Aortic root geometry following composite valve graft implantation: Implications for future valve-in-valve procedures

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ABSTRACT

Objectives: Biological composite valve grafts (CVGs) are being performed more frequently, which increases the need for interventions treating bioprosthetic valve failure. The feasibility of valve-in-valve procedures in this population is uncertain. This study aimed to assess changes in aortic root geometry and coronary height following CVG implantation to better understand future interventions.

Methods: We retrospectively identified 64 patients following bioprosthetic CVG replacement with pre- and postoperative computed tomography angiography. Root assessment was conducted as in preprocedural transcatheter aortic valve evaluation using a virtual valve simulation.

Results: In 64 patients (age, 67.6 ± 9.3 years; 76.6% men) the preoperative coronary height was 14.3 ± 6.8 mm for the left coronary artery (LCA) and 17.9 ± 5.9 mm for the right coronary artery (RCA), which significantly decreased after CVG implantation, with 8.7 ± 4.4 mm for the LCA and 11.3 ± 4.4 mm for the RCA (P < .001). The virtual valve-to-coronary distances measured 4.0 ± 1.3 mm (LCA) and 4.6 ± 1.4 mm (RCA). Overall, 59.4% (n = 38) of patients with bio-CVGs would have been at risk for coronary obstruction, 29.7% (n = 19) for LCA, 10.9% (n = 7) for RCA, and 18.8% (n = 12) for combined LCA and RCA.

Conclusions: Coronary height significantly decreased following CVG implantation. The majority of patients after bio-CVG were at a potential risk for coronary obstruction in future valve-in-valve procedures. Further studies are needed to identify the best possible technique for coronary reimplantation and other measures to diminish the risk for future coronary obstruction in this population. (J Thorac Cardiovasc Surg 2023;166:1635-43)

CENTRAL MESSAGE

CTA analysis after CVG surgery revealed a significantly decreased coronary height and showed that a majority of patients with bio-CVGs are at risk for coronary obstruction if a ViV procedure is required.

PERSPECTIVE

Aortic root replacement using biological CVGs is being performed at increasing rates, yet the feasibility of ViV procedures in bio-CVGs is uncertain. A majority of patients after bio-CVG are at risk for coronary obstruction in future ViV procedures. Further studies are needed to assess modifiable risk factors to obviate patients after bio-CVG from coronary obstruction in future ViV procedures.
Composite valve graft (CVG) implantation according to the modified Bentall technique is considered the gold standard of treatment for aortic root pathologies in an all-comer collective that requires combined aortic-root and valve replacement. The procedure, initially reported by Bentall and deBono in 1968, has been continuously adapted and is currently a standardized approach; the aortic root is completely excised and replaced by a composite valve graft (a prosthetic valve, either mechanical or stented xeno-prosthesis, included in a Dacron (DuPont) aortic tube graft or sinus of Valsalva aortic prosthesis). The coronary arteries are reimplanted at the ostial level with a remaining cuff of aortic wall tissue (the coronary button) at the corresponding site of the aortic graft. The shift toward increased numbers of stented bioprosthesis valves used in surgical aortic valve replacement (SAVR) within recent decades has also led to increased numbers of implanted biological CVGs. Consequently, more patients who previously underwent aortic root replacement with a bio-CVG will present with degenerated bioprostheses in the near future. Transcatheter options, specifically valve-in-valve (ViV) procedures, have become a common solution for interventions in degenerated bioprostheses. Nevertheless, they are associated with an up to 6 times higher risk of coronary obstruction than transcatheter aortic valve replacement (TAVR) in native aortic valves. Data from the Valve-in-Valve International Data Registry showed an incidence of 2.3% for symptomatic coronary obstruction following ViV-TAVR. Several risk factors for coronary obstruction have been identified, most importantly a low coronary ostia height (<12 mm), a shallow sinus of Valsalva, and a short (<4 mm) virtual valve to coronary ostium distance (VTC). We therefore investigated changes in aortic root geometry and coronary ostia height after CVG implantation to evaluate the risk for coronary obstruction in future ViV procedures in this specific population.

**METHODS**

**Ethical Statement**

The present study was performed within the framework of the Vienna Registry for composite valve graft implantation, which was reviewed and approved by the ethical committee of the Medical University of Vienna (EC-Nr: 2311/2020; date of approval January 19, 2021). The patients provided informed written consent for the publication of the study data.

**Patients and Study Design**

Patients were eligible for study inclusion if they were enrolled in the Vienna Registry for composite valve graft implantation. This registry comprises 507 patients who underwent CVG aortic root replacement after the modified Bentall technique, and the inclusion and exclusion criteria were recently described in detail. Patients were included in this analysis if they underwent a biological CVG procedure, if computed tomography angiography (CTA) of the aortic root and the thoracic aorta was performed preoperatively (within 1 year preoperatively) and postoperatively with regard to the index procedure (ie, the initial CVG replacement), and if imaging data were of sufficient quality for specified root geometry measurements (ie, complete depiction of the region of interest [aortic annulus, sinuses of Valsalva, coronary origins, and sinotubular junction] with no or minimal movement artifacts within the aortic root). Therefore, CTA scans were acquired with electrocardiogram gating or fast acquisition protocols with modern scanners were included.

**CTA-Based Aortic Root Measurements**

CTA scans were analyzed using dedicated software for preprocedural TAVR planning (Aortic Valve Package, 3 Mensio; Pie Medical Imaging) by 2 independent study team members. Patients received either gated CTA of the chest or high-pitch CTA of the whole aorta, which allows for sufficient root analysis without cardiac motion-induced artifacts. Initially, markers for axial alignment of the aortic root and ascending aorta were manually placed. Following correct alignment, measurements for the aortic annulus (ie, valve orifice area), coronary arteries, sinuses of Valsalva (right, left, and non), and the sinotubular junction were performed. The virtual VTC was assessed after a standardized method using a virtually inserted valve within the frame of the bioprosthetic struts with slight reduction of the diameter to fit the outside end of the struts. Measurement of the VTC was performed in the subgroup of patients who displayed a coronary height (left or right) below the height of the bioprosthetic stent frame.

**Potential Risk for Coronary Obstruction**

The risk of coronary obstruction with regard to future ViV procedures was assessed after the Vancouver method (Figure 2). We defined risk for coronary obstruction when both of the following criteria were met: the postoperatively measured height of either the right or the left coronary was below the height of the bioprosthetic stent frame and the measured VTC of the affected coronary was at or below 4 mm.

### Abbreviations and Acronyms

- **CTA** = computed tomography angiography
- **CVG** = composite valve graft
- **ICC** = intraclass correlation coefficient
- **LCA** = left coronary artery
- **RCA** = right coronary artery
- **SAVR** = surgical aortic valve replacement
- **TAVR** = transcatheter aortic valve replacement
- **ViV** = valve-in-valve
- **VIVID** = Valve-in-Valve International Data Registry
- **VTC** = virtual valve to coronary ostium distance
Continuous variables were described by the mean ± SD or median (interquartile range) in cases of nonnormal distributions and compared between groups of patients using a dependent-sample Student t test or Wilcoxon rank-sum test, respectively. Categorical data were compared using the χ² test or Fisher exact test. For assessment of interobserver reliability, aortic root measurements of postoperative CTA scans were performed independently by 2 study team members (P.W. and I.C.). This assessment was based on the sample size calculation, which yielded a minimum sample size of 50 patients necessary to achieve an intraclass correlation coefficient (ICC) >0.80 with an alpha of 0.05 and a power of 0.80. Interrater reliability was calculated with ICC and corresponding 95% CI and was graded as slight (ICC, <0.2), fair (ICC, 0.2-0.4), moderate (ICC, 0.41-0.6), good (ICC, 0.6-0.8), and almost perfect agreement (ICC, >0.8). Statistical analysis was performed using IBM SPSS Statistics version 27 (IBM Corp).

RESULTS
Preoperative and Operative Characteristics
Following exclusion of patients with missing imaging (n = 333), insufficient imaging data (n = 26), and mechanical CVGs (n = 84) a total of 64 patients were included in the study (Figure E1). In the study cohort (76.6% men, aged 67.6 ± 9.3 years, and body mass index 26.8 ± 4.3), the primary indications for aortic root replacement were aortic aneurysm in 68.8% (n = 44), aortic dissection in 29.7% (n = 19), and endocarditis in 1.6% (n = 1). At the time of the index CVG implantation, 73.4% (n = 47) of patients presented with tricuspid aortic valve morphology, 20.3% (n = 13) of patients with bicuspid morphology, and 6.3% (n = 4) had already undergone previous SAVR. Surgical details and the implanted devices utilized are summarized in Table 1.

Aortic Root Geometry and Interobserver Reliability
The median time to performance of the postoperative CTA was 5 months (IQR, 0-35 months). In the study cohort, the mean preoperative annular diameter and area were 25.5 ± 3.7 mm² and 514.5 ± 152.6 mm², respectively. The mean preoperative sinus of Valsalva height was 29.8 ± 7.4 mm, and the sinus of Valsalva width was 40.1 ± 6.3 mm, 40.2 ± 6.5 mm, and 41.0 ± 7.1 mm for the right, left, and noncoronary sinus, respectively. The preoperative mean coronary height was 14.3 ± 6.8 mm for the left coronary...
artery (LCA) and 17.9 ± 5.9 mm for the right coronary artery (RCA). Postoperative root measurements yielded statistically significantly smaller values than preoperative measurements. The mean postoperative annular diameter was 21.0 ± 1.8 mm (P < .001), and the mean annular area was 348.6 ± 60.5 mm² (P < .001). The postoperative mean height of the sinus of Valsalva was 27.4 ± 4.4 mm (P < .001), with sinus widths of 32.6 ± 2.4 mm, 32.3 ± 2.6 mm, and 332.2 ± 2.9 mm for the right, left, and non-coronary sinus, respectively (P < .001). The mean height of the LCA and RCA following CVG implantation was significantly decreased by 8.7 ± 4.4 mm and 11.3 ± 4.4 mm, respectively (P < .001). Pre- and postoperative measurements are summarized in Table 2.

Interobserver reliability was excellent for the greater proportion of measurements, with ICC values of 0.90 (95% CI, 0.83-0.94) for annular diameter, 0.89 (95% CI, 0.82-0.93) for annular area, 0.80 (95% CI, 0.67-0.88) for right sinus of Valsalva width, 0.93 (95% CI, 0.88-0.96) for non-coronary sinus of Valsalva width, 0.92 (95% CI, 0.87-0.95) for LCA height, 0.84 (95% CI, 0.73-0.9) for RCA height, and 0.85 (95% CI, 0.74-0.91) for LCA VTC. Good interobserver reliability was observed with an ICC of 0.6 (95% CI, 0.31-0.77) for sinus of Valsalva height, 0.78 (95% CI, 0.64-0.87) for sinotubular junction width, and 0.67 (95% CI, 0.36-0.83) for RCA VTC. Moderate interobserver reliability was observed for the left sinus of Valsalva height with an ICC of 0.58 (95% CI, 0.28-0.74).

Risk of Coronary Obstruction

All patients were evaluated for predicted risk of coronary obstruction in future ViV procedures. In this study, 43.8% (n = 28) received a Magna Ease (Edwards Lifesciences) prosthesis, 25% (n = 16) received a Mosaic prosthesis (Medtronic), 17.2% (n = 11) received an Inspiris prosthesis (Edwards Lifesciences), 12.5% (n = 8) received an Avalus prosthesis (Medtronic), and 1.6% (n = 1) received a Trifecta prosthesis (Abbott). The valve sizes used were 21 mm in 7.8% (n = 5), 23 in 25% (n = 16), 25 mm in 45.3% (n = 29), 27 mm in 20.3% (n = 13), and 29 mm in 1.6% (n = 1). A sinus of Valsalva aortic prosthesis (Terumo Aortic) was used in 68.8% (n = 44) of patients. The

TABLE 1. Preoperative characteristics and procedure details of the overall cohort

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall cohort (n = 64)</th>
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<tbody>
<tr>
<td>Age (y)</td>
<td>67.6 ± 9.3</td>
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<tr>
<td>Sex (male)</td>
<td>76.6</td>
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<tr>
<td>BMI</td>
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<tr>
<td>EuroSCORE II (%)</td>
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<tr>
<td>Indication for CVG</td>
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<tr>
<td>Aneurysm</td>
<td>68.8 (44)</td>
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<tr>
<td>Aortic dissection</td>
<td>29.7 (19)</td>
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<td>Endocarditis</td>
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</tr>
<tr>
<td>Valve model</td>
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</tr>
<tr>
<td>Abbott Trifecta</td>
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</tr>
<tr>
<td>Medtronic Mosaic</td>
<td>25 (16)</td>
</tr>
<tr>
<td>Medtronic Avalus</td>
<td>12.5 (8)</td>
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<tr>
<td>Edwards Magna Ease</td>
<td>43.8 (28)</td>
</tr>
<tr>
<td>Edwards Inspiris</td>
<td>17.2 (8)</td>
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<tr>
<td>Valve size (mm)</td>
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<td>21</td>
<td>7.8 (5)</td>
</tr>
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<td>45.3 (29)</td>
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<td>20.3 (13)</td>
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<td>29</td>
<td>1.6 (1)</td>
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<tr>
<td>Valsalva prosthesis</td>
<td>68.8 (44)</td>
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<tr>
<td>Aortic graft size (mm)</td>
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<td>26</td>
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<td>30</td>
<td>32.8 (21)</td>
</tr>
<tr>
<td>32</td>
<td>21.9 (14)</td>
</tr>
</tbody>
</table>

Values are presented as mean ± SD, %, median (interquartile range), or % (n). BMI, Body mass index; EuroSCORE II, European System for Cardiac Operative Risk Evaluation II; CVG, composite valve graft.

aortic prostheses sizes used were 26 mm in 9.4% (n = 6), 28 mm in 34.4% (n = 22), 30 mm in 32.8% (n = 21), and 32 mm in 21.9% (n = 14).

The coronary height was below the bioprosthetic valve height in 96.9% (n = 62) of cases. The mean values for the VTC were 4 ± 1.3 mm for the LCA and 4.6 ± 1.4 mm for the RCA. Measurements of left and right VTC did not differ statistically significant (LCA VTC P = .97 and RCA VTC P = .1) between patients who received a Valsalva graft (n = 44 [68.8%], LCA VTC 4.02 ± 1.48 mm, and RCA VTC 4.4 ± 1.43 mm), and patients with a straight tube graft (n = 19 [29.9%], LCA VTC 4.04 ± 1.03 mm, RCA VTC 5.16 ± 1.28 mm).

The VTC was below 4 mm in 59.4% (n = 38) of patients; therefore, 59.4% (n = 38) of patients were at risk for coronary obstruction. Of all patients, 29.7% (n = 19) were at risk for LCA obstruction, 10.9% (n = 7) were at risk for RCA obstruction, and 18.8% (n = 12) were at risk for obstruction of both coronaries. Pre- and postoperative measurements are summarized in Table 2 and depicted in Figure 3.

Specific Self-Expandable Valve Simulation

A specific simulation with simulated insertion of a self-expandable third-generation TAVR (Medtronic Evolut) was performed with complete expansion of the simulated TAVR stent frame. Recommended valve sizes for insertion were 23 mm (n = 7 [10.9%]), 23 or 26 mm (n = 1 [1.6%]), 26 mm (n = 23 [35.9%]), 26 or 29 mm (n = 15 [23.4%]), and 29 mm (n = 18 [28.1%]). (In case of 2 possible sizes, the smaller model was chosen). Mean VTC values were 3.2 ± 1.3 mm for the LCA and 3.5 ± 1.8 for the RCA and 37.5% (n = 24) were at risk for LCA obstruction, 7.8% (n = 5) at risk for RCA obstruction, and 31.3% (n = 20) at risk for LCA and RCA coronary obstruction.

DISCUSSION

Lifetime management of aortic valve disease in young patients is essential, should be heart-team guided, and starts at the index procedure. Aortic valve bioprostheses are being implanted with increasing frequency with the future outlook of ViV procedures. This trend can also be translated to aortic root surgery, with an increasing proportion of biological CVG replacements being performed within the past decade.5 We therefore investigated the feasibility of ViV procedures in this specific patient collective in a CTA-based simulation study (Figure 4 and Video 1).

Our study presents 3 main findings: the height of the LCA and RCA was significantly decreased following CVG implantation with reimplantation of the coronary ostia; the majority of patients (56.25%) who underwent biological CVG implantation were found to be at risk for coronary obstruction in the case of a future valve-in-valve procedure; and in 18.8% of all patients, both coronary arteries were at risk, whereas 29.7% presented with sole risk for LCA occlusion and 10.9% were at sole risk for RCA occlusion.

Following the first ViV procedures in clinical practice <15 years ago,13 this modality has become an integral element in the treatment of degenerated surgical bioprostheses. The feasibility of ViV procedures is substantially determined by the risk of coronary obstruction because this is a potentially lethal event, occurring more frequently in ViV procedures compared with native TAVR.9,15 Several studies have investigated patients who underwent transcatheter valve implantation after SAVR to identify risk factors for unsuccessful or complicated ViV procedures. In 1 of the largest contemporary cohorts of ViV cases (VIVID Registry), 1598 patients with previous stented (81.8% [n = 1307]) or stentless (18.2% [n = 291]) SAVR cases were analyzed for procedural success and midterm outcomes.15 A statistically significantly increased incidence of coronary obstruction (6.0% vs 1.5%) was observed in the patients with stentless valves, nevertheless, 30-day and 1-year mortality did not differ statistically significantly between groups.15 Another landmark analysis
of the VIVID Registry cohort in 1612 patients revealed that prostheses with external leaflet mounting predisposed individuals to a higher risk for coronary obstruction than valves with internal leaflet mounting. Given the results of this investigation, a cutoff level of 4 mm for virtual transcatheter valve to coronary ostium distance was found to be a strong predictor for the occurrence of coronary obstruction. Computed tomography-based simulation studies for aortic ViV feasibility in patients after cardiac surgery are currently limited; however, they are of great interest because they might add relevant information and considerations in this patient collective. We recently investigated changes in coronary height following surgical aortic valve replacement with either conventionally sutured or rapid-deployment bioprosthetic aortic valves. In this collective, a significantly decreased coronary height for the RCA and LCA following SAVR with conventional sutured bioprostheses compared with SAVR with rapid-deployment valves was observed. Another CTA-based simulation study observed the risk of complex TAVR in a heterogeneous cohort of patients following aortic root interventions, including stentless valve replacements, homograft replacements, valve-sparing reconstructions, and CVG root replacements. Their findings in 81 patients revealed a large proportion of expected complex TAVR in this cohort (50.6%). Corresponding to results from the VIVID Registry, they found

### TABLE 2. Postoperative computed tomography angiography aortic root measurements after biological composite valve graft implantation

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Overall cohort (n = 64)</th>
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<tbody>
<tr>
<td></td>
<td>Preoperative</td>
</tr>
<tr>
<td>Annular diameter (mm)</td>
<td>25.5 ± 3.7</td>
</tr>
<tr>
<td>Annular area (mm²)</td>
<td>514.5 ± 152.6</td>
</tr>
<tr>
<td>SOV height (mm)</td>
<td>29.8 ± 7.4</td>
</tr>
<tr>
<td>SOV width (mm)</td>
<td></td>
</tr>
<tr>
<td>Right-coronary (mm)</td>
<td>40.1 ± 6.3</td>
</tr>
<tr>
<td>Left-coronary (mm)</td>
<td>40.2 ± 6.5</td>
</tr>
<tr>
<td>Noncoronary (mm)</td>
<td>41.0 ± 7.1</td>
</tr>
<tr>
<td>STJ width (mm)</td>
<td>42.5 ± 10.0</td>
</tr>
<tr>
<td>Valve to STJ distance (mm)</td>
<td>13.2 ± 2.7</td>
</tr>
<tr>
<td>Left coronary height (mm)</td>
<td>14.3 ± 6.8</td>
</tr>
<tr>
<td>Right coronary height (mm)</td>
<td>17.9 ± 5.9</td>
</tr>
<tr>
<td>LCA VTC (mm)</td>
<td>4.0 ± 1.3</td>
</tr>
</tbody>
</table>

Values are presented as mean ± SD. SOV, Sinus of Valsalva; STJ, sinotubular junction; LCA, left coronary artery; RCA, right coronary artery; VTC, virtual valve-to-coronary distance.

### FIGURE 3. Bubble plot depicting the dispersion of root proportions in patients after bio-composite valve graft (CVG) (n = 64). Bubble dimensions are depicting the numbers of patients with specific CVG size compositions, whereas coloration of bubbles is indicating the proportion of patients with risk for coronary obstruction (CO) at the specific CVG composition.
patients after stentless SAVR at higher risk for complex ViV, as well as patients with atypical root morphologies and straight tube grafts.

**Coronary Height Following Reinsertion**

Given the availability of pre- and postoperative CTA in a large cohort of patients undergoing CVG implantation, we were able to investigate changes in coronary height after index surgery. The mean height of the LCA significantly decreased from 14.8 to 8.4 mm, and correspondingly, the RCA height decreased from 18.2 to 12.7 mm. This remarkable reduction in coronary height is likely attributable to reduction of the sinus of Valsalva diameter with a subsequent necessity of a different routing for the coronary origins. To allow a tension-free coronary reapproximation, a lower reinsertion is a natural consequence because it requires less length and less extensive mobilization (which reduces the risk of coronary kinking, another rare but feared complication, especially considering the RCA). The low insertion height of the coronaries frequently implicates an origin of the coronaries below the prosthetic strut or the prosthetic rail (upper margin of the prosthetic leaflet, which is usually 1-2 mm lower than the strut), as almost all available 19 mm bioprosthetic valves already exceed a strut height of 13 mm (a notable exception here is the Mitroflow [LivaNova] prosthesis with 11 mm).

**Root Morphology**

In the analyzed patients with biological CVG implantation, the obtained mean VTC was 4 mm for the LCA and 4.6 mm for the RCA, which is borderline because 4 mm is considered a cutoff value for coronary obstruction risk. Upon closer examination, these numbers do not come as a surprise, considering the components of a CVG and modes of intraoperative sizing. Intraoperative sizing of the valve using the custom sizer determines the required valve size. Subsequently, a sinus of Valsalva graft corresponding to valve size with either 3 or 5 mm larger in size is chosen.
Because the labeled valve size refers to the inner diameter (labeled sizes vary between manufacturers), the outer diameter is naturally larger. This only leaves a 3 to 5 mm difference between the size of the aortic prosthesis and the valve prosthesis for the whole diameter, which must be divided (ideally equally) into 2, inevitably generating a VTC smaller than 4 mm. Nevertheless, only half of patients after bio-CVG implantation presented with a VTC smaller than 4 mm, which might be partially attributed to the additional extension of the sinus of Valsalva grafts when filled and pressurized under systemic flow conditions.

Coronary Obstruction Risk and Future Implications

The statistically significant lowering of the coronary origins and the narrow root morphology after CVG implantation leads to poor preconditions for ViV procedures in this collective. The majority of patients following bio-CVG in the present study were found to be at risk for coronary obstruction for LCA (n = 19 [29.7%]), whereas a smaller proportion were at risk for combined (n = 12 [18.8%]) or RCA obstruction (n = 7 [10.9%]).

In general, coronary flow obstruction during the index CVG implantation is mostly due to inappropriate reimplantation of the coronary arteries leading to kinking or stretching of the vessel with subsequent flow impairment. Especially when placing the right coronary artery to low or to leftward, filling of the right ventricular outflow tract can negatively influence the routing and thus the flow of the RCA. In contrast, coronary flow obstruction during ViV procedures (after a bio-CVG) will most likely be caused by direct coronary ostia obstruction by the degenerated bioprosthetic leaflets that are pushed outward due to the radial force of the TAVR prosthesis. In consideration of the presented study results, there is a need for precautionary measurements available to the surgeon at the time of the index procedure to obviate the patient from the risk of coronary obstruction in case of a future ViV procedure. When reimplanting the coronary ostia, one must aim for a reimplantation as high as possible. To provide favorable conditions for future aortic valve interventions, targeted coronary artery height (measured from the sewing ring of the prostheses) should ideally be at or above the level of the bioprosthetic valve rail, which varies between 12 and 19 mm, depending on the type and size of the used bioprosthetic valve (eg, Medtronic Avalus 13-17 mm, Medtronic Mosaic 13-19 mm, Edwards Magna Ease 13-18 mm, or Edwards Inspiris 13-19 mm). Nevertheless, tension, kinking or distortion of the coronaries must be avoided at all costs and might necessitate a lower than favored reimplantation in a number of cases to obviate the patient from coronary events during the index procedure. The current challenge is that there is yet no commonly accepted model or measurement tool for intraoperative assessment of coronary artery reimplantation height.

A relationship between the size of the aortic graft, the prosthetic valve and the risk of coronary obstructions can be assumed; hence, a smaller aortic prosthesis and a larger valve size possibly increase the risk of coronary obstruction (Figure 3). A graft-to-valve size difference of 7 mm might be beneficial in terms of avoiding the risk for coronary obstruction. Additionally, a sinus of Valsalva graft should be used as it provides a wider sinus compared with straight tube grafts, therefore possibly increasing VTC in case of a low coronary reimplantation. Furthermore, patients requiring aortic valve interventions following CVG implantation should always be discussed in a multidisciplinary heart team and treated at tertiary care centers with onsite cardiac surgery and advanced transcatheter options available. These options include the Basilica technique, where intentional leaflet laceration preserves coronary perfusion, and protected ViV with coronary access already secured before valve implantation for emergent (chimney) stent deployment.18,19

Strengths and Study Limitations

To our knowledge, this is the first study to systematically assess changes in coronary morphology after CVG implantation using pre- and postoperative CTA, with specific regard to ViV procedures. Nevertheless, it is retrospective in nature; therefore, only a limited but homogenous patient subset was available for analysis. Given the relatively small patient sample with multiple different components influencing root geometry with varying degrees of freedom, no testing for risk factors was performed. However, the numbers available enabled assessment of aortic root geometry with sufficient statistical power to demonstrate the robustness of the evaluated parameters. Furthermore, the presented data reflect a single-center experience and a specific surgeon subset and therefore cannot be generalized without further studies.

CONCLUSIONS

In patients following aortic root replacement with composite valve grafts, the coronary height significantly decreased after the index surgery. TAVR-based assessment of the aortic root geometry after biological CVG implantation revealed that the majority of patients after bio-CVG are at risk for coronary obstruction in the case of future ViV procedures. Larger multicentric studies with an increased number of patients are needed to identify (modifiable) risk factors for coronary obstruction after bio-CVG implantation.

Conflict of Interest Statement

Dr Ad is a consultant and speaker for Atricure and Medtronic, consultant and proctor for LivaNova, co-owner of LAA occlusion LLC, and on the advisory board of Vascular Graft Solutions. Dr Laufer is a consultant and speaker for...
Edwards. Dr Andreas is proctor for Abbott and Edwards and an advisor for Medtronic. All other authors reported no conflicts of interest.

The Journal policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

References


**Key Words:** coronary height, aortic root geometry, valve-in-valve, composite valve graft implantation
Patients who underwent CVG aortic root replacement between 2000 and 2021 at a single center (n = 507)

Patients excluded after screening for pre and postoperative CTA (n = 333)

Patients following CVG replacement with pre- and postoperative CTA (n = 174)

Exclusion due to insufficient imaging data (n = 26)
Exclusion due to mech-CVG (n = 84)

Patients with CVG implantation and pre- and postoperative CTA included in the study (n = 64)

FIGURE E1. Consort flow chart of patient inclusion in the present study. Study screening and inclusion process. CVG, Composite valve graft; CTA, computed tomography angiography.