Outcomes of double valve surgery for active infective endocarditis

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Objective: In active infective endocarditis the need for operating simultaneously on the aortic and mitral valves is frequent. There are no studies in the literature documenting long-term outcomes of double valve surgery for active endocarditis.

Methods: Ninety patients underwent double valve surgery for active endocarditis over a 26-year period (mean age, 53 ± 16 years; 71% male patients). Prosthetic endocarditis was seen in 32 patients. *Staphylococcus* species was isolated in 29%. Forty-six (51%) patients had abscesses. Surgical intervention consisted of valve repair or replacement with limited infection or radical resection, patch reconstruction, and valve replacement for abscesses. Mean follow-up was 5.9 ± 4.7 years (range, 0–18 years) and was complete.

Results: There were 14 (15.6%) in-hospital deaths and 29 (32.2%) late deaths. Overall survival at 5, 7, and 10 years was $68\% \pm 5\%$, $59\% \pm 6\%$, and $49\% \pm 6\%$, respectively, and was reduced in those undergoing operations for prosthetic compared with native endocarditis (7-year survival, $39\% \pm 9\%$ vs $71\% \pm 7\%$; $P < .001$). Freedom from recurrent endocarditis was $84\% \pm 5\%$ at 10 years. Freedom from reoperation was $91\% \pm 4\%$ at 10 years. Event-free survival at 7 and 10 years was $60\% \pm 6\%$ and $47\% \pm 7\%$, respectively. No difference was observed between the native and prosthetic groups for recurrent endocarditis, late reoperation, or event-free survival. Prosthetic endocarditis, increasing age, preoperative shock, and diabetes mellitus were independent predictors of death from all causes.

Conclusions: Double valve surgery for active endocarditis remains technically challenging and associated with significant morbidity and mortality perioperatively and in the longer term. Outcomes are worse in those who have prosthetic valve endocarditis.

Extensive tissue destruction and abscess formation in patients with infective endocarditis can make surgical intervention for infective endocarditis especially difficult. Radical debridement and reconstruction form the cornerstone of surgical management in infective endocarditis.¹⁻³ The complexity of the operation is markedly increased when more than 1 valve is involved. Double valve surgery (aortic and mitral) for active endocarditis is second in frequency only to isolated aortic valve involvement.⁴ There have been no studies that have documented long-term outcomes of double valve surgery in patients who have active infective endocarditis. We therefore undertook this study.

MATERIALS AND METHODS

A review of the Toronto General Hospital cardiac surgery database from 1979 to 2004 revealed 90 patients who had undergone surgical intervention for active endocarditis in which both the mitral and aortic valves underwent

surgical intervention. Either 1 or both valves had active infection. We included patients undergoing double valve surgery with 1 actively infected valve and a second diseased but noninfected valve because the pathology encountered and the operation required are complex. Patients with remote or healed endocarditis were excluded. Patients with additional endocarditis involvement of the right-sided valves or in whom further surgical intervention was required to the right-sided valves were also excluded. Where necessary, relevant information was also derived by reviewing hospital medical records. Approval was obtained from the ethics review board of the hospital. Indications for surgical intervention were 1 or more of the following: shock, 14 (16%); congestive cardiac failure, 64 (72%); cerebral embolism, 26 (29%); and perivalvular abscess, 46 (51%). Table 1 shows the clinical characteristics of the patients.

Infecting Organisms

Data for the infecting organism were available for 75 patients. *Staphylococcus* species was most commonly encountered: *Staphylococcus aureus* in 14 (16%) patients and *Staphylococcus epidermidis* in 12 (13%) patients. *Streptococcus viridans* was found in 13 (14%) patients, *Enterococcus faecalis* was found in 8 (9%) patients, other *Streptococcus* species were found in 13 (14%) patients, *Pseudomonas* species were found in 2 (2%) patients, other bacteria were found in 4 (4%) patients, and culture-negative endocarditis was found in 9 (10%) patients.

Operative Procedures

The extent of tissue destruction from the endocarditis was assessed. Where infection was limited to the leaflets of the native or prosthetic valve, simple replacement or repair, if feasible, in the case of the mitral valve, was performed. Where infection had extended to or beyond the annulus, surgical intervention consisted of radical resection of all infected tissue, followed by reconstruction as necessary with valve replacement, as has been previously

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Abbreviations and Acronyms

CI = confidence interval

HR = hazard ratio

described.^{1-3,5} Pre-existing mitral and aortic valve pathology is described in Table 2. Operative data are summarized in Table 3. The average cardiopulmonary bypass time was 158 ± 60 minutes with a crossclamp time of 124 ± 42 minutes.

Follow-up

All patients were reviewed annually by the referring cardiologist, and data were collected prospectively. Our dedicated research personnel verified all cardiac events and maintained a comprehensive database. The mean follow-up was 5.9 ± 4.7 years (range, 0–18 years) and was complete.

Statistics

Continuous variables were reported as the mean $\pm$ standard deviation. All data analyses were performed with SAS 9.1 Software (SAS Institute, Inc, Cary, NC). Fisher's exact or χ^2 tests were used to evaluate categorical variables univariately and were reported as frequencies. Student's *t* test was used to analyze continuous variables that had normal distribution, and the Wilcoxon rank test was used for variables that had nonparametric distribution. The Kaplan-Meier method was used to calculate estimates for long-term survival, freedom from late reoperation, freedom from recurrent endocarditis, and event-free survival. Event-free survival was defined as the freedom from thromboembolism (including stroke), valve thrombosis, hemolysis, structural valve dysfunction, perivalvular leak, major bleeding event, endocarditis, reoperation, and death in hospital survivors. In line with the recent Society of Thoracic Surgeons guidelines on reporting outcomes after valve surgery,⁶ we have defined operative mortality as death within 90 days of the operation. All preoperative variables with a univariate *P* value of less than .25 or those judged to be clinically important were submitted to the multivariable model for Cox regression analysis to determine the independent predictors of operative and late deaths.

RESULTS

Eighty-one patients had active endocarditis involving both the aortic and mitral valves. In 9 patients there was active infection of one valve, and the other valve also underwent surgical intervention for the following reasons: dilated mitral annulus, 2; myxomatous or prolapsing mitral valve, 2; rheumatic mitral valve, 1; ischemic mitral valve, 1; rheumatic aortic valve, 1; and prolapsing aortic valve, 2.

There were 14 (16%) operative deaths (death within 90 days). Operative mortalities are summarized for the various subgroups in Table 4. Although cause of death was usually multifactorial, the main causes were as follows: cardiogenic shock, 5; cardiac arrest, 1; stroke, 3; multiorgan failure, 3; excessive postoperative hemorrhage, 1; and failure to wean from cardiopulmonary bypass, 1. In this group, of the significant factors identified in the univariate analysis for operative deaths, prosthetic endocarditis was present in 9 patients, diabetes in 5 patients, hypertension in 6 patients, and preoperative shock in 7 patients. Of borderline statistical significance was female sex (*P* = .058); 7 patients were female. Ten patients had paravalvular abscesses. Double

TABLE 1. Clinical characteristics

	No.	Percentage
Mean age (y)	53.3 ± 15.8	
Male sex	64	71
Comorbid conditions		
Diabetes mellitus	13	15
Hypertension	19	22
Chronic obstructive lung disease	7	8
Renal failure	20	22
Recent myocardial infarction (<30 d)	2	2
Recent stroke or transient ischemic attack (<30 d)	26	29
Peripheral vascular disease	4	5
New York Heart Association class		
I	3	3
II	4	5
III	6	7
IV	76	85
Preoperative rhythm		
Sinus rhythm	69	77
Atrial fibrillation	21	23
Cardiogenic or septic shock	14	16
Congestive cardiac failure	64	72
Endocarditis		
Native	58	64
Prosthetic	32	36
Previous cardiac surgery	34	38
Coronary artery bypass	5	6
Aortic valve replacement	27	30
Aortic valve repair	1	1
Mitral valve repair	1	1
Mitral valve replacement	18	20
Tricuspid valve repair	0	
Aortic annular enlargement	27	35
Annulus	12	15
Sinuses	4	5
Both	11	14
Left ventricular ejection fraction		
$\geq 40\%$	71	85
$< 40\%$	13	16
Timing of operation		
Elective/same hospitalization	35	42
Urgent/emergency	49	58

TABLE 2. Pre-existing valve pathology

	No.	Percentage
Aortic valve pathology		
Bicuspid	15	17
Rheumatic	8	9
Calcific degeneration	7	8
Prosthetic dysfunction	16	18
Mitral valve pathology		
Rheumatic	12	13
Myxomatous	5	6
Ischemic	1	1
Prosthetic dysfunction	11	12
Annular dilatation	2	2

TABLE 3. Operative data

	No.	Percentage
Mitral valve operation performed		
Mitral valve repair	25	28
Mitral valve replacement	65	72
Mitral valve prosthesis used		
Mechanical	46	51
Bioprosthesis	19	21
Repair ring/band	7	8
Mitral valve annulus reconstruction	29	29
Autologous pericardium	8	9
Bovine pericardium	18	20
Chordal preservation in mitral valve replacement		
Posterior only	10	11
Anterior and posterior	10	11
Polytetrafluoroethylene* sutures	14	16
Aortic valve operation performed		
Aortic valve replacement	78	87
Tissue prosthesis	27	30
Mechanical prosthesis	51	57
Aortic root replacement	12	13
Composite mechanical graft	5	6
Freestyle stentless	2	2
Composite tailored tissue graft	1	1
Homograft	4	4
Reconstruction of intervalvular fibrous body	25	28
Concomitant procedures		
Coronary artery bypass grafting	12	13
Replacement of supracoronary ascending aorta	2	2
Abscess	46	51.1

*Gore-Tex sutures; W. L. Gore & Associates, Inc, Newark, Del.

valve replacement with reconstruction of the intervalvular fibrous body and aortic root replacement were not associated with increased operative mortality. When examining for any change over time, we found no difference in operative mortality between the first and second halves of the study (17% for 1979–1994 vs 14% for 1995–2004, $P = .69$).

The mean stay in the intensive care unit was 7.9 ± 18.3 days (median, 3 days), with mean ventilation times of 4.4 ± 12 days (median, 1 day). Postoperative complications are summarized in Table 5. Mean hospital stay was 19 ± 15 days (median, 16 days). Six patients required repeat operations during the same admission, 5 for technical complications: mitral annulus patch dehiscence, 2; Gerbode-type ventricular septal defect, 1; ascending aortic false aneurysm, 1; aortic sinus fistula to the pulmonary artery, 1; and recurrent endocarditis, 1. There was 1 death associated with these repeat early operations. There were no cases of deep sternal wound infection.

A further 29 patients died during follow-up. There were 10 valve-related deaths (recurrent endocarditis in 6, perivalvular leak in 1, anticoagulation-related hemorrhage in 1, cardiac arrest in 1, and sudden death in 1) and a further 10 cardiac deaths (congestive heart failure in 6 and myocardial infarction in 4). There were 9 noncardiac deaths (cancer in 6, renal

TABLE 4. Operative mortalities in various subgroups

Variable	No.	Mortality (%)	P value
Patient characteristics			
Native endocarditis	58	8.6	
Prosthetic endocarditis	32	28.1	.015
Female sex	26	26.9	.058
Diabetes	13	38.5	.015
Hypertension	19	31.6	.02
Preoperative shock	14	50	.0001
Preoperative renal failure	20	20	.5
Preoperative stroke, transient ischemic attack	26	23.1	.22
Preoperative atrial fibrillation	21	4.8	.17
Preoperative congestive heart failure	64	17.2	.75
Preoperative syncope	5	40	.178
Paravalvular abscess	46	21.7	.15
<i>Staphylococcus aureus</i>	14	14.3	1
Ejection fraction <40%	13	15.4	1
NYHA class			
I/II/III	13	7.69	
IV	76	17.1	.68
Timing of operation			
Elective/same hospitalization	35	8.6	
Urgent/emergency	49	18.4	.34
Any redo operation	34	26.5	.026
Previous mitral valve surgery	19	31.6	.03
Previous aortic valve surgery	28	25	.097
Operative factors			
Mitral valve chordal preservation	20	15	1
Mitral valve annulus reconstruction	26	23.1	.24
Mitral valve repair	25	4	.1
Mitral valve replacement	65	20	
Aortic valve prosthesis			
Tissue	34	14.7	
Mechanical	56	16.1	.86
Double valve replacement with reconstruction of intervalvular fibrous body	25	20	.47
Aortic root replacement	12	8.3	1

NYHA, New York Heart Association.

failure in 2, and bowel ischemia in 1). Survival was $68\% \pm 5\%$, $59\% \pm 6\%$, and $49\% \pm 6\%$ at 5, 7, and 10 years, respectively (Figure 1). Survival was greater in those undergoing operations for native valve endocarditis than for prosthetic valve endocarditis (7-year survival, $71\% \pm 6\%$ vs $39\% \pm 9\%$, respectively; $P < .001$; Figure 2). Cox regression analysis identified diabetes (hazard ratio [HR], 4.91; 95% confidence interval [CI], 2.15–11.23; $P < .001$), prosthetic valve endocarditis (HR, 4.1; 95% CI, 1.92–8.56; $P < .001$), preoperative shock (HR, 2.63; 95% CI, 1.1–6.3; $P = .03$), and increased age (HR, 1.3; 95% CI, 1.14–1.54; $P < .001$) as independent predictors of death from all causes. Double valve replacement with reconstruction of the intervalvular fibrous body, a sizeable surgical undertaking, and aortic root replacement were not predictors of late death.

TABLE 5. Postoperative complications

Complication	No.	Associated mortality (%)	P value
Reopening			
For bleeding	8	25	.61
For tamponade	3	0	
Arrest	1	100	
Redo operation	6	17	1
Stroke	5	80	.002
Intraoperative	3		
Postoperative	2		
Renal failure	7	57.1	.012
Sepsis	4	0	1
Pulmonary complications	22	9.1	.5
Insertion of permanent pacemaker	12	16.7	1
Need for inotropes	68	17.7	.5

Recurrence of endocarditis was seen in 10 patients. Of the significant factors associated with operative and late deaths, prosthetic endocarditis was present in 2 patients, and preoperative shock was present in 2 patients. Paravalvular abscess was present in 6 patients at the first operation for endocarditis. Four had early endocarditis (≤ 1 year). The infecting organism was different from the original episode in 5 patients and the same in 1 patient, and in 4 patients this information was missing because the patients were readmitted to other hospitals. Three of these patients underwent reoperations and survived. Of the 7 patients managed conservatively with antibiotic therapy, there was only 1 survivor. Of the 6 endocarditis-related deaths, 1 was an intravenous drug abuser. Freedom from recurrent endocarditis overall was $88\% \pm 4\%$ at 5 years and $84\% \pm 5\%$ at 10 years. There was no significant difference in freedom from recurrence of endocarditis between the native and prosthetic endocarditis groups (7-year freedom from endocarditis was $80\% \pm 6\%$ for native valve and $95\% \pm 5\%$ for prosthetic endocarditis, $P = .16$).

Late morbidity events are summarized in Table 6. There were no instances of valve hemolysis. There were 10 late re-

FIGURE 1. Long-term actuarial survival for all patients.

FIGURE 2. Long-term actuarial survival for the native versus prosthetic endocarditis groups.

operations, for which there were no operative mortalities for patients undergoing reoperation. In one of the 3 patients requiring a reoperation for paravalvular leak, mitral annulus patch reconstruction with bovine pericardium had been performed, and the patch had subsequently calcified and fractured, giving rise to mitral prosthesis dehiscence. Freedom from reoperation was $93\% \pm 4\%$ at 7 years and $90\% \pm 4\%$ at 10 years (Figure 3). Freedom from reoperation was similar between the native and prosthetic endocarditis groups (at 7 years, $92\% \pm 5\%$ vs $95\% \pm 5\%$; $P = .72$).

At the latest follow-up, 47 patients were alive, of whom 38 were free from reoperation and were in New York Heart Association functional class I (27 [71%]), II (7 [18%]), and III (4 [11%]). Overall event-free survival at 7 and 10 years was $60\% \pm 6\%$ and $47\% \pm 7\%$, respectively, and no difference was observed between the native and prosthetic groups (at 7 years, $65\% \pm 7\%$ vs $51\% \pm 11\%$; $P = .21$; Figure 4). In analyzing the patient and operative characteristics of the prosthetic and native endocarditis groups, the groups were similar other than a higher incidence of preoperative atrial fibrillation (43% vs 12% , $P < .001$) but a lower incidence of congestive heart failure (50% vs 84% , $P < .001$) and New York Heart Association class IV (72% vs 93% , $P = .01$) in the patients with prosthetic endocarditis, respectively. The incidence of abscess was similar in both groups (prosthetic, 63% vs 45% ; $P = .1$).

We also examined long-term outcomes in patients who had at least 1 abscess at the time of surgical intervention with those who had no abscess formation. Paravalvular abscess was associated with an operative mortality of 21.7% versus 9.1% ($P = .15$), and no difference was seen between groups in actuarial survival or for freedom from recurrent endocarditis, freedom from reoperation, or event-free survival.

Four patients in our series underwent aortic homograft root replacement. Three of these had concurrent mitral valve repair and are alive and free from reoperation and recurrent endocarditis at the latest follow-up (longest of 10 years). One patient

TABLE 6. Late morbidity events

Complication	No.	Died
Endocarditis recurrence	10	6
Thromboembolic events		0
Stroke	2	
Transient ischemic attack	3	
Reoperations	10	0
Bioprosthetic structural valve deterioration	1	
Recurrent endocarditis	3	
Perivalvular leak	3	
Pannus formation	1	
Recurrent mitral regurgitation	2	
Perivalvular leak	5	1
Major anticoagulation-related hemorrhage	3	1
Valve thrombosis	1	0

had concurrent mitral valve replacement and died postoperatively from stroke. No patients had mitral homografts.

DISCUSSION

There have been a number of studies that have examined surgical outcomes after infective endocarditis.^{4,7,8} We have previously found that surgical intervention for active endocarditis most commonly comprised isolated aortic valve surgery, followed in equal frequency by isolated mitral valve surgery and double valve (aortic and mitral) surgery.⁴ There have, to date, been no reports on the long-term outcomes of patients with active endocarditis in whom both the aortic and mitral valves underwent surgical intervention.

We have presented the early and late outcomes of double valve surgery for active infective endocarditis in a cohort of 90 patients over a 26-year period. A significant mortality (15.6%) was seen in the short term and also in the longer term, with a 51% mortality at 10 years. Postoperative recovery was protracted: in our series the mean intensive care unit stay was 8 days, with a mean hospital stay of 19 days, and complications were common. One third of late deaths were valve related, and the incidence of recurrent endocarditis was 13% in hospital survivors.

FIGURE 3. Long-term freedom from reoperation for all patients.

FIGURE 4. Event-free survival for the native versus prosthetic groups.

Gillinov and colleagues⁷ from the Cleveland Clinic reported on the surgical outcomes of 54 patients with native double valve endocarditis over a 22-year period. There were no operative mortalities and 9 late deaths, with a 10-year actuarial survival of 73%. In their series, however, the endocarditis was active in only half and remote/healed in the other half. Patients with active endocarditis tend to be sicker than those undergoing surgical intervention for healed endocarditis, and greater tissue destruction is likely to be encountered. This makes surgical risk greater in patients with active endocarditis. The degree of tissue destruction appears to be more limited in comparison with that seen in our series. Only 11% had abscesses, and there was no contiguous spread between valves or involvement of the fibrous trigones. By contrast, 51% of our patients had abscesses, and intervalvular fibrous body involvement necessitating patch reconstruction, a tremendous surgical undertaking, was required in 28%. Gillinov and colleagues⁷ determined increasing age and earlier date of operation to be independent predictors of late death by means of multivariate analysis. We also identified increasing age as a predictor of late death.

The Cleveland Clinic series was confined to native valve infection. It is well established that prosthetic valve endocarditis carries a worse outcome than native valve endocarditis.^{4,9,10} In our study prosthetic endocarditis was associated with increased operative mortality and was also a significant independent predictor of late death. Interestingly, there was no difference between the groups in freedom from recurrent endocarditis, freedom from reoperation, and event-free survival, with the latter being a measure of overall morbidity and mortality in hospital survivors. It appears that the greater long-term mortality for prosthetic endocarditis relates to the higher operative mortality and that survivors' late morbidity and mortality become similar to that for native endocarditis, as is evident from Figure 2. This effect appears independent of the incidence of abscesses because there was no significant difference between the native and prosthetic groups for abscess formation.

Siniawski and associates¹¹ evaluated hospital mortality in 108 surgical patients with active endocarditis and the presence of an aortic root abscess. Hospital mortality was 17.6%, and they identified, using multivariable analysis, the need for double valve surgery as strongly predictive of death, along with female sex, shock, and left ventricular dysfunction or dilatation. They further evaluated 53 patients who underwent operations for aortic valve endocarditis with secondary infection of the mitral valve. Hospital mortality was 26% overall and highest (29%) in the group requiring aortic root replacement with mitral valve repair/replacement. Independent predictors of death were contiguous spread of infection from the aortic to the mitral valve, whereas jet lesion involvement of the mitral valve was not a risk factor.

Surgical management of a paravalvular abscess can be technically challenging. After radical debridement of an abscess, complex reconstructive surgery might be required. We have previously found paravalvular abscess to be an independent predictor of operative mortality in all patients undergoing surgical intervention for active infective endocarditis.⁴ Surgical intervention for endocarditis (of any valve) complicated by a paravalvular abscess was associated with high operative mortality (15.5%) and a 10-year actuarial survival of 57%.¹² In our current study almost half the patients undergoing double valve surgery for active endocarditis had at least 1 abscess, and frequently multiple abscesses were present. In keeping with our previous work, a paravalvular abscess was again found to be associated with high operative mortality (21.7%), although this did not reach statistical significance ($P = .15$).

It is not surprising that highly complex operations might be necessary in patients with active endocarditis in whom both the aortic and mitral valves require intervention. Aortic root replacement was performed in 12 patients, 4 with a homograft. Ten of these patients had aortic root abscesses, sometimes enveloping the coronary arteries, which required modified Cabrol interposition grafts to reattach the coronary arteries. Double valve replacement with reconstruction of the intervalvular fibrous body was performed in 25 patients, 19 of whom had abscess formation. Remarkably, such complex procedures were not associated with increased operative mortality nor were they predictors of long-term death. It is noteworthy that in this series early redo operations (ie, within the same hospital admission) were required in 6 (6.7%) patients. This is indicative of the extent of tissue destruction that was seen and the complexity of reconstruction that was required. Although there is much discussion regarding the use of homografts in active endocarditis,^{13,14} we would emphasize that homograft use does not substitute for the principle of radical debridement with appropriate reconstruction. Mitral homograft use is rare,¹⁵ and no benefit is obtained by performing aortic homograft replacement if a stented mitral prosthesis is used.

In addition to increasing age and prosthetic endocarditis, preoperative shock and diabetes mellitus were independent predictors of death from all causes. Preoperative shock is well documented as being an independent risk factor for operative and late death.^{4,11,12,16} Diabetes mellitus is increasingly being identified as a risk factor for in-hospital mortality in patients with infective endocarditis who are medically treated,¹⁷⁻¹⁹ as well as those undergoing surgical intervention.^{16,20} A French prospective population-based survey found insulin-dependent diabetes mellitus to be an independent predictor of in-hospital death (odds ratio, 7.82) in 559 cases of definite infective endocarditis.¹⁸ Subanalysis demonstrated insulin-dependent diabetes to be associated with greater mortality (50% vs 19%) than oral medication-treated diabetes and remained predictive of death, whereas the latter was not predictive of death.¹⁹

Rosamel and coworkers²⁰ noted diabetes mellitus to be associated with increased operative mortality in 98 patients undergoing surgical intervention for active endocarditis of any valve. Of 6627 patients in a large retrospective review of the Society of Thoracic Surgeons National Cardiac Database, Gammie and colleagues¹⁶ found diabetes to be an independent predictor of operative mortality when examining outcomes of surgical intervention for mitral valve endocarditis (odds ratio, 1.59), although only 40% of the cohort had active endocarditis. To the best of our knowledge, this is the first report that demonstrates diabetes to be an independent predictor of long-term death after surgical intervention for endocarditis.

In summary, we have presented the early and late outcomes of double valve surgery for active infective endocarditis. Double valve surgery is a substantial undertaking in the setting of active endocarditis. Operative mortality and perioperative morbidity are significant, but reasonable long-term survival can be achieved. Good freedom from reoperation and recurrent endocarditis are seen. Survival is worse in patients with prosthetic valve endocarditis, but hospital survivors attain event-free survival comparable with that of patients with native valve endocarditis.

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