# Open hemiarch versus clamped ascending aorta replacement for aortopathy during initial bicuspid aortic valve replacement



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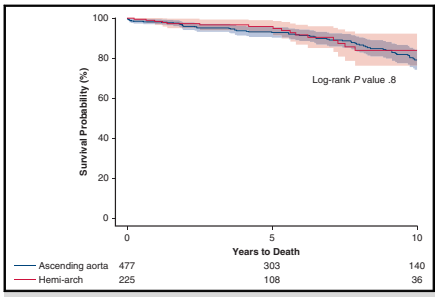
## ABSTRACT

**Background:** There is controversy regarding the extent of aortic resection necessary in patients with aortopathy related to bicuspid aortic valve disease. To address this issue, we reviewed our experience in patients undergoing ascending aorta replacement during bicuspid aortic valve replacement.

**Methods:** We reviewed 702 patients who underwent ascending aorta replacement at the time of initial nonemergent native bicuspid aortic valve replacement at our institution between January 2000 and June 2017. Treatment cohorts included an open hemiarch replacement group (n = 225; 32%) and a clamped ascending aorta replacement group (n = 477; 68%).

**Results:** Median patient age was 60 years (interquartile range [IQR], 51-67 years), female sex was present in 113 patients (16%), ejection fraction was 62% (IQR, 56%-66%), and aortic arch diameter was 33 mm (IQR, 29-36 mm). Cardiopulmonary bypass time was longer in the hemiarch replacement group (188 minutes vs 97 minutes; $P < .001$). Procedure-related complications (36%) and mortality (<1%) were similar in the 2 groups; however, the hemiarch group had an increased odds of blood transfusion (odds ratio, 1.62; 95% confidence interval [CI], 1.15-2.28; $P = .006$). The median duration of follow-up was 6.0 years (95% CI, 5.3-6.8 years). Overall survival was 94 ± 1% at 5 years and 80 ± 2% at 10 years. Multivariable analysis demonstrated similar survival in the 2 groups (hazard ratio, 0.83; 95% CI, 0.51-1.33; $P = .439$). No repeat aortic arch operations were done for aortopathy over the duration of clinical follow-up.

**Conclusions:** Compared with patients in the clamped ascending aorta replacement group, patients in the hemi-arch replacement group had longer cardiopulmonary bypass and aortic cross-clamp times, along with an increased risk of blood transfusion, but similar freedom from repeat aortic arch operation and survival. We identified no advantage of performing hemiarch replacement in the absence of aortic arch dilation. (J Thorac Cardiovasc Surg 2021;161:12-20)




Kaplan-Meier estimates of survival in the ascending and hemiarch groups.

### Central Message

We identify no advantage to hemiarch replacement in comparison to ascending aorta replacement with respect to follow-up repeat arch operation or survival in the absence of aortic arch dilation.

### Perspective

Hemiarch and ascending aorta replacement can be done with low morbidity and mortality during bicuspid aortic valve replacement. Hemiarch replacement had longer bypass and cross-clamp times, higher risk of blood transfusion, but similar follow-up freedom from repeat aortic arch operation and survival. We identify no advantage of hemiarch replacement in the absence of aortic arch dilation.

See Commentaries on pages 21 and 23.

Ascending aortopathy is common in patients with a bicuspid aortic valve. The reported prevalence of aneurysm

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**Abbreviations and Acronyms**
CI = confidence interval
HR = hazard ratio
OR = odds ratio

ranges from 20% to 40% in patients with a bicuspid aortic valve.[1,2] Current United States and European guidelines are in agreement that concomitant ascending aorta replacement should be performed in selected patients at the time of bicuspid aortic valve replacement[3-5]; however, how best to replace the ascending aorta—hemiarch replacement or clamped ascending aorta replacement—remains a matter of debate.[6-8]

There are limited published studies comparing the outcomes of hemiarch replacement versus simple clamped ascending aorta replacement during bicuspid aortic valve replacement. No study to date has demonstrated a clear benefit for hemiarch replacement in patients with bicuspid aortic valve.[6,7] In a study of 168 patients, a St George's Hospital group concluded that prophylactic arch replacement was not supported in patients with bicuspid aortic valve.[6] A University of Pittsburg group found that hemiarch replacement did not increase operative risk and thus concluded that its use should not be limited.[7]

Despite the lack of any demonstrable evidence-based clinical benefit to hemiarch replacement, controversy persists. The Inova Fairfax Hospital and University of Colorado groups entitled a recent review article "Hemiarch: The real operation for ascending aortic aneurysm."[8] To address this controversy, we reviewed our experience in patients with aortopathy and bicuspid aortic valve disease. The focus of the study was on the outcomes of freedom from repeat aortic arch operation and survival in patients who underwent either hemiarch replacement or simple clamped ascending aorta replacement during initial bicuspid aortic valve replacement.

## MATERIALS AND METHODS

This study was approved by our Institutional Review Board (approved September 29, 2017, approval 17-007553). We retrospectively reviewed the records of 723 consecutive patients who underwent ascending aorta replacement at the time of initial nonemergent bicuspid aortic valve replacement between January 2000 and June 2017. The initial cohort query excluded patients with aortic dissection. We then excluded 21 patients (3%), including 20 with active infective endocarditis and 1 with a connective tissue disorder. Thus left a total of 702 patients (97%) eligible for the study.

We assessed differences in outcomes between patients who underwent clamped ascending aorta replacement (ascending group; n = 477, 68%) and those who underwent open hemiarch and ascending aorta replacement during circulatory arrest (hemiarch group; n = 225, 32%). The choice of procedure was at the discretion of the operating surgeon. This included the decision to perform hemiarch replacement versus clamped ascending aorta replacement, as well as any other additional operative procedure (eg, valve conduit vs separate valve and ascending aorta replacement). Yearly case volumes are reported in Figure E1.

Patient baseline, operation, and outcome data were recorded using criteria defined in the Society of Thoracic Surgeons adult cardiac surgery database. Coronary artery disease was a compilation of the variables of previous myocardial infarction, coronary artery bypass graft operation, or coronary artery stenosis of ≥50%.

Aorta measurements were recorded for the mid-ascending aorta at the level of the right main pulmonary artery and the aortic arch at the level just proximal to the left common carotid artery. Data were first obtained from direct measurement of a computed tomography or magnetic resonance imaging scan, then from the echocardiography report, and finally from the surgeon's notes. The source of the measurement is reported in Table E1 for mid-ascending aorta diameter and Table E2 for aortic arch diameter.

The endpoints of the study were in-hospital procedure-related complications, repeat aortic arch operation after discharge, and survival. The last dates of clinical and vital status follow-up were determined through a review of the electronic medical record and Department of Cardiovascular Surgery patient surveys sent out to patients at 1, 3, 5, 10, 15, and 20 postoperative years. A yearly vital status review was obtained through Accurint (LexisNexis, New York, NY).

Categorical data are reported as count (percent), and continuous data are reported as median (interquartile range [IQR]). Categorical data were analyzed with Fisher's exact test or the $\chi^2$ test, as appropriate. Continuous data were analyzed with the Wilcoxon rank-sum test. Logistic regression models were used to assess treatment effect of hemiarch replacement and concomitant valve conduit replacement on procedure-related blood transfusion and complication endpoints.

The median duration of follow-up was calculated using the reverse Kaplan-Meier estimator, whereas survival estimates were calculated using the Kaplan-Meier estimator. The cumulative incidence of a repeat aortic arch operation was estimated accounting for the competing risk of death. Cause-specific Cox proportional hazard models were used to compare variables with time-dependent distributions. Multivariable model covariates were selected a priori. The $\alpha$ level was set at 0.05. All statistical analyses were done with R version 3.4.2 (R Project for Statistical Computing, Vienna, Austria).

## RESULTS

The median patient age was 60 years (IQR, 51-67 years), 113 patients were female (16%), the median ejection fraction was 62% (IQR, 56%-66%), aortic valve moderate/severe stenosis was present in 462 patients (66%), and aortic valve moderate/severe regurgitation was present in 354 patients (50%). Baseline patient characteristic data were similar in the hemiarch and ascending groups except for a greater prevalence of hypertension in the hemiarch group (64% vs 55%; $P < .015$) (Table 1).

The mid-ascending aorta diameter measurement data were obtained from echocardiography in 511 patients (73%), radiologic scan in 185 (26%), and surgeon notes in 6 (1%). The median diameter of the mid-ascending aorta was 48 mm (IQR, 45-51 mm) in the ascending group and 50 mm (IQR, 46-53 mm) in the hemiarch group ($P < .001$). Importantly, the range of diameters of the ascending group (27-70 mm) encompassed that of the hemiarch group (34-66 mm) (Figure 1). The aortic arch measurement data were obtained from echocardiography in 332

**TABLE 1. Patient baseline data in the ascending and hemiarch groups**

| Variable | Ascending group (N = 477; 68%) | Hemiarch group (N = 225; 32%) | *P* value |
|---|---|---|---|
| Age, y, median (IQR) | 60 (51-67) | 61 (53-67) | .770 |
| Body mass index, kg/m$^2$ median (IQR) | 28 (26-32) | 29 (26-33) | .084 |
| Creatinine, $\mu$g/dL, median (IQR) | 1.0 (0.9-1.2) | 1.0 (0.9-1.2) | .551 |
| Ejection fraction, %, median (IQR) | 63 (57-67) | 62 (55-66) | .115 |
| Aortic arch diameter, mm, median (IQR) | 33 (30-36) | 34 (30-37) | .127 |
| Ascending aorta diameter, mm, median (IQR) | 48 (45-51) | 50 (46-53) | <.001 |
| Female sex, n (%) | 83 (17) | 30 (13) | .171 |
| Diabetes, n (%) | 40 (8) | 24 (11) | .327 |
| Hypertension, n (%) | 261 (55) | 145 (64) | .015 |
| Chronic lung disease, severe, n (%) | 5 (1) | 4 (2) | .478 |
| Peripheral vascular disease, n (%) | 23 (5) | 14 (6) | .438 |
| Coronary artery disease, n (%) | 132 (28) | 63 (28) | .928 |
| Atrial fibrillation, n (%) | 57 (12) | 27 (12) | .985 |
| Aortic valve stenosis, moderate/severe, n (%) | 320 (67) | 142 (63) | .300 |
| Aortic valve regurgitation, moderate/severe, n (%) | 239 (50) | 115 (51) | .804 |
| Urgent status, n (%) | 28 (6) | 12 (5) | .775 |

*IQR*, Interquartile range.

patients (47%) and radiologic scan in 187 (27%), and were missing in 183 (26%). The median aortic arch diameter was 33 mm (IQR, 30-36 mm) in the ascending group and 34 mm (IQR, 30-37 mm) in the hemiarch group ($P$ = .127) (Figure 2).

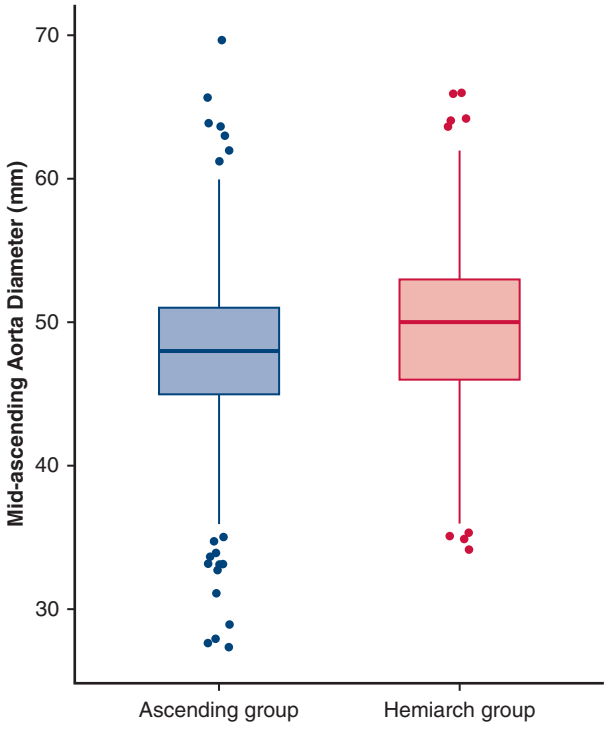


**FIGURE 1.** Mid-ascending aorta diameter median, interquartile range, 10% and 90% levels, and range in the ascending and hemiarch groups.

Valve composite root replacement was performed less commonly in the ascending group compared with the hemiarch group (36% [n = 173] vs 63% [n = 142]; $P$ < .001), but other operative procedures were distributed similarly in the 2 groups (Table 2). Procedure times were shorter in the ascending group for both cardiopulmonary bypass (97 minutes vs 188 minutes; $P$ < .001) and aortic cross-clamp time (78 minutes vs 136 minutes; $P$ < .001), even when stratified by the presence of concomitant valve conduit replacement (all $P$ < .001) (Table 2). The median circulatory arrest time was 18 minutes (IQR, 15-21 minutes), and median temperature was 18°C (IQR, 18°C-18°C). Adjunctive cerebral perfusion was done in 64 patients (28%), including antegrade cerebral perfusion in 5 patients and retrograde perfusion in the other 59.

Procedure-related morbidity rates were low in both groups with respect to new-onset dialysis (ascending group, <1%; hemiarch group, 0; $P$ = 1.000), sepsis (1% each group; $P$ = .658), stroke (2% vs 1%; $P$ = 1.000), and mortality (1% vs 0; $P$ = .555) (Table 3). Overall complication rates were also similar in the 2 groups (35% vs 38%; $P$ = .440), but the repeat operation for bleeding rate was higher in the ascending group (5% vs 1%; $P$ = .017). After adjusting for concomitant valve conduit replacement, hemiarch replacement was associated with an increased odds of the need for blood transfusion (odds ratio [OR], 1.62; 95% confidence interval [CI], 1.15-2.28; $P$ = .006) but not the

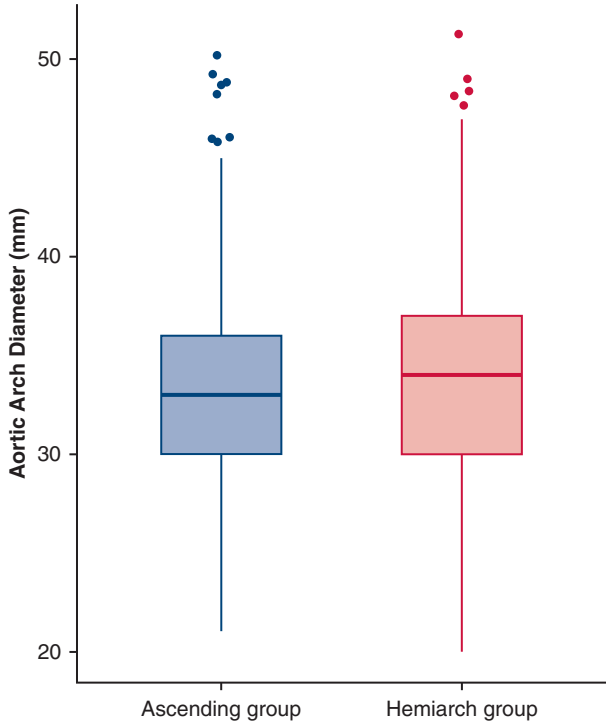


**FIGURE 2.** Aortic arch diameter median, interquartile range, 10% and 90% levels, and range in the ascending and hemiarch groups.

occurrence of any complication (OR, 1.10; 95% CI, 0.78-1.55; $P = .582$).

Clinical follow-up was complete at a median duration of 5.4 years (IQR, 2.0-10.0 years) for all patients, 6.5 years (IQR, 2.7-10.1 years) for the ascending group, and 4.3 years (IQR, 1.7-7.0 years) for the hemiarch group ($P < .001$). An aortic arch operation under circulatory arrest was done after discharge in 9 patients: 6 in the ascending group (3 with structural valve deterioration, 2 with endocarditis, and 1 with valve thrombosis) and 3 in the hemiarch group (all for endocarditis). No operations were done for arch aortopathy or aneurysm. The cumulative incidence of repeat aortic arch operation after discharge (while accounting for the competing risk of death) was 1% at 5 years and 2% at 10 years. The rate of repeat aortic arch operation after discharge appears to be higher in the hemiarch cohort at earlier time points, although there was no statistically significant difference (HR, 1.66; 95% CI, 0.41-6.68; $P = .480$) (Figure 3).

Vital status follow-up was complete in all patients at 6.0 years (95% CI, 5.3-6.8 years) for all patients, 5.0 years (95% CI, 3.7-5.1 years) for the hemiarch group, and 7.6 years (95% CI, 6.7-8.7 years) for the ascending group ($P < .001$). Survival was 94 ± 1% at 5 years, 80 ± 2% at 10 years, 57 ± 5% at 15 years. The median time to death using the Kaplan-Meier estimator was 16 years (IQR, 12 years to not available); in total, there were 97 deaths. A multivariable Cox proportional hazard model was created for survival with 9 clinically relevant variables listed in Table 4. Hemiarch replacement was not statistically associated with reduced mortality (HR, 0.83; 95% CI, 0.51-1.33; $P = .439$) (Figure 4). The predictors of mortality were increasing age (years; HR, 1.05; 95% CI, 1.03-1.08; $P < .001$), diabetes (HR, 2.69; 95% CI, 1.59-4.54; $P < .001$), severe chronic lung disease (HR, 3.69; 95%

**TABLE 2. Procedure-related data in the ascending and hemiarch groups**

| Variable | Ascending group (N = 477) | Hemiarch group (N = 225) | *P* value |
|---|---|---|---|
| Valve conduit, n (%) | 173 (36) | 142 (63) | <.001 |
| Concomitant other cardiac operation, n (%) | 146 (31) | 73 (32) | .624 |
| Coronary artery bypass graft, n (%) | 81 (17) | 39 (17) | .908 |
| Mitral valve operation, n (%) | 17 (4) | 9 (4) | .775 |
| Tricuspid valve operation, n (%) | 2 (<1) | 2 (1) | .597 |
| Other cardiac operation, n (%) | 76 (16) | 37 (16) | .863 |
| Valve type, n (%) | | | .167 |
| Mechanical | 264 (55) | 121 (54) | |
| Biological | 202 (42) | 103 (46) | |
| Homograft | 11 (2) | 1 (<1) | |
| Aortic cross-clamp time, min, median (IQR) | 78 (58-98) | 136 (95-166) | <.001 |
| Valve conduit operation | 90 (75-121) | 155 (126-176) | <.001 |
| Separate aortic valve and ascending aorta replacement | 69 (50-90) | 100 (75-127) | <.001 |
| Cardiopulmonary bypass time, min, median (IQR) | 97 (74-126) | 188 (158-210) | <.001 |
| Valve conduit operation | 113 (93-148) | 197 (175-218) | <.001 |
| Separate aortic valve and ascending aorta replacement | 87 (64-114) | 173 (140-196) | <.001 |

*IQR*, Interquartile range.

**TABLE 3. Procedure-related morbidity and mortality in the ascending and hemiarch groups**

| Variable | Ascending group (N = 477) | Hemiarch group (N = 225) | *P* value |
|---|---|---|---|
| Mortality, n (%) | 3 (1) | 0 (0) | .555 |
| Any complication, n (%) | 168 (35) | 86 (38) | .440 |
| Atrial fibrillation, n/N (%)* | 128/420 (30) | 69/198 (35) | .276 |
| Pacemaker, n/N (%)* | 25/467 (5) | 14/222 (6) | .613 |
| Stroke, n (%) | 7 (2) | 3 (1) | 1.000 |
| Sepsis, n (%) | 3 (1) | 2 (1) | .658 |
| Dialysis, n/N (%)* | 1/476 (<1) | 0 | 1.000 |
| Blood transfusion, n (%) | 268 (56) | 145 (64) | .038 |
| Repeat operation for bleeding, n (%) | 24 (5) | 3 (1) | .017 |

*New-onset atrial fibrillation, pacemaker insertion, or dialysis, which excludes patients who had the characteristic(s) before the operation.

CI, 1.28-10.64; $P = .015$), and coronary artery disease (HR, 1.65; 95% CI, 1.04-2.59; $P = .032$). Year of surgery was not related to survival in univariate or multivariable models.

## DISCUSSION

This study compared the outcomes of hemiarch and ascending aorta replacement during concomitant bicuspid aortic valve replacement in 702 consecutive patients without aortic arch aneurysm (Figure 5). We found that hemiarch replacement required longer cardiopulmonary bypass time (188 minutes vs 97 minutes; $P < .001$) and aortic cross-clamp time (136 minutes vs 78 minutes; $P < .001$). Procedure-related complications (36%) and mortality (<1%) were similar in the 2 groups; however, the risk of receiving blood transfusion was higher in the hemiarch replacement group (OR, 1.62; 95% CI, 1.15-2.28; $P = .006$). Finally, the 2 groups had a similar cumulative incidence of repeat aortic arch operation after discharge (HR, 1.66; 95% CI, 0.41-6.68; $P = .480$) and survival (HR, 0.83; 95% CI, 0.51-1.33; $P = .439$).

Our treatment groups had similar baseline demographic and comorbidity characteristics with the exception of hypertension, which was more common in the hemiarch group (64% vs 55%; $P = .015$). Another important difference was the higher percentage of concomitant valve conduit

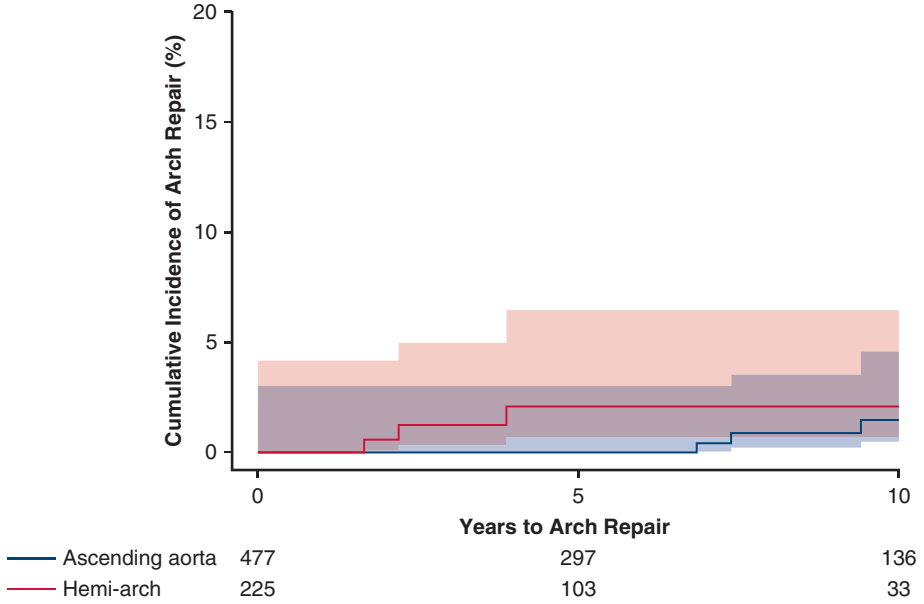


**FIGURE 3.** Cumulative incidence of repeat aortic arch operation after discharge in the ascending and hemiarch groups. Hemiarch group: hazard ratio, 1.66; 95% confidence interval, 0.41–6.68; $P = .480$.

**TABLE 4. Multivariable Cox proportional hazard model of survival**

| Variable | Univariate analysis | | Multivariable analysis | |
|---|---|---|---|---|
| | OR (95% CI) | *P* value | OR (95% CI) | *P* value |
| Age | 1.08 (1.05-1.10) | <.001 | 1.05 (1.03-1.08) | <.001 |
| Hypertension | 2.37 (1.50-3.74) | <.001 | 1.33 (0.81-2.18) | .255 |
| Diabetes | 3.01 (1.81-4.99) | <.001 | 2.69 (1.59-4.54) | <.001 |
| Chronic lung disease, severe | 6.06 (2.21-16.62) | <.001 | 3.69 (1.28-10.64) | .015 |
| Peripheral vascular disease | 1.64 (0.72-3.75) | .242 | 1.18 (0.50-2.78) | .702 |
| Coronary artery disease | 0.33 (0.22-0.49) | <.001 | 0.61 (0.39-0.96) | .032 |
| Hemiarch operation | 1.06 (0.67-1.68) | .800 | 0.83 (0.51-1.33) | .439 |
| Valve conduit operation | 0.58 (0.37-0.89) | .012 | 0.92 (0.57-1.47) | .720 |
| Valve type mechanical | 1 (Reference) | | 1 (Reference) | |
| Valve type biological | 2.52 (1.65-3.83) | <.001 | 1.25 (0.77-2.06) | .369 |
| Valve type homograft | 0.93 (0.29-3.05) | .908 | 0.77 (0.22-2.70) | .689 |

*OR*, Odds ratio; *CI*, confidence interval.

replacement procedures in the hemiarch group (63% vs 36%; $P < .001$). We addressed the differences by including hypertension in the adjusted model for survival; furthermore, we included concomitant valve conduit replacement in the adjusted models for complication, blood transfusion, and survival. Given the number of patients in the study (n = 702), we feel that the multivariable analysis was appropriate to address potential confounding of our prespecified variables.

The United States and European guidelines are in general agreement that ascending aorta replacement should be performed in selected patients with aortopathy at the time of bicuspid valve replacement.[3-5] The general recommendations are to replace the ascending aorta in selected asymptomatic patients (diameter ≥5.5 cm), asymptomatic patients with additional risk factors (diameter ≥5.0 cm), and patients undergoing aortic valve replacement (diameter ≥4.5 cm). Compliance with the

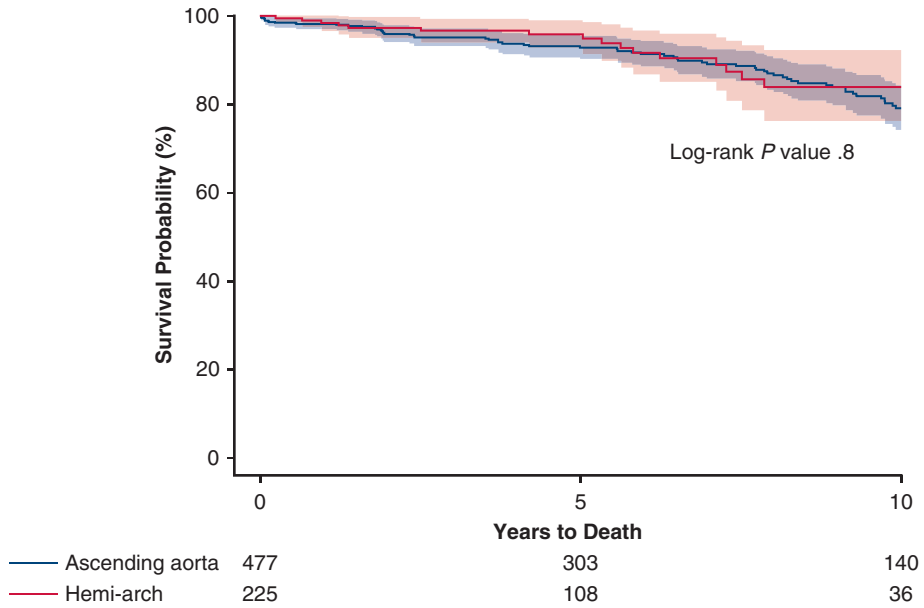


**FIGURE 4.** Kaplan–Meier estimates of survival in the ascending and hemiarch groups.

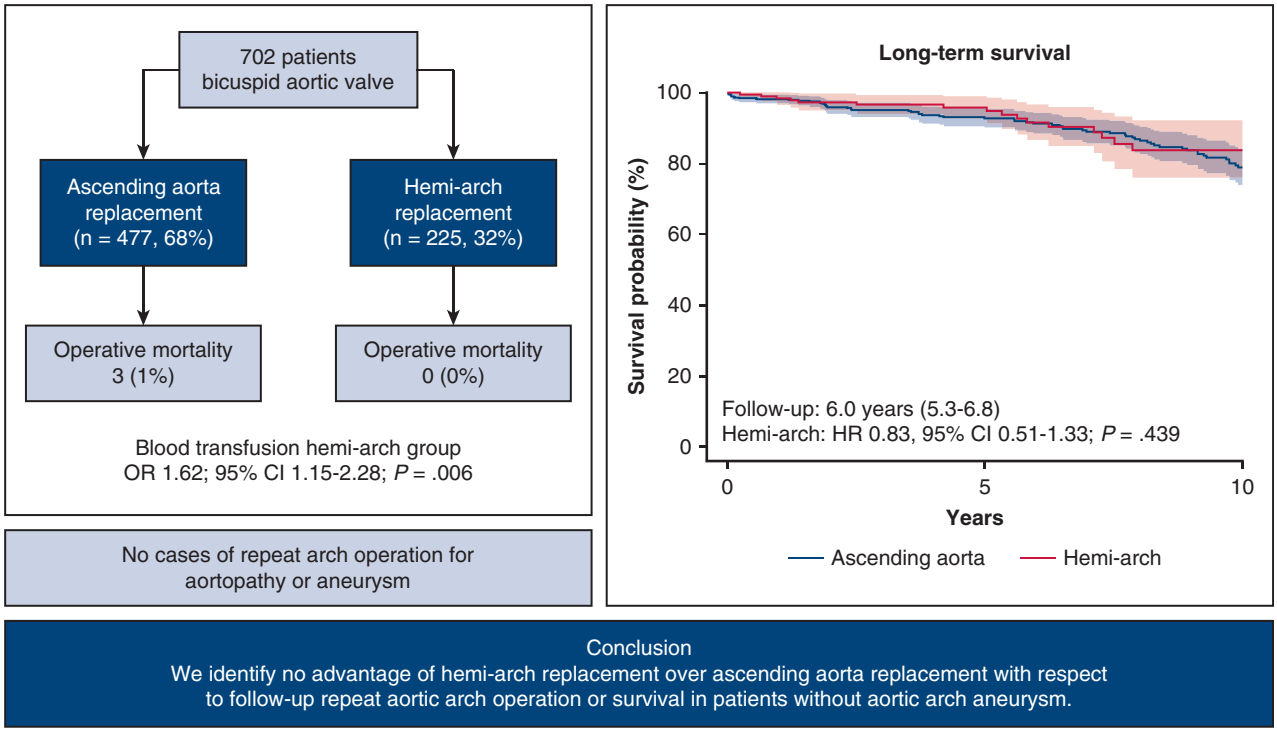


**FIGURE 5.** Study reporting important operative outcomes, need for repeat aortic arch operation, and survival. *OR*, Odds ratio; *CI*, confidence interval; *HR*, hazard ratio.

guidelines appears safe.[9] The controversy surrounds how much of the aorta to replace.[6-8]

We found that hemiarch replacement required more cardiopulmonary bypass and aortic cross-clamp time to perform than ascending aorta replacement even when stratified by concomitant valve conduit replacement (differences of 91 and 58 minutes, respectively; both $P < .001$). The increased times are consistent with those reported by Malaisrie and colleagues[7] in their propensity-matched aortic root replacement study (differences of 65 and 36 minutes, respectively; both $P < .001$) and by Sultan and colleagues[10] in their propensity-matched all types of cardiac surgery study (differences of 39 and 16 minutes; both $P < .050$). The findings are important because the duration of cardiopulmonary bypass time has been identified as an independent risk factor for procedure-related complications to include death.[11]

We believe that the additional time needed to perform hemiarch replacement resulted in greater need of blood transfusion in the hemiarch group compared with the ascending aorta group (64% vs 56%; $P = .038$). This is consistent with the findings of Salis and colleagues,[11] who reported that increased cardiopulmonary bypass time was an independent risk factor for blood transfusion. Malaisrie and colleagues[10] also found a higher rate of blood transfusion in their hemiarch group compared with their aorta replacement group (67% vs 51%; $P = .009$). Sultan and colleagues,[7] in contrast, reported markedly lower blood transfusion rates in the hemiarch and ascending groups (28% versus 24%). Although their hemiarch group had a higher transfusion rate, the difference was not statistically significant ($P = .455$).

The open anastomosis of hemiarch replacement has been postulated to be technically easier or safer than ascending aorta replacement.[8] This may be perceived as being supported in our experience based on fewer repeat operations for bleeding. Malaisrie and colleagues[10] reported no difference in repeat operation for bleeding ($P = .84$). Sultan and colleagues reported a significantly lower rate of repeat operations following hemiarch operation (1% vs 16%; $P < .001$); however, this was all-cause return to the operating room and not specifically identified as for bleeding.[7] It is possible that our ascending aorta group was more aggressively returned to the operating room for exploration whereas the hemiarch group was observed, resulting in a higher rate of blood transfusion.

We found low and similar procedure-related morbidity event rates of dialysis (all patients, <1%; between-group difference, $P = 1.000$), stroke (1%; $P = 1.000$), and mortality (<1%; $P = .555$) in both treatment groups. Similar low event rates were also noted by Malaisrie and colleagues[10] in

their propensity-matched groups with respect to dialysis (2%; $P = .31$), stroke (3%; $P = .31$), and mortality (2%; $P = .41$). Sultan and colleagues[7] likewise reported comparable low event rates in their propensity-matched cohorts for dialysis (6%; $P = .775$), stroke (3%; $P = .408$), and mortality (3%; $P = .408$). Our event rates are in line with those reported following even isolated bicuspid aortic valve replacement.[12] The low percentages may be deceptively reassuring, because they are counter to the reported independent relationship between the duration of cardiopulmonary bypass and procedure-related complications, as noted by Salis and colleagues.[11]

We found a 2% incidence of repeat aortic arch operation at 10 years after discharge; importantly, there were no cases of repeat aortic arch operation for arch aortopathy or aneurysm; furthermore, we found that hemiarch replacement was not associated with improved freedom from any repeat arch operation. Bilkhu and colleagues[6] reported no repeat operation on the arch or the remaining aorta at a median follow-up of 5.9 years after ascending aorta replacement. Malaisrie and colleagues[10] similarly noted no repeat operation on the arch at a mean follow-up of 3.8 years after ascending aorta replacement. From our own institution in 2011, Park and colleagues[13] reported that in patients with paired echocardiography scans, the diameter of the aortic arch remained unchanged over a median follow-up of 4.2 years.

Our median patient follow-up was 6.0 years (95% CI, 5.3-6.8 years) with Kaplan-Meier estimated survival of $94 \pm 1\%$ at 5 years and $80 \pm 2\%$ at 10 years. Multivariable analysis demonstrated that hemiarch replacement was slightly protective of mortality (HR, 0.83; 95% CI, 0.51-1.33), but the difference was not statistically significant ($P = .439$). Malaisrie and colleagues[10] reported reduced survival at 5 years in the hemiarch group (88%) compared with the ascending aorta group (91%), but again the difference was not statistically significant ($P = .24$). Sultan and colleagues[7] noted better survival at 5 years in the hemiarch group (86% vs 81%); however, the difference was also not statistically significant ($P = .420$). Mortality is a hard endpoint. We extended the Kaplan-Meier estimate of survival out to 10 years in the present series. In that regard, there appears to be equipoise between the 2 groups.

This study included only patients without aortic arch aneurysm and is limited by its retrospective nature. This was an as-treated group of patients with incomplete data and a limited duration of follow-up, especially with respect to baseline and follow-up aortic arch diameter and modality of measurement. We cannot discern why the surgeon chose hemiarch replacement over ascending aorta replacement, which is a potential for both selection and treatment bias; furthermore, the low rates of procedure-related complications put the study at risk of both type I and II statistical errors. Finally, we lack information on other factors important to the development of aortopathy, such as quality of the aortic tissue, management of hypertension after operation, and others.

## CONCLUSIONS

Hemiarch and ascending aorta replacement can be done with low procedure-related morbidity and mortality during initial bicuspid aortic valve replacement. Hemiarch replacement requires longer cardiopulmonary bypass and aortic cross-clamp times and is associated with a greater risk of blood transfusion. We found that repeat aortic arch operation and survival were similar in the 2 treatment groups. We identified no specific advantage to hemiarch replacement in the absence of aortic arch dilation. Our current practice is to remove the abnormal and aneurysmal aorta. Surgical judgement guides the use of hemiarch replacement.

### Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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**Key Words:** bicuspid aortic valve, aortopathy, aneurysm, hemiarch replacement, circulatory arrest

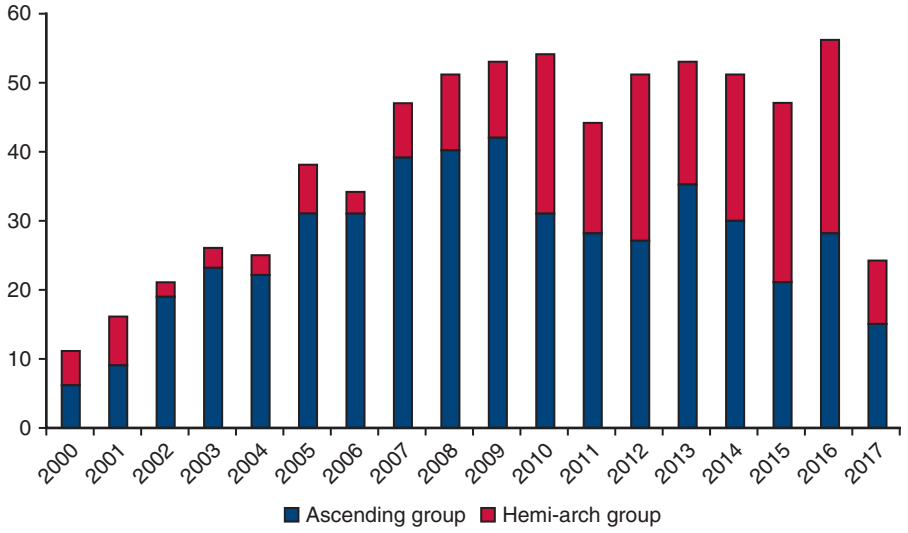


**FIGURE E1.** Yearly case volumes in the ascending and hemiarch groups.

**TABLE E1. Preoperative mid-ascending aorta measurement source in the ascending and hemiarch groups ($P < .001$)***

| Group | Echocardiography | Radiologic scan | Surgeon's note | Total |
|---|---|---|---|---|
| Ascending group, n (%) | 369 (77) | 104 (22) | 4 (1) | 477 |
| Hemiarch group, n (%) | 142 (63) | 81 (36) | 2 (1) | 225 |
| Total, n (%) | 511 (73) | 185 (26) | 6 (1) | 702 |

*There were no missing data.

**TABLE E2. Preoperative aortic arch measurement source in the ascending and hemiarch replacement groups ($P < .001$)**

| Group | Echocardiography | Radiologic scan | Missing data | Total |
|---|---|---|---|---|
| Ascending group, n (%) | 223 (47) | 106 (22) | 148 (31) | 477 |
| Hemiarch group, n (%) | 109 (48) | 81 (36) | 35 (16) | 225 |
| Total, n (%) | 332 (47) | 187 (27) | 183 (26) | 702 |