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CARDIOVASCULAR SURGERY AND INTERVENTIONS

Long-term outcomes of aortic valve-sparing root reimplantation surgery (David procedure): A single-center experience

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ABSTRACT

Objectives: Aortic valve-sparing root reimplantation (AVSRR) offers distinct advantages, particularly in younger patients with aortic root dilatation and aortic insufficiency (AI), when performed in experienced centers. This study aimed to evaluate the long-term clinical outcomes of AVSRR in a single-center cohort.

Patients and methods: Sixty-one consecutive patients who underwent the David procedure at our center between 2010 and 2025 were analyzed. Preoperative demographics, operative data, and early postoperative and long-term outcomes were evaluated. Survival, freedom from severe AI, and freedom from reoperation at 1, 5, and 10 years were assessed using the Kaplan-Meier method.

Results: In-hospital mortality was 1.6% (n=1); the patient died of multiorgan failure in the early postoperative period. The median follow-up duration was 65 months. Kaplan-Meier survival rates at 1 5, and 10 years were 98.4%. Freedom from severe AI was 96.5%, 90.0%, and 86.4%, while freedom from aortic valve–related reoperation was 98.4%, 91.3%, and 91.3% at 1, 5, and 10 years, respectively.

Conclusion: David procedure has safe long-term outcomes with excellent survival and freedom from aortic valve-related reoperation rates. Experienced high-volume centers are important to achieve optimal results.

Keywords: Aortic valve-sparing root replacement, aortic valve, aortic insufficiency, David procedure.

In young patients with aortic root dilatation, severe aortic regurgitation and good native tissue quality, valve-sparing aortic root reimplantation (David procedure) is preferred over the composite valve graft (Bentall procedure) when performed at experienced centers.[1] Even though the Bentall procedure offers a long-term durable solution, lifelong anticoagulation requirement and associated complications such as hemorrhage and thromboembolism remain a well-recognized drawback, particularly in younger patients.[2,3] Additionally, the use of bioprosthetic valves in Bentall operations—Bio-Bentall procedure—may lead to long-term leaflet degeneration.[3] The David procedure may offer a solution to these issues by preserving native aortic leaflets. A recent meta-analysis showed that the David procedure was associated with less postoperative stroke, reduced early mortality, and higher long-term survival rates compared to Bentall procedure.[4] High-volume, specialized centers are likely to be the cornerstone of long-term success in valve-sparing root replacement (VSRR) due to the procedure's technical complexity. Recent American and European aortic guidelines also recommend considering VSRR in patients—particularly younger ones—with aortic root dilatation and non-diseased or repairable AV leaflets, when performed by experienced surgeons.[5,6] In this study, we aim to present our mid- and long-term outcomes of the David procedure at a single-center.

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PATIENTS AND METHODS

A total of 61 consecutive patients underwent David procedure between May 2010 and May 2025 at our institution. One patient underwent modified Yacoub (David II) procedure was excluded from the study for the uniformity of the cohort. This patient had asymmetric dilatation of the non-coronary and right coronary sinuses of Valsalva. Therefore, the left coronary sinus of Valsalva was preserved, and a partial root reimplantation was performed. Pre-operative patient demographics, operative details, post-operative outcomes and follow-up data were retrospectively retrieved from institutional and national databases. Preoperative transthoracic echocardiography (TTE) and computed tomography angiography were performed in all patients, and relevant measurements were obtained, including the diameters of the aortic annulus, sinus of Valsalva, sinotubular junction, and ascending aorta. Additionally, perioperative transesophageal echocardiography (TEE) was routinely used in all patients to evaluate the aortic valve intraoperatively. The primary outcomes of the study were mid- and long-term survival, freedom from severe aortic insufficiency (AI) and freedom from reoperation during the 10-year follow-up period.

Surgical Technique

Following induction of general anesthesia and endotracheal intubation, a TEE probe was routinely placed, and the AV was assessed prior to the initiation of the procedure. All surgeries were performed via median sternotomy or mini-J sternotomy. After entering the mediastinum, pericardial stay sutures were placed, and epi-aortic ultrasonography was performed to identify optimal, non-atherosclerotic sites for aortic cannulation and distal aortic cross-clamping. Cardiopulmonary bypass (CPB) was initiated following arterial and venous cannulation. The site of arterial cannulation was determined based on the extent of the procedures, concomitant interventions, anatomical considerations, and the type of sternotomy. Ascending aorta, axillary artery and femoral artery were the choice of arterial cannulation sites. Central venous cannulation via right atrium was used for median sternotomy procedures, whereas peripheral femoral venous cannulation was preferred for mini-J sternotomy. Majority of the operations were performed under systemic moderate hypothermia (28-32 °C). The total of nine patient required total or hemi-aortic arch replacement was operated under deep hypotermic (18 °C) total circulatory arrest (TCA). Additionally, two of the three total aortic arch replacements were performed under TCA combined with antegrade cerebral perfusion (ACP) via axillary artery cannulation. Brachiocephalic artery was cross-clamped or suspended with the vascular tapes to prevent retrograde flow towards the aortic arch. The remaining one patient did not undergo ACP despite performing total aortic arch replacement because this patient was scheduled for hemiarch replacement preoperatively. However, operative evaluation revealed aortic arch aneurysm and total aortic arch replacement decision was made intraoperatively. Aortic arch vessels were reimplanted using island technique and a 26 minutes short TCA duration was achieved. The patient did not encounter any neurologic complication during postoperative period. A suction vent was routinely placed in the right superior pulmonary vein. Aortic cross-clamping was performed, and cardiac arrest was achieved following cardioplegia administration. Cardioplegia was delivered through the coronary ostia in patients with moderate or severe AI. AV leaflets were inspected after aortotomy. Aneurysmal segments of the sinus of Valsalva were resected, the height of left-non-coronary commissure was measured from the base of the interleaflet triangle to the top of the commissure to decide appropriate Dacron graft size (Figure 1A). Straight tubular Dacron grafts were used in all operations while Valsalva grafts can also be preferred. The majority of the grafts used were size 30 or 32. The left and right coronary buttons were subsequently prepared. Dacron graft was implanted into the aortic annulus using horizontally placed, pledgeted, interrupted sutures. A critical nuance at this stage was the vertical placement of sub-annular sutures at the right–non-coronary commissure to avoid injury to the his bundle in the membranous septum (Figure 1B). AV leaflets were then repositioned and reimplanted within the Dacron graft using Prolene sutures (Figure 1C). Coaptation of the AV leaflets were evaluated with saline test to ensure the absence of backward leakage. If any prolapsed aortic valve leaflets were detected at this stage, aortic valve leaflets were repaired using plication technique with Prolene sutures. The left and right coronary buttons were anastomosed to the Dacron graft in sequence using 5/0 Prolene sutures. In patients without hemiarch or total aortic arch replacement, distal anastomosis was performed on the distal ascending aorta under aortic cross clamping (ACC) using 4/0 Prolene sutures. For those undergoing hemiarch or total arch replacement, open distal anastomosis was carried out under TCA with or without ACP. After rewarming and deairing, the patients were weaned off CPB upon achieving optimal hemodynamic conditions. All procedures were completed with chest tube placement and standard layered closure of the surgical incision.

Statistical Analysis

BM SPSS Statistics software package 27.0 was used to perform statistical analyses. Continuous parameters are presented as mean ± standard deviation and median (minimum-maximum), while categorical parameters are shown as counts and percentages. Kaplan-Meier survival analysis was performed to assess 1-, 5-, 10-year survival and freedom of reoperation.

RESULTS

The mean age of the patients was 50.5±13.9 years and 55 (90 %) of the patients were male. The most encountered comorbidities were hypertension in 34 (56%) patients, hyperlipidemia in 10 (16%) patients and diabetes mellitus 9 (15%) patients. The majority of the patients were

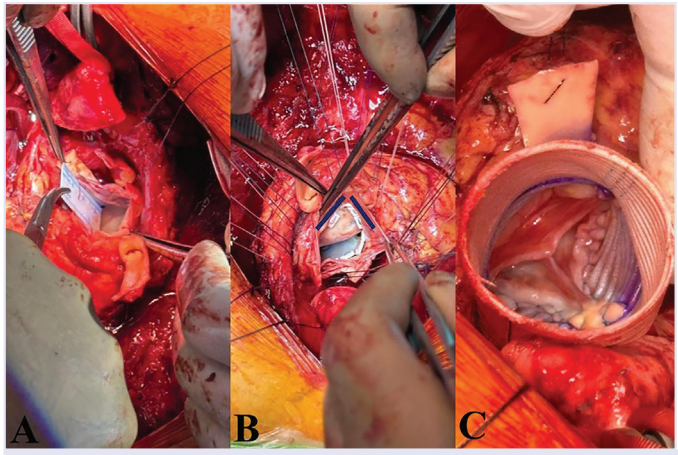

Figure 1. A-Measurement of the height of left-non-coronary commissure, B- Vertical placement of sub-annular sutures at the right–non-coronary commissure, C- Aortic valve leaflet reimplantation within the Dacron graft.

in NYHA Class I with 38 (62%) patients. The mean EUROSCORE II values of the population were 7.1±2.3. The mean diameters of the ascending aorta, sinotubular junction, and sinus of Valsalva were 50.9±9.1 mm, 49.2±6.3 mm, and 51.5±5.8 mm, respectively. In the preoperative echocardiographic evaluation, 26 (43%) patients had severe AI, 16 (26%) had moderate AI, 12 (20%) had mild AI, and 7 (11%) had trace or no AI. Eighteen (30%) patients had bicuspid aortic valve (BAV), six patients (10%) had aortic dissection, and three patients (5%) had Marfan syndrome. The patient demographics were demonstrated in Table 1.

A total of 36 (59%) patients underwent isolated David procedure and concomitant procedures were performed in 25 (41%) patients. The most performed concomitant procedure was coronary artery bypass grafting in nine patients. Aortic leaflet plication was performed in two (3%) patients. After the valve leaflets were reimplanted within the Dacron graft, they were evaluated, and any prolapsed leaflets were repaired using the plication technique. There was a total of three (5%) redo cases. Median sternotomy was the preferred procedural approach in 54 (89%) and mini-J-sternotomy in 7 (11%) patients. The ascending aorta was the site of arterial cannulation in 38 (62%) patients, the femoral artery in 18 (30%) patients, and the axillary artery in 5 (8%) patients. Central venous cannulation was performed in 42 (69%) patients and femoral venous cannulation was preferred in 19 (31%) patients. The mean durations of CPB and ACC were 143±37 minutes and 115±29 minutes, respectively. A total of 9 (15%) cases were performed under TCA with a median duration of 14 (8-76) minutes, and two cases were performed with ACP with a median duration of 45 (40-50) minutes. Operative data is presented in Table 2.

Table 1. Preoperative demographics of the patients (n=61)

Demographics	Mean ± SD or n (%)
Age (years)	50.5±13.9
Female gender	6 (10%)
EUROSCORE II score	7.1±2.3
Comorbidities	
HT	34 (56%)
HL	10 (16%)
DM	9 (15%)
NYHA category	
Class I	38 (62%)
Class II	18 (30%)
Class III	3 (5%)
Class IV	2 (3%)
CTA measures	
Ascending aorta (mm)	50.9±9.1 mm
Sinotubular junction (mm)	49.2±6.3 mm
Sinus of valsalva (mm)	51.5±5.8 mm
Echocardiography	
Aortic insufficiency	
Severe	26 (43%)
Moderate	16 (26%)
Mild	12 (20%)
Trace	5 (8%)
No	2 (3%)
Mean LVEF (%)	60±6
BAV	18 (30%)
Aortic dissection	6 (10%)
Marfan syndrome	3 (5%)

BAV: Bicuspid aortic valve; SD: Standard deviation; HT: Hypertension; HL: Hyperlipidemia; DM: Diabetes mellitus; NYHA: New York Heart Association; CTA: Computed tomography angiography.

The median mechanical ventilation times and intensive care unit stay were 6 (1-39) hours and 20 (14-86) hours, respectively (Table 3). The median duration of hospital stay was 7 (4-20) days. Postoperative atrial fibrillation was encountered in 11 (18%) patients. Complete AV block was seen in two (3%) patients postoperatively and these patients underwent permanent pacemaker implantation. Two (3%) patients needed reexploration for bleeding and one (1.6%) patient required reintubation. Postoperative echocardiography revealed no or trace AI in the majority of the patients. In-hospital mortality was encountered in one (1.6%) patient. The patient was 67 years old and had a history of hypertrophic cardiomyopathy. His death was associated with post-operative multi-organ failure. Sixty patients were followed up for a median of 65 months (1-182 months). There was no late mortality in the entire cohort during follow-up. Kaplan-Meier analysis revealed 1-, 5-, and 10-year survival rates of 98.4% (Figure 2). Follow-up TTE demonstrated mild, trace, or no AI in 51 (87%) of the patients, while six and two patients showed severe and moderate AI, respectively. Freedom from severe AI was 96,5%, 90% and 86.4% in 1, 5 and 10 years, respectively (Figure 3). Four (6.6%) patients required reoperation due to aortic valve dysfunction during the follow-up period. Two of the reoperations were in the BAV group, while the remaining two is in the dissection group. One case in the BAV group

Table 2. Operative data of patients undergoing David procedure (n=61)

Operative data	Mean ± SD or n (%)
Concomitant cardiac procedures	
Cases with concomitant surgery	25 (41%)
Coronary artery bypass grafting	9
Aortic hemiarch replacement	6
Total aortic arch replacement	3
Mitral valve repair	4
Other procedures	8
Redo cases	3 (5%)
Procedural approach	
Midline sternotomy	54 (89%)
Mini-J-sternotomy	7 (11%)
Cannulation sites	
Arterial cannulation	
Ascending aorta	38 (62%)
Femoral artery	18 (30%)
Axillary artery	5 (8%)
Venous cannulation	
Right atrium	42 (69%)
Femoral vein	19 (31%)
CPB time (minutes)	143±37
ACC time (minutes)	115±29
TCA time (minutes)	14 (8-76)
ACP time (minutes)	45 (40-50)

SD: Standard deviation; CPB: Cardiopulmonary bypass; ACC: Aortic cross clamping.

was due to infective endocarditis (IE)-related severe AI and required early reoperation within one month of the initial surgery. The second patient underwent reoperation at 54 months following the initial operation due to severe AI caused by degeneration of the aortic valve leaflets. Among the remaining 16 BAV patients, no additional patients developed severe AI or required reoperation during the follow-up period. The other two cases in the dissection group underwent reoperation for severe AI caused by prolapse or degeneration of the aortic leaflets. The remaining two patients with severe AI did not undergo reoperation. One had severe paravalvular AI that was hemodynamically insignificant and therefore did not require surgery. The other patient was managed with medical therapy. Kaplan-Meier analysis revealed freedom from aortic-valve related reoperation rates of 98.4%, 91.3%, and 91.3% at 1, 5, and 10 years, respectively (Figure 4).

DISCUSSION

This single-center study of the patient cohort undergoing the David procedure establishes that the David procedure can be safely performed in both elective and emergent settings by experienced surgeons in specialized centers, yielding favorable short- and long-term outcomes.

Our in-hospital and long-term mortality rate was low (1.6%). It is also worth noting that there were no in-hospital deaths among the six patients who presented in emergency settings with acute aortic dissection. These statistics are consistent with previous findings in the literature. Beckmann et al.[3] presented data from their large cohort with a 25-year follow-up period, revealing that the overall in-hospital mortality rate was 1.9% in elective settings, while it was 3.8% in the entire population, which included a high proportion of aortic dissection cases. The survival rates at 5 and 10 years in this study were 88% and 77%, respectively. In the series of 465 patients reported by David et al.,[7] the operative mortality was 1%, and the 20-year survival and event-

Table 3. Early and late postoperative outcomes

Mechanical ventilation time (hours)	6 (1-39)
ICU stay (hours)	20 (14-86)
Hospital stay (days)	7 (4-20)
POAF	11 (18%)
Permanent pacemaker implantation	2 (3%)
Postoperative reexploration for bleeding	2 (3%)
Reintubation	1 (1.6%)
Early postoperative AI (n=59)	
Severe	0
Moderate	0
Mild	11 (19%)
Trace	24 (41%)
No	24 (41%)
In-hospital mortality	1 (1.6%)
Survival rate (%) at	
1-year	98.4%
5-year	98.4%
10-year	98.4%
Follow-up AI (n=59)	
Severe	6 (10%)
Moderate	2 (3%)
Mild	21 (36%)
Trace	23 (39%)
No	7 (12%)
Freedom from severe AI at	
1-year	96.5%
5-year	90%
10-year	86.4%
Freedom from aortic valve-related reoperation at	
1-year	98.4%
5-year	91.3%
10-year	91.3%

ICU: Intensive care unit; AI: Aortic insufficiency; POAF: Postoperative atrial fibrillation.

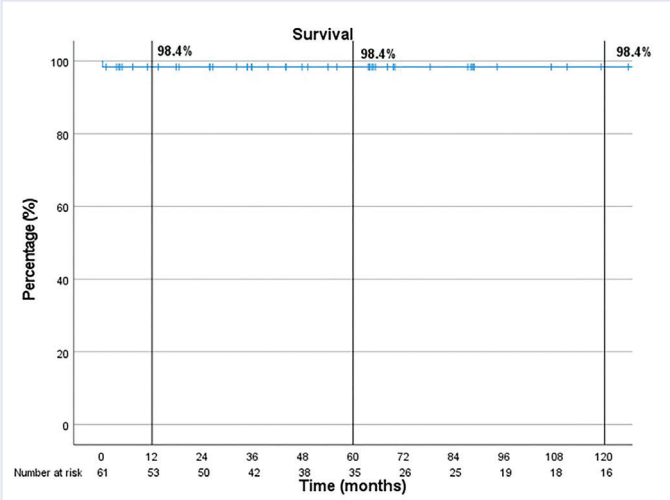

Figure 2. Kaplan-Meier analyses for 1-year, 5-year and 10-year survival.
AI: Aortic insufficiency.

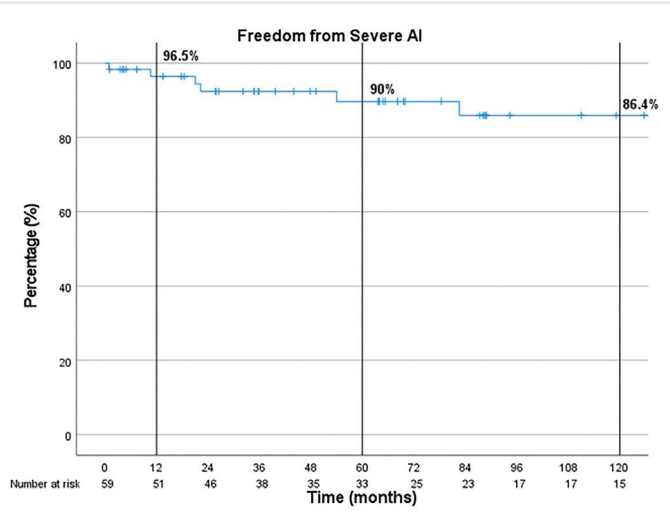

Figure 3. Kaplan-Meier analyses for 1-year, 5-year and 10-year freedom from severe AI.
AI: Aortic insufficiency.

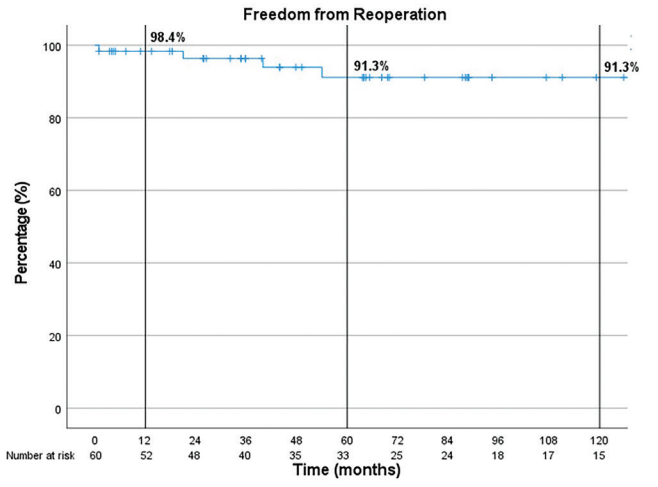

Figure 4. Kaplan-Meier analyses for 1-year, 5-year and 10-year freedom from reoperation.

free survival rates were 75.1% and 69.1%, respectively. Yang et al.[8] also showed that the operative mortality rate in 40 Type A aortic dissection patients who underwent the David procedure was 3%, compared to 13% in the 95 patients who underwent the Bentall procedure. Based on both our data and findings from the literature, we propose that the David procedure is a safe alternative, even in emergent settings, when performed by experienced hands.

When the early postoperative complications were analyzed, our data showed low rates of complications. The POAF rate was 18%, while permanent pacemaker implantation was required in 3.2% of cases. David et al. [9] reported a 22% rate of POAF and a 1.5% rate of permanent pacemaker insertion in their 20-year experience. It is crucial to note that our technique for Dacron graft implantation at the aortic annulus, which involves the vertical placement of sub-annular sutures at the right non-coronary commissure, contributes to the low rates of complications related to the conduction system by preserving important structures in the membranous septum. The overall postoperative reexploration rate for bleeding was 3.2%. In the same study, David et al. [9] reported that 8.7% of the patients underwent reexploration for bleeding or cardiac tamponade. Our overall reexploration rate is extremely low and comparable to the current literature, considering the significant presence of aortic dissection and concomitant procedures in the cohort, including total aortic arch replacement.

Preoperative severe or moderate AI was present in 69% of the patients in our study, while early postoperative echocardiography revealed no severe or moderate AI in our cohort. Furthermore, follow-up echocardiography results showed that only 13% of the patients had severe or moderate AI. Freedom from severe or moderate AI was 94.9% and 73.9% at the 2- and 6-year follow-ups in the report published by Coselli et al.,[2] while it was 98% at 5 years and 96% at 10, 15, and 20 years in David et al.'s[9] 20-year experience. In our cohort, freedom from severe AI was 90% at 5 years and 86.4% at 10 years, which is comparable to the rates reported in the literature. During the follow-up period, four of our patients underwent reoperation due to aortic valve-related causes. All the reoperations were within the first 5 years of follow-up. There was no reoperation in patients with tricuspid aortic valve structure. Two reoperated patients were in the aortic dissection subgroup, while the other two were in the BAV subgroup. On the other hand, our data are consistent with the previously mentioned literature, which highlights the high rate of reoperation within the first 5 years. Freedom from reoperation rates were 98.4% at 1 year and 91.3% at 5 and 10 years in our study. Liebrich et al.[10] published their data, demonstrating 94% and 87% freedom from aortic valve replacement at 5 and 10 years, respectively.[11,12] Beckmann et al.'s[3] data were also similar to those of Liebrich et al.,[10] with 93% and 88% freedom from reoperation rates at 5 and 10 years, respectively. While our numbers were very comparable to those of the two studies, David's series demonstrated higher rates of freedom from reoperation, with 96.9% at 10, 15, and 20 years. Lastly, the incidence of IE after David reoperation warrants discussion. In our cohort, one patient (1.6%) developed IE in the early postoperative period and underwent reoperation one month after the initial surgery, as noted above. In their report on late outcomes of the David procedure, Manganiello et al.[11] documented 5 endocarditis-related reoperations among 19 valve-related reoperations within a 300-patient cohort.

Lastly, comparative studies between the David and Bentall procedures have shown largely similar early and long-term outcomes. Leontyev et al.[12] reported comparable perioperative and late results but a higher incidence of major bleeding in the Bentall group. Similarly, Svensson et al.[13] found no significant differences in 10-year survival or reintervention rates, though severe AI was more frequent after the David procedure in 8 years. A recent meta-analysis by Formica et al.[4] further demonstrated lower early mortality and stroke rates with the David procedure but higher reoperation rates within the first five years.The David procedure can be safely performed in patients with aortic root aneurysms who have non-diseased or repairable aortic valve leaflets, yielding excellent early and late outcomes. High-volume centers and experienced surgeons are essential for achieving optimal results, given the procedure's technical complexity and the need for a high level of expertise. This study is limited by its retrospective design, single-center and single-surgeon experience, and a relatively small cohort size. Although our follow-up extends to 10 years, longer-term data from larger series in the literature—exceeding 20 years—may provide broader generalizability.

Ethics

Ethics Committee Approval: Ethics committee approval was waived due to retrospective design.

Informed Consent: This study was conducted as a retrospective case series, approval from the hospital administration was obtained to access and analyze data from the institutional database.

Footnotes

Authorship Contributions

Surgical and Medical Practices: G.A., M.B., A.K., M.K., Ş.Ş., C.A.; Concept: G.A., İ.G., M.B., A.K., Z.S.Ö., Ş.Ş., C.A.; Design: G.A., İ.G., M.B., A.K., Z.S.Ö., M.K., Ş.Ş., C.A.; Data Collection or Processing: G.A., İ.G., M.B., A.K., Z.S.Ö., Ş.Ş.; Analysis or Interpretation: G.A., İ.G., M.B., A.K., Z.S.Ö., Ş.Ş., C.A.; Literature Search: G.A., İ.G., M.B., A.K., Z.S.Ö., Ş.Ş.; Writing: G.A, İ.G., M.B., A.K., Z.S.Ö., Ş.Ş.

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