Aortic Root Geometry following Composite Valve Graft Implantation - Implications for Future Valve-in-valve Procedures

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Further studies are needed to identify modifiable risk factors for coronary obstruction during CVG implantation.

CVG = composite valve graft, CTA = computed tomography angiography, ViV = Valve-in-Valve

A majority (59.4%) of patients after bio-CVG aortic root replacement was found to be at risk for coronary obstruction in case of future ViV procedures.
Title: Aortic Root Geometry following Composite Valve Graft Implantation - Implications for Future Valve-in-valve Procedures

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Abbreviations

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

VTC: virtual valve to coronary ostium distance
Central Message

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

Perspective Statement (400/400 characters)

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.

Central Image Legend (77/90 characters)

Structured Abstract (232/250)

**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 (ViV) 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% male) 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<0.001). 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 ViV 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.
Key words (3-5)

coronary height, aortic root geometry, valve-in-valve, composite valve graft implantation,
Introduction

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 (1-3) (Figure 1A). The procedure, initially reported by Bentall and deBono in 1968 (4), 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 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 (Figure 1B). The shift toward increased numbers of stented bioprosthetic valves used in surgical aortic valve replacement (SAVR) within recent decades has also led to increased numbers of implanted biological CVGs (2,5). 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 (6,7). Nevertheless, they are associated with an up to six times higher risk of coronary obstruction than transcatheter aortic valve replacement (TAVR) in native aortic valves (7). Data from the VIVID registry showed an incidence of 2.3% for symptomatic coronary obstruction following ViV-TAVR(8). 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) (9). 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 19.01.2021). The patient provided informed written consent for the publication of the study data.

Patients & 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 (5). Patients were included in this analysis if 1) they underwent a biological CVG procedure 2) if computed tomography angiography (CTA) of the aortic root and the thoracic aorta was performed preoperatively (within one year preoperatively) and postoperatively with regard to the index procedure (i.e., the initial CVG replacement) and 3) if imaging data were of sufficient quality for specified root geometry measurements (i.e., 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, CTs with electrocardiogram gating or fast acquisition protocols with modern scanners were included.

CTA-based aortic root measurements

CTA scans were analyzed using a dedicated software for preprocedural TAVR planning (Aortic Valve Package, 3 Mensio, Pie Medical Imaging; Maastricht, Netherlands) by two 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 (=valve orifice area), coronary arteries, sinuses of Valsalva (right, left and non) and the sinotubular junction were performed. The virtual valve-to-coronary distance (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 outside end of the struts (10). 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 (11) (Figure 2). We defined risk for coronary obstruction when both of the following criteria were met: 1) the postoperatively measured height of either the right or the left coronary was below the height of the bioprosthetic stent frame and 2) the measured VTC of the affected coronary was at or below 4 millimeters (9).

Statistical Methods

Continuous variables were described by the mean (± standard deviation) or median [quartiles] in cases of nonnormal distributions and compared between groups of patients using a dependent-sample Student’s t test or Wilcoxon rank-sum test, respectively. Categorical data were compared using the chi-squared test or Fisher’s exact test. For assessment of interobserver reliability, aortic root measurements of postoperative CTA scans were performed independently by two study team members (PW & IC). 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) greater than 0.80 with an alpha of 0.05 and a power of 0.80. Interrater reliability was calculated with ICC and corresponding 95%
confidence intervals (CI) and was graded as slight (ICC<0.2), fair (0.2-0.4), moderate (0.41-0.6), good (0.6-0.8) and almost perfect agreement (ICC>0.8) (12). Statistical analysis was performed using IBM SPSS Statistics 27 (V. 27, released 2019; IBM Corp., New York, USA)
Results

Preoperative & 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 (Supplement 1). In the study cohort (76.6% male, age 67.6±9.3 years, BMI 26.8±4.3 kg/m²), 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 & Interobserver Reliability

The median time to performance of the postoperative CTA was 5 [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 LCA and 17.9±5.9 mm for the RCA. Postoperative root measurements yielded statistically significantly smaller values than preoperative measurements. The mean postoperative annular diameter was 21.0±1.8 mm (p<0.001), and the mean annular area was 348.6±60.5 mm² (p<0.001). The postoperative mean height of the sinus of Valsalva was 27.4±4.4 mm (p<0.001), with sinus widths of 32.6±2.4 mm, 32.3±2.6 mm and 332.2±2.9mm for the right, left and noncoronary sinus, respectively (p<0.001). 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<0.001). 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 [0.82-0.93] for annular area, 0.80 [0.67-0.88] for right sinus of Valsalva width, 0.93 [0.88-0.96] for noncoronary sinus of Valsalva width, 0.92 [0.87-0.95] for LCA height, 0.84 [0.73-0.9] for RCA height and 0.85 [0.74-0.91] for LCA VTC. Good interobserver reliability was observed with an ICC of 0.6 [0.31-0.77] for sinus of Valsalva height, 0.78 [0.64-0.87] for sino-tubular junction width and 0.67 [0.36-0.83] for RCA VTC. Moderate interobserver reliability was observed for the left sinus of Valsalva width with an ICC of 0.58 [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, Irvine, CA, USA) prosthesis, 25% (n=16) received a Mosaic prosthesis (Medtronic, Minneapolis, MN, USA), 17.2% (n=11) received an Inspiris prosthesis (Edwards Lifesciences, Irvine, Ca, USA), 12.5% (n=8) received an Avalus prosthesis (Medtronic, Minneapolis, MN, USA) and 1.6% (n=1) received a Trifecta prosthesis (Abbott, Abbott Park, IL, USA). The valve sizes used were 21 in 7.8% (n=5), 23 in 25% (n=16), 25 in 45.3% (n=29), 27 in 20.3% (n=13) and 29 in 1.6% (n=1). A sinus of Valsalva aortic prosthesis (Terumo Aortic, Glasgow, United Kingdom) was used in 68.8% (n=44) of patients. The 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=0.97,
RCA VTC $p=0.1$) between patients who received a Valsalva graft ($n=44, 68.8\%$, LCA VTC 4.02±1.48 mm, 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, $p= RCA VTC 5.16±1.28 mm$).

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 two 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 the young 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 last decade (5). We therefore investigated the feasibility of ViV procedures in this specific patient collective in a CTA-based simulation study (Figure 4, Video).

Our study presents three main findings: 1) the height of the left and right coronary arteries was significantly decreased following CVG implantation with reimplantation of the coronary ostia; 2) 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; 3) In 18.8% of all patients, both coronaries 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 valve-in-valve procedures in clinical practice less than 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, as this is a potentially lethal event, occurring more frequently in ViV procedures compared to native TAVR (9,14). Several studies have investigated patients who underwent transcatheter valve implantation after SAVR to identify risk factors for unsuccessful or complicated ViV procedures. In one 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 mid-term 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 (8). Given the results of this investigation, a cutoff level of 4 mm for virtual transcatheter valve to coronary ostium distance was found to be an strong predictor for the occurrence of coronary obstruction. Computed tomography based simulation studies for aortic ViV feasibility in post cardiac surgery patients are currently limited, however, they are of great interest as 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 to SAVR with rapid-deployment valves was observed (16). 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 (17). 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 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 Re-Insertion**

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, as 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 1-2mm 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, London, UK] 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 as 4 mm is considered a cutoff value for coronary obstruction risk (8). 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. As the labeled valve size refers to the inner diameter (labeled sizes vary between manufacturers), the outer diameter is naturally larger. This only leaves a 3-5 mm difference between the size of the aortic prosthesis and the valve prosthesis for the whole diameter, which must be divided (ideally equally) into two, 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 & 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 leftwards, filling of the right ventricular outflow tract can negatively affect 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 which are pushed outwards 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 re-implanting the coronary ostia, one must aim for a re-implantation 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 to 19 mm, depending on the type and size of the used bioprosthetic valve (e.g. Medtronic Avalus 13-17 mm, Medtronic Mosaic 13-19 mm, Edwards Magna Ease 13-18 mm, 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 to 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 on-site 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 & 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.
References


18. Khan JM, Babaliaros VC, Greenbaum AB et al. Preventing Coronary Obstruction During Transcatheter Aortic Valve Replacement: Results From the Multicenter International BASILICA Registry. JACC Cardiovasc Interv 2021;14:941-948.

Legends

**Figure 1:** Composite valve graft implantation for treatment of aortic root pathologies A) Aortic root replacement with biological composite valve grafts is currently the gold standard for the treatment of aortic root aneurysms with associated valve pathologies in an elderly (>65a) population. B) The aortic root and the aortic valve are excised, and a composite valve graft comprising a Dacron prosthesis and an aortic valve bioprosthesis is implanted. Coronary arteries are reimplanted at the ostial level.

**Figure 2:** CTA based assessment of aortic root geometry with a dedicated software for TAVR planning based on the Vancouver approach: A) aortic valve annular diameter and area B) sinus of valsalva (SOV) height and sino-tubular junction (STJ) diameter C) sinus of valsalva width for each sinus D) right coronary artery (RCA) height E) left coronary artery (LCA) height F) virtual valve-to-coronary ostia distance (VTC)

**Figure 3:** Bubble plot depicting the dispersion of root proportions in patients after bio-CVG (n=64). Bubble dimensions are depicting the numbers of patients with specific composite valve graft (CVG) size compositions, whereas coloration of bubbles is indicating the proportion of patients with risk for coronary obstruction (CO) at the specific CVG composition.

**Figure 4 (Graphical Abstract)** The majority of patients after biological composite valve graft implantation are at risk for coronary obstruction in the case of Valve-in-valve procedures due to low coronary height and narrow root morphology.

**Supplement 1:** Consort flow chart of patient inclusion in the present study. Study screening and inclusion process. CVG = composite valve graft, CTA = computed tomography angiography

**Video:** Aortic root geometry after composite valve graft implantation – procedural aspects and summary of study results
Table 1: Preoperative characteristics and procedural details of the overall cohort

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</tr>
<tr>
<td>32</td>
<td>21.9% (n=14)</td>
</tr>
</tbody>
</table>

BMI=Body Mass Index, CVG= Composite Valve Graft
Table 2: Postoperative CTA aortic root measurements after biological CVG implantation

<table>
<thead>
<tr>
<th></th>
<th>Overall Cohort (n=64)</th>
<th></th>
<th></th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>preoperative</td>
<td>postoperative</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annular diameter (mm)</td>
<td>25.5±3.7</td>
<td>21.0±1.8</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Annular area (mm²)</td>
<td>514.5±152.6</td>
<td>348.6±60.5</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SOV height (mm)</td>
<td>29.8±7.4</td>
<td>27.4±4.4</td>
<td></td>
<td>0.013</td>
</tr>
<tr>
<td>SOV width (mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>right-coronary (mm)</td>
<td>40.1±6.3</td>
<td>32.6±2.4</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>left-coronary (mm)</td>
<td>40.2±6.5</td>
<td>32.3±2.6</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>noncoronary (mm)</td>
<td>41.0±7.1</td>
<td>32.2±2.9</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>STJ width (mm)</td>
<td>42.5±10.0</td>
<td>31.8±2.3</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Valve to STJ distance (mm)</td>
<td></td>
<td>13.2±2.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left coronary height (mm)</td>
<td>14.3±6.8</td>
<td>8.7±4.4</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Right coronary height (mm)</td>
<td>17.9±5.9</td>
<td>11.3±4.4</td>
<td></td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>LCA VTC (mm)</td>
<td></td>
<td>4.0±1.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RCA VTC (mm)</td>
<td></td>
<td>4.6±1.4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SOV= sinus of Valsalva, STJ= Sino-tubular junction, LCA= left coronary artery, RCA= right coronary artery, VTC= virtual valve-to-coronary distance.
Patients after root replacement with bio-CVG (n=64)

Pre- & postoperative CTA of Aorta

Coronary height below bioprosthetic valve height in 96.9% (n=62)

Virtual Valve-to-coronary-ostia distance below 4 mm in 59.4% (n=38)

Further studies are needed to identify modifiable risk factors for coronary obstruction during CVG implantation

CVG: composite valve graft, CTA: computed tomography angiography, ViV: Valve-in-Valve

A majority (59.4%) of patients after bio-CVG aortic root replacement was found to be at risk for coronary obstruction in case of future ViV procedures
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)