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Evolving practice pattern changes and outcomes in the era of hybrid aortic arch repair

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Abstract

Objective—The role of hybrid repair in the management of aortic arch pathology, and long-term outcomes with these techniques, remains uncertain. We report a decade of experience with hybrid arch repair (HAR) and assess institutional practice patterns with regard to the use of hybrid and open techniques.

Methods—Hybrid and open total and distal arch procedures performed between July 2005 and January 2015 were identified from a prospectively maintained, institutional aortic surgery database. Perioperative morbidity and mortality, freedom from reintervention, and long-term survival were calculated. Hybrid and open procedural volumes over the study period were assessed to evaluate for potential practice pattern changes.

Results—During the study period 148 consecutive procedures were performed for repair of transverse and distal aortic arch pathology, including 101 hybrid repairs and 47 open total or distal arch repairs. Patients in the hybrid repair group were significantly older with a greater incidence of chronic kidney disease, peripheral vascular disease, and chronic lung disease. Perioperative mortality and outcomes were not significantly different between the hybrid and open groups, aside

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from decreased median length of stay after hybrid repair. Need for subsequent reintervention was significantly greater after hybrid repair. Unadjusted long-term survival was superior after open repair (70% 5-year survival open vs 47% hybrid; $P = .03$), although aorta-specific survival was similar (98% 5-year aorta-specific survival open vs 93% hybrid; $P = .59$). Institutional use of HAR decreased over the final 3 years of the study, with an associated increased use of open total or distal arch repairs. This was primarily the result of decreased use of native zone 0 hybrid procedures. Concurrent with this apparent increased stringency around patient selection for HAR, perioperative morbidity and mortality was reduced, including avoidance of retrograde type A dissection.

Conclusions—HAR remains a viable option for higher-risk patients with transverse arch pathology with perioperative outcomes and long-term aorta-specific survival similar to open repair, albeit at a cost of increased reintervention. This observational single-institution study would suggest decreased use in more recent years in favor of open repair due to avoidance of native zone 0 hybrid procedures. This decline in the institutional use of native zone 0 hybrid repairs was associated with improved perioperative outcomes.

Conventional open transverse aortic arch repair (OTAR) remains a challenging procedure associated with significant morbidity and mortality despite continued improvements in graft design, cerebral protection strategies, and circulatory management.[1,2] In March 2005, the U.S. Food and Drug Administration approved the use of an endovascular device for the treatment of thoracic aneurysms. This ushered in a new era of approved and “off-label” applications for thoracic endovascular aortic repair, including “hybrid” arch debranching and stent graft exclusion of transverse arch aneurysms.[3]

After the U.S. Food and Drug Administration approval of thoracic endovascular aortic repair, hybrid arch repair (HAR) has been increasingly used as a treatment strategy for high-risk patients who were previously not thought to be candidates for OTAR because of age, comorbidities, or anatomy.[4-9] The published literature on HAR includes mostly single-center series with level B to C evidence only and significant heterogeneity of results between studies.[10] Our own published experience has demonstrated HAR to be associated with significant perioperative mortality, with patients who undergo proximal endograft landing zone in native ascending aorta (ie, proximal landing zone [PLZ] 0), accounting for the bulk of perioperative deaths in this cohort[11]; retrograde type A aortic dissection (rAAD) appeared to be a particularly lethal complication that occurred at increased frequency after zone 0 repair.[5] Additionally, the long-term results of HAR are largely unknown. Because of these limitations of the current literature, the present study sought to evaluate the role of hybrid repair in the management of aortic arch pathology by examining institutional practice patterns with regard to the use of hybrid and open techniques, and assess long-term outcomes after hybrid and open total and distal arch repair, in light of our now decade-long experience with these techniques.

METHODS

Patient population and data collection

This retrospective study was approved by the institutional review board of Duke University, and the need for individual patient consent was waived. Hybrid and open total and distal arch procedures (performed for the same anatomic considerations) performed between July 2005 and January 2015 were identified from a prospectively maintained, institutional aortic surgery database. Surgeries classified as open proximal (hemi-) arch replacement[12] were not included in this analysis. Techniques used for HAR[8,11,13,14] and open repair[15] have been described previously and were performed jointly by a team including cardiothoracic and vascular surgeons. All PLZs were defined using the Ishimaru classification.[16] HARs were defined as those that involved endograft coverage of the innominate or left common carotid artery or both (zone 0 or zone 1 PLZ), or endovascular completion after total arch replacement (stented elephant trunk). As in our previously published algorithmic approach to HAR,[11] total arch replacement with stented elephant trunk is included as a type of HAR because the open portion of the arch replacement typically addresses only up to the mid arch, whereas the endovascular portion of the repair addresses the distal arch (with or without any downstream descending thoracic aortic pathology). Surgeries involving coverage of the left subclavian artery only (zone 2 PLZ) were excluded. Indications for surgery were classified as degenerative aneurysm (fusiform, saccular, or penetrating atherosclerotic ulcers), acute dissection, or chronic dissection. Patient selection criteria for hybrid vs open repair were also as presented previously,[11] with hybrid approaches generally favored in patients with advanced age, significant comorbidities previously identified as risk factors for major morbidity or mortality in open arch repair[17] such as cardiac, pulmonary, cerebrovascular, or renal disease; frailty[18]; or high-risk anatomical features such as pathology which would require bilateral thoracosternotomy (“clamshell”) incision or two-stage open repair. However, these selection criteria were only relative factors in the surgical planning process and did not serve as absolute indications or contraindications for HAR. Follow-up protocol for HAR patients was as previously described[3] with computed tomography angiography at 1-, 6-, and 12-months postoperatively, and annually thereafter. Open arch repair patients likewise underwent postoperative surveillance with cross-sectional imaging at 3 to 6 months after surgery and then annually thereafter. Comorbid conditions were defined using Society of Thoracic Surgeons definitions (www.sts.org).

Statistical analyses

To assess for any change in practice patterns and outcomes after publication of our midterm results with HAR,[11] procedures performed before and subsequent to February 2012 (the cutoff date of the previous study period[11]) were compared to examine for differences in patient selection for HAR vs OTAR and perioperative outcomes. Aortic reinterventions, whether via open or endovascular means, for aortic disease within the segment of aorta originally treated at the index HAR or OTAR were reviewed and compared between groups. Procedures for metachronously developing aortic pathology in a different segment of the thoracic or abdominal aorta distant from that originally treated with HAR or OTAR were not counted as reinterventions. Freedom from reintervention and survival were assessed after HAR and OTAR at 1-, 3-, and 5-year time points using individual chart review and dedicated

follow-up. Categorical variables were compared between groups using χ^2 and Fisher exact tests, and continuous variables were compared using Wilcoxon rank sum tests. Freedom from reintervention and overall and aorta-specific survival were estimated using the Kaplan-Meier method. Statistical analyses and calculations were conducted using R software, version 3.1.3 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Demographic and procedural characteristics, and 30-day in-hospital outcomes

During the study period 148 consecutive procedures were performed by two principal cosurgeons (R.L.M., G.C.H.) for repair of transverse and distal aortic arch pathology, including 101 hybrid repairs and 47 open total or distal arch repairs with similar anatomic indications for repair in both groups. This represents 9.5% (n = 148 of 1558) of the total thoracic aortic procedural volume performed at our institution during this same time period. HARs included zone 1 in 22, native zone 0 in 31, Dacron zone 0 in 26, and stented elephant trunk in 22 patients. Patient demographic characteristics are presented in Table I. Median age was 63 years for the entire cohort, with a significantly younger median age for the OTAR group (55 vs 65 years; $P = .0002$). Additionally, a greater proportion of patients who underwent HAR had a history of tobacco abuse (66.3% vs 46.8%; $P = .03$), chronic obstructive pulmonary disease (35.6% vs 10.6%; $P = .001$), baseline renal dysfunction (26.7% vs 10.6%; $P = .03$), and diagnosis of peripheral vascular disease (23.8% vs 2.1%; $P = .0007$).

Intraoperative characteristics are presented in Table II. Procedure status did not differ between populations. Patients who underwent HAR had significantly higher median American Society of Anesthesiologists (ASA) physical status scores ($P = .02$), with 37% of HAR patients having an ASA score of 4, compared with 19.1% of OTAR patients. There were significant differences among the groups for surgical indication ($P = .003$), with a greater proportion of HAR patients (58.4% vs 29.8%; $P = .001$) who underwent repair for the indication of degenerative aneurysm vs OTAR patients who more frequently underwent repair for chronic dissection (63.8% vs 37.6%; $P = .004$). Although all OTAR (n = 47) procedures were performed with cardiopulmonary bypass (CPB), significantly fewer HAR procedures (n = 44; 43.6%) were performed using CPB ($P < .0001$). Median CPB times, however, were not found to be significantly different between the groups ($P = .4$).

Perioperative outcomes are presented in Table III. Thirty-day/in-hospital mortality, stroke, and renal failure rates were similar between the HAR and OTAR groups, as was the incidence of spinal cord ischemic complications. The only outcome that differed significantly between the groups was median length of stay, with patients who underwent HAR having a shorter length of stay than those who underwent OTAR (5 vs 6 days; $P = .04$). In subgroup analysis, a comparison of perioperative outcomes with zone 1 HAR (n = 22), which avoids median sternotomy and CPB, vs all other HARs (n = 79; Table IV) showed numerically lower rates of mortality and major morbidity, although most variables did not reach statistical significance because of small patient numbers. Further, the results with zone 1 HAR were likewise numerically favorable compared with those with OTAR (Table III).

Long-term follow-up outcomes

Follow-up was complete in 132 of 148 (89%) patients. Over a median follow-up time of 34 (range, 8-53) months for all patients, there was a significantly higher reintervention rate in the HAR group, which was approximately fivefold higher than in the OTAR cohort (20.8% vs 4.3%; $P = .01$). There were no significant differences in median follow-up times between the HAR and OTAR groups ($P = .88$). The most common indication for reintervention was endoleak in 57% (n = 12) of cases (Supplemental Table, online only). Freedom from reintervention is shown in Fig 1 with patients who underwent HAR having a significantly lower freedom from reintervention on late follow-up ($P = .009$).

Kaplan-Meier estimates of unadjusted overall survival are shown in Fig 2. Overall unadjusted survival for the entire HAR cohort at 1 year, 3 years, and 5 years was 70.6%, 58.4%, and 46.6%, respectively, compared with 82.6%, 79.8%, and 70%, respectively, in the OTAR group ($P = .03$). Aorta-specific survival is shown in Fig 3, and was not significantly different between the two groups over long-term follow-up (92.6% HAR vs 97.8% OTAR at 5 years; $P = .39$).

Examination of institutional use of HAR

Institutional procedural volumes of OTAR and HAR varied according to year and are presented in Figs 4 and 5. As can be seen in the figures, institutional volumes of HAR began to trend downward after 2012 (the end of our previous study period) and were subsequently eclipsed by OTAR procedural volumes in the year 2014. To put this finding in perspective, a total of 1027 thoracic aortic procedures were performed between July 1, 2005 and January 31, 2012 (an average of 147 procedures per year), with 88 HAR and 29 OTAR procedures, and from February 1, 2012 to the study end date of January 31, 2015, a total of 531 thoracic aortic procedures were performed (an average of 177 procedures per year) including 13 HAR and 18 OTAR procedures. As such, annualized volumes of HAR have decreased from the first to second eras (13.5 HAR procedures per year vs 4.3 HAR procedures per year), and annualized volumes of OTAR have increased (4.5 OTAR procedures per year vs 6.0 OTAR procedures per year). Notably, native zone 0 PLZ has not been used since 2012 after publication of our previous data,[11] which showed significantly worse outcomes in this cohort.

Procedural outcomes (Table V) were also examined for the pre- and post-“native zone 0” eras, in which all HAR procedures that were performed before February 2012 were compared with those performed in the 3 years since, coinciding with the observed practice pattern change. As noted herein, 88 HAR procedures were performed before February 1, 2012, with 13 performed after this time interval. No statistically significant difference could be appreciated between these two groups, because of the small number of patients in the latter cohort, in a comparison of perioperative mortality and most major morbidity before and after February 2012. However, the trends in these complications were generally in favor of improved outcomes using an apparently more restrictive approach to patient selection for hybrid repair. Further, no hybrid arch patients in the latest era have required reintervention or suffered rAAD. Of note, there was a significantly higher incidence of spinal cord ischemic complications in the latter cohort, both in patients with total thoracic aortic pavement down

to the celiac axis. However, because of the small number of patients and similarity in the performance of procedures between eras, this likely represents a type I error.

DISCUSSION

Since the initial description of combined open arch debranching and endovascular exclusion for an arch aneurysm,[19] HAR procedures have been proposed as a means to circumvent the perioperative morbidity and mortality associated with conventional OTAR in high-risk patients, such as the frail and elderly.[5,20,21] The results of the current study suggest that hybrid repair of arch aneurysms is generally safe and effective forAorta-specific survival according to procedure type. On long-term follow patients believed to be inappropriate for conventional open arch repair. Specifically, no difference was observed in 30-day/in-hospital mortality, major neurologic complications, renal failure, or tracheostomy rates between patients who underwent hybrid compared with open total or distal arch repair despite the hybrid cohort being, on average, a decade older with a significantly greater comorbid disease burden and higher ASA physical status score. Not surprisingly, because of their advanced age and greater comorbid burden, long-term survival was worse in the hybrid cohort, although the deaths were generally not as a result of their aortic disease, as evidenced by similar aorta-specific long-term survival between groups. This latter finding suggests that hybrid repair is an effective treatment for transverse arch pathology, albeit at a cost of more reinterventions, demonstrated also in this study. The overall survival of the hybrid group in the current study is consistent with that reported by others, with 5-year survivals ranging from 48% to 72%.[7,21-24]

We have previously demonstrated a high incidence of rAAD (11.1%) and surgical mortality (29.6%) in patients who underwent native zone 0 HAR,[11] and the results of the current study suggest an institutional shift away from use of this procedure since our previous work was published. To our knowledge, this is the first study of its kind to examine institutional outcomes in a chronological fashion that is coincident with alterations in the procedural volumes of hybrid and open arch repairs, coupled with long-term follow-up data. Specifically, in the past 3 years, institutional volumes of all HAR have decreased, with general avoidance of native zone 0 PLZ, and open repair has proportionally increased. Additionally, we observed lower overall rates of perioperative morbidity associated with HAR, a decreased need for reintervention, and no new occurrence of rAAD or perioperative mortality in the post-“native zone 0 hybrid repair era” cohort since elimination of the institutional use of native zone 0 HAR.

Because of the heterogeneity in definitions and results with hybrid repair,[10] the initial enthusiasm for HAR has more recently been followed by a series of comparisons of OTAR with HAR.[25-28] Iba et al,[29] in a propensity matched comparison of open total vs HAR in Japan, found similar early and late outcomes in the groups with a higher reintervention rate in the hybrid cohort, similar to the results of the current study. A small meta-analysis by Benedetto et al[30] revealed that HAR did not appear to significantly improve surgical or late mortality, with a nonsignificant but slightly increased risk of perioperative permanent neurologic complications compared with open arch repairs. Our own results presented herein, although not a direct comparison of the two procedures, reflected similar findings.

Finally, in the largest such analysis to date, Moulakakis and colleagues[10] published a large meta-analysis of all studies (n = 26; 956 patients) that described HAR with supra-aortic debranching and found a pooled mortality rate of 11.9%, similar to the current study. Pooled stroke (7.6%) and paraplegia (3.6%) rates were somewhat higher than in the current report, and the authors noted a significant heterogeneity of reported results between studies. Moulakakis et al concluded that HAR provides a safe alternative to open repair with acceptable short- and midterm results, but that future prospective trials comparing conventional open and hybrid methods are needed.[10] Because of the collective results of this previous work and the current study, we advocate that careful consideration be given to patient risk factors and anatomy before the performance of any hybrid procedure, with special caution reserved for the native zone 0 hybrid repair. Additionally, because of the repeatedly demonstrated greater incidence of reintervention for treatment failure, not to mention the not infrequent development of metachronous aortic disease in this population, further strength is given to the previous notion that routine aortic surveillance with cross-sectional imaging by an experienced aortic center is an absolute necessity.[8,31]

Additional approaches to management of transverse arch aneurysms are under development and require further validation. Use of total endovascular means for arch repair with specially-designed branch grafts or “chimney and/or snorkel” techniques have been described with acceptable technical results, although feasibility and outcomes data for these procedures remains limited because of their novelty.[32,33]

The current study has several important limitations. First, the study was limited by the potential bias inherent in any single-institution, retrospective analysis. Although others have performed propensity-matched analysis and directly compared OTAR with HAR,[34] the small sample size and significant differences in patient age and comorbid conditions precluded doing this in the current study, because a large proportion of the HAR cohort would be excluded from matching. Moreover, the aim of the current study was not to directly compare outcomes of HAR and OTAR, but rather to examine relative use of the two procedures and their perioperative outcomes after publication of our previous report,[11] and to report long-term follow-up data with each repair strategy. Although the results of hybrid repair in the most recent era are encouraging, the small sample size of HAR performed in the “post native zone 0” era makes safety claims prone to type II error, thus, caution should be taken in assuming that nonnative zone 0 hybrid procedures are safe.

CONCLUSIONS

Hybrid repair is generally safe for the treatment of transverse arch pathology in patients unfit for conventional repair with perioperative outcomes similar to conventional repair despite an older and sicker treatment population. Further, hybrid repair is effective for mitigating death from aortic disease, evidenced by similar aorta-specific long-term survival after hybrid vs open repair; this similar aorta-specific survival does, however, come at the cost of a significantly greater reintervention rate after hybrid repair. Results of the institutional experience presented herein suggest that perioperative morbidity and mortality might be improved with real-time and outcomes-based alteration in the algorithmic approach to surgical selection. In these circumstances, the elimination of the hybrid approach in which

native ascending aorta (zone 0) is used as PLZ has yielded improved perioperative morbidity and mortality outcomes.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Biographies

Dr Anil Hingorani (*Brooklyn, NY*). I just had a question about the reinterventions. I thought most of the reinterventions would be endoleaks, but you identified that only 55% were endoleaks.

Dr Ehsan Benrashid. That is correct, most reinterventions were for endoleak. The bulk of those reinterventions not listed were for thrombotic complications, with patients having thrombosis of their branch vessel grafts requiring reintervention.

Dr Benjamin Starnes (*Seattle, Wash*). I have a question for you, Dr Benrashid. You do these in combination with your cardiac surgeons, I assume?

Dr Benrashid. Yes, sir. It's a joint venture between Dr McCann, who is one of our vascular surgeons, and Dr Hughes, who is a cardiothoracic surgeon who specializes in complex thoracic aortic work.

Dr Starnes. You showed a slide where your procedure volume dropped off in 2011. To what do you attribute that? Do you attribute that to more cardiac surgeons becoming involved in this space and taking on endovascular procedures, or do you attribute that to a change in practice patterns in your region?

Dr Benrashid. That's a great question. And one of the things that we're interested in with this study is examining our volume and/or outcomes relationships. I think that the one thing, which we demonstrated, is that more patients are getting open repairs, and one of the reasons why is that our circulation and hypothermia management strategies are changing to make these procedures safer for a lot of "high risk" patients. I'm not sure if more cardiac surgeons are becoming more well versed in endovascular repair. I do know that all of these procedures are done with a vascular surgeon, Dr McCann, who is in the audience, and Dr Hughes together.

Dr Ravi Veeraswamy (*Atlanta, Ga*). I have a point of clarification. If a patient received a carotid/carotid/carotid subclavian bypass, was that included in this series or not included in this series?

Dr Benrashid. Where was the proximal landing zone of the stent?

Dr Veeraswamy. If it was zone 1, was that included?

Dr Benrashid. Yes, sir.

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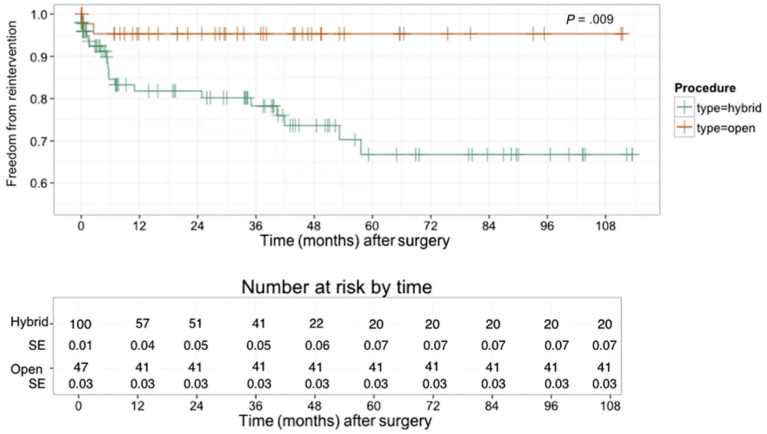

Fig 1.

Kaplan-Meier freedom from re-intervention after hybrid vs open transverse arch repair. Freedom from reintervention was significantly greater after open repair ($P = .009$). *SE*, Standard error.

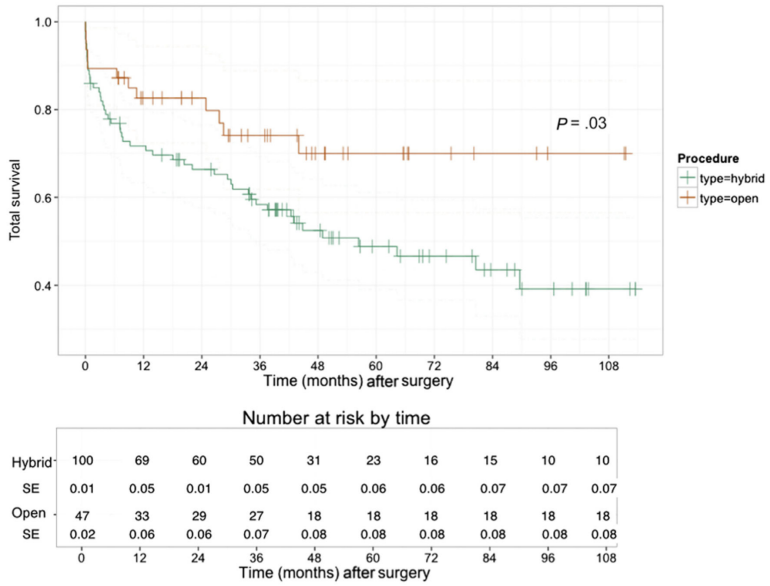

Fig 2.

Kaplan-Meier overall survival according to procedure type. Unadjusted long-term survival was significantly worse ($P = .03$) after hybrid compared with open transverse arch repair. *SE*, Standard error.

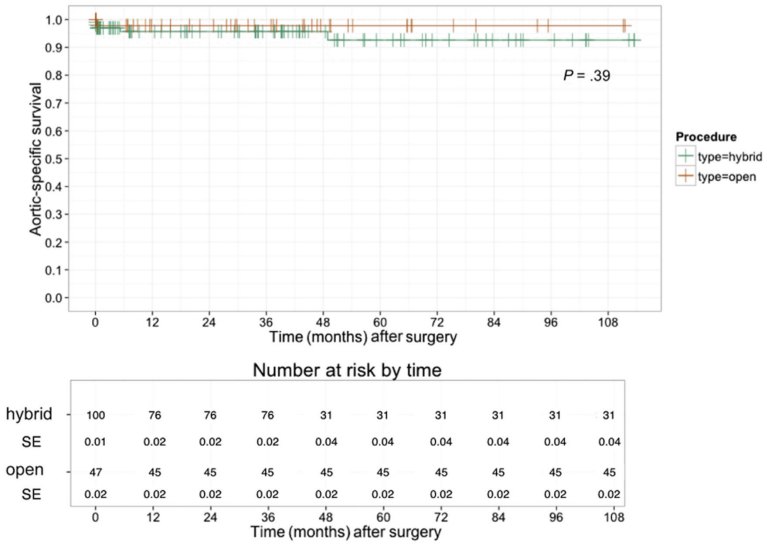

Fig 3.

Aorta-specific survival according to procedure type. On long-term follow-up, there was no difference in aorta-specific survival between hybrid and open transverse arch repairs ($P = .39$). *SE*, Standard error.

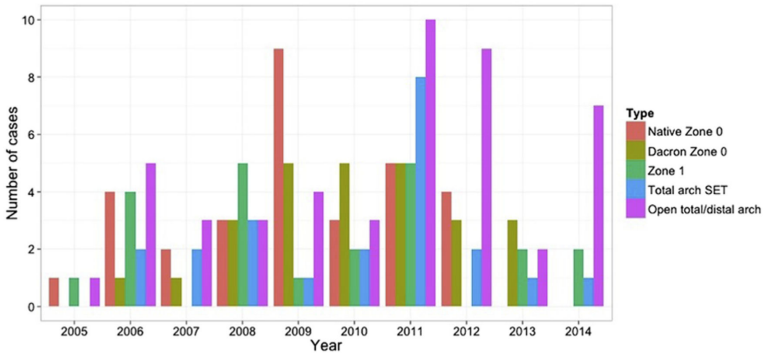

Fig 4.

Institutional variation of hybrid arch repair (HAR) and open transverse arch repair procedural volumes per year. For HAR, procedures are organized according to proximal landing zone (PLZ): native zone 0: arch debranching with PLZ in native ascending aorta zone 0; Dacron zone 0: arch debranching with PLZ in Dacron-replaced ascending aorta zone 0; zone 1: arch debranching with PLZ in zone 1; total arch stented elephant trunk (*SET*): total arch replacement with SET completion; and open total/distal arch.

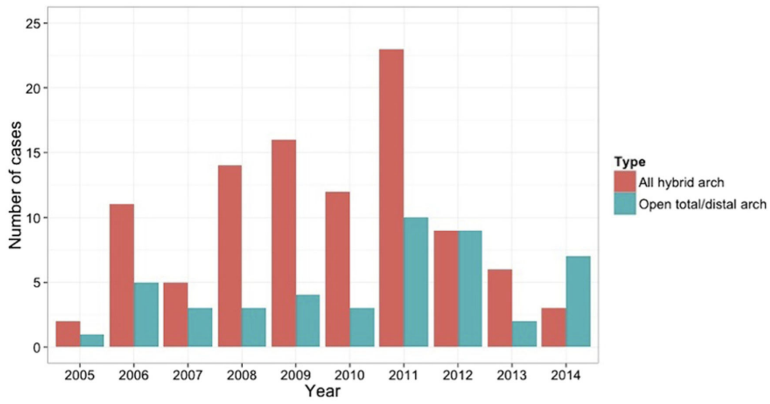

Fig 5.

Institutional variation of procedural volumes by year, organized according to hybrid arch repair (HAR) (grouped) vs open transverse arch repair.

Table I

Demographic characteristics

Variable	*Total (N = 148)*	*HAR (n = 101)*	*Open arch repair (n = 47)*	P
Patient characteristics				
Age, years	63 (52-71)	65 (56-73)	55 (42-68)	.0002
Male sex	89 (60.1)	56 (55.4)	33 (70.2)	.11
White race	99 (66.8)	68 (67.3)	31 (66.0)	.99
Body mass index	26.1 (22.8-29.6)	26.3 (22.8-29.6)	25.1 (22.7-29.4)	.79
Patient comorbidities				
Hypertension	135 (91.2)	93 (92.1)	42 (89.4)	.55
Hyperlipidemia	89 (60.1)	63 (62.4)	26 (55.3)	.47
History of tobacco use	89 (60.1)	67 (66.3)	22 (46.8)	.03
Diabetes	12 (8.1)	8 (7.9)	4 (8.5)	.99
Coronary artery disease	48 (32.4)	36 (35.6)	12 (25.5)	.26
History of stroke	27 (18.2)	18 (17.8)	9 (19.1)	.82
COPD	41 (27.7)	36 (35.6)	5 (10.6)	.001
Baseline creatinine > 1.5 mg/dL	32 (21.6)	27 (26.7)	5 (10.6)	.03
Peripheral vascular disease	25 (16.8)	24 (23.8)	1 (2.1)	.0007
Previous aortic surgery	96 (64.8)	66 (65.3)	30 (63.8)	.86

COPD, Chronic obstructive pulmonary disease; *HAR*, hybrid arch repair.

Data are presented as number (%) or median (range).

Table II

Intraoperative characteristics

Variable	*Total (N = 148)*	*HAR (n = 101)*	*Open arch repair (n = 47)*	P
Procedure status				.94
Elective	121 (81.7)	83 (82.2)	38 (80.9)	
Urgent	19 (12.8)	13 (12.9)	6 (12.8)	
Emergent	8 (5.4)	5 (5.0)	3 (6.4)	
ASA physical status score, median				.02
ASA 2	4 (2.7)	1 (1.0)	3 (6.4)	
ASA 3	97 (65.5)	62 (62.0)	35 (74.5)	
ASA 4	46 (31)	37 (37.0)	9 (19.1)	
Indication for procedure				.003
Degenerative aneurysm	73 (49.3)	59 (58.4)	14 (29.8)	.001
Aortic dissection, acute	7 (4.7)	4 (4.0)	3 (6.4)	.68
Aortic dissection, chronic	68 (45.9)	38 (37.6)	30 (63.8)	.004
Maximum aortic diameter, median	6.0 (5.5-7.0)	6.0 (5.5-7.1)	6.1 (5.5-7.0)	.9
Intraoperative lumbar drain	18 (12.1)	9 (9.0)	9 (19.1)	.1
Staged procedures	34 (22.9)	34 (33.7)	NA	NA
Performed on CPB	91 (61.5)	44 (43.6)	47 (100)	<.0001
CPB time, median minutes	221 (175-260)	220 (161-249)	225 (178-268)	.4

ASA, American Society of Anesthesiologists; *CPB*, cardiopulmonary bypass; *HAR*, hybrid arch repair; *NA*, not applicable.

Data are presented as number (%) or median (range).

Table III

Thirty-day/in-hospital outcomes

Complication	*Total (N = 148)*	*HAR (n = 101)*	*Open arch repair (n = 47)*	P
Thirty-day/ in-hospital death	19 (12.8)	14 (13.9)	5 (10.6)	.79
Stroke	4 (2.7)	4 (4.0)	0	.99
Permanent paraparesis and/or -plegia	4 (2.7)	3 (3.0)	1 (2.1)	.99
Acute renal failure	12 (8.1)	6 (5.9)	6 (12.8)	.2
New-onset dialysis	7 (4.7)	3 (3.0)	4 (8.5)	.21
Tracheostomy	8 (5.4)	6 (5.9)	2 (4.3)	.99
Length of stay, days	6 (4-8)	5 (4-8)	6 (5-9)	.04

HAR, Hybrid arch repair.

Data are presented as number (%) or median (range).

Table IV

Zone 1 hybrid arch repair (*HAR*) subgroup analysis of perioperative outcomes

Complication	*Zone 1 HAR only (n = 22)*	*All other HAR (n = 79), %*	P
Thirty-day and/or in-hospital death	1 (4.5%)	13 (16.5)	.29
Stroke	0	4 (5.1)	.57
Permanent paraparesis and/or -plegia	1 (4.5%)	2 (2.5)	.53
Acute renal failure	0	6 (7.6)	.33
New-onset dialysis	0	3 (3.8)	.99
Tracheostomy	0	6 (7.6)	.33
Length of stay, days	4 (3-6.5)	6 (4-8.5)	.03

Data are presented as number (%) or median (range).

Table V

Thirty-day/in-hospital outcomes of the pre-and post-“native zone 0” eras (hybrid repairs only)

Complication	*Jul 2005 to Jan 2012 (n = 88)*	*Feb 2012 to Jan 2015 (n = 13)*	P
Thirty-day/in-hospital death	14 (15.9)	0	.21
Stroke	4 (4.5)	0	.99
Permanent paraparesis/plegia	1 (1.1)	2 (15.4)	.04
Acute renal failure	6 (6.8)	0	.99
New-onset dialysis	3 (3.4)	0	.99
Tracheostomy	5 (5.7)	1 (11.1)	.57
Length of stay, days	6 (4-8)	5 (3-7)	.4

Data are presented as n (%) or median (range).