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ORIGINAL PAPER

Comparative Analysis of Left Ventricular Mass Regression Following Transcatheter Aortic Valve Implantation and Surgical Aortic Valve Replacement – a Single Center Experience from Romania

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ABSTRACT

Introduction: *Severe aortic stenosis is often associated with left ventricular hypertrophy (LVH). Elevated left ventricular mass (LVM) is linked to higher cardiovascular morbidity and mortality. Traditionally, surgical aortic valve replacement (SAVR) has been the standard treatment, but transcatheter aortic valve implantation (TAVI) offers an alternative for high-risk surgical patients. Understanding how these interventions affect left ventricular mass regression is crucial.*

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Materials and methods: *This retrospective study analyzed 315 patients treated between December 2014 and December 2022, categorizing them into surgical and transcatheter treatment groups. Clinical and echocardiographic data were collected at baseline and six-month follow-up. Statistical analysis assessed differences between groups and predictors of LV mass reduction.*

Results: *The overall dataset indicated an average percentage reduction in LVM of 10.86%±29.41%. Segmenting the data, the TAVI subgroup exhibited a reduction of 4.28%±30.31%, while the SAVR subgroup highlighted a pronounced decline of 17.92%±26.76%. Preoperative LVMi and mean pressure gradient positively correlated with LVM reduction, while TAVI negatively impacted it.*

Conclusion: *Both TAVI and SAVR interventions yield benefits in reducing left ventricular mass, with SAVR showing a superior outcome. Recognizing predictors of LV mass regression is crucial for optimizing treatment strategies, and early valve replacement should be considered to prevent irreversible LV hypertrophy.*

Keywords: severe aortic stenosis, SAVR, TAVI, left ventricular mass index.

INTRODUCTION

Aortic stenosis (AS) is a prominent heart valve issue with the potential for serious health repercussions if left untreated (1). Left ventricular hypertrophy (LVH) often accompanies AS, a common occurrence in cardiovascular disease patients (2). Left ventricular hypertrophy serves as a physiological response aimed at balancing increased wall stress and sustaining cardiac output in AS cases. However, this adaptive mechanism leads to ventricular mass and cellular structure changes, culminating in fibrosis (3). Elevated levels of left ventricular mass (LVM) or left ventricular mass index (LVMi) are known to independently predict higher cardiovascular morbidity and mortality rates in general populations (4). Traditionally, surgical aortic valve replacement (SAVR) has been the go-to treatment for AS. However, the recent emergence of transcatheter aortic valve implantation (TAVI) provides a valuable alternative, particularly for patients at high surgical risk (5). While high LVMi has been linked to poorer outcomes in conservatively managed patients, this has not been observed in those who initially underwent SAVR (6). Both TAVI and SAVR have demonstrated their efficacy in promoting positive LV remodelling. However, the extent, characteristics, and clinical implications of this remodelling can differ between the two methods and among diverse patient groups (7). A nuanced understanding of these differences is essential for optimizing patient selection and tailoring post-procedure care.

This study aims to explore the complexities of changes in LV mass following TAVI and SAVR, investigating the factors that influence these changes. As far as we know, this study is the first of its kind reported from Romania. ❑

MATERIALS AND METHODS

Study design

This retrospective unicentric observational study was conducted in the Institute of Cardiovascular Diseases, Iasi, Romania. All patients included in the study were treated between December 2014 and December 2022. The study was approved by the institutional ethical board.

Patient selection

Patients were categorized into two treatment groups based on the intervention they received: TAVI and SAVR. The TAVI group included 180 patients. Of these, seven patients died during their hospital stay, and 10 were lost to follow-up, leaving 163 patients for the final analysis. The SAVR group included 166 patients. Among them, five patients died in the hospital, and nine were lost to follow-up, resulting in 152 patients included in the final analysis. The choice of treatment, whether TAVI or SAVR, was determined by a multidisciplinary heart team (cardiac surgeon, cardiologist, interventional cardiologist, anesthesiologist, and radiologist) after a comprehensive evaluation of each patient. TAVI was specifically chosen for patients identified as having a high surgical risk. All patients signed the informed consent.

Procedure characteristic

For TAVI, all procedures were uniformly performed under general anesthesia by the same resolute team, consisting of an interventional cardiologist and a cardiac surgeon. A range of valves were employed, including the Edwards SAPIEN 3 or SAPIEN XT (Edwards Lifesciences LLC, Irvine, CA, USA), Medtronic CoreValve and the newer-generation Medtronic Evolut R (Medtronic, CA, USA), the ACURATE neo and ACURATE neo 2 (Boston Scientific, Marlborough, MA, USA), Portico and Navitor (Abbott Structural Heart, St Paul, MN, USA), and Myval (Meril Life Sciences, India). The procedure utilized either a transfemoral or transapical approach for valve implantation.

In contrast, SAVR was performed under general anesthesia and was conducted by four different surgeons. The procedure involved a median sternotomy for surgical access. Cardiopulmonary bypass was established, and St. Thomas cardioplegic solution was employed for myocardial protection. All patients received a biological valve, specifically the Medtronic Hancock 2 (Medtronic, CA, USA).

Echography analysis

Transthoracic echocardiography (TTE) was performed on all participants using a Siemens Acuson X300 and General Electric Vivid T8 machines. Standard parasternal long-axis, short-axis, and apical views were obtained. All related cardiac parameters were obtained by the European and American guidelines for cardiac echography assessment (8-10). The LVM, LVMi, left atrial volume (LAV) and the left atrial volume index (LAVi) were calculated according to the recommendations of the American Society of Cardiology (8). The echography analysis primarily focused on measuring parameters of the left heart chambers and aortic valve function. Assessments were conducted at baseline and a six-month follow-up. A team of three certified cardiologists interpreted and analyzed all echography data. The regression ratio of LVM was defined as Regression ratio = [(preoperative LVMi−postoperative LVMi)÷preoperative LVMi]×100.

Statistical analysis

All statistical analyses were conducted using IBM SPSS Statistics 23 software. Categorical data were presented as percentages and continuous data as mean±standard deviation (SD). The normality of the distribution for continuous variables was assessed using the Shapiro-Wilk test. For the comparison of categorical data between groups, the Chi-square test or Fisher's exact test was employed, as appropriate. For continuous data, the independent t-test was used for normally distributed data, and the Mann-Whitney U test was utilized for non-normally distributed data. To compare continuous data before and after the intervention within the same group, the paired t-test or Wilcoxon signed-rank test was applied accordingly. A p-value of less than 0.05 was considered statistically significant. A linear univariate and multivariate regression were conducted to reveal potential predictive factors of LVM reduction. ❑

RESULTS

The evaluation of preoperative data, as detailed in Table 1, revealed several statistically significant differences between the TAVI and SAVR groups. In terms of age, the TAVI group was, on average, older, with an age of 76.36±6.56 years, compared to 71.84±6.00 years in the SAVR group ($p<0.05$). Additionally, prior heart interventions were more frequent in the TAVI group at 8.5%, as opposed to 1.3% in the SAVR group ($p<0.05$). Notably, EUROSCORE II values indicated a higher risk profile for the TAVI group, with a mean score of 16.15±4.25%, compared to 7.11±2.78% in the SAVR group ($p<0.05$).

Focusing on cardiac metrics (Table 2), LVM was significantly higher in the SAVR group, averaging 340.92±99.83 g, in contrast to 323.78±95.33 g in the TAVI group. Concurrently, the LVMi also showed an elevation in the SAVR group at 184.03±52.16 g/m^2, compared to 171.85±47.70 g/m^2 in the TAVI group. Despite this, preoperative measurements did not show a statistically significant difference ($p\geq0.05$).

After the procedure (Table 3), the TAVI group demonstrated a shorter ICU stay, averaging 2.23±2.73 days, *versus* 9.56±8.82 days in the SAVR group ($p<0.05$). The time of OTI time was also reduced in the TAVI group (10.34±16.08 hours) relative to the SAVR group (52.05±133.34 hours, $p<0.05$). Moreover, a marked difference was observed in drug support requirements, with 27.6% of the TAVI cohort needing it, compared

TABLE 1. Patients' preoperative baseline characteristics

	Total (315) % or mean ± SD	TAVI (163) % or mean ± SD	SAVR (152) % or mean ± SD	p-value
Age, years	74.18 ± 6.68	76.36 ± 6.56	71.84 ± 6.00	p<0.05
Male, %				
BMI, kg/m²	28.15 ± 4.80	28.74 ± 5.32	27.52 ± 4.09	p<0.05
Smokers	27.9	23.3	32.8	p≥0.05
Hypertension	68.2	68.1	68.4	p≥0.05
Diabetes	27.9	35.5	19.7	p<0.05
Stroke	8.8	6.7	11.1	p≥0.05
PAD	18.1	21.4	14.4	p≥0.05
Reduced mobility	18.7	34.9	1.31	p<0.05
COPD	12.1	11.6	12.5	p≥0.05
Afi	27.3	25.1	29.6	p≥0.05
Previous heart interventions	5.1	8.5	1.3	p<0.05
Previous PP	4.4	6.1	2.6	p≥0.05
EUROSCORE II, %	11.79 ± 5.79	16.15 ± 4.25	7.11 ± 2.78	p<0.05

BSA=body surface area; BMI=body mass index; PAD=peripheral artery disease; COPD=chronic obstructive pulmonary disease; Afi=atrial fibrillation; PP=permanent pacemaker.

TABLE 2. Preoperative cardiac echography parameters

	Total (315) % or mean ± SD	TAVI (163) % or mean ± SD	SAVR (152) % or mean ± SD	p-value
LVEDD, mm	50.51 ± 7.26	50.14 ± 7.17	50.92 ± 7.35	p≥0.05
LVESD, mm	35.82 ± 7.35	35.54 ± 6.88	36.13 ± 7.84	p≥0.05
IVSd, mm	15.43 ± 2.48	15.42 ± 2.40	15.44 ± 2.57	p≥0.05
PWd, mm	14.24 ± 2.09	14.05 ± 2.12	14.44 ± 2.05	p≥.05
LVEF, %	52.38 ± 12.65	53.04 ± 10.50	51.67 ± 14.61	p≥0.05
Ao annulus, mm	23.03 ± 2.54	22.62 ± 2.33	23.46 ± 2.69	p<0.05
MPG, mm Hg	54.65 ± 17.79	57.11 ± 16.08	52.01 ± 19.17	p<0.05
LAVi, ml/m²	25.72 ± 7.47	28.40 ± 7.43	22.85 ± 6.38	p<0.05
LVM, g	332.05 ± 97.75	323.78 ± 95.33	340.92 ± 99.83	p≥0.05
LVMi, g/m²	177.73 ± 50.19	171.85 ± 47.70	184.03 ± 52.16	p≥0.05
RWT	0.57 ± 0.13	0.57 ± 0.14	0.58 ± 0.13	p≥0.05

LVEDD=left ventricle end diastolic dimension; LVESD=left ventricular end-systolic dimension; IVSd=interventricular septal end diastole; PWd=posterior wall thickness at end-diastole; SF=shortening fraction; LVEF=left ventricular ejection fraction; MPG=mean pressure gradient; Ao annulus=aortic annulus; AA diameter=ascending aorta diameter; LAV=left atrial volume; LVAi=left atrial volume index; LVM=left ventricular mass; LVMi=left ventricular mass index; RWT=relative wall thickness

TABLE 3. Post-procedural data

	Total % or mean ± SD	TAVI (163) % or mean ± SD	SAVR (152) % or mean ± SD	p-value
ICU stay, days	5.77 ± 7.40	2.23 ± 2.73	9.56 ± 8.82	p<0.05
OTI, h	30.46 ± 95.50	10.34 ± 16.08	52.05 ± 133.34	p<0.05
Drugs support	53.0	27.6	80.2	p<0.05
AMI	0.3	0.0	0.6	p≥0.05
AKI	10.4	7.9	13.1	p≥0.05
Hemodialysis	3.1	1.8	4.6	p≥0.05
New arrhythmias	40.9	14.1	69.7	p<0.05
GI complications	6.3	4.9	7.8	p≥0.05
New - PPI	4.8	6.1	3.3	p≥0.05

ICU=intensive care unit; OTI=oro-tracheal intubation; AMI=acute myocardial infarction; AKI=acute kidney injury; GI=gastro-intestinal; PPI=permanent pacemaker implantation

to a substantial 80.2% in the SAVR group (p<0.05).

A comprehensive baseline *versus* follow-up data assessment accentuated the evolution in left ventricular remodelling (Table 4). In particular, the LVMi underwent significant transformations for both the TAVI and SAVR cohorts. The overall dataset indicated an average percentage reduction in left ventricular mass of 10.86%±29.41%. Segmenting the data, the TAVI subgroup exhibited a reduction of 4.28%±30.31%, while the SAVR subgroup highlighted a pronounced decline of 17.92%±26.76%. Analysis between the TAVI and SAVR subgroups illuminated a statistically significant difference in left ventricular mass reduction ($p<0.05$). All geometric parameters (LVEDD, LVESD, IVSd, PWd) decreased significantly after SAVR ($p < 0.05$), while in the TAVI group only IVSd and PWd experienced a valuable shift. Alongside, both groups displayed distinct functional improvement (LVEF, MPG), emphasizing the shifting dynamics of cardiac function post-intervention.

In our analysis, several variables emerged as significant predictors for the reduction ratio of LVMi following valve replacement procedures, both in univariate and multivariate models (Table 5). Importantly, the Preoperative MPG had a positive impact on LVMi reduction in both models (Univariate: Beta = 0.18; 95% CI 0.12 to 0.47; $p < 0.001$; Multivariate: Beta = 0.14; 95% CI 0.08 to 0.36; $p < 0.01$). Similarly, Preoperative LVMi also exhibited a positive predictive value (Univariate: Beta = 0.64; 95% CI 0.32 to 0.41; $p < 0.0001$; Multivariate: Beta = 0.59; 95% CI 0.29 to 0.39; $p < 0.0001$). The relationships between preoperative LVMi, MPG and relative LVMi regression ratio are illustrated in Figure 1A, B. Conversely, TAVI showed a negative impact on LVMi reduction (Univa-

TABLE 4. Comparison between preoperative and postoperative echography data

	Baselines data, mean ± SD	Follow-up, mean ± SD	p - value
LVEDD, mm			
TAVI	50.14 ± 7.17	49.02 ± 5.56	p ≥ 0.05
SAVR	50.92 ± 7.35	47.64 ± 5.93	p < 0.05
LVESD, mm			
TAVI	35.54 ± 6.88	35.94 ± 5.11	p ≥ 0.05
SAVR	36.13 ± 7.84	33.37 ± 5.95	p < 0.05
IVSd, mm			
TAVI	15.42 ± 2.4	14.4 ± 1.81	p < 0.05
SAVR	15.44 ± 2.57	14.08 ± 2.05	p < 0.05
PWd, mm			
TAVI	14.05 ± 2.12	13.65 ± 1.82	p < 0.05
SAVR	14.44 ± 2.05	13.11 ± 1.72	p < 0.05
MPG, mm Hg			
TAVI	57.11 ± 16.08	9.98 ± 2.81	p < 0.05
SAVR	52.01 ± 19.17	15.48 ± 5.58	p < 0.05
EF, %			
TAVI	53.04 ± 10.5	55.99 ± 8.07	p < 0.05
SAVR	51.67 ± 14.61	55.53 ± 7.69	p < 0.05
LVMi, g/m²			
Total	177.73 ± 50.19	149.02 ± 38.23	p < 0.05
TAVI	171.85 ± 47.7	155.67 ± 37.48	p < 0.05
SAVR	184.03 ± 52.16	141.89 ± 37.86	p < 0.05
LVMi reduction, %			
Total	10.86 ± 29.41		
TAVI	4.28 ± 30.31		
SAVR	17.92 ± 26.76		

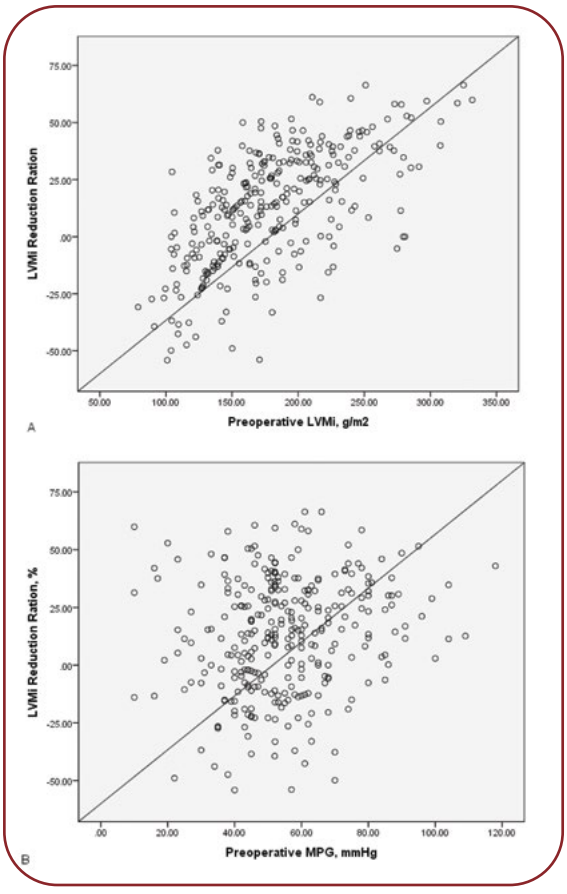

FIGURE 1. The relationships between preoperative LVMi, MPG and relative LVMi regression ratio

	Univariate			Multivariate		
	Beta	**95.0% CI**	**p-value**	**Beta**	**95.0% CI**	**p-value**
Age, years	-0.057	-7.53; 67.67	0.18			
Male	-0.046	-9.05; 3.77	0.41			
BMI	-0.156	-1.59; -0.28	0.006	-0.03	-0.72; 0.36	0.51
Smokers	0.19	5.03; 19.04	0.001	0.06	-1.52; 9.29	0.16
Hypertension	-0.06	-10.56; 3.12	0.29			
Diabetes	-0.16	-17.35; -3.32	0.004	-0.04	-8.30; 3.22	0.39
Stroke	-0.09	-21.08; 1.23	0.08			
PAD	-015	-19.14; -2.74	0.009	-0.12	-15.18; -2.49	0.006
Reduced mobility	-0.12	-17.04; -0.81	0.03	0.02	-5.20; 8.77	0.62
COPD	0.072	-3.39; 16.15	0.20			
AFi	-0.05	-10.19; 4.12	0.41			
Previous heart interventions	-0.08	-24.05; 4.11	0.16			
Previous PP	-0.06	-23.77; 7.14	0.29			
EUROSCORE II	-0.18	-1.42; -0.34	0.002	0.04	-0.45;0.88	0.52
LVEF	-0.06	-0.37; 0.13	0.33			
Ao annulus	0.15	0.43; 2.94	0.009	-0.03	-1.28; 0.70	0.57
AA diameter	0.11	-0.02; 1.25	0.06			
MPG	0.18	0.12; 0.47	0.001	0.14	0.08; 0.36	0.002
Preop-LVAi	-0.06	-0.67; 019	0.27			
Preop-LVMi	0.64	0.32; 0.41	0.0001	0.59	0.29; 0.39	0.0001
TAVI	-0.24	-20.21; -7.83	0.0001	-0.21	-20.112; -4.360	0.002
New - PPI	-0.04	-20.19; 9.76	0.49			
Ao insufficiency	-0.04	-10.05; 4.99	0.51			

TABLE 5. Univariate and multivariate linear regression results regarding the impact on the LVMi reduction ratio

riate: Beta = -0.24; 95% CI -20.21 to -7.83; p < 0.0001; Multivariate: Beta = -0.21; 95% CI -20.112 to -4.360; p < 0.01). Additionally, peripheral artery disease (PAD) also emerged as a significant predictor in both models, although the direction of its impact needs to be clarified.

These robust predictors warrant further clinical investigation for their implications on LVMi reduction following valve replacement therapies. ❑

DISCUSSION

The preoperative data analysis in the study cohorts revealed a series of differences between TAVI and SARV groups. Specifically, patients in the TAVI group were older, with a higher rate of diabetes and reduced mobility. Furthermore, the EUROSCORE II was higher in the transcatheter intervention cohort. On the echocardiographic data front, TAVI patients exhibited a smaller aortic annulus, higher mean transaortic gradient, and larger LAV compared to those undergoing traditional surgical treatment. These findings are consistent with the national program for transcatheter therapy of severe aortic stenosis in Romania, which is geared towards patients with elevated surgical risk. Similar differences have been reported in other observational studies, patients recommended for surgery had a higher surgical risk profile (11, 12).

Regarding the immediate postoperative results, several authors have reported similar outcomes to ours. Thus, Umegaki *et al* indicated a longer duration of stay in the intensive care unit and a greater need for inotropic support in patients undergoing SAVR (13). Additionally, a comparative study involving 366 patients in the SAVR group and 415 in the TAVI cohort, published by Shahim *et al*, confirmed a higher rate of arrhythmias in the surgical treatment group (14). Although it is generally confirmed that the rate of pacemaker implantation is higher in those treated with TAVI (15), our comparative study did not confirm this, with the differences not reaching statistical significance.

Our findings corroborate with a study that showed superior hemodynamic outcomes in TAVI patients, particularly in terms of lower trans-prosthetic gradients (16). However, this advantage comes with a caveat: TAVI patients had a higher incidence of aortic regurgitation (17). This raises the question of whether the hemodynamic benefits of TAVI are offset by this complication, warranting further investigation.

In both intervention groups, the preoperative and postoperative assessments of LV geometry and hemodynamic function revealed noteworthy changes. Following aortic valve intervention, all geometric parameters exhibited significant decreases in the SAVR group, while only IVSd and PWd changed in TAVI patients. Similarly, most hemodynamic function parameters showed substantial post-intervention modification, except for the RWT ratio, which did not show a correlation with the regression of LVMi. This lack of correlation may be attributed to irreversible non-hemodynamic factors, such as increased fibrosis or preoperative functional deterioration in our patient groups.

We observed an average percentage reduction in LVM of 10.86%. When segmented, the TAVI subgroup showed a reduction of 4.28, whereas the SAVR subgroup exhibited a more pronounced decline of 17.92%. These findings are in line with the 14.5% reduction reported in the PARTNER Trials and Registries (18). However, our data also corroborate another study that found a more significant 17.5% LVM regression in patients undergoing SAVR compared to a 7.2% reduction in TAVI patients (19). This suggests that, while TAVI is effective, SAVR may offer superior LVMi regression, potentially due to fewer complications. Furthermore, a higher preoperative LVMi was significantly associated with a more substantial reduction in LV mass, similar results were reported by Chen *et al* (20).

In our regression model, several parameters emerged as potential predictors of the regression ratio of LVM. Specifically, the preoperative higher MPG and LVMi were associated with a greater reduction in the rate of LVM regression. Conversely, the TAVI procedure was associated with less reduction.

Post-procedure outcomes, especially in terms of left ventricular remodelling, appear to vary between TAVI and SAVR and among different patient groups. For example, women with severe AS often have better long-term outcomes following TAVI than SAVR, where their survival rates are not as favourable as men (21). The process of LV remodelling, specifically the reduction in LVM, is crucial in determining patient prognosis post-valve intervention for AS (22).

Finally, the road ahead is paved with opportunities for improving patient post-TAVI outcomes (23). From early interventions in asymptomatic aortic stenosis to individualized management of comorbidities, a holistic approach is likely to yield the best results (16).

Study limitations

There are several limitations to consider in this study. Firstly, it was a nonrandomized retrospective analysis involving a limited number of patients. Secondly, the accuracy of echocardiographic assessments depended on the individual observers. Thirdly, the short follow-up period may not have allowed an adequate time for significant changes to occur in the left ventricular myocardium. Lastly, the inclusion of a variety of TAVI valve types could introduce potential biases when compared to using a single type of valve in SAVR patients. ❑

CONCLUSIONS

Both interventions provide benefits in terms of reducing left ventricular mass, although classical surgical treatment still offers a superior outcome. Nonetheless, it is crucial to bear in mind that individuals undergoing TAVI procedures often present with a higher prevalence of comorbidities, advanced age, and more severe cardiac dysfunction. Furthermore, the persistence of hypertrophy following the relief of left ventricular pressure overload may be attributed to enduring alterations in interstitial fibrosis resulting from prolonged illness, potentially influencing the study outcomes. Scheduling valve replacement at an earlier stage should be considered to prevent irreversible, maladaptive left ventricular hypertrophy. Additionally, it is important to identify predictors of myocardial fibrosis. ❑

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