the delivery catheter inserted facing 3 o'clock, to attempt to position the "Hat" at the OC of the descending aorta and annulus at the initial Evolut deployment. Commissural alignment and coronary artery overlap among these 107 patients were compared with the 121 patients who underwent Evolut TAVR prior to March 2019, when the delivery catheter was inserted with flush port facing 12 o'clock. We found that having the flush port starting at 3 o'clock significantly improved the "Hat" position at OC or CF during initial deployment from 70.2% to 91.6% ($p = 0.002$). Only 5 of 107 cases (4.7%) required forced counterclockwise rotation of the delivery catheter to turn the "Hat" from IC to OC in the descending aorta, all but 1 of which achieved "Hat" marker at the OC or CF at initial Evolut deployment. As a result, the overall incidence of coronary artery overlap was significantly reduced, for the LM from 31.4% to 18.7% ($p = 0.033$), for the RCA from 20.7% to 11.2% ($p = 0.071$), for both coronary arteries from 14.0% to 5.6% ($p = 0.047$), and for 1 or both coronary arteries from 38.0% to 24.3% ($p = 0.032$). This means that when the Evolut THV is deployed with "Hat" at OC or CF, it achieves the highest likelihood of commissural alignment.

ACURATE-NEO THV. Among the 100 ACURATE-neo cases, 16 (16%) had 1 of the 3 commissural posts seen at CB, 28 (28%) had a commissural post seen as a "line" at IC, 27 (27%) at OC, and 29 (29%) had 1 commissural post seen at CF (Figure 3). The overall incidence of coronary artery overlap was 28.0% with the LM, 42.0% with the RCA, 19.0% with both coronary arteries, and 51.0% with 1 or both coronary arteries (Figure 7). When the commissural post was at CB and IC at initial deployment, the incidence of coronary artery overlap was much lower: 0% and 7.1% with the LM, 12.5% and 7.1% with the RCA, 0% with both coronary arteries, and 12.5% and 14.3% with 1 or both coronary arteries. This initial orientation compared favorably with a commissural post initially at OC and CF, with CF being the worst in coronary artery overlap ($p < 0.001$).

In 7 cases, the operators attempted to torque the delivery catheter to position the commissural post to IC to improve commissural alignment. This resulted in commissural alignment in 5 of 7 of these cases (71.4%).

RELATIONSHIP BETWEEN THE ORIENTATION OF AORTIC ROOT STRUCTURES AND CORONARY ARTERY OVERLAP. SAPIEN 3 THV. There were no differences between the incidence of severe and nonsevere coronary artery overlap on the basis of the distribution of clockface-designated orientations of the interatrial septum, base of the right coronary sinus, LM and RCA orifice, and the 3 native commissures. Mean aortic root angle measurements, available in 47.2% of SAPIEN3 cases (n = 228), trended

FIGURE 5 Incidence of Severe Coronary Artery Overlap With a SAPIEN 3 Commissure Based on Initial Crimping Orientation



Initial crimping orientation had no impact on the severity of coronary artery overlap with a SAPIEN 3 commissure, except that crimping at 6 o'clock had a higher incidence of severe right coronary artery overlap (51.6%). Abbreviations as in Figure 4.

greater in the severe than nonsevere coronary artery overlap group for the LM (54.2 ± 10.6° vs. 51.6 ± 11.7°; p = 0.08) and RCA (54.4 ± 11.4° vs. 51.5 ± 11.1°; p = 0.06).

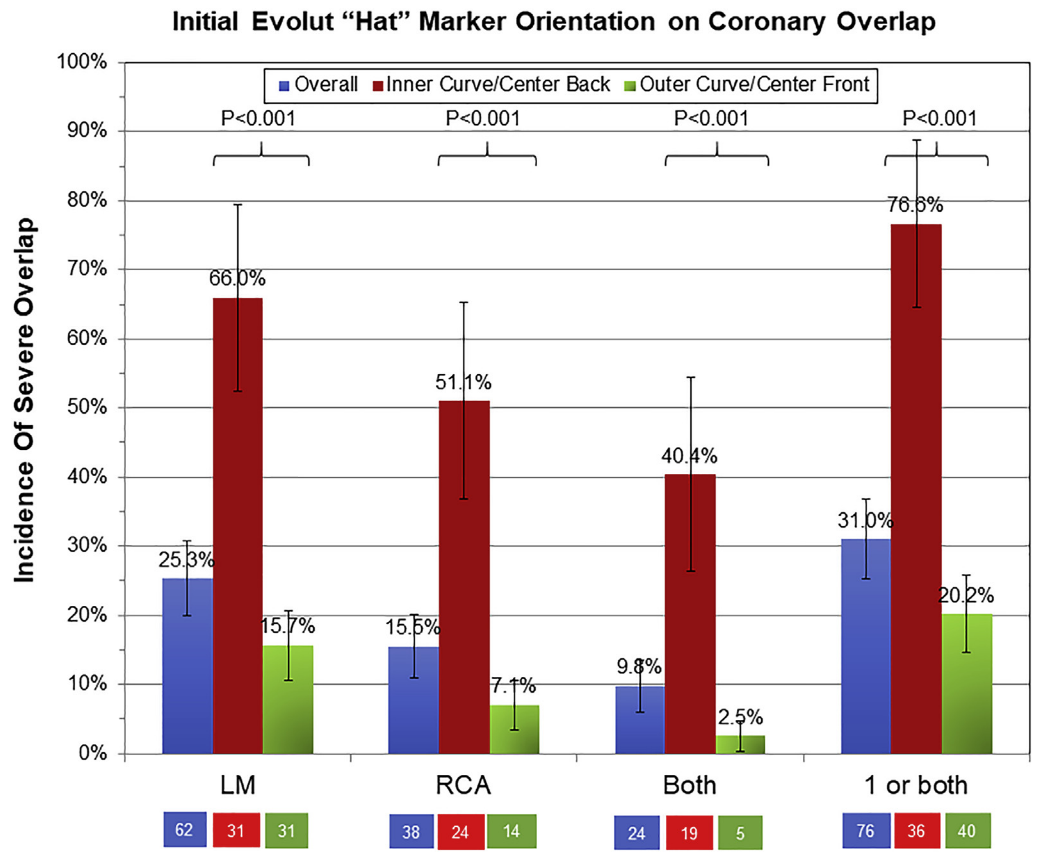
Evolut THV. There were no differences between the incidence of severe and nonsevere coronary artery overlap on the basis of the distribution of clockface-designated orientations of the interatrial septum, base of the right coronary sinus, LM and RCA orifice, and the 3 native commissures. Mean aortic root angle measurements, available in 92.2% of Evolut cases (n = 226), were greater in the severe than nonsevere coronary artery overlap for the LM (52.0 ± 10.4° vs. 49.1 ± 9.2°; p = 0.049) and RCA (51.1 ± 10.9° vs. 49.6 ± 9.3°; p = 0.039).

DISCUSSION

The main findings of our pilot study are as follows (Central Illustration): 1) crimping the SAPIEN 3 THV at specific orientations had no impact on commissural alignment and coronary artery overlap; 2) positioning the Evolut THV "Hat" marker at OC during initial deployment improved commissural alignment and significantly reduced coronary artery overlap; and 3) having a commissural post of the ACURATE-neo THV at CB or IC at initial deployment improved commissural alignment and reduced coronary artery overlap, but the ability of to achieve intentional alignment remains preliminary.

IMPACT OF COMMISSURAL ALIGNMENT ON CORONARY ARTERY ACCESS AND REDO TAVR. Surgical aortic valve replacement is fundamentally different from TAVR, in that the native leaflets are resected, and surgeons align the commissural posts of bioprosthetic valves to native commissures to avoid coronary obstruction. In TAVR, not only do the native leaflets remain in situ, but the location of commissural posts relative to the coronary orifices appeared random (4,5). Although the incidence of coronary artery access after TAVR remains low and mostly successful (1), interventional cardiologists who are not familiar with TAVR may have difficulty in coronary artery access due to the random location of the commissural posts relative to the coronary orifices. Although this issue may be less important in THVs with short stent frames, it may be more problematic with supra-annular THVs with tall stent frames, because of the need for a coronary

FIGURE 6 **Incidence of Severe Coronary Artery Overlap Based on Initial "Hat" Marker Orientation During Evolut Transcatheter Valve Deployment**

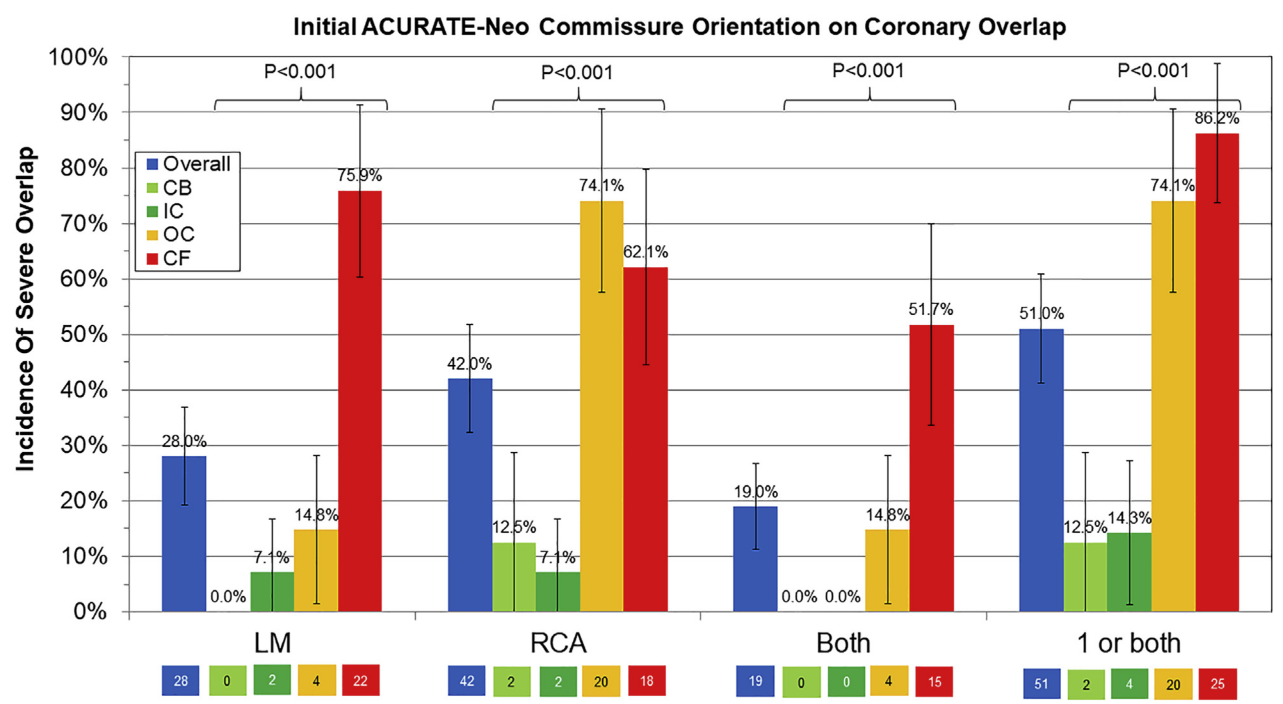


Positioning the "Hat" marker at the outer curve or center front during initial deployment substantially reduced the incidence of severe coronary artery overlap with either the LM or the RCA, or both ($p < 0.001$). Abbreviations as in Figure 4.

catheter to traverse around the commissural post and across the stent frame to engage the coronary artery (1). Commissural alignment in TAVR may therefore allow the THV neocommissures be placed away from the coronary arteries to facilitate coronary artery access more directly across the stent frame (1,6).

Commissural alignment is important in 2 other clinical scenarios. First, in TAVR in degenerated surgical bioprostheses in which the risk for coronary obstruction is high, BASILICA (bioprosthetic or native aortic scallop intentional laceration to prevent iatrogenic coronary artery obstruction) can be performed to improve coronary flow and reduce obstruction risk (7). However, if a THV commissure is misaligned and it ends up facing the lacerated part of the leaflet, coronary obstruction may still occur and has been reportedly fatal (D. Dvir, personal communication). Second, performing TAVR in a failed THV (redo TAVR) presents 2 issues in a small aortic root. First, the first THV may have leaflets extending close to or above the sinotubular junction and would occlude the coronary arteries when a second THV is implanted, particularly if the distance between the fully pinned-open leaflets and sinotubular junction is short (2,8,9). Two recent studies suggest that redo TAVR after SAPIEN 3 TAVR may not be feasible in 13% and 20% of patients respectively, because of unfavorable aortic root anatomy and high risk for coronary obstruction when a second THV is placed within the first one (8,9). Second, a number of THVs have leaflets at the same level as the stent frame. Because the initial THV commissures are often not aligned with native commissures, BASILICA may not be feasible or effective because of the suboptimal trajectory of the electrified piercing wire (J. Khan, personal communication). This is more relevant with THVs in which the leaflets

FIGURE 7 Incidence of Severe Coronary Artery Overlap Based on Initial ACURATE-neo Commissural Orientation



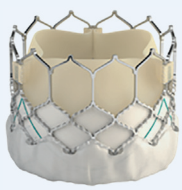
Having an ACURATE-neo commissure positioned at center back (CB) or inner curve (IC) substantially reduced the incidence of severe overlap with either the LM or the RCA, or both ($p < 0.001$). CF = center front; OC = outer curve; other abbreviations as in Figure 4.

extend above the sinotubular junction and when commissural alignment is not achieved (2).

COMMISSURAL ALIGNMENT AMONG THV TYPES. To the best of our knowledge, our study is the first to systematically characterize the impact of initial THV orientation on coronary artery overlap and commissural alignment. Our study found that crimping the SAPIEN 3 THV at different orientations did not improve commissural alignment. This may be due to the flexibility of the delivery catheter as it courses along the patient's vasculature. The low stent frame profile of the SAPIEN 3 makes commissural alignment less relevant for coronary artery access, because of the ability for coronary wires and catheters to engage above and through the top row of the stent frame to access the coronary artery. However, in certain aortic root types in which the SAPIEN 3 stent frame extends above a narrow sinotubular junction, coronary artery access may be challenging (1,2,9). Moreover, if the SAPIEN 3 lacks commissural alignment, BASILICA may not be feasible or optimally performed to facilitate redo TAVR, because of the creation of a cylinder-like effect by the SAPIEN 3 leaflets in the aortic root. Therefore, there may be indirect benefits of commissural alignment even with a balloon-expandable valve.

In terms of the ACURATE-neo THV, coronary artery access may not be an issue given the lack of a stent frame encapsulating the aortic root. However, when one of the tall commissural posts faces a coronary orifice, direct coronary artery access may still be potentially challenging. In addition, redo TAVR may be an issue with this THV, given the supra-annular and tall leaflets of the ACURATE-neo, and its commissural posts may extend above a narrow sinotubular junction. In our study, 56% of cases had 1 of the 3 commissural posts at the OC or CF at deployment, resulting in a position in front of the coronary ostium, potentially precluding consideration of a BASILICA procedure during redo TAVR. Having a commissural post of the ACURATE-neo THV at CB and IC at initial deployment improved the chance of achieving commissural alignment. Further in vitro testing will be necessary to confirm our hypothesis. We have only 7 cases in which we intentionally attempted to improve commissural alignment with

CENTRAL ILLUSTRATION Summary of the ALIGN TAVR Study on Transcatheter Valve Orientation and its Impact on Commissural Alignment and Coronary Artery Overlap

	Sapien 3	Evolut	ACURATE-neo
			
Method of Transcatheter Valve Orientation	1 commissure crimped at 3,6,9,12 o'clock	"Hat" marker position at initial deployment	Commissure position at initial deployment
Impact of Initial Deployment Orientation on Commissural Alignment	None	• Insert catheter with flush port facing 3 o'clock • Alignment improves when "Hat" at outer curve(OC) / center front(CF)	• Insert catheter with flush port facing 12 o'clock • Alignment improves when commissure at center back(CB) / inner curve (IC)
Severe Overlap with Left Main	32.7-39.7%	15.7% (OC/CF) vs 66.0%	0-7.1% (CB/IC) vs 14.8%-75.9%
Severe Overlap with Right Coronary Artery	28.8-51.6%	7.1% (OC/CF) vs 51.1%	7.1-12.5% (CB/IC) vs 62.1-74.1%

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the ACURATE-neo, and further studies will be necessary to determine if this can be performed safely and reproducibly.

Our study found that it is possible to orient the Evolut delivery catheter and improve commissural alignment. There are potential benefits in improving commissural alignment with a supra-annular THV with a tall stent frame. First, coronary artery access may become simpler without the tall commissural post in front of the coronary artery ostium. Second, if redo TAVR is necessary, BASILICA to lacerate the supra-annular leaflet and enable safe implantation of a second THV may be conceivable, albeit more challenging (J. Khan, personal communication). The "Hat" positioned at OC or CF had significantly better commissural alignment and reduced coronary artery overlap versus the "Hat" at IC or CB. The mechanism underlying our study finding is unclear but may have to do with the spine location within the Evolut delivery catheter, which limits significant rotation as it tracks from the descending aorta to the annulus. Positioning the "Hat" marker on the OC or CF was facilitated by inserting the Evolut delivery catheter with flush port facing 3 o'clock, with <5% of cases requiring additional counterclockwise rotation of the delivery catheter to turn the "Hat" marker to the OC in the descending aorta. We recommend performing this maneuver only in the descending aorta, as once the delivery catheter is in the arch and ascending aorta, the spine within the catheter will limit the ability to deliberately rotate to a favorable "Hat" position. We would caution other operators that this maneuver is only a proof of concept, and further validation is necessary to confirm its safety and reproducibility.

Despite our 3 o'clock flush-port orientation, the incidence of severe coronary artery overlap with 1 or both coronary arteries after Evolut TAVR decreased from 38.0% to only 24.3% ($p = 0.032$). Despite this modest improvement in commissural alignment, we believe that our result is still better than random THV orientations observed in prior studies (4,5). Our goal in this study is to raise the awareness on the importance of commissural alignment in TAVR, now that the therapy is approved in patients with symptomatic severe aortic stenosis without age or surgical risk restriction. In younger patients in whom lifelong management of their aortic valve disease (native and bioprosthetic) needs to be taken into consideration, achieving commissural alignment during the initial TAVR may have important future clinical implications. Both TAVR operators and device manufacturers should place more emphasis on this subject area, given that younger patients are now undergoing TAVR, and aortic valve reintervention will be likely in this population with longer life expectancies.

Although an individual patient's aortic root and vascular anatomy may affect final THV orientation and coronary artery overlap, we found no association between the relative orientations of aortic root structures and severe coronary artery overlap for both the SAPIEN 3 and Evolut THVs. However, the incidence of severe coronary artery overlap was higher in patients with greater aortic root angles (i.e., a more horizontal root anatomy) in Evolut cases and trended higher in SAPIEN 3 cases. Achieving commissural alignment to avoid severe coronary artery overlap may be more difficult in a more horizontal root anatomy for these 2 THV devices. Newer THVs that require commissural alignment for implantation, such as the JenaValve (JenaValve Technology, Irvine, California) and J-Valve (JC Medical, Burlingame, California), may more likely achieve commissural alignment and avoid severe coronary artery overlap, irrespective of native aortic root and vascular anatomy. Further clinical evaluation of these devices will be necessary to confirm this hypothesis.

STUDY LIMITATIONS. First, our CT-fluoroscopic coregistration technique requires a larger scale validation with post-TAVR follow-up imaging to confirm the actual THV orientation. We believe that our 77 post-TAVR CT samples with the 3 THV types can confirm the validity of our methodology.

Second, the association between commissural alignment and the ability to perform coronary artery access and redo TAVR remains hypothetical, given that only a handful of cases were done in this large series. Multiple anatomic and procedural factors may be important when evaluating the feasibility of both procedures.

Finally, we did not evaluate the THVs that are designed to align the neocommissures with native commissures for implantation.

CONCLUSIONS

This is the first systematic evaluation of commissural alignment in TAVR. More than 30% to 50% of cases had overlap with 1 or both coronary arteries. Initial SAPIEN 3 orientation had no impact on alignment, but specific initial orientations of the Evolut and ACURATE-neo improved alignment. Optimizing valve alignment to avoid coronary artery overlap will be important in coronary artery access and redo TAVR.

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PERSPECTIVES

WHAT IS KNOWN? Coronary artery access after TAVR can be challenging. Transcatheter valve commissural alignment may facilitate coronary artery access and redo TAVR.

WHAT IS NEW? Whereas SAPIEN 3 THV crimping orientation had no impact on commissural alignment, certain orientations of the Evolut and ACURATE-neo at initial deployment could improve commissural alignment and reduce coronary artery overlap.

WHAT IS NEXT? Transcatheter valves and delivery system designs could ensure optimal THV alignment with native commissures to facilitate coronary artery access and redo TAVR.

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KEY WORDS commissural alignment, coronary artery access, transcatheter aortic valve replacement

APPENDIX For a supplemental table and a supplemental figure, please see the online version of this paper.