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ORIGINAL ARTICLE

Early surgery with aggressive surgical approach to improve 6-month outcomes in patients with active infective endocarditis: contribution of cerebral preoperative magnetic resonance imaging

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Abstract

Objectives We investigated the hypothesis that early surgery for infective endocarditis (IE) attenuates the rate of death or embolic events and does not increase the rate of relapse or postoperative valvular dysfunction (PVD) at 6 months.

Methods 21 consecutive patients who underwent surgical treatment of IE were prospectively included. We assessed 6-month postoperative clinical outcomes by comparing early surgery (Group E, surgery within 72 h) and conventional treatment (Group C). Nine patients (43%) were assigned to Group E based on a combination of preoperative evaluation parameters, including the findings of cerebral magnetic resonance imaging (MRI), which was performed in all patients with left-sided IE.

Results Six surgical plans (5 advancements and 1 postponement) were modified by routine MRI. Although preoperative echocardiography did not confirm all annular invasions, the rate of periannular infection, which was treated by pericardial annular patch plasty (56%) in patients with native-valve IE, was higher in Group E than C ($P=0.006$). Early surgery based on MRI findings resulted in no postoperative embolic events or cerebral bleeding. The 6-month mortality rate was 0% in both groups, although the calculated 6-month IE mortality rate was $49.2 \pm 25\%$ and $28.8 \pm 18\%$, respectively. No recurrence of IE or PVD occurred in Group E. The 6-month rate of freedom from composite events was 100% in Group E.

Conclusions Aggressive treatment (periannular resection and disuse of a prosthetic annuloplasty ring) and optimal antibiotic therapy based on intraoperative microorganisms, even in patients who underwent early surgery, reduced the 6-month relapse and PVD rates.

Keywords Infective endocarditis · Early surgery · Periannular complication · Mitral valve plasty · Cerebral preoperative magnetic resonance imaging

Introduction

Infective endocarditis (IE) is a devastating disease and surgical treatment is challenging [1]. The 6-month outcome is clinically important with respect to achieving a complete cure, because many studies have revealed the risk factors for not only in-hospital mortality [2] but also 6-month mortality and relapse of IE [3]. The 2006 American College of Cardiology–American Heart Association guidelines [4] advocated the early surgery not only to control cardiogenic shock, heart failure, or uncontrolled infection but also to prevent embolic events unless a contraindication for early surgery is present. In contrast, Thuny et al. [5] reported that the early surgery was associated with a trend toward an increased rate of relapse and postoperative valve dysfunction (PVD) in their entire cohort (16%

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vs. 4%; adjusted odds ratio, 2.9; 95% confidence interval, 0.99–8.40; $P = 0.005$). The optimal timing and indications for surgical intervention of IE remain controversial.

We hypothesized that the early surgery using aggressive treatment would not increase the 6-month rates of mortality, relapse, or PVD compared with the conventional treatment.

Materials and methods

Twenty-one consecutive patients who were definitively diagnosed with IE and underwent surgical treatment in our institution from June 2010 to June 2016 were prospectively included in the present study. We retrospectively analyzed these patients' clinical characteristics and outcomes. All patients underwent transthoracic echocardiography (TTE) preoperatively and transesophageal echocardiography (TEE) in the operating room. The maximal vegetation length was measured, and an abscess with or without a fistula was suspected in front of a thickened area or mass with a heterogeneous echogenic or echolucent appearance. All patients with left-sided IE underwent cerebral MRI before the development of hemodynamic instability, including diffusion-weighted imaging, fluid-attenuated inversion recovery imaging, T2 imaging, and magnetic resonance angiography, to determine the presence of hemorrhagic transformation, aneurysm, subarachnoid hemorrhage, and silent cardiocerebral embolism. All patients also underwent systemic enhanced CT to detect cardio-systemic embolism. Although cerebral hemorrhage was a contraindication for the early surgery, patients with T2* positive lesions without subarachnoid hemorrhage were permitted to undergo the early surgery in this study.

The probability score for 6-month mortality in patients with IE was calculated based on patient-related factors (age, dialysis), IE characteristics (prosthetic or nosocomial IE, causative organism, left-sided valve vegetation), and IE-related complications (severe heart failure, stroke, paravalvular complications, and persistent bacteremia) [3]. The probability score for 6-month mortality was calculated using the formula established by a large multinational prospective registry of definite IE ($n = 4049$) (3).

The endpoints were mortality, IE relapse, or PVD, and the composite endpoint at 6 months. PVD was diagnosed by echocardiography and included valve repair failure and prosthesis dysfunction unrelated to IE relapse [5]. The composite event was defined as death from any cause, an embolic event after surgery, recurrence of IE, or repeat hospitalization due to congestive heart failure. Patients with IE related to nonvalvular cardiovascular devices, such as pacemakers and catheters, were excluded from the analysis.

Patients

The patients were divided into two groups: Group E (early surgery) comprised patients who underwent a radical operation within 72 h after diagnosis. Group C (conventional surgery) comprised patients who underwent an operation after 72 h (range 6–68 days). Early surgery was performed in 9 of 21 patients, and 16 of 21 patients had active IE. Table 1 shows the patients' clinical and echocardiographic characteristics at baseline. Preoperative cerebral MRI was performed in all patients with left-sided IE. Preoperative cerebral embolism was detected in 89% of patients in Group E and 67% of patients in Group C. Most patients in both groups had preoperative systemic embolism (89% in Group E and 92% in Group C). The only significantly different parameters were the mean vegetation diameter and the prevalence of New York Heart Association (NYHA) class IV (Table 1). All patients met the Duke criteria for definite IE; the site of IE and the pathogens in Groups E and C are shown in Table 1 (not statistically significant).

Early surgery was selected based on the indications for the timing of surgery in patients with left-sided valve IE and management of neurological complications in the 2009 European Society of Cardiology (ESC) guideline [6].

Surgical approach and techniques

When the infection (including root abscess formation) had invaded the aortic or mitral annulus and myocardium, patch repair with glutaraldehyde-treated autologous pericardium in patients with native-valve IE (NVE) or xenopericardium in patients with prosthetic-valve IE (PVE) was performed for larger defects after radical debridement of the infected and necrotic tissue. The pericardial patch provided a strong fixation point for the newly implanted prosthesis to prevent perivalvular leakage (Fig. 1a). If the infection was limited to the native mitral or tricuspid valvular tissue, valve repair was attempted without the use of a prosthetic annuloplasty ring in Group E (Fig. 1b). Intraoperative tissue culture was performed for all patients except one patient with a negative blood culture. If tissue cultures are positive, then an entire antimicrobial course is reasonable for 4–6 weeks postoperatively [7].

Statistical analysis

Statistical analyses were performed with the Statistical Package for the Social Sciences, version 17 (SPSS Inc., Chicago, IL, USA). Continuous variables are expressed as mean with standard deviation and were compared using

Table 1 Baseline clinical and echocardiographic characteristics

	Group E ($n=9$)	Group C ($n=12$)	P value
Age (years)	64 ± 15 (29–78)	61 ± 11 (33–77)	0.604
Male sex	5 (56)	8 (67)	1.00
Diabetes mellitus	1 (11)	2 (17)	1.00
Hypertension	3 (33)	5 (42)	1.00
Immunocompromised status	3 (33)	3 (25)	1.00
Chronic hemodialysis	2 (22)	2 (17)	1.00
Platelet count ($\times 10^4$)	21 ± 14 (3.3–41)	18 ± 10 (3.3–41)	0.49
CRP (mg/dl)	9.6 ± 6.3 (2.9–21.1)	4.7 ± 5.2 (0.1–18.3)	0.07
WBC count ($\times 10^3$)	13.1 ± 5.9 (7.1–25.0)	9.0 ± 5.2 (2.9–21.3)	0.11
Preoperative NYHA class IV	4 (44)	0 (0)	0.021
Preoperative intubation	2 (22)	2 (17)	1.00
Execution of MRI (left-sided IE)	9 (100)	11 (100[a])	1.00
Systemic embolism	8 (89)	11[b] (92)	1.00
Cerebrum	8 (89)	8 (67)	0.338
Spleen	4 (44)	2 (17)	0.331
Aorta	1 (11)	0 (0)	0.429
Eye	1 (11)	0 (0)	1.0
Pulmonary artery	0 (0)	1 (8)	0.659
Kidney	2 (22)	4 (33)	0.661
LVEF (%)	64 ± 13 (43–75)	67 ± 6 (60–82)	0.487
Max. diameter of vegetation (mm)	21 ± 14 (3.3–41)	12 ± 8 (0–25)	0.025
Site of IE			
Aortic valve	4 (44)	7 (58)	0.67
Mitral valve	7 (78)	5 (42)	0.18
Both aortic and mitral valves	2 (22)	2 (17)	1.00
Tricuspid valve	1[c] (11)	1 (8)	1.00
Left ventricle	0 (0)	1 (8)	1.00
Microorganism			
Streptococcus spp.	4 (44)	5 (42)	1.00
Staphylococcus spp.	3 (33)	5 (42)	1.00
Enterococcus spp.	1 (11)	1 (8)	1.00
Acinetobacter spp.	1 (11)	0 (0)	0.429
Unknown	0 (0)	1 (8)	1.00

Data are presented as mean ± standard deviation (range) or n (%)

Immunocompromised: steroid use or end-stage renal failure with hemodialysis or drug abuse

CRP C-reactive protein, *WBC* white blood cell, *NYHA* New York Heart Association, *NYHA class IV* only cardiogenic shock (excluding septic shock), *MRI* preoperative cerebral magnetic resonance imaging, *IE* infective endocarditis, *LVEF* left-ventricular ejection fraction

[a]Only one patient with isolated tricuspid valve IE did not undergo cerebral MRI

[b]Two episodes that occurred during preoperative medical therapy were included

[c]IE at the aortic valve extended to the tricuspid valve

a two-tailed t test after Levene's test for equality of variance. Categorical variables, expressed as percentages, were analyzed with a two-sided Fisher's exact test. Estimates of cumulative event rates were calculated by the Kaplan–Meier method and compared using the log-rank test. All two-tailed P values of < 0.05 were considered significant.

Results

Patient selection and risk factors

The rate of indications for an early operation was 100% in Group E and 67% in Group C (Table 2). In five patients, a silent cerebral embolism detected by MRI was the only reason for an early operation. Although 8 of 12 patients in

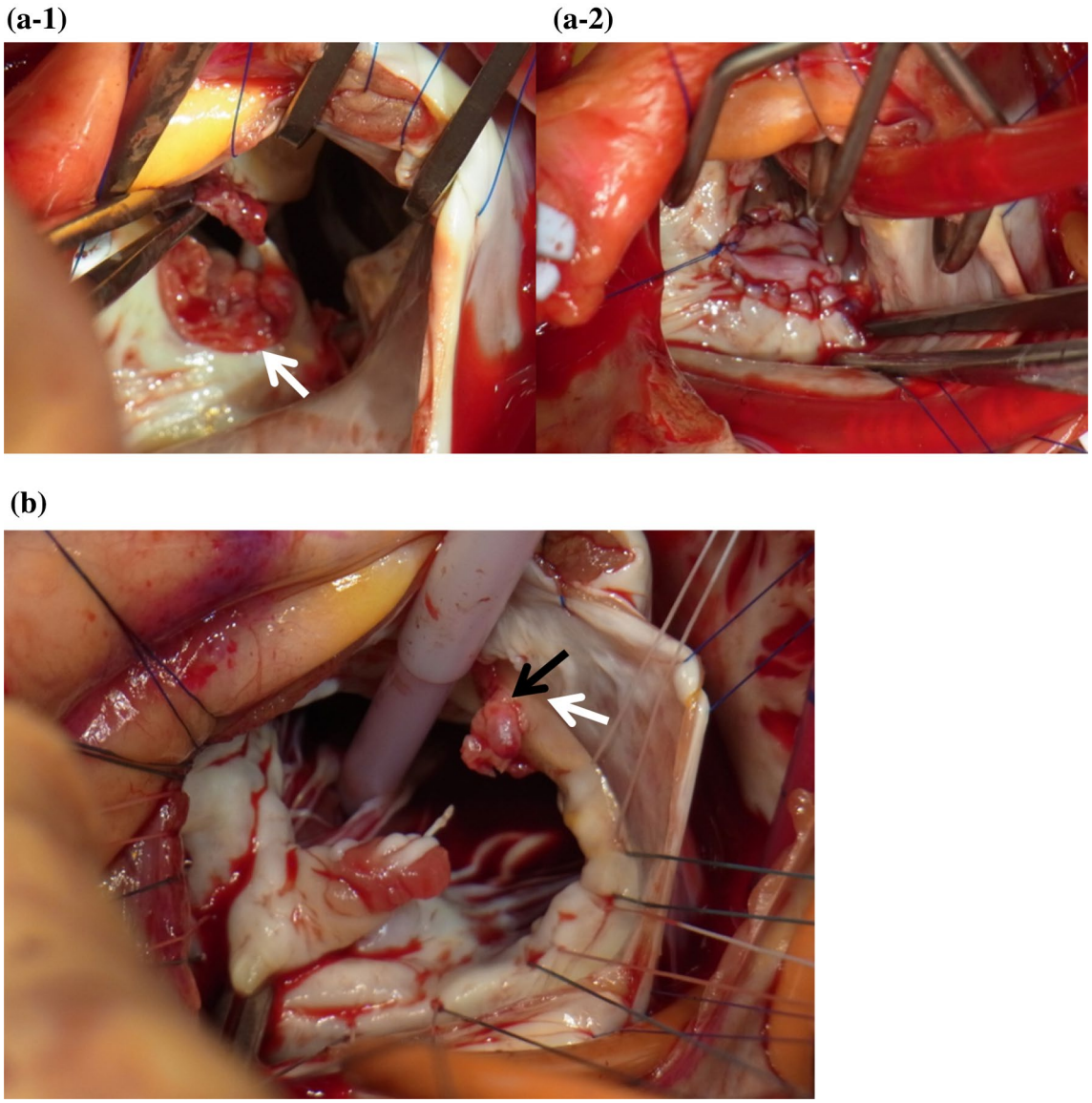

Fig. 1 **a** Annular extension of IE. **a-1** The infection of the posterior mitral leaflet extended into the posterior annulus and surrounding tissue, including the myocardium. The white arrow shows the posterior annulus. **a-2** After radical debridement of the infected and necrotic tissue, a glutaraldehyde-treated autologous pericardial patch was sutured to reinforce the annulus for mitral valve replacement. **b** Mitral valvuloplasty for A3 and P2 vegetation with prolapse. A vegetation (operative culture positive for *Staphylococcus aureus*), small perforation, and leaflet with torn chordae at P2 were treated by triangular resection and suturing. The vegetation at A3 (black arrow), which was superficially present on the leaflet, was completely resected without leaflet resection. However, it was located close to the anterior annulus (white arrow); therefore, the sutures for ring annuloplasty were totally removed

Group C had an indication for an early operation, delayed surgery was performed because of neurologic complications ($n=6$), heparin-induced thrombocytopenia ($n=1$), and reticular bleeding ($n=1$) ($P=0.005$). The neurologic complications were cerebral bleeding ($n=2$), subarachnoid hemorrhage ($n=1$), coma ($n=1$), mycotic aneurysm ($n=1$), and a huge cerebral infarction ($n=1$). One small subarachnoid hemorrhage was detected by MRI (undetected by CT). Therefore, six surgical plans (5 advancements, 1 postponement) were modified by preoperative MRI (Fig. 2a). T2*-positive lesions were found by MRI in three patients of each group (Fig. 2b). Three patients with PVE were assigned to Group C (7, 26, and 62 days after diagnosis, respectively) because of neurological complications (huge infarction with cerebral bleeding and minor bleeding with multiple infarctions), although two of these three patients had an indication for early surgery.

The operative risks of each patient were calculated by the euroSCORE (% risk) and probability score for 6-month mortality. The euroSCORE (% risk) was $29.6 \pm 11.0\%$ in

Table 2 Operative indications, calculated risk, and operative findings

	Group E ($n=9$)	Group C ($n=12$)	P value
Indications for early operation	9 (100)	6 (50)	0.005
Cardiogenic shock	4 (44)	0 (0)	0.021
Prevention of systemic embolism	6 (67)	6 (50)	0.067
Uncontrolled infection	5 (56)	4 (33)	0.396
Contraindications for early operation	0 (0)	8 (67)	0.005
Execution of T2* imaging	6	9	
T2*-positive lesion	3 (50)	3 (33)	0.622
euroSCORE	11.8 ± 1.7	8.3 ± 4.2	0.030
euroSCORE (% risk)	29.6 ± 11	18.6 ± 20.5	0.161
Probability score for 6-month mortality in IE	49.2 ± 25	28.8 ± 18	0.043
Intraoperative findings			
Annular invasion	5/9 (56)	2/12 (17)	0.159
Annular invasion in NVE	5/9 (56)	0/9 (0)	0.006
Isolated mitral NVE	6	3	
No annular invasion of mitral NVE	4	3	
Mitral valvuloplasty without ring	2/4 (50)	0/3 (0)	0.429
Mitral valvuloplasty with ring	0/4 (0)	2/3 (67)	0.143
MVR	2/4 (50)	1/3 (33)	1.0
Positive of intraoperative culture	5 (56)	4 (33)	0.396

Data are presented as n (%) n, or mean ± standard deviation

IE infective endocarditis, *PVE* prosthetic-valve infective endocarditis, *NYHA* New York Heart Association, *NVE* native-valve infective endocarditis, *MVR* mitral valve replacement

Group E and 18.6 ± 20.5% in Group C ($P=0.161$). There was a significant difference in the calculated 6-month mortality score for IE between Groups E and C (49.2 ± 25.0% and 28.8 ± 18.0%, respectively; $P=0.043$).

Operative findings

The operative findings are shown in Table 2. NVE extended into the annulus and surrounding tissue in 5 of 9 (56%) patients in Group E, although preoperative echocardiography led us to suspect annular invasion but did not confirm it (except in one patient with a root abscess). Therefore, these patients underwent pericardial annular patch repair after radical debridement of the infected and necrotic tissue at the aortic annulus ($n=3$) and mitral annulus ($n=2$) (Fig. 1a). In Group C, no invasion to the annulus occurred among patients with NVE. The rate of annular patch repair for the patients with NVE in Group E was significantly higher than that in Group C ($P=0.006$). 2 of the 3 patients with PVE were treated with a pericardial patch to reinforce the aortic annulus, and one underwent a Bio-Bentall operation reinforced with xenopericardium.

Among patients with isolated mitral valve IE in Group E, mitral valvuloplasty (MVP) without ring annuloplasty (Fig. 1b) was performed for 2 of 4 patients to decrease the risk of artificial material-related infection (Table 2). In Group C, however, MVP with artificial ring annuloplasty was performed.

Tricuspid valvuloplasty was performed for a patient with isolated tricuspid IE due to drug abuse. Because two leaflets (anterior and posterior) were destroyed by infection, the patient underwent patch augmentation and leaflet closure with artificial chorda. However, no artificial ring was used to prevent reinfection because of the patient's drug abuse and active IE.

One patient in Group C underwent left ventriculotomy for resection of a left-ventricular ball vegetation.

The intraoperative valve cultures were positive in 5 of 9 (56%) patients in Group E but in only 4 of 12 (33%) patients in Group C, without statistical significance.

Early results

No in-hospital death, symptomatic postoperative embolism, or cerebral bleeding occurred in either group. The other postoperative complications shown in Table 3 were comparable between the two groups. Two patients in Group C with preoperative cerebral embolism underwent urgent operations to prevent another stroke. The incidence rate of preoperative cerebral embolism was not significantly different between the groups.

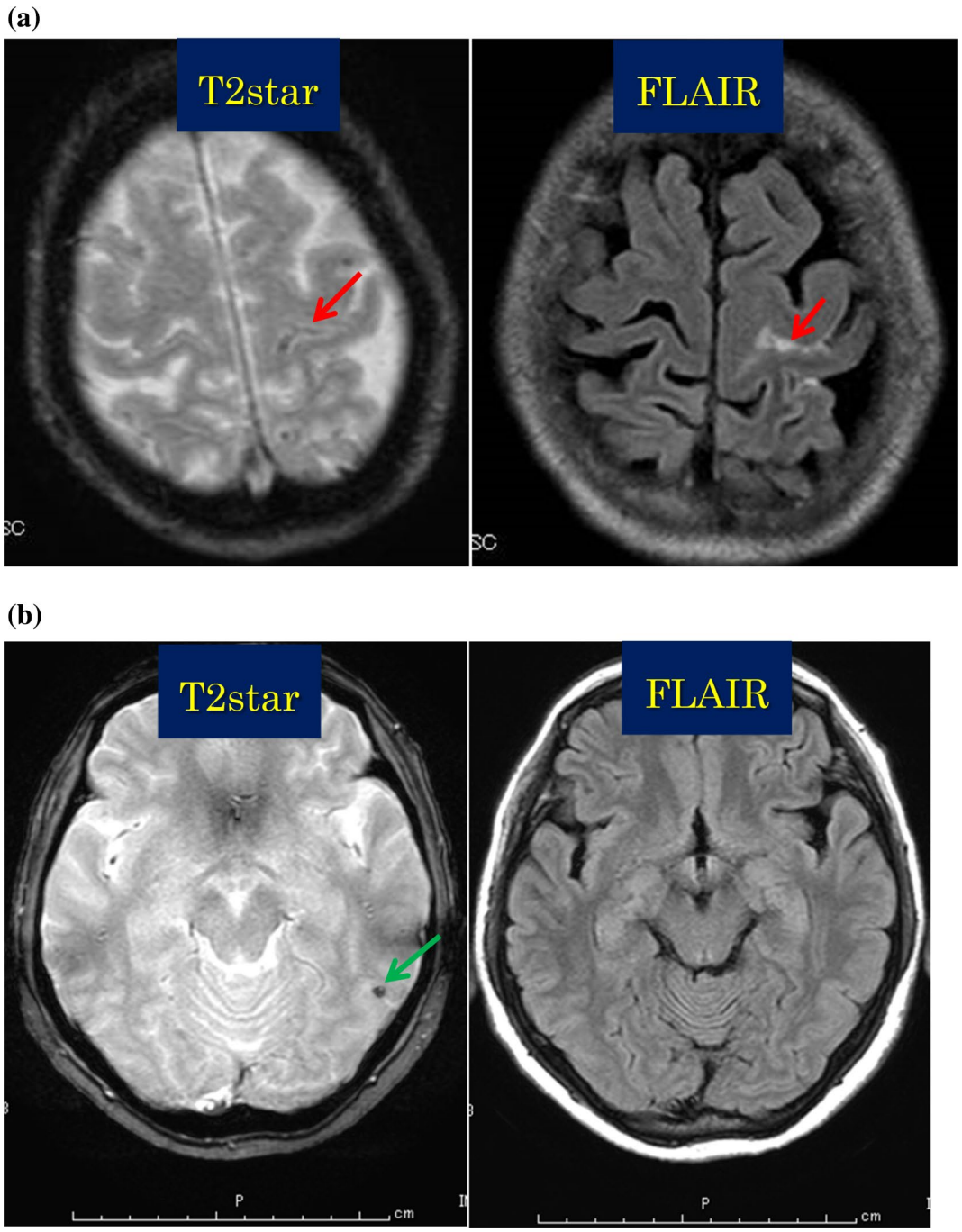

Fig. 2 Preoperative cerebral MRI findings. **a** Delayed surgery was selected due to detection of SAH (red arrow) by T2* and FLAIR MRI, although the diffusion-weighted image showed a silent infarction. The SAH was defined as linear FLAIR hyperintensities or T2* hypointensities. **b** T2 star-positive lesion (T2* hypointensities with a diameter of ≤10 mm, green arrow) without SAH suggested microbleeds related to infective endocarditis. This was not a contraindication for early surgery. *SAH* subarachnoid hemorrhage, *MRI* magnetic resonance imaging, *FLAIR* fluid-attenuated inversion recovery

Six-month results

No all-cause mortality had occurred at 6 months postoperatively in either group. In addition, no patients in Group E developed IE recurrence, but one patient in Group C developed IE recurrence (Table 3). The patient with recurrence initially underwent repeated aortic valve replacement for PVE in the active phase followed by a satisfactory Bio-Bentall operation 5 months after the initial operation. No recurrence of infection was observed thereafter. This was

Table 3 Early results and 6-month results

	Group E ($n=9$)	Group C ($n=12$)	P value
In-hospital death	0	0	NC
Morbidity			
Cerebral bleeding	0	0	NC
Symptomatic cerebral infarction	0	0	NC
Reopen for bleeding	1 (11)	0	0.429
Late tamponade	0	2 (17)	0.486
Respiratory failure	2 (22)	1 (8)	0.553
Worsened CKD; new dialysis	1 (11)	0	0.429
Pneumonia	1 (11)	1 (8)	1.0
Atrial fibrillation	5 (56)	4 (33)	0.396
Cerebral embolism during preoperative medical treatment	0	2 (17)	0.486
Six-month results			
All-cause mortality	0	0	NC
Relapse and PVD	0	1 (8[a])	0.571
Composite events	0	1 (8)	0.571
Freedom from 6-month composite events	100%	91.7%±8.0%	0.386

Data are presented as *n* (%) or mean ± standard deviation

Respiratory failure intubation time of > 72 h, *CKD* chronic kidney disease, *PVD* postoperative valvular dysfunction, *composite event* death from any cause, postoperative embolic events, recurrence of infective endocarditis, or repeat hospitalization due to the development of congestive heart failure

[a]Bentall operation was performed 5 months after active PVE operation

the only composite event at 6 months; thus, the composite event rate was comparable between the groups (0% vs. 8%, $P=0.571$). The median follow-up time was 21.6 months (interquartile range 11.3–37.5 months) in Group E and 36.9 months (interquartile range 6.5–89.7 months) in Group C. During follow-up, neither cardiac death nor relapse of IE occurred in either group. The cumulative survival rates at 6 months and 3 years were 100% and 88.9 ± 10.5% in Group E and 100% and 83.3 ± 10.8% in Group C, respectively (log-rank $P=0.683$). The rates of freedom from PVD and relapse at 6 months and 3 years were 100% and 100% in Group E and 91.7 ± 8.0% and 91.7 ± 8.0% in Group C, respectively. Two patients who underwent MVP without ring annuloplasty were followed by echocardiography annually. These patients did not develop recurrence of infection or major mitral regurgitation (only trivial and mild) at 28 and 24 months postoperatively, respectively. The late-grade tricuspid regurgitation was moderate in the patient with tricuspid plasty without a ring at 49 months postoperatively, but no recurrence of infection or cardiac failure occurred in this patient.

Discussion

The 2009 ESC guideline recommends the early surgery as a class IIb indication in patients with an isolated, very large vegetation (> 15 mm in diameter) without an embolic history but as a class I indication in patients with an embolism and vegetation of even 10 mm in diameter. This recommendation was based on a study, showing that the prevention of major stroke was the most important factor for the improvement of long-term results [8]. Therefore, in the present study, cerebral MRI was routinely performed before the development of unstable hemodynamics. Our findings revealed that the rates of silent cerebral infarction (89% and 67% in Groups E and C, respectively) were much higher than those in the previous reports (22–30%) [3, 9]. This difference may be explained by the higher rate of performance of cerebral MRI, which detected stroke more effectively than CT. In the present study, a recent paper reported that preoperative cerebral MRI detected cerebral lesions at a high rate (82%) [10]. In 2012, Kang et al. [9] performed a prospective randomized trial to compare the early surgery with the conventional treatment in patients with active IE. Although there was no significant difference in all-cause mortality at 6 months, the rate of the 6-month composite endpoint (mainly embolic events) was significantly better in the early surgery (28% vs. 3%, respectively; $P=0.003$). In the present study, however, good composite outcomes were shown in both groups, and only two patients had cerebral embolism before the operation. This difference was due to the detection of silent embolism using cerebral MRI and the decision to perform the early surgery, because the rate of preoperative cerebral infarction was only 30% in the study by Kang et al. [9]; this rate was much lower than that in the present study. Although

preoperative MRI did not predict postoperative neurological complications [11], cerebral MRI changed the therapeutic plan, including the surgical plan [10]. Our findings showed that six (28.5%) surgical plans were modified by MRI findings to prevent major stroke (both embolism and bleeding).

In contrast, the early surgery is reportedly associated with a trend toward increased relapses and PVD [5]. In the present study, we not only performed the early surgery but also chose an aggressive surgical approach to prevent the late relapse and PVD. Importantly, our aggressive surgical approach included three main factors: (1) aggressive resection of the periannular extension of active IE and reconstruction of the tissue defect; (2) aggressive disuse of any artificial material, especially an annuloplasty ring; (3) aggressive use of intraoperative microorganisms for total antibiotic therapy.

In the present study, 56% of patients in Group E needed autologous pericardial patch repair; no patients in Group C had periannular infection. Periannular invasion is a reported risk factor for 6-month mortality [3] and relapse [12], and requires more complex surgery involving challenging reconstruction and longer surgery times [2, 7]. The incidence of periannular invasion is significantly high in the early surgery, although preoperative echocardiography did not lead us to confirm all annular invasions. Therefore, aggressive resection and reconstruction of periannular invasion, which is not a novel but still a fundamental treatment for active IE, may be one of the factors that improves the 6-month outcome.

MVP in native mitral valve endocarditis offers superior in-hospital and long-term survival compared with valve replacement, with superior freedom from recurrent endocarditis and reoperation [13]. Although a prosthetic annuloplasty ring is reportedly well tolerated and has a low reinfection rate [13], incomplete resection of infected tissue and the use of prosthetic annuloplasty may increase the risk of recurrent infection. Although complete resection is essential for the IE treatment, one case of MVP may have involved incomplete resection of the superficial vegetation on the leaflet at A3 (Fig. 1b) because of the preservation of the repairable tissue. In such cases, an artificial material should not be used. Therefore, we attempted MVP with no prosthetic material except monofilament sutures and pericardium for two patients. Although the midterm functional results were satisfactory, further follow-up and additional cases are needed to confirm the benefits of this surgical method.

The feasibility of tricuspid valve repair is based on the extent of the infection and the degree of destruction of the subvalvular apparatus. When 2 or 3 leaflets are entirely involved or more than half of the marginal chordae of the anterior leaflet are involved, the repair is compromised [14]. Although tricuspid valve excision without prosthetic-valve replacement is another option in intravenous drug users, tricuspid valve repair is definitively better if it can be done. In the present study, one patient in whom the IE involved two leaflets underwent tricuspid repair and had not developed recurrent infection or cardiac failure at 5 years.

The 2015 ESC guideline recommended that a new full course of treatment (4–6 weeks) should only be started if valve cultures are positive, and the choice of antibiotic should be based on the susceptibility of the latest recovered bacterial isolate [7]. In this study, final valve cultures were positive in 56% of patients in Group E. The optimal duration of antibiotic therapy was determined based on the results of the valve culture, which confirmed continuous infection. Although *Staphylococcus aureus* infection was shown to be an independent predictor of mortality and increased paravalvular complications [15], we found no relationship between early surgery and microorganisms such as *Staphylococcus aureus*.

In this study, a T2*-positive lesion without a subdural hematoma was not a contraindication for early surgery. The patients with T2*-positive lesions did not develop postoperative cerebral bleeding. The 2015 guideline [7] reported that cerebral MRI often detects microbleeds (round T2* hypointensities with a diameter of ≤ 10 mm) in patients with IE. The lack of an association with parenchymal hemorrhage and the absence of postoperative neurological complications in patients with microbleeds suggest that microbleeds should not be interpreted as active bleeding and should not lead to postponed surgery when this is indicated. Thus, our indications for early surgery with regards to T2*-positive lesions could be acceptable, although a multi-institutional large prospective study may provide definitive results.

Limitations

Despite the fact that we analyzed the data of consecutive patients treated with the same protocol, this study was limited by the retrospective collection of data, the relatively small sample size, and the single-center design. In addition, the number of patients was too small to prove the surgical benefits of patch plasty for annular defects and MVP without ring annuloplasty. All patients with IE, including five with inactive IE, were enrolled in this study. No comparison data regarding dedicated antibiotic therapy based on valve tissue culture were available. The data provide no explanation about the differences between the results of intraoperative culture and the rate of periannular invasion, although an active infection (confirmed by intraoperative culture) may affect periannular invasion.

Conclusion

Our IE treatment achieved an all-cause 6-month mortality rate of 0% and no postoperative embolic events or major cerebral bleeding. Six surgical plans (28.5%) were modified by routine cerebral MRI findings to prevent postoperative stroke. This study showed that aggressive treatment (aggressive periannular resection supported by patch plasty and aggressive disuse of a prosthetic annuloplasty ring for valve repair) and optimal antibiotic therapy based on valve culture, even in patients who underwent the early surgery, reduced the 6-month relapse and PVD rates, although the rate of periannular invasion was very high in this group.

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Compliance with ethical standards

Conflict of interest The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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