Variability and Utilization of Concomitant Atrial Fibrillation Ablation During Mitral Valve Surgery

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Background. **Concomitant surgical ablation for atrial fibrillation (AF) at the time of mitral valve surgery is a Society of Thoracic Surgeons Class IA recommendation with evidence from randomized trial data. We hypothesized that concomitant AF ablation rates have increased over time with implementation of this evidence-based practice.**

Methods. **All patients (N = 7261) undergoing mitral valve operations (2011-2018) were queried from a regional Society of Thoracic Surgeons database. Patients with preoperative AF were stratified by concomitant AF ablation. Trends in concomitant ablation were evaluated over time as well as by center and surgeon mitral surgical volume. The associations between patient and center factors on implementation of concomitant ablation were assessed with multivariate regression.**

Results. **A total of 1675 patients with preoperative AF underwent isolated mitral valve operations, with 1044 (64.6%) undergoing concomitant ablation. The utilization of concomitant ablation decreased over the study period (-2.82%/year), and was strongly associated with surgeon mitral valve volume (high 78.2% vs medium 62.5% vs low 59.0%; $P < .001$). Multivariate regression demonstrated age and comorbidities were strong predictors, but high volume mitral surgeons (odds ratio [OR], 2.2; $P < .001$) were twice as likely to perform concomitant AF ablation. Finally, patients with preoperative AF undergoing ablation were significantly less likely to be in AF at discharge (10.1% vs 53.8%; $P < .001$).**

Conclusions. **Despite increasing evidence and societal recommendations, we demonstrate a persistent underutilization of concomitant AF ablation during isolated mitral surgery across a large number of low-volume and high-volume centers. These data suggest significant variability and may represent an opportunity for improvement.**

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Atrial fibrillation (AF) is the most common cardiac arrhythmia and is associated with increased morbidity, mortality, and reduced quality of life.[1] Among the multiple pathophysiologic causes of AF, structural heart disease, chiefly mitral valve pathology, is a major associated cause.[2] Up to 50% of patients referred for mitral valve surgery carry a diagnosis of AF.[3] Mitral valve surgery presents an ideal opportunity to provide surgical ablation, given that the left atrium is opened to access the target lesions. In January 2017, the Society of Thoracic Surgeons (STS)[2] released its most recent update to its clinical practice guidelines pertaining to concomitant ablation for the treatment of AF.[4] In reviewing a large body of evidence gathered since its last update in 2014, the 2017 STS guidelines stratify its recommendations for surgical ablation by concomitant open atrium (mitral) vs closed atrium (aortic or coronary bypass) procedures, as well as making recommendations for standalone surgical ablation. Specifically, with regard to mitral valve surgery, the STS guidelines state that surgical ablation can be performed concomitantly at

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the time of mitral intervention without increasing operative morbidity or mortality, and thus should be pursued. The STS grades this recommendation as Class I, Level of Evidence A, based on several randomized controlled trials and meta-analyses showing improved outcomes without increased risk. Most notably, a 2015 study by the Cardiothoracic Surgical Trials Network demonstrated concomitant surgical ablation for mitral operations improved freedom from AF at 1 year without a significant difference in overall morbidity or mortality measures, despite incrementally longer bypass time and an increased risk of future permanent pacemaker requirement.[3]

Subsequent to the STS update, the American Association for Thoracic Surgery[5] and the Heart Rhythm Society[1] both released expert consensus statements recommending concomitant surgical ablation at the time of other cardiac surgery, in agreement and complimentary to the STS guidelines. New long-term data suggest that concomitant surgical ablation is associated with improved overall survival[6] at 5 years across a spectrum of cardiac surgery subgroups. Given the clinical evidence, there is little question as to the efficacy of concomitant surgical ablation for AF patients presenting for mitral valve surgery; however, the decision to pursue concomitant surgical ablation for any individual patient depends on preoperative risk as well as on surgeon experience and bias with performing ablation procedures.[7] There have been little data published regarding the implementation of the newest 2017 STS guidelines across practice groups in the United States. This study aims to evaluate recent trends in concomitant surgical ablation at the time of mitral valve surgery across multiple U.S. centers, ranging from large academic centers to smaller, community program. Moreover, the goal of this study was to investigate patient and surgeon factors that influence the rate at which concomitant surgical ablation is performed. Given the extensive data and societal recommendations, we hypothesized that concomitant surgical ablation has increased across a regional consortium since the STS guidelines.

Patients and Methods

Patient Data

The Virginia Cardiac Services Quality Initiative (VCSQI) comprises 19 hospitals and cardiac surgical practices across the Commonwealth of Virginia and North Carolina. Data are collected using the STS clinical data entry form to capture administrative, demographic, baseline clinical, operative, and 30-day outcomes data. VCSQI clinical and charge data acquisition and matching have been described previously.[8-11] Hospital charges are converted to costs and adjusted to 2018 equivalent dollars using the Centers for Medicare and Medicaid Services Inpatient Prospective Payment System adjustment for medical-related inflation.

All patients undergoing mitral valve surgery (N = 7261) in the VCSQI database from January 2011 to December 2018 were evaluated. After excluding endocarditis (868 patients), emergent operations (114 patients), and concomitant operations (n = 2192); patients with preoperative AF (n = 1675, 41.0%) were stratified by whether they underwent concomitant AF ablation. Further subgroup analysis evaluated concomitant ablation for patients with persistent vs paroxysmal AF. Trends in concomitant ablation were evaluated over time using linear regression as well as by center and surgeon mitral surgical volume. High (>50 cases/year), medium (20-50 cases/year), and low (<20 cases/year) surgeon volume was defined by the total number of mitral valve cases performed by each surgeon during the years they practiced in the VCSQI. These cutoffs are based on previously validated numbers used by Chikwe and colleagues.[12] The association between patient and center factors on implementation of concomitant ablation was assessed with multivariate logistic regression.

All variables use standard STS definitions including operative mortality (in-hospital or at 30 days) and major morbidity (renal failure, reoperation, stroke, deep sternal wound infection, and prolonged ventilation).[13] Analysis of lesion set for patients in STS data version 2.81 and 2.9 in which variables were available is included in the Supplemental Material (10% missing rate). This was a secondary analysis of the VCSQI database, which is primarily utilized for quality improvement purposes. As the dataset is devoid of Health Insurance Portability and Accountability Act patient identifiers, this study is exempt by the institutional review board at the University of Virginia (Tracking #21321).

Statistical Analysis

Continuous variables are presented as median and interquartile range, with categorical variables as count and percentage. Patients were stratified by concomitant AF ablation vs no concomitant AF ablation for univariate analysis using the chi-square or Mann Whitney *U* tests as appropriate. Hierarchical logistic regression was used to assess risk-adjusted association between concomitant surgical ablation and composite STS major morbidity or mortality with hospital center as a random effect. A model was also fit to assess risk-adjusted association between clinical as well as center or surgeon factors on use of concomitant ablation. Covariates for both models were selected a priori to include baseline demographics, comorbidities, and surgical factors based on STS risk models and full model statistics are included in the tables. All statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC). All figures were created using GraphPad Prism Version 8.0.1 (GraphPad Software, San Diego, California).

Results

Demographic and Patient Characteristics

A total of 1675 patients with preoperative AF underwent isolated mitral valve surgery during the study period and

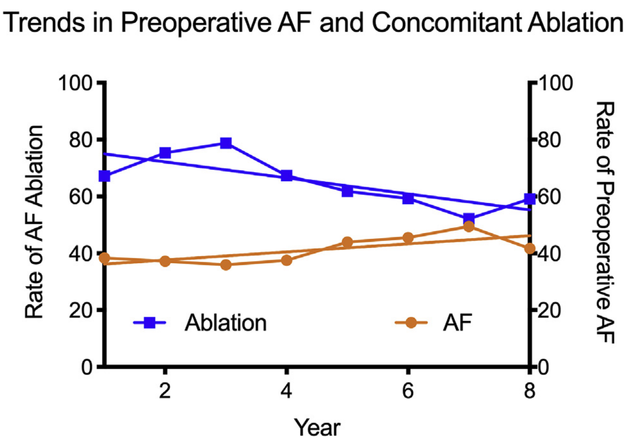

Figure 1. Trends in preoperative atrial fibrillation (AF) and concomitant ablation. The yearly rate of preoperative AF (right axis is shown in orange and concomitant ablation (left axis) is shown in blue. The regression line also plotted to demonstrate positive trend for preoperative AF (slope = +1.4%/year), while concomitant ablation had negative trend over the study period (slope = -2.8%/year) which was statistically significantly different (P = .002).

were included in the analysis, with only 1044 (64.6%) undergoing atrial ablation. The rate of preoperative AF increased over the study period (slope = +1.4%/year), while concomitant ablation decreased over the study period (slope = -2.8%/year), which was statistically significantly (P = .002) (Figure 1). Patients undergoing concomitant ablation were significantly younger (68 years of age vs 73 years of age; $P < .0001$) and more likely to be undergoing mitral valve repair (62.3% vs 46.2%; $P < .001$). Additionally, patients who underwent concomitant ablation had significantly lower rates of comorbidities (Table 1), resulting in significantly lower STS-predicted risk of major morbidity or mortality (20.1% vs 28.6%; $P < .001$).

Table 1. Baseline Characteristics and Demographics

Variable	Ablation (n = 1044)	No Ablation (n = 631)	P Value
Age, y	68 (61-74)	73 (63-80)	<.001[a]
Male	496 (45.6)	281 (47.9)	.372
Persistent AF	598 (54.9)	293 (49.9)	.048[a]
Tobacco use	292 (27.0)	221 (37.8)	<.001[a]
Heart failure	616 (56.6)	386 (65.8)	.003[a]
Hypertension	747 (68.7)	466 (79.4)	<.001[a]
Coronary artery disease	159 (14.6)	195 (33.2)	<.001[a]
Prior myocardial infarction	83 (7.6)	85 (14.5)	<.001[a]
Cerebrovascular disease	163 (15.0)	137 (23.3)	<.001[a]
Prior stroke	89 (8.2)	73 (12.4)	.005[a]
Peripheral arterial disease	55 (5.1)	74 (12.6)	<.001[a]
Dialysis	8 (0.7)	16 (2.73)	.001[a]
Diabetes mellitus	195 (17.9)	161 (27.4)	<.001[a]
Severe chronic lung disease	151 (14.4)	129 (22.6)	<.001[a]
Aortic insufficiency (>mild)	30 (2.8)	26 (4.4)	.069
Aortic stenosis (>mild)	31 (2.8)	33 (5.6)	.005[a]
Mitral regurgitation (>mild)	1019 (93.7)	522 (88.9)	.001[a]
Mitral stenosis (>mild)	197 (18.1)	144 (24.5)	.002[a]
Tricuspid regurgitation (>mild)	418 (38.4)	302 (51.5)	<.001[a]
Intraaortic balloon pump	39 (3.5)	19 (3.2)	.710
Urgent status	209 (19.2)	138 (23.5)	.038[a]
Reoperative status	106 (9.7)	238 (41.5)	<.001[a]
Prior valve surgery	87 (8.0)	202 (34.4)	<.001[a]
Mitral repair	634 (62.3)	313 (46.2)	<.001[a]
Left atrial appendage ligation	974 (93.3)	290 (46.0)	<.001[a]
Predicted morbidity or mortality, %	20.1 ± 12.7	28.6 ± 15.0	<.001[a]

[a]Statistically significant.

Values are n (%) or mean ± SD.

AF, atrial fibrillation.

Outcomes Stratified by Concomitant Ablation

Patients undergoing concomitant ablation had significantly longer cardiopulmonary bypass times (153 minutes vs 139 minutes; $P < .001$) but lower rate of intraoperative blood transfusions (27.1% vs 32.6%; $P = .018$). However, there was no difference in STS major morbidity or operative mortality (Table 2). Importantly, in all patients with preoperative AF, patients undergoing concomitant ablation were significantly less likely (10.1% vs 53.8%; $P < .001$) to be in AF at hospital discharge. Additionally, there was no difference in the rate of new permanent pacemaker placement before discharge (6.9% vs 6.2%; $P = .821$). Analysis of resource utilization demonstrated that patients undergoing concomitant ablation had significantly lower healthcare inflation–adjusted hospital cost ($43,804 vs $52,557; $P < .001$). After risk adjustment, concomitant ablation was not associated with composite morbidity or mortality after mitral valve surgery (odds ratio [OR], 1.02; 95% confidence interval, 0.74-1.40; $P = .903$; C-statistic = .834) (Table 3).

Factors Associated With Concomitant Ablation

Patients were then stratified by presence of persistent or long-standing persistent (891 patients) or paroxysmal (784 patients) AF, with higher rates of concomitant ablation in patients with persistent AF (67.1% vs 62.6%; $P = .001$). No trends were identified on analysis of lesion set used (Supplemental Table 1).

The rate of concomitant AF ablation was then assessed by center volume of mitral valve surgery, demonstrating that the rate of AF ablation ranged from 22.2% to 100% across the 19 centers, with case volume–isolated mitral surgery volume ranging from 342 to 7 over the study period (Figure 2). Next, cases were analyzed by surgeon total mitral volume across the 117 surgeons contributing cases during the study period. Only 3 surgeons met the criteria for high volume (>50 cases/year), with 15 surgeons stratified as medium volume (20-50 cases/year), and the remainder as low-volume (<20 cases/year) mitral valve surgeons, with 69 surgeons performing less than 10 mitral valve operations per year. Use of concomitant

Table 2. Outcomes

Variable	Ablation (n = 1044)	No Ablation (n = 631)	*P* Value
Intraoperative blood products	294 (27.1)	191 (32.6)	.018[a]
Cardiopulmonary bypass time, min	153 (123-185)	139 (104-177)	<.001[a]
Mortality	49 (4.5)	39 (6.6)	.061
Major morbidity	168 (15.4)	111 (18.9)	.069
Stroke	10 (0.9)	8 (1.4)	.396
AF on discharge	110 (10.1)	340 (53.8)	<.001[a]
New permanent pacemaker	72 (6.9)	39 (6.2)	.821
Renal failure	38 (3.5)	27 (4.6)	.263
Prolonged ventilation (>24 h)	125 (11.5)	89 (15.2)	.032[a]
Deep sternal wound infection	0 (0)	0 (0)	>.999
Reoperation	52 (4.8)	26 (4.4)	.746
Total ICU hours	66 (28-112)	64 (28-120)	.347
Hospital length of stay, d	7 (5-10)	6 (4-10)	<.001[a]
Discharge not home	206 (19.7)	153 (24.2)	.023[a]
Total cost, $	43,804 ± 30,809	52,557 ± 78,737	<.001[a]

[a]Statistically significant.

Values are n (%), median (interquartile range), or mean ± SD.

AF, atrial fibrillation; ICU, intensive care unit.

ablation was significantly different by surgeon total mitral volume (high 78.6% vs medium 62.5% vs low 59.0%; $P <$ .001) in patients with preoperative AF undergoing isolated mitral valve surgery.

Multivariable logistic regression highlighted several factors independently associated with concomitant ablation in our population (C-statistic =0.786) (Table 4). Patient factors associated with reduced rate of concomitant ablation included age (OR, 0.97), prior cardiac surgery (OR, 0.45), persistent AF (OR, 1.50), heart failure (OR, 0.64), tricuspid regurgitation (OR, 0.69), coronary artery disease (OR, 0.54), and dialysis dependent renal failure (OR, 0.34) (Table 4). Surgical factors including mitral valve repair vs replacement (OR, 1.35) and surgeon volume (high vs medium) (OR, 2.15) strongly predicted concomitant AF ablation in a risk-adjusted model.

Comment

The present study demonstrates wide variation in rate of concomitant surgical AF ablation during mitral valve surgery in a regional consortium with a decreasing rate (-2.8%/year) despite increasing rates of preoperative AF (+1.4%/year), as well as evidence and guidelines supporting its benefits. Patients who were older and with more medical comorbidities equating to greater surgical risk were less likely to undergo concomitant ablation. However, patients who underwent surgical

Table 3. Logistic Regression for Composite STS Major Morbidity or Mortality

Variable	Odds Ratio	95% CI	*P* Value
Intraaortic balloon pump	18.06	8.97-36.34	<.001[a]
Hypertension	1.66	1.14-2.40	.008[a]
Mitral repair (vs replace)	0.64	0.46-0.90	.011[a]
Tricuspid regurgitation	1.47	1.09-1.97	.011[a]
Chronic lung disease	1.55	1.10-2.20	.013[a]
Urgent status	1.35	0.97-1.89	.078
Continuous AF (vs paroxysmal)	0.78	0.59-1.05	.101
Aortic insufficiency (moderate/severe)	1.73	0.88-3.41	.112
Diabetes	1.28	0.92-1.78	.143
Prior stroke	1.51	0.83-2.74	.179
Peripheral arterial disease	1.38	0.84-2.27	.204
Aortic stenosis (moderate/severe)	1.50	0.79-2.86	.220
Female	1.15	0.85-1.55	.363
Mitral regurgitation (moderate/severe)	0.81	0.49-1.36	.433
Tobacco use	0.88	0.62-1.24	.449
Heart failure	1.10	0.79-1.53	.585
Prior cardiac surgery	1.06	0.78-1.44	.703
End-stage renal disease	0.83	0.29-2.36	.727
Age	1.00	0.99-1.02	.743
Prior myocardial infarction	0.95	0.59-1.52	.824
Coronary artery disease	0.97	0.67-1.41	.871
Concomitant AF ablation	1.02	0.74-1.40	.903
Hospital effect	1.06	0.53-2.11	.978
Mitral stenosis (moderate/severe)	0.99	0.66-1.50	.979

[a]Statistically significant.

AF, atrial fibrillation; CI, confidence interval; STS, Society of Thoracic Surgeons.

ablation had outstanding outcomes with low mortality and were significantly more likely to be in sinus rhythm at discharge. Additionally, patients with persistent AF who underwent valve repair by high-volume surgeons were more likely to undergo concomitant ablation. Furthermore, we demonstrate an adjusted association between surgeon mitral valve volume and performance of concomitant ablation, with the highest-volume surgeons more than twice as likely to perform surgical ablation.

A patient's risk profile is critical in determining the surgical approach and plan for their operation, including the decision to perform a concomitant AF ablation. Surgeons must balance the long-term benefit of surgical AF ablation with the immediate risk of prolonged bypass time and performing additional procedures when making these decisions. There is no doubt that the tipping point for these decisions certainly change as a surgeon gains experience with complex mitral valve surgery, and they are more able to balance this risk-benefit ratio. These factors may lead to lower rates of concomitant ablation because of risk-averse surgeons.[14] However, current data

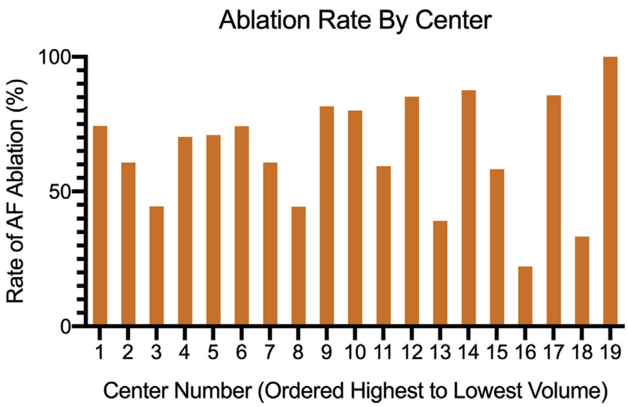

Figure 2. Rate of concomitant ablation by hospital. Rate of atrial fibrillation (AF) ablation during isolated mitral valve surgery ranged from 22.2% to 100% across the 19 centers. Results are presented in order of volume of mitral valve cases over the 8-year study period from left (highest volume) to right (lowest volume).

suggesting no additional risk with concomitant ablation may mislead policymakers and junior surgeons who are faced with these difficult decisions because these studies have selection bias. Many studies suggesting no increased risk with concomitant AF ablation excluded the sickest, lowest ejection fraction hearts that also required other concomitant procedures to identify a more homogenous group for trials and retrospective analyses.[15-17] Therefore, this study is in line with the STS guidelines supporting concomitant AF ablation during mitral valve surgery; however, this certainly does not apply to 100% of patients undergoing mitral valve surgery with preoperative AF, as there are patient and surgeon or center factors that must be considered. Our data suggest that centralization of complex mitral valve surgery may allow for increased rates of concomitant AF ablation, approaching 80% compared with the 64.6% reported in the current study.

The present study again highlights that surgeon mitral valve experience is strongly associated with the decision to perform concomitant AF ablation. Numerous prior studies have demonstrated a strong association between surgeon mitral valve volume and outcomes, long-term reoperation, and survival.[12,18-20] Specifically, many of these studies cited an increased rate of mitral repair vs replacement as a critical measure of surgeon experience when approaching complex mitral valve pathology.[21,22] Interestingly, in our risk-adjusted model, mitral valve repair was independently predictive of performance of concomitant AF ablation, suggesting collinearity between surgeon experience and mitral valve repair, as demonstrated by these previous studies.

Importantly, we demonstrate outstanding outcomes in selected patients undergoing concomitant AF ablation during mitral valve surgery. These results support prior literature, including the Cardiothoracic Surgery Trials Network randomized trial demonstrating safety of concomitant ablation.[3] Additionally, we highlighted no risk-adjusted association between composite STS

Table 4. Logistic Regression for Concomitant Ablation

Variable	Odds Ratio	95% CI	*P* Value
Surgeon volume (high vs mid)	2.15	1.47-3.15	<.001[a]
Age	0.97	0.96-0.98	<.001[a]
Prior cardiac surgery	0.45	0.35-0.58	<.001[a]
Coronary artery disease	0.54	0.40-0.74	.001[a]
Persistent AF	1.50	1.17-1.93	.002[a]
Heart failure	0.64	0.48-0.86	.002[a]
Tricuspid regurgitation	0.69	0.54-0.89	.004[a]
Sex (female)	1.39	1.07-1.80	.012[a]
Dialysis dependent	0.34	0.12-0.94	.038[a]
Mitral valve (repair vs replace)	1.35	1.01-1.81	.044[a]
Peripheral arterial disease	0.64	0.41-1.00	.051
Severe lung disease	0.73	0.53-1.00	.053
Mitral regurgitation	1.46	0.90-2.37	.126
Intraaortic balloon pump	1.71	0.85-3.43	.131
Cerebrovascular disease	0.78	0.50-1.20	.251
Diabetes mellitus	0.85	0.63-1.14	.275
Aortic stenosis	0.85	0.45-1.59	.607
Aortic insufficiency	0.87	0.47-1.62	.660
Tobacco use	0.96	0.72-1.27	.761
Mitral stenosis	1.05	0.73-1.53	.787
Hypertension	0.97	0.72-1.30	.811
Prior myocardial infarction	0.96	0.64-1.44	.830
Urgent status	0.97	0.71-1.33	.851
Prior stroke	0.96	0.55-1.66	.873
Surgeon volume (low vs medium)	0.98	0.70-1.38	.923
Hospital effect	1.58	1.00-2.48	.953

[a]Statistically significant.

AF, atrial fibrillation; CI, confidence interval.

major morbidity or mortality and concomitant ablation in this large multicenter cohort. Furthermore, we demonstrate that patients who undergo ablation were significantly more likely to be in sinus rhythm at hospital discharge. These data support the use of concomitant ablation during isolated mitral valve surgery for patients with AF at the discretion of the surgeon. Additional implementation science approaches should investigate barriers to adoption including surgeon inexperience, challenges in billing or reimbursement, or surgeon skepticism about efficacy of surgical AF ablation.

The limitations of the present study include the retrospective nature that precludes demonstration of causality. The present study was limited to 30-day outcomes, given the deidentified nature of the study compiling data from a regional STS consortium, which precludes determination of survival and long-term sequelae of AF. Additionally, our 8-year study period crosses 3 STS data versions that all use slightly different definitions of lesion set performed, limiting our ability to report these data. Finally, these results describe the use of concomitant ablation across a regional consortium accounting for approximately 99% of cardiac operations performed in the Commonwealth of Virginia, representing a real-world experience, but may not be applicable to other regions of the country.

The present study demonstrates that surgical AF ablation at the time of isolated mitral valve surgery continues to be underutilized in a real-world regional consortium despite Class 1A recommendations by the STS. This risk-adjusted analysis supports that concomitant ablation is not associated with increased morbidity or mortality after isolated mitral valve surgery. Finally, these data suggest that the significant variability may be related to surgeon volume and baseline patient risk, representing an opportunity for improvement.

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