Bypass grafting with coronary endarterectomy: Immediate and long-term results

Giuseppe Marinelli, MD^a
Bruno Chiappini, MD^a
Marco Di Eusanio, MD^a
Roberto Di Bartolomeo, MD^a
Ilaria Caldarera, MD^b
Cinzia Marrozzini, MD^b
Antonio Marzocchi, MD^b
Angelo Pierangeli, MD^a

Background: Increased morbidity and mortality have been associated with coronary artery bypass grafting when an adjunctive coronary endarterectomy is performed. In this study we retrospectively reviewed our experience with coronary bypass and endarterectomy to evaluate the early and late outcome and to determine the independent predictors of early mortality and morbidity of this procedure.

Methods: Between May 1989 and December 2000, 107 patients underwent myocardial revascularization with coronary endarterectomy to achieve a complete revascularization. There were 90 men and 17 women; the mean age was 64 ± 8.1 years. Sixty-three (58.9%) patients had a previous myocardial infarction, and 29 (27.1%) were operated on on an emergency basis. An ejection fraction of less than 30% was present in 9 (8.4%) patients. The most frequently endarterectomized vessel was the left coronary artery (74.8%). Follow-up information was obtained from 97 patients (100% of the long-term survivors).

Results: There were 5 (4.7%) early deaths. The 72-month survival was $91.2\% \pm 4.9\%$. Seventy-seven (83.7%) of the survivors were symptom free, and 15 (16.3%) were in Canadian Cardiovascular Society class II to III. An improvement of the ejection fraction after the operation was shown in the 97 patients who underwent echocardiographic control ($P = .03$) and angiography. The 30.4-month patency rate of the endarterectomized coronary arteries was $72\% \pm 11\%$.

Conclusion: Coronary endarterectomy is a safe and effective procedure for achieving a complete revascularization in patients with end-stage coronary disease.

From the Departments of Cardiovascular Surgery^a and Cardiology,^b Policlinico S. Orsola, University of Bologna, Bologna, Italy.

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Address for reprints: Bruno Chiappini, MD, Department of Cardiovascular Surgery, University of Bologna, via G. Massarenti, 9-40138 Bologna, Italy (E-mail: bruno_chiappini@hotmail.com).

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In the 1950s, coronary endarterectomy (CE) was introduced as a method of treating coronary artery disease (CAD)¹ and then was adopted by several institutions, mostly associated with coronary artery bypass grafting (CABG).

After initial reports, CE was questioned as an effective treatment for diffuse CAD because of increased myocardial infarction and early mortality rates² and was thereafter used much less frequently.

In the last 2 decades, however, increasing surgical population morbidity associated with advances in cardiac surgery and a better patient selection has prompted the resurgence of CE. A complete revascularization showing acceptable results was then made feasible, even in patients with end-stage CAD.³⁻⁶

In our institution CE was carried out on a small group of highly selected patients when distal anastomosis to an adequately sized vessel was not possible.

The aim of this study was to assess, retrospectively, the early and late results of

Figure 1. Actuarial survivals after CABG and CE. Operative and late deaths are included.

CE and CABG and to determine the independent predictors of early mortality and myocardial infarction after surgical intervention.

Material and Methods

Patients' Profiles

Between May 1989 and December 2000, 107 patients underwent myocardial revascularization with CE at the University of Bologna to achieve a complete revascularization. There were 90 (84.1%) men and 17 (15.9%) women, with a mean age of 64 ± 8.1 years (range, 41-81 years). Fifty (46.7%) patients had a previous history of smoking; hypertension was present in 49 (45.8%) patients, and previous myocardial infarction had been experienced in 63 (58.9%). Unstable angina was present in 54 (50.5%) patients. Twenty-nine (27.1%) patients were operated on as an emergency. Impairment of the ventricular function (ejection fraction [EF] $<30\%$) was present in 9 (8.4%) patients. Three (2.8%) patients had undergone a previous myocardial revascularization (Table 1).

All procedures were performed with extracorporeal circulation and moderate hypothermia (31°C); myocardial protection was obtained by means of intermittent antegrade crystalloid cardioplegia (St Thomas Hospital Solution) and topical cooling with cold saline (4°C). An endarterectomy was performed by using a manual technique⁷ and, for the most part, was performed on occluded (65.4%) vessels in the preoperative coronary angiogram. As much plaque as possible was removed, typically between 4 and 10 cm. If residual plaque was thought to remain in the distal vessel, the arteriotomy was enlarged as much as necessary to allow complete removal of the plaque, especially on the left anterior descending artery (LAD). The endarterectomized vessels were flushed with heparinized solution to remove small residual particles. When a CE was performed on the LAD, the internal thoracic artery was sewn to a saphenous vein patch, which was used to reconstruct the vessel in all cases. A saphenous vein graft was used as a conduit to the arteriotomy site in the other vessels.

A CE was performed in a single vessel for each patient on the arteries having a diameter of greater than 1.5 mm; the vessels were

the left coronary artery in 80 (74.8%), the right coronary artery in 8 (7.5%), the descending posterior artery in 8 (7.5%), the obtuse marginal artery in 7 (6.5%), and the diagonal artery in 4 (3.7%) patients.

The mean extracorporeal circulation and aortic crossclamp times were 124 ± 43 minutes (minimum, 60 minutes; maximum, 400 minutes) and 80 ± 25 minutes (minimum, 28 minutes; maximum, 165 minutes), respectively. The associated procedures were aortic valve replacement in 5 (4.7%), mitral valve replacement in 4 (3.7%), left ventricular aneurysmectomy in 2 (1.9%), and ascending aorta replacement in 2 (1.9%) patients (Table 2).

Patients were anticoagulated postoperatively. Low-molecular-weight heparin was initiated 6 hours after arrival in the intensive care unit. After 2 days, this was replaced by warfarin sodium for the following 6 months, maintaining an international normalized ratio of 2.0 to 2.5. Then aspirin (300 mg/d) was initiated and continued indefinitely.

Data Collection

The medical records of all patients were retrospectively reviewed. The data collected included the following: (1) demographics; (2) comorbidity risk factors; (3) operative data; (4) mortality; and (5) postoperative complications defined as myocardial infarction (new Q-wave or loss of R-wave progression across the chest leads; creatine kinase MB $>10\%$), low cardiac output (a newly placed intra-aortic balloon pump [IABP] or the use of inotropes for >48 hours), malignant ventricular arrhythmias, bleeding requiring a rethoracotomy, stroke, respiratory insufficiency (mechanical ventilatory support >48 hours), renal failure requiring dialysis, and mediastinal infection.

Follow-Up

A questionnaire was administered to the patients included in the study investigating survival, symptoms, long-term medical management, readmissions and reinterventions, and any surgery-re-

TABLE 1. Demographic characteristics

Variables	Patients (n)	Patients (%)
Sex		
Male	90	84.1
Female	17	15.9
Age (y)	64 ± 8.1	
Hypertension		
Yes	49	45.8
No	58	54.2
Smoking		
Yes	50	46.7
No	57	53.3
Family history		
Yes	43	40.2
No	64	59.8
Diabetes		
Yes	22	20.6
No	85	79.4
Hyperlipidemia		
Yes	43	40.2
No	64	59.8
Previous myocardial infarction		
Yes	63	58.9
No	44	41.1
Previous stroke		
Yes	6	5.6
No	101	94.4
Aortic valve disease		
Yes	6	5.6
No	101	94.4
Mitral valve disease		
Yes	4	3.7
No	103	96.3
Left ventricular aneurysm		
Yes	2	1.9
No	105	98.1
Unstable angina		
Yes	54	50.5
No	53	49.5
EF <30%		
Yes	9	8.4
No	98	91.6
NYHA		
I	1	0.9
II	33	30.8
III	54	53.3
IV	14	15
Status		
Elective	78	72.9
Urgent	29	27.1
COPD		
Yes	17	15.9
No	90	84.1
Chronic renal failure		
Yes	4	3.7
No	103	96.3
Previous CABG		
Yes	3	2.8
No	104	97.2

Continuous data are expressed as mean ± 1 SD. COPD, Chronic obstructive pulmonary disease.

TABLE 2. Operative characteristics

Variables	Patients (n)	Patients (%)
AVR		
Yes	5	4.7
No	102	95.3
MVR		
Yes	4	3.7
No	103	96.3
Ventricular aneurysmectomy		
Yes	2	1.9
No	105	98.1
CE on nonoccluded vessel		
Yes	70	65.4
No	37	34.6
CPB time (min)	124 ± 43	
Aortic crossclamp time (min)	80 ± 25	

AVR, Aortic valve replacement; MVR, mitral valve replacement; CPB, cardiopulmonary bypass.

lated complications. A series of 97 patients underwent echocardiographic examination and angiographic control.

Statistical Analysis

Statistical analysis was performed by using SPSS 7.0 statistical software (SPSS Inc, Chicago, Ill). Continuous variables were expressed as mean ± 1 SD, and categorical variables were expressed as percentages. All variables were first analyzed with univariate analysis (impaired 2-tailed *t* test, χ^2 test, or Fisher exact test when appropriate) to determine whether any single factor influenced hospital mortality and postoperative myocardial infarction. Variables that achieved *P* values of less than .05 in the univariate analysis were examined with multivariate analysis by means of forward stepwise logistic regression to evaluate independent risk factors for hospital mortality and myocardial infarction after surgical intervention.

Survival data were analyzed by using the standard Kaplan-Meier actuarial technique for estimation of survival probabilities.

Results

Early Outcome

Five (4.7%) patients died during hospitalization as a result of multiorgan failure (*n* = 1), ventricular fibrillation (*n* = 2), and low cardiac output (*n* = 2). Of these 5 patients, 4 were preoperatively critical and operated on as an emergency.

The first patient was a 70-year-old man operated on as a result of a severe acute ischemic mitral insufficiency and treated with CABG and mitral anuloplasty. The CE was performed on the right coronary artery supplying an already infarcted territory. Despite high inotropic support and temporary mechanical circulatory support with IABP, he died as a result of low cardiac output 3 days after the operation. The second patient was an 80-year-old man with unstable angina and preoperative renal failure requiring dialysis. A stroke occurred postoperatively, and multiorgan failure was

TABLE 3. Postoperative results

Variables	Patients (n)	Patients (%)
Acute myocardial infarction		
Yes	2	1.9
No	105	98.1
Hemodynamic instability		
Yes	10	9.3
No	97	90.7
IABP		
Yes	6	5.6
No	101	94.4
Ventricular fibrillation		
Yes	4	3.7
No	103	96.3
Stroke		
Yes	1	0.9
No	106	99.1
Atrial fibrillation		
Yes	23	21.5
No	84	78.2
Renal failure		
Yes	4	3.7
No	103	96.3
Respiratory failure		
Yes	2	1.9
No	105	98.1
Bleeding		
Yes	2	1.9
No	105	98.1
Mediastinal infection		
Yes	1	0.9
No	106	99.1

the cause of death. The last 2 patients had associated valve surgery (one of them had an EF of <30%). In these cases death was caused by postoperative ventricular fibrillation and the impossibility of completing cardiopulmonary bypass (Table 3).

On univariate analysis, the following factors had a significant influence on hospital mortality: advanced age ($P = .026$), history of smoking ($P = .032$), chronic renal failure ($P < .001$), unstable angina ($P = .023$), mitral valve disease ($P < .001$), prolonged cardiopulmonary bypass time ($P < .001$), mitral valve replacement ($P < .001$), postoperative hemodynamic instability ($P = .016$), postoperative acute renal failure ($P < .001$), postoperative respiratory insufficiency ($P = .002$), and ventricular fibrillation ($P < .001$; Table 4). Multivariate analysis revealed unstable angina (odds ratio [OR] = 7.3, $P = .006$), mitral valve replacement (OR = 9.1, $P = .002$), and ventricular fibrillation (OR = 5.2, $P = .021$) to be independent predictors of hospital mortality (Table 5).

Postoperative myocardial infarction occurred in 2 (1.9%) patients. Postoperative hemodynamic instability was observed in 10 (9.3%) patients, and 6 (5.6%) patients were treated with IABP. Ventricular fibrillation occurred in 4

(3.7%) patients, causing death in 2. The independent predictors of increased myocardial infarction rate, assessed by means of univariate analysis, were aortic valve replacement ($P = .002$), prolonged cardiopulmonary bypass ($P = .04$), and crossclamp times ($P = .019$; Table 6). In the multivariate analysis aortic valve replacement remained the only independent predictor of myocardial infarction (Table 7). Other postoperative complications were atrial fibrillation (21.5%), renal failure (3.7%), acute respiratory failure (1.9%), bleeding (1.9%), and mediastinal infection (0.9%).

Late Outcome

Follow-up was 95.3% complete. The overall survival curve is depicted in Figure 1. The 72-month survival was $91.2\% \pm 4.9\%$.

During a mean follow-up period of 38.03 ± 24.5 months (range, 1-124.4 months), there was a total of 5 deaths: 2 patients died from primary cardiac failure, 2 from malignancy, and 1 from a cerebrovascular problem. Seventy-seven (83.7%) patients were angina free; 15 (16.3%) had angina (12 in Canadian Cardiovascular Society class 2, 1 in class 3, and 2 in class 4). Thirty-two (34.8%) patients was classified as being in New York Heart Association (NYHA) II, 10 (10.9%) in NYHA III, and 1 (1.1%) in NYHA IV. Myocardial infarction occurred in 2 (2.2%) patients. Ninety-seven (100%) patients underwent echocardiographic control, which showed an EF improvement after surgical intervention ($49.8\% \pm 8.8\%$ vs $56.1\% \pm 14.1\%$ mean EF, $P = .03$). They underwent angiographic control at a mean period of 30.4 ± 16 months after surgical intervention, and the patency rate for the endarterectomized coronary arteries was $72\% \pm 11\%$. The patency rate for bypass grafts to non-endarterectomized coronary arteries was $73\% \pm 12\%$, which is not different significantly from that of the endarterectomy grafts. According to the endarterectomized arteries and bypass grafts used, the patency rates were 75% for the LAD (internal thoracic artery graft), 90% for the RCA (saphenous vein graft), 80% for the descending posterior artery (saphenous vein graft), 60% for the obtuse marginal artery (saphenous vein graft), and 55% for the diagonal artery (saphenous vein graft).

Discussion

The completeness of revascularization has been shown to correlate with improved early and late patient outcomes after CABG.⁸⁻¹¹ Currently, in patients with end-stage coronary atherosclerosis, the options available include performing CABG to small distal vessels not performing any bypass to the diseased coronary territory or using CE as an adjunctive tool to CABG to achieve a complete revascularization. However, CE is reported as a time-consuming and challenging procedure, and its beneficial effect has been questioned because an increased risk of perioperative mortality and

TABLE 4. Univariate analysis of hospital mortality

Variables	Death		P value
	n	%	
Sex			
Male	3	3.3	NS
Female	2	2.8	
Age (y)	67.4 ± 10.2		.026
Hypertension			
Yes	2	4	NS
No	3	5.1	
Smoking			
Yes	5	8.8	.032
No	—	—	
Family history			
Yes	1	2.3	NS
No	4	6.3	
Diabetes			
Yes	1	4.5	NS
No	4	4.7	
Hyperlipidemia			
Yes	2	4.7	NS
No	3	4.7	
Previous myocardial infarction			
Yes	2	3.2	NS
No	3	6.8	
Previous stroke			
Yes	—	—	NS
No	5	5	
Aortic valve disease			
Yes	1	16.7	NS
No	4	4	
Mitral valve disease			
Yes	2	5	.000
No	3	2.9	
Left ventricular aneurysm			
Yes	—	—	NS
No	5	4.8	
Unstable angina			
Yes	5	9.3	.023
No	—	—	
EF <30%			
Yes	—	—	NS
No	5	5.1	
NYHA			
I	—	—	NS
II	—	—	
III	3	5.3	
IV	2	12.5	
Status			
Elective	2	2.6	NS
Urgent	3	10.3	
COPD			
Yes	—	—	NS
No	5	5.6	
Chronic renal failure			
Yes	2	50	.000
No	3	2.9	
Previous CABG			
Yes	—	—	NS
No	5	4.8	

(continued)

TABLE 4—Cont'd.

Variables	Death		P value
	n	%	
AVR			
Yes	1	20	NS
No	4	3.9	
MVR			
Yes	2	50	.000
No	3	2.9	
Ventricular Aneurismectomy			
Yes	—	—	NS
No	5	4.8	
CE on non-occluded vessel			
Yes	4	5.7	NS
No	1	2.7	
Acute myocardial infarction			
Yes	—	—	NS
No	5	4.8	
Hemodynamic instability			
Yes	2	20	.016
No	3	3.1	
CPB time (min)	204 ± 132		.000
Aortic crossclamp time (min)	91 ± 38		NS
IABP			
Yes	1	16.7	NS
No	4	4	
Ventricular fibrillation			
Yes	2	50	.000
No	3	2.9	
Stroke			
Yes	1	100	NS
No	4	3.8	
Atrial fibrillation			
Yes	2	8.7	NS
No	3	3.6	
Renal failure			
Yes	2	50	.000
No	3	2.9	
Respiratory failure			
Yes	1	50	.002
No	4	3.8	
Bleeding			
Yes	—	—	NS
No	5	4.8	
Mediastinal infection			
Yes	—	—	NS
No	5	4.7	

Continuous data are expressed as mean ± 1 SD. NS, Not significant; COPD, chronic obstructive pulmonary disease; AVR, aortic valve replacement; MVR, mitral valve replacement CPB, cardiopulmonary bypass.

TABLE 5. Multivariate analysis of Hospital mortality

Variables	OR	P value
Unstable angina	7.35	.006
Mitral valve replacement	9.18	.002
Postoperative VF	5.2	.021

VF, Ventricular fibrillation.

TABLE 6. Univariate analysis of postoperative myocardial infarction

Variables	Myocardial infarction		P value
	n	%	
Sex			
Male	2	2.2	NS
Female	—	—	—
Age (y)		67.5	NS
Hypertension			
Yes	—	—	NS
No	2	3.4	—
Smoking			
Yes	—	—	NS
No	2	4	—
Family history			
Yes	2	4.7	NS
No	—	—	—
Diabetes			
Yes	—	—	NS
No	2	2.4	—
Hyperlipidemia			
Yes	1	2.3	NS
No	—	—	—
Previous myocardial infarction			
Yes	1	1.6	1.6
No	—	—	—
Previous stroke			
Yes	—	—	NS
No	2	2	—
Aortic valve disease			
Yes	1	16.7	.006
No	1	1	—
Mitral valve disease			
Yes	—	—	NS
No	2	1.9	—
Left ventricular aneurysm			
Yes	—	—	NS
No	2	1.9	—
Unstable angina			
Yes	1	1.9	NS
No	1	1.9	NS
EF <30%			
Yes	—	—	NS
No	2	2	—
NYHA			
I	—	—	NS
II	1	3	—
III	1	1.8	—
IV	—	—	—
Status			
Elective	—	—	NS
Urgent	2	2.6	—
COPD			
Yes	—	—	NS
No	2	2.2	—
Chronic renal failure			
Yes	—	—	NS
No	2	1.9	—

(continued)

TABLE 6—Cont'd.

Variables	Myocardial infarction		P value
	n	%	
Previous CABG			
Yes	—	—	NS
No	2	1.9	—
AVR			
Yes	1	20	.002
No	1	1	—
MVR			
Yes	—	—	NS
No	2	1.9	—
Ventricular aneurismectomy			
Yes	—	—	NS
No	2	1.9	—
CE on nonoccluded vessel			
Yes	1	1.4	NS
No	1	2.7	—
CPB time (min)		151	.04
Aortic crossclamp time (min)		106	.019
Acute myocardial infarction			
Yes	—	—	—
No	—	—	—
Hemodynamic instability			
Yes	1	10	.046
No	1	1	—
IABP			
Yes	1	16.7	.006
No	1	1	—
Ventricular fibrillation			
Yes	—	—	NS
NO	2	1.9	—
Stroke			
Yes	—	—	NS
No	2	1.9	—
Atrial fibrillation			
Yes	—	—	NS
No	2	2.4	—
Renal failure			
Yes	—	—	NS
No	2	1.9	—
Respiratory failure			
Yes	—	—	NS
No	2	1.9	—
Bleeding			
Yes	—	—	NS
No	2	1.9	—
Mediastinal infection			
Yes	—	—	NS
No	2	—	.006

Continuous data are expressed as a mean $\pm$ 1 SD. NS, Not significant; COPD, chronic obstructive pulmonary disease; AVR, aortic valve replacement; MVR, mitral valve replacement; CPB, cardiopulmonary bypass.

AVR morbidity often accompanies this technique, especially when performed on the LAD.^{2-5,12,13}

Contrary to institutions^{5,6,14} in which CE is performed in a relatively high percentage (20%-50%) of cases, we limited this procedure to a small group of patients (3.7% of the

TABLE 7. Multivariate analysis of postoperative myocardial infarction

Variables	OR	P value
AVR	5.23	.022

AVR, Aortic valve replacement.

patients with CAD) with severely stenosed or totally occluded arteries having a diameter of greater than 1 mm, in which a complete revascularization would have been otherwise impossible. There is a wide variation in the reported results of CE in conjunction with CABG.

Brenowitz and colleagues⁵ reported a 30-day mortality of 6.3% for patients with a single endarterectomy. Livesay and colleagues⁴ reported an early mortality rate of 4.4% in a group of 3369 patients in whom the right coronary artery was the most common site (83%) requiring CE.

In our series 5 (4.7%) hospital deaths occurred. Of these, 4 patients were preoperatively critical and operated on on an emergency basis. We performed one endarterectomy for each patient. The most frequently endarterectomized vessel was the left coronary artery (74.8%). Initially, endarterectomy of the right system was preferred because of its technical simplicity and a lower risk. Brenowitz and colleagues⁵ reported a mortality rate of 4.8% for the isolated right CE and 7.9% for the LAD. Livesay and coworkers⁴ reported a significantly increased early mortality rate (8.5%) when CE was performed on the LAD, as compared with endarterectomy of vessels other than the LAD. In our experience no hospital deaths or postoperative myocardial infarctions occurred in this group of patients.

Using multivariate analysis, mitral valve replacement ($P = .002$) and unstable angina ($P = .006$) were the most important independent predictors of early mortality, probably reflecting the critical status of these patients and the necessity for prolonged cardiopulmonary bypass and aortic crossclamp times. In this series the mean cardiopulmonary bypass and aortic crossclamp times were 124 ± 43 and 80 ± 25 minutes, respectively.

Myocardial infarction resulting from thrombosis or residual obstruction of the vessel is reported as the main cause of postoperative morbidity and mortality. In the literature the postoperative myocardial infarction rate ranges from 5% to 25%, with mortality rates of 0% to 15%.⁸⁻¹² In our experience 2 postoperative myocardial infarctions occurred, and the rate was 1.9%. Multivariate analysis revealed aortic valve replacement ($P = .02$) as an independent predictor of postoperative infarction. Interestingly, performing a CE on a nonoccluded vessel was not indicated as a risk factor for a myocardial infarction.

Continuous data are expressed as a mean $\pm$ 1 SD. NS, Not significant; COPD, chronic obstructive pulmonary disease; AVR, aortic valve replacement; MVR, mitral valve

replacement; CPB, cardiopulmonary bypass. The 6-year actuarial survival was $91.2\% \pm 4.9\%$. This compares favorably with the rate in other studies, typically ranging from 75% and 90%.^{4,5,15}

Clinically, 83.7% of our survivors were angina free at an average interval of 33.4 ± 20.2 months after surgical intervention. An improvement of myocardial contractility after surgical intervention was also shown by means of echocardiographic control. At angiography, the patency rate of the grafts anastomosed to the endarterectomized vessels was $72\% \pm 11\%$ at a mean follow-up period of 30.4 ± 16 months and is similar to that seen in previously published studies.¹³⁻¹⁵ In conclusion, our data show that CE is a safe and effective procedure for a complete revascularization in patients with end-stage CAD and shows acceptable early and late results.

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Appendix.

Factors assessed for hospital mortality and postoperative myocardial infarction

- Sex
- Age
- Hypertension
- Smoking
- Family history
- Diabetes
- Hyperlipidemia
- Previous myocardial infarction
- Previous stroke
- Aortic valve disease
- Mitral valve disease
- Left ventricular aneurysm
- Unstable angina
- EF <30%
- NYHA class
- Status
- Chronic obstructive pulmonary disease
- Chronic renal failure
- Previous CABG
- Aortic valve replacement
- Mitral valve replacement
- Ventricular aneurismectomy
- CE on nonoccluded vessel
- Cardiopulmonary bypass time
- Aortic crossclamp time
- Acute myocardial infarction
- Hemodynamic instability
- IABP
- Ventricular fibrillation
- Stroke
- Atrial fibrillation
- Renal failure
- Respiratory failure
- Bleeding
- Mediastinal infection