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ORIGINAL ARTICLE

A running suture line for aortic valve replacement does not increase the rate of postoperative complete heart block

Ibrahim Sultan[1,2] · Keith A. Dufendach[1] · Arman Kilic[1,2] · Valentino Bianco[1] · Forozan Navid[1,2] · Thomas G. Gleason[1,2]

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Abstract

Background Surgical implantation of a prosthetic aortic valve is typically done with multiple interrupted sutures. We adapted a running suture line technique for prostheses implantation to decrease the rate of complete heart block necessitating permanent pacemaker.

Methods 374 patients undergoing isolated aortic valve replacements were identified between 2015 and 2017. Patients with preoperative heart block, patients undergoing concomitant MAZE procedure and those undergoing multivalve procedures were excluded. Interrupted technique was performed with multiple non-pledgeted sutures. Running technique was performed with three 2–0 polypropylene sutures. Propensity-score matching (caliper distance = 0.10) was used to match based on patient age, gender, BMI, diabetes mellitus, renal failure, heart failure, arrythmias, use of anti-arrhythmics, and STS PROM.

Results Propensity score matching yielded 103 pairs of running technique and interrupted technique patients for analysis. Within the propensity score-matched cohort, there were no differences in sustained complete heart block and need for pacemaker, 4 (3.8%) for running technique vs 3 (2.9%) for interrupted technique ($p = 0.307$). At 4 weeks, there was no difference in mean prosthetic aortic valve gradients calculated on transthoracic echocardiogram (6.39 ± 2.47 mmHg vs 6.46 ± 2.86, $p = 0.850$). There was no difference in paravalvular leak (0 (0%) vs 2 (1.9%), $p = 0.070$).

Conclusions Surgical implantation of a prosthetic aortic valve may be performed with a running suture technique without any significant increase in risk of heart block, need for permanent pacemaker or paravalvular leak. Long-term data will be critical to evaluate any development of paravalvular leaks in the future.

Keywords Aortic valve replacement · Pacemaker · Heart block · Surgical technique

Introduction

Valve technology and surgical technique have progressed over the decades, improving both patient eligibility and procedural success of surgical aortic valve replacement (AVR) [1–3]. Surgical replacement of the aortic valve is most commonly performed by removal of the diseased valve and implantation of a mechanical or bioprosthetic valve. Most commonly, this is performed with a series of pledgeted or non-pledgeted interrupted sutures and intrannular or supranular placement of the surgical valve.

Conduction abnormalities following AVR are a common complication and are thought to result from disruption of the AV node and the bundles of HIS while passing sutures through the aortic annulus [4, 5]. Postoperatively, patients may have isolated left bundle branch block (BBB) or right BBB which may be better tolerated than complete heart block [6]. Complete heart block necessitating permanent pacemaker is associated with worse outcomes following AVR when compared to those without postoperative heart block which continues to be seen in the long-term period [7].

Strategies to eliminate cardiac conduction defects following AVR have left a small, but significant number of patients who suffer heart block postoperatively [5, 8]. There have been mixed results when comparing patients with running vs interrupted suture line in some small studies in the past

✉ Ibrahim Sultan
sultani@upmc.edu

[1] Division of Cardiac Surgery, Department of Cardiothoracic Surgery, University of Pittsburgh, 5200 Centre Ave, Suite 715, Pittsburgh, PA 15232, USA

[2] Heart and Vascular Institute, University of Pittsburgh Medical Center, Pittsburgh, USA

with heterogenous patient populations [9–12]. Unsatisfied with the rate of heart block in the contemporary postoperative AVR population, we hypothesize that the use of running sutures to implant an aortic prosthesis may result in fewer conduction abnormalities without compromising the success of the operation.

Patients and methods

374 patients undergoing isolated aortic valve replacements between 2015 and 2017 were included in the analysis. Patients with endocarditis, preoperative right bundle branch block and complete heart block, patients undergoing concomitant MAZE procedure and those undergoing multivalve procedures were excluded. Patients undergoing reoperative sternotomy were included, but reoperations with valve surgery were excluded. Interrupted technique was performed with multiple non-everting non-pledgeted 2–0 Ti-Cron™ (Covidien, Ireland) sutures. Running technique was performed with three 2-0 polypropylene sutures. Sutures were placed at each commissure and in the case of a bicuspid valve at commissures and the raphe. Each arm of the suture was then passed through the sewing cuff of the prosthesis till the nadir of the sinus where the suture from the neighboring sinus was met. Once the valve was lowered and seated into the annulus, the sutures were tightened and the valve secured by tying the knots in place [13]. The primary outcome was need for pacemaker implantation after AVR. All patients with complete heart block had permanent pacemakers placed prior to discharge. All pacemakers implanted within 30 days after surgery were captured. Echocardiographic end points were also studied including prosthetic valve mean gradients and any prosthetic aortic regurgitation at discharge and the most recent follow-up.

Statistical methods

Continuous variables are reported as median (range); categorical variables are reported as frequency (percentage). Baseline characteristics are compared using Wilcoxon–Mann–Whitney rank-sum tests for continuous variables and Chi-squared tests for categorical variables (Fisher's exact tests when necessary due to small cell sizes). Due to the observed baseline differences between the treatment groups, we also performed a propensity score-matched analysis. The multivariable logistic regression model used to generate the propensity scores included age and the STS-predicted risk of mortality score. After calculating the propensity scores, patients with the running suture technique were randomly sequenced and matched 1:1 without replacement to patients that received the interrupted suture technique using a caliper distance of 0.10, resulting in 103 matched pairs. Between-group comparisons were repeated in the propensity-matched population to ensure adequate balance in risk profile, and outcomes were then summarized in the matched population. Primary outcome was need for pacemaker. We also analyzed echocardiographic data at 1 month and at the latest follow-up. Fisher's exact tests were used to compare the incidence of binary outcomes, given the small sample size. Survival in the propensity-matched cohort is presented using a Kaplan–Meier curve. All statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC).

Results

A total of 374 patients who underwent surgical AVR between 2015 and 2017 met the inclusion criteria. Preoperative characteristics are presented in Table 1. 157 (42.0%) patients underwent AVR with the running suture technique vs 217 (58.0%) with the interrupted technique. Patients who underwent the interrupted suture technique were older (76.0 vs 68.5 years; $p < 0.001$) and had increased STS PROM score (3.0 vs. 2.0%; $p < 0.001$) when compared with patients who underwent a running suture technique. Furthermore, while biologic valves were used almost exclusively in the interrupted group ($n = 212/217$, 97.7%), these were used in just under half of the running suture group ($n = 74/157$, 47.1%). Following 1:1 propensity matching, 206 patients remained, with 103 patients in both the running and interrupted suture groups. The preoperative characteristics of these patients are presented in Table 2 ,demonstrating no significant difference in baseline characteristics.

Table 1 Baseline characteristics in patients undergoing isolated aortic valve replacement with the running or interrupted technique

	Running	Interrupted	*p* value
Number of patients	157	217	
Age	68.5 (24.0–88.0)	76.0 (49.0–92.0)	< 0.001
Male gender (% male)	98 (62.4%)	138 (63.6%)	0.878
BMI	29.3 (19.0–46.4)	28.7 (17.9–64.7)	0.751
Mediastinal radiation	2 (1.3%)	5 (2.3%)	0.473
Ejection fraction (EF)	58.0 (23.0–71.0)	58.0 (15.0–70.0)	0.195
LV end diastolic dimension	48.0 (20.0–69.0)	47.0 (30.0–71.0)	0.039
Aortic valve area (cm^2)	0.8 (0.2–2.0)	0.7 (0.3–2.0)	0.072
STS PROM risk %	2.0 (0.4–62.2)	3.0 (0.6–33.8)	< 0.001
Severe AS	117 (74.5%)	186 (85.7%)	0.005
Severe AI	30 (19.1%)	17 (7.8%)	0.005
Bioprosthesis	74 (47.1%)	212 (97.7%)	< 0.001
Mechanical prosthesis	83 (52.9%)	5 (2.3%)	< 0.001

Table 2 Baseline characteristics in the matched cohort

	Running	Interrupted	*p* value
Number of patients	103	103	
Age	71.0 (55.0–88.0)	71.0 (55.0–87.0)	0.988
Male gender (% male)	69 (67.0%)	66 (64.1%)	0.660
BMI	29.6 (19.0–46.4)	28.7 (17.9–52.5)	0.468
Mediastinal radiation	1 (1.0%)	3 (2.9%)	0.313
Ejection fraction (% EF)	58.0 (23.0–71.0)	58.0 (15.0–70.0)	0.549
LV end diastolic dimension	48.5 (20.0–67.0)	46.0 (33.0–71.0)	0.182
Aortic valve area (cm^2)	0.7 (0.2–2.0)	0.7 (0.4–2.0)	0.576
STS PROM risk %	2.3 (0.6–62.2)	2.6 (0.6–24.5)	0.219
Severe AS	85 (82.5%)	83 (80.6%)	0.513
Severe AI	13 (12.6%)	11 (10.7%)	0.472

Among all patients in the unmatched groups, 30-day mortality was 3.5% ($n=13$, Table 3). The rate of postoperative PPM placement was 4.3% ($n=16$) overall. There was no significant difference in either 30-day mortality or PPM placement between groups. Mean AV gradient was slightly higher in those who underwent running suture technique (7.29 vs 6.36 mmHg, $p=0.007$). Of note, there were more deaths overall within the period of follow-up in the interrupted group vs the running suture group (12.0 vs. 3.2%). However, the follow-up time was more than three times greater in the interrupted group (20.1 vs 6.6 months);so, these data are not comparable.

When comparing the propensity-matched cohorts, there were no significant differences in outcomes between groups (Table 4). 30-day mortality among all 206 patients was 2.4% ($n=5$), with 1 death in the running group and 4 in the interrupted group ($p=0.174$). Heart block requiring PPM was present in 4 (3.4%) patients from the running group

Table 3 Outcomes in the unmatched cohort

	Running	Interrupted	*p* value
Number of patients	157	217	
30-day mortality	3 (1.9%)	10 (4.6%)	0.160
Permanent pacemaker implant	8 (5.1%)	8 (3.7%)	0.506
CPB time	95.0 (35.0–227)	103 (35.0–336)	0.047
Ischemic time	73.5 (28.0–174)	83.0 (27.0–216)	0.029
1st outpatient ECHO			
AV mean gradient	7.29 ± 3.48	6.36 ± 2.67	0.007
Any prosthetic aortic regurgitation	1 (0.6%)	4 (1.8%)	0.095
Most recent ECHO			
Number of patients	41	97	
AV mean gradient	7.51 ± 5.46	8.53 ± 8.08	0.479
Any prosthetic aortic regurgitation	1 (0.6%)	2 (0.9%)	0.136
Total deaths	5 (3.2%)	26 (12.0%)	NA
Total follow-up time (months)	6.6 (0.1–36.9)	20.1 (0.0–44.5)	< 0.001

NA not applicable

Table 4 Outcomes of propensity-matched cohort

	Running	Interrupted	*p* value
Number of patients	103	103	
30 day mortality	1 (1.0%)	4 (3.9%)	0.174
Permanent pacemaker implant	4 (3.8%)	3 (2.9%)	0.307
CPB time	90.0 (35.0–227)	105 (46.0–209)	0.003
Ischemic time	69.0 (28.0–140)	84.0 (29.0–161)	0.006
1st outpatient echocardiogram			
AV mean gradient	6.39 ± 2.47	6.46 ± 2.86	0.850
Any prosthetic aortic regurgitation	0 (0.0%)	2 (1.9%)	0.070
Most recent ECHO			
AV mean gradient	7.03 ± 2.88	6.93 ± 4.21	0.922
Any prosthetic aortic regurgitation	1 (1.0%)	1 (1.0%)	0.870
Total deaths	2 (1.9%)	11 (10.7%)	NA*
Total follow-up time (months)	6.7 (0.3–36.9)	21.4 (0.0–41.1)	< 0.001

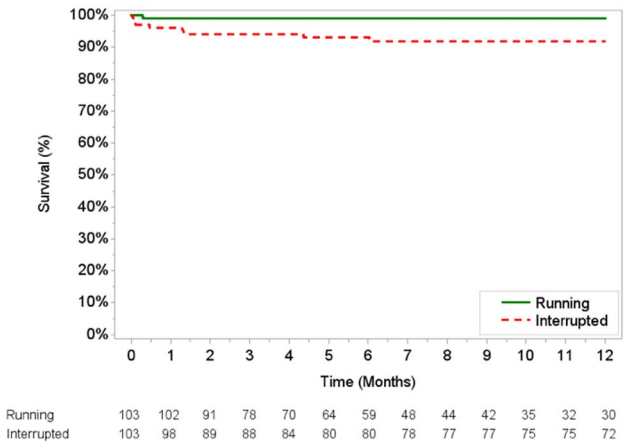

Fig. 1 Association between mortality and surgical technique in the propensity-matched cohort

vs 3 (2.9%) in the interrupted group ($p = 0.307$). Of note, paravalvular leak was present in 1 patient (1%) in both the running and interrupted groups. Freedom from reoperation was 100% in both groups. A Kaplan–Meier survival curve comparing propensity-matched patients is shown in Fig. 1 which revealed 3.0% mortality at 1 year for the running group vs 9.9% for the interrupted group ($p = 0.025$). The matched study population indicated a 1.0% mortality at 1 year for the running group vs 8.2% for the interrupted group ($p = 0.079$). It should be noted that the time to follow-up was highly uneven between the two groups (Tables 3, 4), so the estimates of mortality at longer time intervals may not be as reliable for the running technique; however, it is still noteworthy that survival appears to be quite good in those patients. We noted 100% freedom from reintervention for reoperative aortic valve replacement between the two groups. There were no episodes of prosthetic endocarditis.

Discussion

Surgical AVR remains one of the most commonly performed cardiac surgical operations and heart block necessitating PPM placement, which is a complication that increases morbidity and mortality with AVR [5]. Published rates of heart block following surgical aortic valve replacement are between 3.5 and 7%, which are consistent with the 4.3% rate of PPM placement in our overall patient cohort [5, 8, 14, 15]. PPM placement is associated with longer hospital stays, increased costs, device and procedure-related complications, and death [7]. Thus, improved surgical technique and decision-making are necessary to reduce patient risks resulting from heart block and PPM placement.

In recent years, there has been a consistent increase in the use of transcatheter AVR (TAVR) as a means of replacing the aortic valve in patients who are at intermediate risk or at high risk for open surgery. This has increased the population of individuals who are eligible for AVR, particularly among the elderly. However, with increasing age there is an increased percentage of preoperative cardiac conduction abnormalities which is known to increase the risk for heart block necessitating PPM placement [16, 17]. In addition, numerous studies have demonstrated an increased risk of heart block following TAVR compared with SAVR, ranging from 9 to 18% [5, 8, 15]. The increased conduction abnormalities following TAVR are thought to be due to the strain on the AV node and bundle of HIS by the catheter-based expandable valves [5]. This is thought to be less of an issue with surgical implanted valves, and therefore we aimed to further refine the surgical implantation technique to keep postoperative conduction abnormalities low when compared with rapidly advancing TAVR experience and technology.

The running surgical technique in a running suture line allows for specific advantages that may not be evident with an interrupted suture technique. The mattress sutures in the interrupted technique provide direct upward tension along the annulus including at the level of the non-right commissure where deeper sutures may increase the risk of partial or complete heart block. The continuous suture line may allow for more even distribution of tension with indirect tension throughout the annulus. To ensure that minimal upward tension is around the level of the commissures, the three sutures in the continuous technique are tied closer to the nadir of each sinus. Once past the initial learning curve, we have noticed that this is an expeditious technique without any increase in paravalvular leak. Few groups have published results using a continuous suture technique for surgical AVRs [9, 11, 12, 18, 19]. Two studies examining cardiac conduction following AVR with continuous suture technique have produced conflicting results. In one study, there was a significantly higher rate of PPM placement in those who received an AVR with running suture technique (17.5 vs 2.2%) [9]. Another retrospective study suggests the opposite, showing a decreased need for PPM in patients who underwent AVR with the running suture technique [19]. These conflicting results are likely related to small patient numbers and confounders between treatment cohorts. Additional studies comparing suture technique have demonstrated less patient–prosthesis mismatch and shorter operative times when using running sutures. The strength of this study is in the propensity matching of patients who underwent running or interrupted AVR. While the unmatched patient cohorts showed significant differences in age, preoperative medications, echocardiographic findings, and STS risk parameters, matched analysis controlled for most of these differences between cohorts. There is a higher incidence of mechanical valve utilization in the running group which may act as a surrogate for a healthier or younger patient with less arrythmias.103 patients in each

group were appropriately matched, which is to our knowledge the largest study of propensity-matched cohorts comparing running or interrupted suture technique. This study demonstrates no difference in heart block necessitating PPM between the groups, indicating that the running technique is safe for the cardiac conduction system. These data, despite small numbers, is encouraging regarding ongoing use of this technique. Both cohorts have an STS PROM denoting a low risk group for AVR. It is interesting to note that there appears to be a survival difference in favor of the running suture line cohort over the interrupted group despite propensity matching and the fact that the STS PROM was similar in both groups which should account for most factors influencing short-term mortality. However, several confounding factors may be responsible It is possible that a higher number of mechanical prostheses in the running group were a consequence of surgeon bias that led to a recommendation for a mechanical valve when the patient's life expectancy was expected to be near normal. This is in line with most large registry data in North America for patients older than 70 years. Rodriguez-Gabella et al. presented their long-term follow-up for similar profile patients recently that indicated nearly 64% had died at 10 years after surgical AVR [20]. Most of these deaths were non-cardiac and this is likely to be seen in our patients as well at follow-up.

It is conceivable that using three sutures as opposed to a dozen or more interrupted sutures may increase the risk of paravalvular leak, but we do not see that in our study population. We do not know if there will be increased risk of endocarditis, increased transvalvular gradients or paravalvular risk in the long run, but this will require close long-term follow-up [21]. We are slowly transitioning to using the continuous technique as the default suture technique for AVR. However, it can be challenging to teach trainees, particularly in the setting of a small annulus and sinus segment and does require a learning curve but can be universally used for all surgically implanted valves. We have also expanded the use of the running suture technique to implant mitral and tricuspid replacements with no technical challenges.

Limitations

This study is limited by a small sample size, which may have insufficient power to demonstrate differences between groups. Additionally, this single-institution study may not be replicable at other institutions, and the choice of suture technique should be made carefully at each institution. Finally, there was a significant difference between tissue and mechanical valve placement in the unmatched cohorts, with a greater number of mechanical valves being placed in those who had a valve placed with the running technique. This could not be corrected for in the propensity-matched cohort, which could be a confounder in our data.

Conclusions

Using a running suture technique for surgical AVR is a safe and effective alternative to the interrupted suture line technique with no significant difference in postoperative heart block. We recently adopted this technique with positive results.

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Compliance with ethical standards

Conflict of interest The authors report no conflict of interest.

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